Health Technology Assessment
Imagerie par Résonance Magnétique

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Federaal Kenniscentrum voor de gezondheidszorg
Centre fédéral d'expertise des soins de santé
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PREFACE

Pionnière de l'imagerie médicale dès la fin du dix-neuvième siècle, la radiographie s'est vue compléter de techniques de plus en plus sophistiquées, précises et couvrant des champs d'indications toujours croissants. La tomodensitométrie a pu voir le jour grâce au développement décisif de l'informatique. La recherche de techniques d'imagerie permettant de se passer de radiations ionisantes a quant à elle donner le jour entre autres à l'imagerie par résonance magnétique. L'engouement pour ces nouvelles technologies ne s'est pas fait attendre et le nombre d'examens augmente sensiblement d'année en année. Car, en effet, ces technologies diagnostiques coûteuses, lorsqu'elles sont utilisées à bon escient, permettent d'augmenter la qualité des soins dispensés au patient et parfois aussi d'éviter d'entamer des procédures invasives.

La sensibilité de l'imagerie médicale, à savoir le nombre de pathologies qu'elle dépiste continue en effet à augmenter. Et il s'agit souvent d'un progrès considérable. Mais nous sommes amenés à nous demander si certains examens ne sont pas trop sensibles. Peu d'examens présentent, en effet, une spécificité de 100% (un examen spécifique à 100% permet de toujours distinguer correctement les groupes de patients sains des groupes de malades). La croissance continue des examens s'accompagne donc aussi d'une augmentation des résultats faux-positifs. Pour citer un exemple, certains études montrent que 2/3 des personnes ne se plaignant pas d'un mal de dos présentent des anomalie sur un IRM de la colonne vertébrale. Les conséquences d'un usage inconsidéré pour le patient comme pour l'assurance maladie sont faciles à imaginer. Or, en Belgique, le recours a l'imagerie médicale est typiquement très important. Il suffit de penser aux études antérieures menées par les organismes assureurs qui comparent le nombre d'examens d'imagerie préopératoire et de radiographie de la colonne vertébrale en Belgique avec le nombre de ces examens pratiqués au niveau international.

La forte concentration actuelle de scanners CT en Belgique, comparé à d'autres pays européens a certainement des répercussions en matière de volume d'examens. En outre, l'existence d'appareils vieillissant voire dépassés entrave l'exigence du maintien ou de l'amélioration de la qualité. Le parc de scanners IRM se voit à présent augmenté de 40 appareils. Cette augmentation sous-tend l'idée d'une substitution du CT en faveur de l'IRM. Le présent HTA vise entre autres à évaluer dans quelle mesure cette substitution peut avoir lieu. Entre-temps, les scanners CT continuent d'évoluer et il est même possible que nous assistions dans le futur à la substitution inverse.

Dans la littérature internationale, les scanners représentent un exemple typique de demande induite par l'offre. En d'autres termes, un scanner supplémentaire entraîne davantage d'examens. Ceci est d'autant plus surprenant que le radiologue ne prescrit lui-même aucun examen. Le prescripteur peut se référer aux recommandations en matière de prescription médicale élaborées par le Consilium Radiologicum belge. Les décideurs se battent depuis longtemps pour trouver la manière d'atteindre le meilleur rapport coût-efficacité possible pour l'imagerie médicale. Le présent rapport n'offre pas la solution idéale suprême. Les différences avec les autres pays sont en effet trop importantes pour permettre de tirer des conclusions plus poussées. Ce qui n'empêche pas le KCE d'avancer un nombre d'options bien étayées.

Une grande partie de cette étude a été réalisée par un groupe de radiologues issus de différentes universités. Ils font ainsi preuve non seulement de leur expertise clinique mais également de leur préoccupation quant à un usage efficient des ressources en imagerie médicale. Nous tenons également à remercier les fabricants et distributeurs d'unités de résonance magnétique mobiles pour leur pertinente contribution.

Jean-Pierre CLOSON
Directeur général adjoint

Dirk RAMAEKERS
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RESUME

INTRODUCTION

Depuis son introduction au milieu des années '80, l'imagerie par résonance magnétique (IRM) a connu un succès grandissant dans le cadre de l'examen de toute une série de troubles cliniques. L'abandon de la tomodensitométrie ou tomographie axiale commandée par ordinateur (CT) au profit de l'IRM a été inférieur aux prévisions et l'on constate même une augmentation de la pratique du CT. Bien que l'IRM soit un examen accepté pour certaines indications cliniques, la valeur réelle de son utilisation fait l'objet d'une certaine controverse et de quelques incertitudes. Les preuves soutenant l'usage de l'IRM dans la pratique clinique sont plutôt minces.

Un système d'IRM s'avère coûteux à l'achat et à l'exploitation. Avec 40 unités de résonance magnétique supplémentaires installées au cours des deux prochaines années, une augmentation des coûts est plus que probable. Différents systèmes de remboursement existent en Europe. Une comparaison de ces systèmes avec le système belge est intéressante pour quiconque est impliqué dans les soins de santé. L'utilisation d'unités d'IRM mobile se doit d'être étudiée en tenant compte de l'installation des unités d'IRM supplémentaires dans les deux années à venir.

OBJECTIFS

L'objectif de cette étude était triple :

- Résumer les preuves de la littérature scientifique disponible faisant état de l'efficacité clinique de l'IRM dans la pratique clinique, avec une attention spéciale aux possibilités de remplacer le CT par l'IRM.
- Décrire et analyser les avantages et inconvénients des différents systèmes de financement de l'IRM et du CT et comparer les systèmes de remboursement de l'IRM dans différents pays européens avec le système belge.
- Évaluer la faisabilité et l'opportunité de la mise en œuvre d'unités IRM mobiles en Belgique.

EXAMEN CLINIQUE

Méthodes

La littérature publiée entre janvier 2000 et janvier 2006 a été identifiée et extraite en utilisant une stratégie de recherche bien définie englobant aussi bien les bases de données électroniques que la littérature grise.

La stratégie de recherche consistait en une approche commune et en une approche plus spécifique pour chaque sous-spécialité du domaine de la radiologie.

À partir des références sélectionnées, les informations ont été extraites sous forme de tableaux et ensuite analysées. L'efficacité diagnostique de l'imagerie médicale a été examinée en utilisant les critères de Fryback et Thornbury.

Résultats

L'IRM produit des images de haute qualité et devrait toujours être utilisée de manière sélective et en conjonction avec l'historique et l'examen clinique, car de nombreuses anomalies se produisent chez les individus asymptomatiques et ne sont par conséquent pas nécessairement la cause des symptômes du patient.

Un audit de l'IRM révèle que les examens réalisés dans des centres non spécialisés sont souvent de qualité inférieure. Le niveau d'expérience du radiologiste et l'unité d'IRM devraient par conséquent être soumis à un contrôle de qualité.

En neuroradiologie, l'IRM est un examen indiqué pour de nombreuses maladies, comme par exemple la sclérose multiple et l'épilepsie. Mais en général, des évaluations quantitatives rigoureuses de l'effet clinique de l'IRM lors d'essais comparatifs bien contrôlés à grande échelle, manquent. L'évaluation formelle de l'efficacité clinique de l'IRM a été éclipsée par sa diffusion dans l'usage clinique pour les problèmes du système nerveux central.

L'IRM est plus sensible que le CT pour évaluer les patients souffrant d'épilepsie et de céphalée, mais tous ces patients ne devraient pas subir une IRM et le rendement diagnostique dépend fortement de la population de patients. L'IRM a récemment été incluse dans les critères révisés pour le diagnostic des scléroses multiples cliniquement définies. Le CT n'est pas envisageable dans le bilan diagnostique de cette maladie. L'IRM joue un rôle crucial dans l'infection cérébrale. Pour les traumatismes cérébraux, le rôle de l'IRM n'est pas encore suffisamment prouvé bien que l'utilisation de l'imagerie de diffusion semble prometteuse. Jusqu'à présent, le CT reste une méthode privilégiée dans les traumatismes craniocérébraux.

Chez les patients victimes d'un accident vasculaire cérébral, la supériorité en terme de précision diagnostique de l'IRM semble avérée, mais l'accès rapide au CT demeure un avantage non négligeable.

Pour certaines indications, l'IRM a remplacé des examens plus invasifs tels que l'angiographie digitalisée par soustraction (ADS) et la myélographie. Pour l'évaluation des anévrysmes, l'angiographie par résonance magnétique (ARM) semble prometteuse mais ne peut remplacer l'ADS chez tous les patients. L'ARM est un outil précieux pour le dépistage des patients à risque et dans le suivi après un traitement endovasculaire. Le rôle de l'IRM est limité aux troubles cérébraux dégénératifs mais les mesures de volume semblent prometteuses pour l'avenir.

L'imagerie cérébrale chez l'enfant est considérée comme supérieure par IRM comparé au CT en raison de sa précision diagnostique, mais il n'existe aucune preuve solide dans la littérature scientifique venant l'attester.

L'absence de recherche clinique de haute qualité et l'usage très répandu de l'IRM sont des problèmes difficiles à surmonter dans les études d'évaluation technologique fondées sur les preuves. Le meilleur compromis est de présenter une série d'approches suggérées ainsi que des informations concernant la qualité de la recherche utilisée pour étayer ces suggestions.

Il est encore trop tôt pour évaluer l'efficacité clinique des techniques plus récentes telles que la spectroscopie par RM, l'imagerie par RM de perfusion, l'imagerie du tenseur de diffusion et l'IRM interventionnelle.

L'impact de l'IRM sur le résultat clinique du patient, a été démontré chez les patients souffrant de lombalgie et de déficit neurologique. Chez la grosse majorité des patients souffrant de lombalgie, les études d'imagerie ne devraient être réalisées que lorsque la lombalgie dure plus de 6 semaines, car l'usage précoce de l'imagerie semble ne pas affecter l'ensemble du traitement et augmente considérablement les coûts. Il n'existe actuellement pas suffisamment de preuves soutenant par exemple l'utilisation de routine de « l'imagerie rapide par RM » en lieu et place de la radiographie conventionnelle de la colonne lombaire en cas de lombalgie, ou pour le dépistage du cancer en tant qu'origine de lombalgies chez les patients en soins primaires envoyés au service d'imagerie pour exclure le cancer en tant que cause potentielle de leur douleur.

L'IRM est un examen privilégié en cas de suspicion d'une compression de la moelle épinière ou dans tous les cas impliquant la moelle épinière, par exemple après un traumatisme ou dans le cas de tumeurs malignes sous-jacentes.

Pour la radiologie de la tête et du cou, il existe des preuves venant attester la supériorité de l'IRM chez les patients présentant une suspicion de névrome acoustique. Mais étant donné la faible prévalence de la maladie et le coût élevé de l'IRM, l'évaluation audiologique des potentiels évoqués du tronc cérébral devrait être envisagée comme premier outil de dépistage. Certains experts recommandent l'IRM dans l'évaluation préopératoire en cas de pose d'un implant cochléaire, mais le CT peut s'avérer suffisante chez certains patients.

En cas de dérangement interne de l'articulation temporo-mandibulaire, l'IRM constitue la meilleure technique chez les patients symptomatiques.

Dans l'ensemble, il n'existe aucune preuve évidente d'une valeur ajoutée de l'IRM par rapport au CT pour l'évaluation du cancer de la tête et du cou. Ce n'est que pour le cancer rhino-pharyngien que l'usage de l'IRM présente un impact significatif sur les résultats thérapeutiques, en offrant une image plus nette de l'ampleur de la tumeur.

En radiologie cardiaque, l'IRM s'est avérée être une excellente technique pour étudier la fonction cardiaque, valvulaire et ventriculaire, la perfusion myocardique et la viabilité myocardique. De plus en plus d'éléments viennent attester que l'IRM offre davantage d'informations utiles que d'autres techniques. Dans ce domaine, l'IRM n'a pas été comparée au CT mais à d'autres techniques cardiaques établies telles que l'échocardiographie, la médecine nucléaire et la cathétérisation cardiaque. L'impact de l'IRM sur la prise de décision doit encore être défini mais elle est de plus en plus utilisée pour étudier l'impact thérapeutique et le résultat clinique du patient dans toute une série de maladies cardiaques.

En radiologie vasculaire, l'angiographie par résonance magnétique de la carotide et des artères vertébrales est généralement acceptée, souvent conjuguée aux ultrasons, en lieu et place de l'angiographie digitalisée par soustraction plus invasive. Il est important de souligner que cette technique de l'ARM utilisant des produits de contraste est la seule technique acceptable de nos jours. Les techniques de RM plus anciennes, sans administration de liquide de contraste, régulièrement utilisées jusqu'en 2000/2001, devraient être abandonnées.

L'IRM, l'ARM et le CT sont des techniques précises pour évaluer une maladie aortique thoracique congénitale et dans le cadre du bilan diagnostique de l'anévrisme aortique abdominal. L'ARM n'est sensible qu'en cas de prévalence élevée d'une sténose artérielle rénale significative. L'ARM est plus précise pour la détection des artères rénales accessoires que les ultrasons mais moins précise comparée à l'angiographie par CT et à l'angiographie digitalisée par soustraction. L'ARM avec contraste et l'angiographie par CT sont toutes deux précises pour la détection et la détermination de la sévérité d'une sténose significative de l'artère cœliaque, de l'artère mésentérique supérieure et des artères périphériques. Chez les patients atteints d'une ischémie chronique aiguë des membres, une angiographie par résonance magnétique avec contraste peut modifier le choix de la stratégie thérapeutique.

L'IRM abdominale est considérée comme utile pour la détection d'une concentration de fer hépatique et peut être utilisée pour corriger un mauvais diagnostic de l'ultrasonographie et du CT en cas de stéatose focale. L'IRM fournit une caractérisation supérieure des masses hépatiques. Comparée au CT et au FDG-PET, l'IRM détecte des masses de plus en plus petites et plus en plus nombreuses.

La cholangiopancréatographie par résonance magnétique est excellente pour identifier la présence et le niveau d'obstruction biliaire maligne et sert d'outil de dépistage pour les calculs des voies biliaires, évitant ainsi la nécessité de procéder à une cholangiopancréatographie endoscopique rétrograde ou une cholangiopancréatographie par CT.

L'IRM constitue la meilleure technique pour l'évaluation adrénale. L'IRM évalue bien mieux la stadification loco-régionale du cancer du pancréas. L'IRM du corps tout entier est plus sensible pour détecter les métastases.

L'IRM est considérée comme la meilleure technique pour la stadification préopératoire du cancer de l'endomètre. L'IRM est actuellement utilisée comme une technique de résolution des problèmes dans les cas peu concluants de malformations congénitales de l'utérus.

Les indications les plus fréquentes d'IRM en radiologie musculosquelettique sont les maladies traumatiques, tumorales, ostéoporotiques et dégénératives de la colonne vertébrale, un dérangement interne du genou, de la hanche et d'autres articulations, la nécrose avasculaire de la hanche et d'autres articulations, les maladies traumatiques des muscles et des tendons, les maladies infectieuses, tumorales, idiopathiques (syndrome

de l'œdème de la moelle épinière, syndrome de l'insuffisance sous-chondrale) et les maladies traumatiques de la moelle épinière et les tumeurs des os et des tissus mous.

Dans de nombreuses indications, une précision de diagnostic supérieure a été décrite pour l'imagerie par RM par rapport à la radiographie conventionnelle, la scintigraphie osseuse, le scanner à ultrasons et/ou par tomographie, par exemple dans le cadre d'un dérangement interne du genou, d'une douleur de la hanche aigue non traumatique chez l'enfant, d'une maladie occulte de la moelle osseuse, d'une lombalgie avec déficit neurologique, de métastases vertébrales, d'ostéomyélite, de tumeurs des os et des tissus mous, etc. L'impact sur la pensée diagnostique a été décrite pour la surveillance de la réponse à la thérapie dans les maladies de la moelle osseuse. L'impact thérapeutique de l'IRM a décrit pour les déchirures méniscales et les tumeurs des tissus mous. Les informations de l'imagerie par RM peuvent affecter la planification du traitement en aidant à prédire les déchirures méniscales qui sont potentiellement réparables ou qui peuvent subir une résection et les déchirures qui n'ont pas besoin d'une intervention chirurgicale. Pour les tumeurs bénignes des tissus mous ou les lésions apparentées à des tumeurs, l'IRM est capable d'effectuer un diagnostic précis. Ces patients n'ont pas besoin de biopsie et bien souvent ne doivent pas subir une intervention chirurgicale. Un meilleur rapport coût-efficacité de l'IRM a été décrit dans le dérangement interne du genou. L'usage de l'IRM pour l'examen du genou est associé à un impact diagnostique/thérapeutique positif car la RM influence fortement le diagnostic des cliniciens et les plans de gestion des patients présentant des problèmes de genou : une proportion sensiblement plus faible de patients effectuant une IRM subira une arthroscopie ou une intervention chirurgicale, et ces réductions de coûts compenseront les frais de l'imagerie par résonance magnétique. En utilisant l'IRM en lieu et place de la scintigraphie osseuse, il est possible de réduire le délai de diagnostic chez les patients présentant une suspicion de fracture de la hanche (fractures occultes) dans les institutions effectuant des scintigraphies osseuses retardées. Les coûts finaux se sont avérés substantiellement inférieurs lorsque l'IRM était utilisée. Il s'agit d'une technique plus rentable chez les patients ne présentant aucune contre-indication chirurgicale.

Compte tenu de sa sensibilité élevée mais de sa faible spécificité, l'IRM du sein (mammographie par RM) est indiquée dans un nombre limité d'applications : (1) stadification de l'extension de la tumeur et exclusion de la multicentricité, (2) évaluation du tissu cicatriciel après thérapie conservatrice du sein, (3) évaluation de l'implant de silicone, (4) résolution de problèmes peu après la chirurgie, (5) surveillance de la chimiothérapie néoadjuvante, (6) dépistage chez les patientes à haut risque et (7) écoulement mamelonnaire.

Il n'existe actuellement pas de revue systématique portant sur l'IRM interventionnelle ou intra-opératoire. Selon la littérature récente, cette technique apparaît prometteuse non tant comme technique de routine que comme examen personnalisé au cas de chaque patient.

FINANCEMENT DE L'IRM

Le chapitre 2 traite des mécanismes de financement de l'IRM en Belgique. En avril 2006, il existait officiellement 68 unités d'IRM cliniques agréées en Belgique, soit 6,5 unités par million d'habitants. Selon différentes sources, ce nombre de scanners cliniques est peut-être sous-estimé et approcherait plutôt les 80 unités. À en croire les statistiques de l'OCDE, plusieurs autres pays d'Europe occidentale présenteraient un ratio de scanners par million d'habitants considérablement plus élevé, même après la mise en marche des 40 unités supplémentaires annoncées.

La Belgique ne dispose d'aucun critère de programmation pour le CT. Le nombre exact d'unités de CT n'est pas connu, mais de nombreuses sources indiquent que ce nombre est très élevé en Belgique. C'est également le cas pour le niveau d'activité tomodensitométrique. Le rapport CT/IRM est de 3,2, un chiffre qui figure parmi les plus élevés. La Belgique obtient également un score élevé en ce qui concerne le nombre moyen d'examens CT ou IRM par scanner. Entre 2001 et 2004, le nombre d'IRM a augmenté de 35% en Belgique, tandis que le nombre d'unités IRM officiellement accréditées est resté stable. Au cours de cette même période, l'activité

tomodensitométrique a également augmenté, mais dans une moindre mesure par rapport à l'IRM. Cependant, le volume total de scanners CT a augmenté plus que le volume total d'IRM et cela est principalement dû à la pratique croissante de CT abdominaux, thoraciques et du cou.

Contrairement à la plupart des autres pays étudiés, les systèmes de financement de l'activité IRM et de l'activité tomodensitométrique diffèrent considérablement en Belgique. Les dépenses liées au CT sont financées via la nomenclature (majorité remboursée sur une cotisation par activité) tandis que les dépenses liées à l'IRM sont partiellement financées via le budget de l'hôpital.

IRM MOBILE

Les avantages et inconvénients des systèmes d'IRM mobiles n'ont pas été étudiés en profondeur dans la littérature. Deux exemples, l'un pour le Canada et l'autre pour Paris, ont été identifiés. Le chapitre 3 présente ses exemples et évalue la faisabilité des systèmes IRM mobiles en Belgique.

D'un point de vue technologique, les scanners IRM installés sur une remorque pour en faire des IRM mobiles sont identiques aux scanners IRM fixes de même intensité de champ. L'installation d'un système IRM mobile à proximité d'un hôpital requiert une certaine capacité logistique. En partant du principe que celle-ci est disponible, les coûts d'investissement initiaux pour des systèmes IRM mobiles sont inférieurs aux coûts d'investissement initiaux pour les systèmes IRM fixes. Les frais d'exploitation annuels sont cependant supérieurs pour les unités mobiles que pour les unités fixes.

Du point de vue de l'hôpital, les avantages des systèmes IRM mobiles sont des délais d'installation plus courts, un investissement de départ inférieur, une réponse rapide (potentielle) à une demande excédentaire pour des services d'IRM et le partage des coûts entre les hôpitaux. Du point de vue du patient, les déplacements peuvent être réduits lorsque l'unité d'IRM mobile est présente à l'hôpital le plus proche.

Les inconvénients de l'IRM mobile, du point de vue de l'hôpital, sont l'indisponibilité potentielle de l'IRM en cas d'urgence (lorsque l'hôpital n'a pas de scanner IRM fixe), l'indisponibilité potentielle d'un personnel qualifié et des frais d'exploitation plus élevés. L'IRM mobile engendre plus d'inconfort pour le patient et le personnel.

Actuellement, l'IRM mobile n'est utilisée qu'en Belgique et ce en tant que solution temporaire pour remplacer un IRM fixe en réparation.

CONCLUSIONS

En règle générale, l'IRM propose des images de meilleure qualité que le CT et ce sans utiliser de rayonnement ionisant. Dans un monde idéal, nous pourrions nous attendre à ce que l'IRM remplace le CT dans la majorité, si pas l'ensemble, des indications. Cependant, la technique du CT multicoupe ne cesse de s'améliorer et offre de nouvelles applications dans de nombreuses parties du corps. Par conséquent, il sera difficile de mesurer le degré de substitution entre le CT et l'IRM.

La technique de l'angiographie par résonance magnétique (ARM) a réalisé des progrès considérables au cours de ces 5 dernières années et l'angiographie digitalisée par soustraction est de plus en plus remplacée par l'ARM.

Bien que des évaluations quantitatives rigoureuses du rôle clinique de l'IRM soient manquantes, il semble tout à fait justifié d'affirmer que l'IRM peut améliorer l'identification d'une maladie. Le niveau de preuve est souvent limité à la « précision diagnostique » avec quelques exceptions où l'IRM a un impact diagnostique voire thérapeutique. Très peu d'études ont évalué le rapport coût-efficacité de l'IRM et les résultats n'en étaient souvent pas tranposables directement au système de soins de santé belge.

Cela sera difficile voire impossible dans certains cas d'obtenir des essais comparatifs bien contrôlés en vue de prouver l'impact sur la gestion des patients et le résultat clinique du patient.

La Belgique possède un grand nombre d'unités de CT et le volume d'examens tomodensitométriques a davantage augmenté par rapport au volume des examens d'IRM entre 2001 et 2004. Les systèmes de financement de l'IRM et du CT diffèrent considérablement en Belgique, sans explication précise. L'harmonisation des systèmes de financement est recommandée mais une recherche supplémentaire s'avère nécessaire avant de la mettre en œuvre. En attendant, des améliorations du système de financement actuel peuvent être apportées.

Actuellement, l'IRM mobile n'est utilisée qu'en Belgique et ce en tant que solution temporaire pour remplacer un IRM fixe en réparation. Les solutions apportées par l'IRM mobile offre un certain nombre d'avantages et de désavantages, du point de vue du patient et de celui de l'hôpital.

RECOMMANDATIONS

Révision des recommandations en matière de prescription d'imagerie médicale

- La revue de la littérature scientifique sur l'IRM dans les différentes indications révèle que les recommandations belges en matière de prescription d'imagerie médicale nécessitent une révision. Dans certaines indications le CT ne devrait plus être utilisé. Afin qu'elles soient à jour, les recommandations devraient être révisées tous les deux ans.
- L'implémentation d'un système informatique expert aiderait les prescripteurs de procédures d'imagerie médicale dans la mise en œuvre des recommandations dans leur pratique médicale quotidienne. Un tel système pourrait ainsi suggérer la stratégie optimale d'imagerie en cas de suspicion d'un certain diagnostic ou encore recommander un avis spécialisé. En outre, davantage d'attention devrait être consacrée à la prescription adéquate en imagerie médicale lors de la formation de base des médecins ainsi que lors de la formation continue médicale.
- L'assurance de la qualité des procédures d'imagerie médicale est essentielle à la garantie de l'efficacité clinique et du meilleur résultat pour le patient. Différentes mesures d'assurance de qualité peuvent être suggérées. Les visites des sites par une commission de visitation en constituent une première. Sont également proposées, l'éducation et le soutien par des

radiologues expérimentés que ce soit sur place ou grâce à la téléradiologie, en particulier lors du lancement d'un centre d'IRM. Les autres mesures sont la restriction de l'installation des scanners à bas champ et des scanners dédiés et enfin, l'accréditation de centres experts pour les examens complexes.

Financement

Les divergences entre le système de soins de santé belge et ceux des autres pays sont trop importantes pour conclure à une solution claire qui réconcilierait une offre adéquate avec un usage approprié en imagerie médicale. L'offre élevée (CT) et le système actuel de paiement à l'acte combiné au manque de responsabilisation du prescripteur ne répondent vraisemblablement pas à cet objectif. Cependant, un certain nombre d'options peut être mis en avant afin de remédier à certaines incohérences du financement actuel:

- En ce qui concerne le financement, certaines révisions de la nomenclature doivent être considérées, sur base de la charge de travail associée aux différents examens. Ces révisions doivent avoir lieu au sein des organes compétents de l'INAMI.
- Les mécanismes de financement des scanners CT et des scanners IRM devraient être harmonisés. Les faibles différences dans la structure des coûts ne justifient pas les différences actuelles de financement. Les coûts fixes en équipement devraient être financés au sein du budget de l'hôpital. Les limitations au niveau de l'offre sont alors inévitables pour contenir les coûts. L'attribution des scanners IRM devrait reposer sur les besoins locaux, sur le pole d'attraction que représentent les hôpitaux et sur le rapport CT/IRM de la région.
- Le financement des coûts de fonctionnement et les honoraires des radiologues devraient constituer un incitant à une utilisation efficiente et adéquate de l'IRM et du CT. Certaines options pour le financement des coûts variables sont proposées. Une distinction est faite entre l'imagerie pour les patients hospitalisés et l'imagerie en ambulatoire.
    - Un financement par pathologie pourrait être appliqué dans le cas des patients hospitalisés, y compris en hospitalisation de jour.
    - Dans le cas des patients ambulatoires, aucune donnée relative à la pathologie n'est actuellement collectée, un financement alternatif spécifique doit donc être développé. Une des possibilités revient à déterminer le montant des honoraires de consultance des radiologues en fonction de l'adéquation ou non de la prescription avec les recommandations en matière de prescription. Un tel système nécessite l'introduction d'un formulaire de prescription standard et la création d'une base légale pour le refus des prescriptions par le radiologue. Cette option constituerait un stimulant à la communication entre le radiologue et le médecin prescripteur avant que ce dernier ne formalise sa prescription.
    - Le prescripteur justifierait sa demande sur le formulaire de prescription standardisé si celle-ci sort des recommandations de bonne pratique en matière de prescription. L'inscription des diagnostics suspectés et des diagnostics établis permettrait l'audit et l'évaluation par les pairs.
    - Une autre possibilité serait que le prescripteur adresse son patient au radiologue pour la détermination ou l'exclusion d'un diagnostic suspecté, sans spécifier le type d'imagerie. Le radiologue déciderait ainsi lui-même quelle est l'imagerie la plus indiquée sur base des informations cliniques relatives au patient. Le radiologue percevrait un honoraire de consultance à cette fin.

IRM mobile

Les éléments dont il faut tenir compte lorsque l'IRM mobile est envisagée en Belgique sont: le volume minimal requis pour le fonctionnement optimal d'une unité mobile, la gamme de services qui peuvent être dispensés par l'équipe disponible et l'accessibilité aux services d'IRM en Belgique.

Aucun argument solide ne permet de conclure que les désavantages présentés par l'IRM mobile sont compensés par ses avantages, en particulier dans le contexte belge. C'est la raison pour laquelle il est recommandé de réserver l'IRM mobile comme solution temporaire lorsqu'une unité fixe est mise hors service.

Scientific summary

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GLOSSARY

ABR: Auditory Brainstem Response

CDMS: clinically definite MS

CI: confidence interval

CIS: clinically isolated syndrome

CSF: cerebro-spinal fluid

CT: computed tomography

CTA: computed tomography angiography

DSA: digital subtraction angiography

MRI: magnetic resonance imaging

MRA: magnetic resonance angiography

MS: multiple sclerosis

PPMS: primary progressive MS

RRMR: relapsing-remitting MS

SEP: sensory evoked potentials

US: ultrasound

USPIO: Ultrasmall Superparamagnetic Iron Oxide

VEP: visually evoked potentials

Part 1: Evaluation of the clinical effectiveness of MRI in different indications

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1 INTRODUCTION

This report summarizes the evidence in the literature regarding the clinical efficacy of magnetic resonance imaging (MRI) in clinical practice. Financing mechanisms for MRI in a selection of European countries are presented and compared to our current system. Different options for financing MRI in Belgium are explored. Finally, a short Health Technology Assessment of mobile MRI is performed and presented in the third part of this report.

MRI is a relatively expensive but non-invasive radiological examination. The most important advantage compared to other techniques such as computed tomography (CT) and digital subtraction angiography (DSA) is the absence of ionising radiation. In addition the superior resolution, multiplanar imaging capability and safer contrast agents are the major advantages of MRI. Patients with ferro-magnetic implants cannot be examined by MRI and more co-operation from the patient is generally required, which renders the examination of intensive care patients more difficult. The frequent detection of incidental findings that can be misinterpreted as causing the patient's symptoms is another disadvantage of MRI that is often underestimated.

Since the introduction of MRI, more than 25 years ago, remarkable technological advances have been achieved providing better resolution, increased speed of imaging and new applications. In the first decade, the excellent diagnostic performance of MRI has been demonstrated for many neurological and musculoskeletal applications. The imaging of the brain stem, the spinal cord and the cartilage bone are only a few examples. Later abdominal, breast, cardiac and vascular imaging developed rapidly taking advantage of the advances in MR technology. Functional MRI and interventional MRI are now the most important emerging MR applications. At this stage, there are no systematic reviews on interventional MRI but the application seems to be promising when tailored to the individual patient and in combination with advanced functional imaging techniques.

In the early days, there was hope that MRI might replace not only CT but also more invasive imaging techniques such as DSA, CT-myelography, endoscopic retrograde cholangiopancreaticography and even surgical procedures such as arthroscopy. Due to the limited access, the long examination time and the lack of confidence that is often associated with a new technique, the substitution was far less than expected. While the more invasive examinations and procedures were more easily replaced by MRI, the substitution of CT lagged behind. MRI was often being used as an additional examination rather than as a substitute.

With the introduction of helical CT and multi-slice CT scanners that led to very short examination times, 3D-imaging applications and a renewed interest in some older applications, it has even become more difficult to assess the degree of substitution from CT to MRI. It is not excluded that, for an indication where MRI has replaced CT or DSA, CT may become the examination of choice again in the future.

The appropriate use of MRI is the key issue. Unfortunately, there is a clear lack of high quality evidence regarding the efficacy of MRI. Only few randomized-controlled trials have compared MRI with other diagnostic alternatives and there is almost no proof that the use of MRI in the diagnostic process is significantly associated with improvement in patient quality of life and survival. For many of the more established applications of MRI, randomization is not feasible anymore, on ethical grounds and the judgment of appropriateness of the applications will often be based on observational data. Cost-effectiveness studies regarding MRI are rare and often difficult to apply in the Belgian health care system.

It will be very important to define guidelines for adequate use of MRI, taking into consideration the ongoing technological progress both in CT and in MRI. These guidelines should avoid the simultaneous recommendation of two or more radiological techniques in as many conditions as possible.

In 2006 the Minister of Public Health decided to grant approval to 40 additional MR scanners in Belgium in the next two years. This will have financial implications. A review

of possible financing mechanisms for MRI in Belgium is therefore provided as well as a description of financing mechanisms in a number of European countries.

Finally, in Belgium there is currently no mobile MRI provision. The main question is whether mobile MRI is feasible in a Belgian context and under which conditions mobile MRI can be considered. The advantages and disadvantages of mobile MRI in a Belgian context were assessed.

2 OBJECTIVES

The objectives of this Health Technology Assessment are threefold:

- Examine the substitution possibilities between CT and MRI in different indications;
- Examine possible financing systems for MRI in Belgium;
- Perform a short HTA on mobile MRI systems.

3 METHODS

The possibilities to substitute CT for MRI in different indications was examined by means of an extensive literature review. Starting point was existing HTA reports or systematic reviews. These reports or reviews were updated with more recent literature. If no HTA reports or systematic reviews were available, primary studies were sought.

MEDLINE®, EMBASE®, the HTA Database, NHSEED and DARE were searched. Specific criteria and search strategies for each of the indications are presented in annex.

For most indications, the search was limited to publications from 2000 or later. This was to retrieve literature on contemporary technology. When no recent literature was found, the literature prior to the year 2000 was searched.

Quality of the studies found in the literature was assessed by means of the QUADAS quality assessment tool for diagnostic research. Based on the available studies and the quality assessment, a level of evidence is attributed for the diagnostic efficacy of MRI in each indication.

For some indications, the evidence is limited or absent. This can be related to the low quality of published studies, to the mere absence of clinical diagnostic studies or to the fact that the sample size of the study is too low. For very rare indications, it is often quite difficult to obtain a sufficient number of patients to perform a well powered diagnostic study and hence the evidence base for certain of these indications will remain weak. On the other hand, the mere existence of publications is not sufficient to conclude that there is evidence for the clinical diagnostic efficacy of MRI for a certain indication. Diagnostic studies can be of low quality, the research questions might be irrelevant and several sources of bias can be present.

The hierarchy of diagnostic efficacy described by Fryback and Thornbury is used as the basis of this report.[1] Briefly, this hierarchy defines three levels of evidence (more details and a description of each level of evidence is provided in annex):

- Level 1: technical efficacy
- Level 2: diagnostic accuracy
- Level 3: diagnostic thinking
- Level 4: therapeutic impact
- Level 5: patient outcome
- Level 6: cost-effectiveness

Evidence tables of the retained literature are presented in appendix 3. They specify the types of studies found, summarize the results and identify the evidence level. These tables are the basis for the conclusions formulated in the main text.

4 NEURORADIOLOGY

The experience that neuroradiologists have gained with magnetic resonance imaging (MRI) goes back to 1985. As a consequence, MRI is an established technique within this subspecialty of radiology. There are several clinical conditions where magnetic resonance imaging (MRI) is widely accepted as the modality of choice in the diagnostic work-up and therefore it is considered un-ethical to set up randomized controlled trials. The reason for this superiority is the higher resolution of MRI and the multiplanar imaging capability of MRI. In case of suspected pathology of the brain stem, the cerebellum, the pituitary gland and the spinal cord, MRI is recommended and CT should not be performed.[2] As will be shown in paragraph 4.1.1 and 4.1.2, for some clinical entities such as multiple sclerosis and partial complex seizures, MRI is considered the modality of choice.[3] In pediatric neurological conditions, MRI is also considered the modality of choice, mainly based on the fact that congenital brain and spine malformations are far better depicted on MRI than on CT.[4]

A comprehensive literature search (1987-1992) on the clinical efficacy of MRI was published in 1994.[2] The authors concluded that there was weak scientific support on its efficacy for an expanded role of MRI for diagnosis and therapy. Following this paper, a position paper was published on the indications of magnetic resonance of the brain and spine.[5] The technical efficacy (evidence level I) was generally recognized but many studies contained methodological flaws that did not allow to reach a sufficiently high level of evidence. Quantitative rigorous assessments of the clinical effect of MRI in large case series or well controlled comparison trials are missing.

Another important observation is that MRI is in constant evolution and imaging techniques implemented after 2001 have not been assessed yet. Moreover, some imaging techniques before 2000 are considered outdated.

The impact of false-positive findings and incidental findings has not sufficiently been studied but there are indications that such observations can be encountered in more than 2% of the cases.[6] It is well known that MRI is more sensitive in lesion detection but often lesions can be depicted on MRI without any evidence of a clinical correlation.[2] This carries the potential risk of leading to additional, sometimes invasive, investigations and/or unnecessary treatments

In a study on neurology outpatients, it was shown that if a CT result was available MRI would still be requested in 30% of the patients, which meant that the CT path was not necessarily less expensive than the "MRI alone" path.[7] But, MRI showed more (questionable) abnormalities than CT which led to additional technical examinations that would not have been requested with only a CT result.

The substitution of CT by MRI has not taken place to the expected level.[8, 9] Together with the enormous increase in the number of MRI scans, there has also been an increase in the number of CT scans. This raises several questions:

- Have the indications for CT and MRI really expanded? Or was the access to MRI too limited in the past?
- Are physicians relying more on diagnostic imaging modalities and less on clinical examination?
- Are an increasing number of patients undergoing scans while having only a small likelihood that this will alter management and outcome?

It is likely that a combination of factors has led to these increases in diagnostic imaging tests. Unfortunately there are no evidence-based benchmarks for the appropriate rate of diagnostic testing that can be used to determine the optimal supply of CT and MRI.

The transparency of this substitution process becomes even more difficult with the progress in CT technology. This is leading to emerging applications where CT is being preferred over MRI. Of course, much also depends on the type of CT and/or MRI unit that is available and the local experience of the neuroradiologist.

In a recent Australian paper, on the assessment of the status of MRI in health care, similar conclusions were drawn as far as the scientific evidence of the effectiveness of MRI was concerned.[10] Nevertheless an increase in the number of MR units for Australia was considered appropriate.

The cost-effectiveness of MRI in neurology is even less well studied. There has been a report on the cost-effectiveness of MRI compared to CT for patients with equivocal neurological symptoms.[11] The authors found that the cost-effectiveness of MRI increases as the likelihood of an underlying neurological condition increases. Similar more recent observations will be discussed in paragraph 4.1.9.

It is evident that guidelines should be developed to substitute CT by MRI.[12] Unfortunately, the available scientific evidence is limited and hence expert opinions will play a major role in the definition of such guidelines.

4.1 BRAIN

4.1.1 Epilepsy

With a prevalence of up to 1%, epilepsy is a disorder with major clinical, social, psychological and economical impact.

The few studies comparing the sensitivities and specificities of CT and MRI in detecting epileptogenic lesions demonstrate an important lack of sensitivity for CT, whereas MRI is a very sensitive technique to detect possible lesions.[13-15] In some series, a sensitivity of up to 97% was reported in patients with lesions confirmed by pathology.[13, 16] Bronen et al. (1997)[17] calculated a significant cost saving by replacing CT with MRI in the pre-operative evaluation of epilepsy patients.

The diagnostic yield of MRI depends on many factors, one being the patient population it is applied to. The diagnostic yield ranges from 12,7 % to 14 % of patients presenting with newly diagnosed epilepsy[14] or a first seizure[18]. The yield goes up to 26 % when optimal MRI is applied in an epilepsy patient population with localisation related epilepsies.[19] The highest yield (65%-83%) in detecting epileptogenic lesions is observed in patient groups with intractable (temporal lobe) epilepsy who are considered candidates for epilepsy surgery.[20-22]

MRI is not recommended in patients with febrile seizures, idiopathic generalized epilepsy and children with benign rolandic epilepsy.[23, 24]

Another important factor influencing the diagnostic yield (and hence therapeutic decisions) is the quality of scanning technique, both when considering scanning protocols, expertise of the radiologist and magnetic field strength used. Up to 57% of focal epileptogenic lesions can be missed using a standard MRI scanning protocol, compared to an optimal scanning protocol.[25] Therefore, a quality standard should be implemented in those centres frequently scanning (refractory) epilepsy patients. The current state of the art technique for scanning epilepsy patients is the use of an optimized scanning protocol at the higher field strength of 3.0 Tesla. The use of such high field (3T) systems significantly increases the diagnostic sensitivity and may give additional information that can change clinical management, when compared to the standard field (1,5T) systems.[26] Therefore these systems are essential in tertiary imaging centres and reference centres for refractory epilepsy.

In a review Kuzniecky[27] summarizes the therapeutic impact of MRI in epilepsy as follows:

- When a lesion is detected with MRI in a patient with new onset seizures a recurrence of the seizures can be expected within 2 years in 80% of patients, meaning drug therapy should be started
- Detection of hippocampal sclerosis is a strong prognostic indicator for intractability with anti-epileptic drugs.[28-30]
- In case of tumors, the decision making process is expedited by the imaging features.

- MRI findings in patients with malformations of cortical development are critical for surgical decision making and helpfull for possible genetic diagnosis and counseling.

Overall evidence suggests that MRI is the method of choice for the diagnostic work-up in the epilepsy patients, mainly due its high resolution and tissue contrast. The *only* role for CT is for patients with acute symptoms in the emergency setting, in order to rule out pathologies that need immediate treatment such as haemorrhage.

4.1.2 Multiple Sclerosis

The diagnosis of clinically definite multiple sclerosis (CDMS) is complex and several diagnostic schemes have been proposed over time named after their lead author: Schumacher[31], Poser[32] and McDonald[33]. After about 4 year of evaluation by the neurological communities,[34-37] and recent therapeutic developments[38-40] and the better understanding of the physiopathology of multiple sclerosis,[41, 42] the criteria were revised in 2005 during an international consensus meeting held in Amsterdam.[43] As stated by the authors, the criteria are evidence based wherever possible. The 2005 revisions of the MS diagnostic criteria retain the core features of the original McDonald Criteria: emphasis on objective clinical findings, dependence on evidence of dissemination of lesions in time and space, use of supportive and confirmatory paraclinical examination to speed the process and to help eliminate false-negative and -positive diagnoses, focus on specificity rather than sensitivity, and need to eliminate better explanations for the diagnosis. According to these (revised) criteria for diagnosis of CDMS, magnetic resonance imaging becomes a very important part of the diagnosis, and must be integrated with clinical and other para-clinical diagnostic methods. For the clarity of this report, the important tables of Polman et al.[43] are included here.

Table 1: the revised McDonald criteria for RRMS [43]

Clinical Presentation	Additional Data Needed for MS Diagnosis
Two or more attacks[a]; objective clinical evidence of two or more lesions	None[b]
Two or more attacks[a]; objective clinical evidence of one lesion	Dissemination in space, demonstrated by: ● MRI[c] *or* ● Two or more MRI-detected lesions consistent with MS plus positive CSF[d] *or* ● Await further clinical attack[a] implicating a different site
One attack[a]; objective clinical evidence of two or more lesions	Dissemination in time, demonstrated by: ● MRI[e] *or* ● Second clinical attack[a]
One attack[a]; objective clinical evidence of one lesion (monosymptomatic presentation; clinically isolated syndrome)	Dissemination in space, demonstrated by: ● MRI[c] *or* ● Two or more MRI-detected lesions consistent with MS plus positive CSF[d] *and* Dissemination in time, demonstrated by: ● MRI[e] *or* ● Second clinical attack[a]
Insidious neurological progression suggestive of MS	One year of disease progression (retrospectively or prospectively determined) *and* Two of the following: a. Positive brain MRI (nine T2 lesions or four or more T2 lesions with positive VEP)[f] b. Positive spinal cord MRI (two focal T2 lesions) c. Positive CSF[d]

If criteria indicated are fulfilled and there is no better explanation for the clinical presentation, the diagnosis is MS; if suspicious, but the criteria are not completely met, the diagnosis is "possible MS"; if another diagnosis arises during the evaluation that better explains the entire clinical presentation, then the diagnosis is "not MS."

[a]An attack is defined as an episode of neurological disturbance for which causative lesions are likely to be inflammatory and demyelinating in nature. There should be subjective report (backed up by objective findings) or objective observation that the event lasts for at least 24 hours.[1]

[b]No additional tests are required; however, if tests (MRI, CSF) are undertaken and are *negative,* extreme caution needs to be taken before making a diagnosis of MS. Alternative diagnoses must be considered. There must be no better explanation for the clinical picture and some objective evidence to support a diagnosis of MS.

[c]MRI demonstration of space dissemination must fulfill the criteria derived from Barkhof and colleagues[20] and Tintoré and coworkers[21] as presented in Table 2.

[d]Positive CSF determined by oligoclonal bands detected by established methods (isoelectric focusing) different from any such bands in serum, or by an increased IgG index.[36–38]

[e]MRI demonstration of time dissemination must fulfill the criteria in Table 1.

[f]Abnormal VEP of the type seen in MS.[39,40]

MS = multiple sclerosis; MRI = magnetic resonance imaging; CSF = cerebrospinal fluid; VEP = visual-evoked potential.

Table 2: the revised criteria for PPMS [43]

Original McDonald Criteria	2005 Revisions
1. Positive CSF *and* 2. Dissemination in *space* by MRI evidence of nine or more T2 brain lesions *or* Two or more cord lesions *or* Four to eight brain lesions and one cord lesion *or* Positive VEP with four to eight MRI lesions *or* Positive VEP with less than four brain lesions plus one cord lesion *and* 3. Dissemination in *time* by MRI *or* Continued progression for 1 year	1. One year of disease progression (retrospectively or prospectively determined) 2. *Plus* two of the following: a. Positive brain MRI (nine T2 lesions or four or more T2 lesions with positive VEP) b. Positive spinal cord MRI (two focal T2 lesions) c. Positive CSF[a] (isoelectric focusing evidence of oligoclonal IgG bands or increased IgG index, or both).

[a]MRI demonstration of space dissemination must fulfill the criteria derived from Barkhof and colleagues[20] and Tintoré and coworkers[21] as presented in Table 2.

CSF = cerebrospinal fluid; MRI = magnetic resonance imaging; VEP = visual-evoked potential.

Table 3: adapted Barkhof criteria: dissemination in space [43]:

Original McDonald Criteria	2005 Revisions
Three of the following: 1. At least one gadolinium-enhancing lesion or nine T2 hyperintense lesions if there is no gadolinium-enhancing lesion 2. At least one infratentorial lesion 3. At least one juxtacortical lesion 4. At least three periventricular lesions	Three of the following: 1. At least one gadolinium-enhancing lesion or nine T2 hyperintense lesions if there is no gadolinium enhancing lesion 2. At least one infratentorial lesion 3. At least one juxtacortical lesion 4. At least three periventricular lesions
NOTE: One spinal cord lesion can substitute for one brain lesion/	NOTE: A spinal cord lesion can be considered equivalent to a brain infratentorial lesion: an enhancing spinal cord lesion is considered to be equivalent to an enhancing brain lesion, and individual spinal cord lesions can contribute together with individual brain lesions to reach the required number of T2 lesions.

Based on data from Barkhof and colleagues[20] and Tintoré and coworkers.[21]

Table 4: how to show dissemination in time [43]

Original McDonald Criterion	2005 Revisions
1. If a first scan occurs 3 months or more after the onset of the clinical event, the presence of a gadolinium-enhancing lesion is sufficient to demonstrate dissemination in time, provided that it is not at the site implicated in the original clinical event. If there is no enhancing lesion at this time, a follow-up scan is required. The timing of this follow-up scan is not crucial, but 3 months is recommended. A new T2- or gadolinium-enhancing lesion at this time then fulfills the criterion for dissemination in time. 2. If the first scan is performed less than 3 months after the onset of the clinical event, a second scan done 3 months or longer after the clinical event showing a new gadolinium-enhancing lesion provides sufficient evidence for dissemination in time. However, if no enhancing lesion is seen at this second scan, a further scan not less than 3 months after the first scan that shows a new T2 lesion or an enhancing lesion will suffice.	1. There are two ways to show dissemination in time using imaging: a. Detection of gadolinium enhancement at least 3 months after the onset of the initial clinical event, if not at the site corresponding to the initial event b. Detection of a *new* T2 lesion if it appears at any time compared with a reference scan done at least 30 days after the onset of the initial clinical event

In a sytematic review of 29 studies with 40 publications, Whiting et al.[44] in an effort to determine the accuracy of magnetic resonance imaging criteria for the early diagnosis of multiple sclerosis in patients with suspected disease, quoted two summary statistics for diagnostic accuracy which demonstrated conclusively that MRI is diagnostic for MS (diagnostic odds ratio for cohort studies 9, 95% CI 5 to 16) but that its diagnostic accuracy has been seriously exaggerated in case-control type evaluations that compare results of MRI images in a group of patients with MS with a separate group known not to have MS (diagnostic odds ratio 213, 95% CI 85 to 535). From this it was concluded that "*Many evaluations of the accuracy of magnetic resonance imaging for the early detection of multiple sclerosis have produced inflated estimates of test performance* ***owing to methodological weaknesses****. Use of magnetic resonance imaging to* ***confirm*** *multiple sclerosis on the basis of a single attack of neurological dysfunction may lead to over-diagnosis and over-treatment".* But on the use of MRI for diagnostic work-up of patients with CIS, the authors are more careful. It is clear that several factors need to be considered, in particular the reasons why magnetic resonance imaging is ordered: certainty of the diagnosis, ruling out differential diagnoses such as brain tumors, providing a baseline for monitoring disease progression, patient request, and patient reassurance.

On the McDonalds criteria, Whiting concludes that further research, based on long term cohort studies, is required to evaluate these criteria, and "*...that a limitation consequent on the need for long term clinical follow-up in studies that evaluate the accuracy of magnetic resonance imaging is that such studies inevitably use older technology. Studies with more advanced, and hence recent, technology inevitably had much shorter periods of follow-up. Differences in estimates of sensitivity and specificity according to magnetic resonance imaging technology were therefore confounded by differences in duration of follow-up.*"

None of the identified studies in this report addresses the issue of clinical relevance.

The conclusions from this article have been met with serious criticism from the neurological society (http://bmj.bmjjournals.com/cgi/eletters/332/7546/875) involved in the diagnosis of patients with clinically isolated syndrome suggestive of demyelinating disease (MS). It is feared that the results of this report might compromise the long term efforts of the medical community for early diagnosis and treatment of patients with suspected multiple sclerosis.

The following is a historical review of the evidence to prefer MRI instead of CT in patients referred with neurological symptoms suspected of having MS.

In a very early study Young et al.[45] compared MR and CT in MS and demonstrated that all lesions visible on CT were also seen on MRI, and MRI demonstrated 112 further lesions. The authors conclude that '*NMR ...demonstrates abnormalities in MS on a scale not previously seen except at necropsy.*' This study only used an inversion recovery sequence. The study was well performed, but only in a small group of 10 patients, 8 with definite MS and 2 with probable MS. In a reaction Mastaglia[46] expresses concern about safety issues with not a definite answer yet in those early days of MRI and a speculation that small lesions could also be seen with CT.

Moseley reviewed the literature on CT and MRI.[47] In this review article, references is made to Young[45] and Mastaglia[46], but also to two more studies[48, 49] which compare MRI to CT, but in a variety of pathological conditions, one of which was MS. This author concludes that "*...Early work with nuclear magnetic resonance imaging indicates that this new technique is more sensitive even than computed tomography for the detection of demyelination, and may well prove to be the technique of choice for the investigation of this problem.*"

In a next formal comparison between CT and MRI in 10 definite MS patients, Lukes et al.[50] found that CT did not demonstrate demyelinating lesions with sufficient sensitivity to be useful in the assessment of MS. MRI did, and the additional use of a spin-echo sequence yielded more lesions. The authors conclude that '*Spin-echo and inversion recovery imaging each demonstrate more extensive abnormalities than did computed tomography*'. In reaction to Lukes[50], Sears[51] draws the attention to the lack of a contrast agent to test the integrity of the blood brain barrier (at that time), and concludes that MRI is superior for detection, but contrast enhanced CT is the only technique to show disruption of the blood-brain-barrier and hence active MS.

A larger study of formal comparison between CT and MRI is from Sheldon et al.[52] In this study of 74 patients with definite or probable MS, MRI and clinical evidence had equal sensitivity for the detection of MS lesions, MRI was more specific for the location. The authors also conclude that MR imaging is more sensitive than computed tomography (CT), which was positive in only 25% of 59 patients with definite MS while MRI was positive in 85% in such patients; MR was always positive when CT was positive; and ' *...it probably can replace CT in the diagnosis and follow-up of patients with MS.*"

In a study with 27 patients with MS, Jacobs et al.[53] reported a sensitivity of 78% for MR and 63% for CT for lesion detection.

In a study in adolescents, Osborn et al.[54] reported a higher sensitivity for MR of the brain to detect lesions, 6/12 subjects had normal brain CT while only 3 of these had normal brain MRIs. MRI was always positive if CT was positive, and showed many more lesions in the brain. In this study spinal chord lesions were detected in all 4 patients with a suspicion for such lesions, no CT of the spine was performed.

Nesbit et al.[55], without quoting any numbers, only reported the detection of more lesions with MR than with CT in a series of 22 patients were both techniques were retrospectively reviewed.

In a 2 year follow-up study of 200 patients with suspected MS, Lee at al.[56] reported that in 55/200 patients who converted to CDMS, the initial MRI showed MS-like lesions in 52/55 (95%) while a CT abnormality was found in only 21/55 (38%). Of all the paraclinical tests used (MRI, CT, sensory evoked potentials (SEP), visually evoked potentials (VEP) and cerebro-spinal fluid (CSF) oligoclonal bands), CT had the lowest sensitivity and MRI the highest (95%, 38%, 64%, 69%, 69%). From this study, sensitivity, specificity, positive predictive value and negative predictive value parameters calculated as 95%, 49%, 44% and 95% for MRI, and 38%, 80%, 45% and 75% for CT. The authors conclude that CT was not diagnostically helpful and based on their data felt that when MRI is available, CT is not necessary for proving dissemination of lesions in space.

With the introduction of intravenous contrast agents, e.g. gadolinium chelates, in 1984,[57-59] the early obstacle[50, 60] of not being able to see so called active lesions similar to contrast enhanced CT quickly became a problem of the past.[61, 62] An initial study in 15 patients only [62], also promised a higher sensitivity for contrast enhanced MRI over contrast enhanced CT in the detection of active MS lesions. Another study[63] compared contrast enhanced CT with MRI with gadolinium in 50 subjects with a variety of pathology (brain tumors, multiple sclerosis and nasopharyngeal tumors). For the MS patients, MRI plus gadolinium always performed better than CT with contrast. All of these studies concerned small number of patients (evidence level 1) without producing hard numbers on sensitivity and specificity, and no more extensive systematic comparison is reported in the literature thereafter.

The above literature was enough evidence for the medical community to select MRI as the imaging method above CT whenever a patient was referred for the diagnosis of MS. Therefore and because of circumstantial evidence in daily practice, in recent literature, no more comparative studies were reported using both techniques for the diagnosis of MS. It is considered unethical in the diagnostic work-up to use a much less sensitive technique as CT with a relative high radiation burden and much more contrast hypersensitivity when MRI is available.

4.1.3 Infection

The incidence of central nervous system (CNS) infection has increased significantly in the past 15 years. This can be attributed primarily to the acquired immunodeficiency syndrome (AIDS) epidemic and its devastating effect on the immune system and secondarily to various immunosuppressive agents that are being used in aggressive cancer treatment and in organ transplantations. The early detection and specific diagnosis of infection are of great importance, since brain infections are potentially treatable diseases. Imaging studies play a crucial role in the diagnostic process, along with the history (exposure to infectious agents), host factors (open head trauma, CSF leak, sinusitis, otitis, immune status), physical examination and laboratory analysis of CSF.[64]

4.1.3.1 Bacterial (pyogenic) infections

In a review article, the neuro-imaging findings of these infections are described according to the anatomic site, their complications, and their differential diagnosis.[65] The authors focus their attention on new techniques of MRI like perfusion, spectroscopy, and diffusion, for each specific situation such as meningitis, abscess, ventriculitis, purulent extra axial collections, and vascular complications.

Diffusion-weighted MRI is the preferred technique to differentiate bacterial abscess from necrotic tumor. Diffusion-weighted MRI shows high signal intensity in most cases of pyogenic abscess and low signal intensity in most cases of cystic or necrotic tumor.[66, 67] In another review study, 38 of 39 previously reported abscesses were hyperintense on diffusion-weighted MRI with reduced apparent diffusion coefficient (ADC).[68] Conversely, of 165 nonpyogenic lesions with DWI findings, 87 were hypointense or isointense, 78 lesions had variable hyperintensities, and few manifested the degree of

hyperintensity observed with abscesses. MR spectroscopy shows characteristic metabolites in pyogenic abscesses, distinct from those in cystic or necrotic tumors.

The role of MRI in imaging meningitis is well established.[69] Contrast-enhanced T1-weighted MRI is the preferred imaging technique in bacterial meningitis.[70] Fluid-attenuated inversion recovery (FLAIR) has also shown promise in the detection of subarachnoid space disease, but the sensitivity of FLAIR depends on CSF protein concentration threshold. Hyperintensity on FLAIR generally correlates with contrast enhancement on T1-weighted images. At present FLAIR cannot replace contrast-enhanced T1WI in diagnosing bacterial meningitis.

4.1.3.2 Tuberculosis

Tuberculosis is becoming an increasingly troublesome public health problem. Central nervous system (CNS) infection with Mycobacterium tuberculosis occurs either in a diffuse form as basal exudative leptomeningitis or in a localized form as tuberculoma, abscess, or cerebritis.[71] In a review paper, the authors report on the pathogenesis and radiological findings of meningo-encephalic tuberculosis.[72] Imaging manifestations are very pleomorphic and can mimic parenchymal cerebral mass lesions or meningeal processes of different nature. Although imaging findings are generally non-specific, modern imaging is a cornerstone in the early diagnosis of CNS tuberculosis and may prevent unnecessary morbidity and mortality.[72] Contrast-enhanced MR imaging is generally considered as the modality of choice in the detection and assessment of CNS tuberculosis.[71]

4.1.3.3 Viral infections

Viral infections of the central nervous system encompass a wide range of different processes, mainly inflammation affecting the brain (encephalitis), the meninges (meningitis), or a combined meningoencephalitis.[73]

Viral encephalitis is a medical emergency. The spectrum of cerebral involvement and the prognosis are dependent mainly on the specific pathogen and the immunological state of the host. In a systematic review (SR), the authors searched MEDLINE (National Library of Medicine) for relevant literature from 1966 to May 2004.[74] Review articles and book parts were also included. The authors made recommendations based on this literature and based on their judgment of the relevance of the references to the subject. Recommendations were reached by consensus. Where there was lack of evidence but consensus was clear the authors have stated their opinion as good practice points. Neuroimaging, preferably by magnetic resonance imaging, is an essential aspect of evaluation (recommendation level B). One of the earliest MRI manifestations of adult encepahlitis is the hyperintense signal on diffusion-weighted images, which was the only positive MRI finding.[75]

4.1.3.4 Parasitic infections

Neurocysticercosis is a major public health problem in developing and some developed countries. The most frequent clinical manifestations of neurocysticercosis are seizures. The authors of this review study conclude that currently, the best procedures for diagnosing NC are neuroimaging studies {Carpio, 1998 #2402}. Immunoserologic assays, are useful in identifying a population at risk of contact with the parasite but do not necessarily indicate a systemic active infection. Most seropositive individuals are asymptomatic. There is a discrepancy between the results of serologic assays and neuroimaging studies: >50% of those individuals with neurocysticercosis diagnosed by CT or MRI test EITB negative.

Key points

- **When central nervous system (CNS) infection is suspected clinically, MRI is the exam of choice. CT has a low sensitivity for showing intracranial lesions. Evidence level 2.**
- **Diffusion-weighted MRI is the preferred technique to differentiate bacterial abscess from necrotic tumor. Evidence level 2.**
- **In patients with tuberculosis, contrast-enhanced MR imaging is considered as the modality of choice for detection of CNS involvement. Evidence level 3.**
- **In viral infections involving the brain (encephalitis or meningoencephalitis) magnetic resonance imaging is an essential aspect of evaluation. Evidence level 3-4.**
- **In parasitic infections of the brain, e.g. neurocysticercosis, neuroimaging procedures are useful (Evidence level 2). There is no conclusive evidence as to the choice of imaging procedure, i.e. CT versus MRI.**

4.1.4 Trauma

Traumatic injuries of the brain is a leading cause of death and permanent disability for individuals under 50 years of age.[76] Overall, head injuries account for 1% of all deaths but account for 15%–20% of deaths in the age group comprising 5–35 year olds.[77] More than half of traumatic deaths are associated with head injury, which is most commonly caused by motor vehicle accidents. Modern imaging techniques play an increasingly important role in the management of the patient with craniocerebral trauma and should be used, even in mild head injuries.[78]

The number of systematic review studies regarding the role of imaging in head injuries is rather limited, as shown in the recently published Canadian Health Technology Report.[79] There are studies available from Sweden[80], the United States of America[81, 82] and Scotland.[83]

In patients with "mild" head injury, Af Geijerstam and Briton[80] assessed how often a CT performed on a patient with a mild head injury revealed pathological findings. The reported rate of abnormalities on CT varied significantly from 3.3% to 34%. On the basis of 15 studies with reported use of CT, they found pathological findings in 7.8%. In general, they stated that of 1,000 patients arriving at hospital with a mild head injury, 1 will die, 9 will require surgery or another intervention, 80 will show pathological findings on CT and 80 will require inpatient care. The authors stated that the routine use of skull x-ray to triage patients with mild head injury is of less diagnostic value, but equal cost to CT. The authors stated that their work has severe limitations, due to the substantial variation in the case mix of patients in the included studies, the differences in definitions, and the differences in clinical practice.

Also in patients with "minor" head injury, Eng and Chanmugam[82] evaluated the incidence of injury-related abnormalities on CT. They analyzed 10 studies (with a total of 9,362 patients). They found that, in patients sustaining minor head injuries with a history of loss of consciousness or amnesia, the proportion that subsequently has an abnormal CT scan is not negligible. The incidence of abnormal CT scans ranged from 3% to 14% (mean 7.5% for patients with GCS of 13, 14, or 15; 6.2% for patientswith GCS of 15). Unfortunately, the limitations of this study were: heterogeneous patient groups and only prospective studies were included (narrowing study numbers); only English language articles were taken into account.

Only one review study compared CT and MRI to other imaging modalities. The work of Homer et al.[81] evaluated the pediatric literature to synthesize evidence for an American Academy of Pediatrics on head injury. A total of 108 articles were analyzed in this document. They were abstracted from 1033 abstracts and articles identified through the various search strategies. They found only five articles reporting on imaging modalities: skull x-rays, CT and MRI. CT served as the reference standard. CT is the

most sensitive and specific technique for detection of intracranial abnormalities. The data showed that skull x-rays displayed sensitivity and specificity rates inferior to CT. Although MRI performed well, it offered no clinical advantage compared with CT (this statement may need to be modified in view of technological advances in MRI such as diffusion-weighted imaging). The literature on mild head trauma does not provide a sufficient scientific basis for evidence-based recommendations about most of the key issues in clinical management. A major limitation, according to the authors, is the absence of consistent definitions and multisite assessments. Outcome studies are inconclusive as to the impact of minor head trauma on long-term cognitive function.

The Scottish Intercollegiate Guidelines Network (SIGN group) produced an extensive report on head injury, with imaging (CT) forming one piece.[83] The investigators concluded that "criteria for use of CT in less severe head injuries was the most controversial part of the guidelines development process." The report presents clinical scenarios where CT may be considered appropriate.

As far as the use of plain skull x-rays is concerned, the systematic review studies we consulted indicated that this technology is increasingly falling out of favour[81, 83, 80,83] Homer *et al.* stated that plain X-ray films of the skull do not have sufficiently high sensitivity and specificity to be clinically useful in most cases. The SIGN report commented about the progressive move away from skull x-rays in favour of CT for provision of a definitive answer.

There is increasing evidence that MRI, and especially diffusion-weighted images, contribute to a more accurate diagnosis of traumatic brain lesions. In one study, MRI findings on diffusion-weighted and conventional sequences were found to correlate with initial Glasgow Coma Scale score and score on modified Rankin scale at discharge.[84] The volume of lesions on diffusion-weighted MR images provides the strongest correlation with a score of subacute on modified Rankin scale at discharge. Total lesion number also correlates well with modified Rankin score. In future, diffusion-weighted images may be useful in determining treatment strategies for acute head injury.

Key points

- **Modern neuroimaging techniques play an essential role in the management of the patient with craniocerebral trauma. Evidence level I**
- **Skull X-rays do not, in most cases, have sufficiently high sensitivity and specificity rates to be clinically useful in the management of head trauma. They are inferior to CT. Evidence level 2**
- **In acute craniocerebral trauma, multi-detector CT scan is the preferred technique. Evidence level 3**
- **MRI, with diffusion-weighted images, contributes to a more accurate diagnosis of traumatic brain lesions and may be useful in outcome prediction. Evidence level 4-5**

4.1.5 Stroke

Two systematic reviews and 5 prospective comparisons were included in the evaluation.

One systematic review concluded that there was insufficient evidence to support the use of diffusion-weighted imaging and perfusion imaging in acute stroke.[85]

The other systematic review revealed the lack of information in the literature and the authors launched two prospective observational studies.[86] In 1000 patients, aged 70-74 years, the "scan all strokes immediately" strategy was more cost-effective than the "scan all strokes < 48 hours" strategy.[87] The authors have shown that increasing independent survival by correct early diagnosis ensuring appropriate treatment and management decisions, reduced costs of stroke and increased quality-adjusted life years.

Two prospective studies have assessed the sensitivity and specificity of diffusion-weighted MRI and CT in acute stroke patients.[88, 89] Diffusion-weighted MRI yielded far better results (sensitivity and specificity of respectively 91% and 95% for diffusion-weighted MRI and respectively 61% and 65% for CT).[88] Similar conclusion could be drawn from another paper (sensitivity and specificity of respectively 97% and 100% for diffusion-weighted MRI and respectively 40% and 92% for CT).[89]

For the detection of hemorrhage, CT and MR are comparable in the acute stage while MR is recommended to depict chronic bleeding.[90, 91] Looking at any type of hemorrhage in 200 patients, blood was depicted in 71 MR scans compared to 29 CT scans ($p < 0.001$). For acute hemorrhage MRI and CT yielded comparable results with 96% concordance. In chronic bleeding MR was positive in 49 patients while CT was not able to depict chronic bleeding.

Because CT is more accessible than MRI in the acute emergency situation, the role of CT perfusion and CTA were studied and found to be comparable to diffusion-weighted MRI and perfusion MRI.[92] However the available data are limited. Lesion volume was calculated using Spearman-rank correlation. For assessing time-to-peak perfusion $r= 1.0$ and $r= 0.9$ for MR and CT respectively. For assessing cerebral blood volume $r = 0.98$ and $r= 0.87$ for MR and CT respectively.

In 2003 one evidence based literature systematic review was published concluding that CT is recommended immediately in the acute stage in order to exclude hemorrhage.[93] The routine use of MRI prior to thrombolysis is not supported in the literature and clinical outcome data are lacking.

In a prospective study, patients admitted for an acute neuromedical and neurosurgical condition underwent both CT and MRI [94]. 3% of the strokes were incorrectly reported on CT. There was additional diagnostic information on MRI in 24% of the patients.

4.1.6 Aneurysm

Two systematic reviews, 3 prospective and 4 retrospective clinical studies were included.

The systematic reviews concluded that MRA and CTA performed well but not as good as the reference standard, DSA.[95, 96] The sensitivity and specificity were clearly better when looking at aneurysms > 3 mm (respectively 92.7 % and 96% for CTA and both 94% for MRA). These reviews concerned populations with high aneurysm prevalence.

One prospective clinical study dealt with MRA as screening tool in relatives of patients with an aneurysm.[97] A total of 33 aneurysms were found in 25/626 relatives (4% 95% CI 3-6). The positive predictive value of MRA was 100% (95% CI 79-100) for definite aneurysm and 58% (95/ CI 28-85) for possible aneurysm. The sensitivity was 83% (95% CI 65-94) and the specificity 97% (95% CI 94-98).

Several studies have looked at CTA and found sensitivities/specificities of 97%/50% [98] and 97%/86%.[99] The different results can possibly be explained by the number of patients which was 35 in the former study but 200 in the other retrospective study. In another older paper CTA nor MRA were found to be reliable.[100]

An ever increasing number of aneurysms is being treated by endovascular way. MRA was used in two retrospective studies. In one retrospective paper MRA was compared to the gold strandard DSA. MRA was considered useful as long term follow-up while the initial follow-up was recommended by MRA and DSA.[101] In a second, more recent, retrospective paper a comparison between MRA and DSA yielded a sensitivity/specificity of 89%/91% for MRA and MRA was recommended as a reliable diagnostic tool in the follow-up.[102]

One recent prospective clinical study ompared MRA with DSA for the diagnosis of recuurent/residual aneurysm and found that MRA could partly replace DSA (sensitivity/specificity of 72.7%/90.9% compared with DSA).[103]

4.1.7 Tumour

MRI is now routine part of the diagnostic work-up of an intracranial tumour. This is mainly due to the superior resolution and the multiplanar imaging capability. In a systematic review, Hutter et al. provide a decision tree for work-up of patients with suspected brain neoplasm, but they stress the possible necessity to tailor the work-up to the individual patient.[104]

There is insufficient supporting evidence that MR spectroscopy and newer techniques such as functional MRI and diffusion tensor imaging make a difference for treatment choices or patient outcomes, although it might be of benefit in individual patients.

It is well known that MRI is superior to CT in the detection of small metastases and in the demonstration of more than one metastasis.[2]

As a general rule for the exclusion of metastases in a patient with a known primary cancer, MRI is directly indicated whenever the detection of metastases would alter management.[104] In a prospective study on the use of brain imaging in 125 patients, MRI has been recommended in the staging of small cell lung cancer because of the possible changes in management.[105]

Follow-up imaging after therapy remains poorly studied. In one study the authors studied surveillance imaging after tumour surgery in children.[106] Based on their findings in 59 patients, they recommend imaging every 3 months for the first 2 years, the every 6 months for the next 2 years and yearly for the next 5 years. They found no benefit of imaging following total resection.

In patients with hyperprolactinaemia MRI should always be obtained because of the high incidence of pituitary tumours.[107] Another paper investigated the use of MRI following surgery for a pituitary macoadenoma.[108] MRI was used before surgery, immediately after surgery, after 3 months and after one year. A delayed regression of the sellar contents was observed after surgery. The authors concluded that MRI should be performed not earlier than 3 months after surgery.

Occasionally the visualisation of the venous system can be important in cranial tumour surgery. One paper found that MR venography is reliable as a diagnostic method and that it can replace DSA.[109]

4.1.8 Degenerative diseases

Five systematic reviews, one prospective randomized comparison and one retrospective paper, dealing with degenerative disorders, were included.

In one systematic review, the use of neuroimaging was considered useful in excluding treatable diseases but at that stage the authors found no evidence of clinical rules to identify patients who should undergo imaging.[110, 111] This review was published 6 years ago and MR morphometry had not been applied yet in large patient populations at that time. The increasing use of brain MR volumetry in research conditions is steadily leading to the introduction of this additional tool in clinical practice. However it should be emphasized that these newer techniques mainly have research significance.

Most attention is being paid to Alzheimer dementia. In a systematic review on 626 patients with mild cognitive impairment, a significant hippocampal and entorhinal cortex volume reduction was observed.[112] Similar conclusions were drawn from another review and it was concluded that MRI (including MR volumetry) was useful to predict future development of Alzheimer disease or to depict those at risk of developing Alzheimer disease.[113, 114] Neuroimaging is valuable in predicting future development of Alzheimer disease in individuals with dementia. Quantitative MR techniques and PET are sensitive to the structural and functional changes in the brain of patients with mild cognitive impairment. Hippocampal volume measurements are associated with future development of Alzheimer disease in these individuals.

One retrospective paper reported a high sensitivity and specificity (91%/95%) of diffusion-weighted MRI compared to conventional MRI for Creutzfeldt-Jakob disease, supporting its use whenever there is a clinical suspicion.[115]

In a prospective randomized comparison of CT and MRI prior to pallidotomy, the authors found that the MRI coordinates were significantly closer to the target, however without difference in surgical outcome.[116]

4.1.9 Headache

Five interesting retrospective papers were published on headache and migraine. One paper, on 302 children and adolescents, concluded that MRI is not indicated in uncomplicated migraine or chronic daily headache.[117, 118] Two retrospective reviews respectively on 1233 and 402 adult patients demonstrated the low percentage of clinically significant results of MRI in nonfocal headache.[119, 120] MRI was not considered cost-effective in this indication. Patients with atypical headaches may benefit from imaging because of the higher yield of major abnormalities with possible therapeutic consequences.[120]

The routine use of MR angiography in migraine is not indicated.[121]

A review, using a decision-analytic Markov model and cost-effectiveness analysis , on 315 children with headache and a suspected brain neoplasm, led to the definition of three subgroups: low, intermediate and high risk.[122] In the low risk group -non migraine headache > 6 months- the most effective approach is not to perform imaging. In the intermediate group -migraine headache- the use of CT (and MRI when CT is positive) is the most effective but also the most costly approach. In the high risk group -headache < 6 months with associated red flag signs (e.g. headache at night, vomiting, seizures) - neuroimaging is always indicated and MRI is the most effective approach.

It is important to emphasize that these large studies were performed in tertiary care centers and that the selection of patients was biased.

4.1.10 Cranial Nerves

Three studies were included. One prospective single blinded comparative study demonstrated high sensitivity (90.5%) and specificity (100%) of MRI, compared to the surgical findings, in demonstrating compression in trigeminal nerve neuralgia.[123]

In a retrospective study on the diagnostic evaluation of 6th nerve palsy, MR was considered superior to CT.[124] CT was considered useful in acute trauma and in suspected bone disease. No sensitivity analysis was performed.

Finally, a retrospective observational study concluded that MRI can successfully differentiate optic neuritis from nonarteritic anterior optic nerve neuropathy.[125] MRI was abnormal in 31/32 patients with optic neuritis and in only 5/32 patients with nonarteritic anterior optic nerve neuropathy.

4.1.11 Pediatric neuroimaging

The superiority of MRI compared with CT is generally accepted for pediatric neurological imaging.[4] The imaging of congenital malformations, the relative higher frequency of cerebellar and brain stem lesions and the assessment of myelination are a few examples that illustrate this superiority.

In a retrospective clinical study in neonates, the detection of ischaemia and/or hemorrhage was similar on CT and MRI but the interobserver agreement was greater for MRI.[126] The readers agreed on CT in 40 patients (83.3%) and on MR in 45 patients (93.5%). There was no significant difference between the CT and MR test results for reader 1 and 2. For CT the kappa coefficient (0.68) indicated an excellent interobserver agreement. For MRI the kappa coefficient (0.88) indicated an almost perfect agreement.

A report of the Quality Standards Subcommittee of the American Academy of Neurology and the Practice Committee of the Child Neurology Society has recommended neuroimaging as part of the diagnostic work-up of the child with global

developmental delay.[127] The subgroup presenting with abnormalities on physical examination may particularly benefit from a scan. MRI is preferred over CT.

Non-accidental head injury ("whiplash-shaken infant" or "battered child") is an entity where randomized controlled trials will never be possible. Based on an expert opinion and the available evidence in the literature up to now, a protocol has been suggested for investigating these children.[128] CT remains the mainstay in the diagnosis but MRI is included in the protocol and should preferably be obtained on day 3 or 4 of admission. MRI may show additional abnormalities or may show abnormalities, not visible on CT.

4.1.12 Foetal

Although the field of fetal neuroimaging is rather new, there have been 2 studies comparing ultrasound to MRI. In a prospective observational study on 100 patients, MRI changed diagnosis or provided extra information that altered management in 35%.[129] Similar figures were obtained in a retrospective study on 214 fetuses.[130]

Key points

- Whenever multiple sclerosis (MS) is clinically suspected in a patient, or MS has to be excluded, MRI is the exam of choice. CT is not indicated in the search for multiple sclerosis, the sensitivity is too low. Evidence level 2
- In acute stroke diffusion-weighted MRI is clearly superior to CT, but the easy access to CT and the absence of evidence to support the use of MRA prior to thrombolysis do not allow recommendations. Evidence level 2.
- MRA (or CTA) can replace digital subtraction angiography (DSA) in screening patients at risk of having an aneurysm. MRA can also partly replace DSA in the follow-up after endovascular treatment. Evidence level 2.
- In the assessment of intracranial tumours, MRI is the modality of choice, but the newer MR techniques e.g. spectroscopy, functional MRI and diffusion tensor imaging are not yet validated but appear to be of interest in individually tailored cases. Evidence level 2.
- The role of MR morphometry in the work-up of cognitive impairment is promissing, but in daily practice the tools for this assessment are not yet available in a user-friendly way. Evidence level 1.
- Neuroimaging is not necessary in every type of headache/migraine. When the risk of having a tumor is intermediate or high, MR imaging becomes more effective. Evidence level 2.
- In cranial nerve neuropathy, MRI is superior to CT. Evidence level 2.
- MRI is the examination of choice in paediatric neuroimaging. Evidence level 2.
- Ultrasound remains the mainstay in fetal imaging, but MRI plays an important role in elucidating ultrasonographical abnormalities. Evidence level 2.

4.2 SPINE AND SPINAL CORD

4.2.1 Degenerative disorders of the cervical spine

Cervical spine pathology remains a challenge. MRI has been compared to CT myelography in a prospective study of 18 patients [131] and CT myelography was superior to MRI in assessing the bony structures and the anterior/posterior nerve roots. MRI tends to overestimate abnormalities. This confirms the results of an earlier prospective study, that concluded that there is still a role for CT and CT myelography in cervicobrachialgia and neck pain.[132]

In one study on a rare cervical spinal cord disease, MRI was found useful to support the clinical diagnosis of primary ganglionopathy.[133]

4.2.2 Degenerative disorders of the lumbar spine

Original articles and reviews indicate that magnetic resonance imaging is accurate in detecting and characterising degenerative intervertebral disc disease and more sensitive and specific than plain radiography, computed tomography and bone scintigraphy.[134] For herniated discs, the sensitivity and specificity of MR imaging (Se = 0.6 to 1.0 and Sp = 0.43 - 0.97) is only slightly higher than those for computed tomography (Se = 0.62 to 0.9 and Sp = 0.7 - 0.87).[134]

However, not MR imaging, but discography remains the only test that provides physiologic information regarding what role a given intervertebral disk plays in a patient's symptom complex.[135, 136]

There is only a low to no correlation between imaging findings and clinical symptoms: MR demonstrates a wide spectrum of abnormalities attributable to degenerative intervertebral disc disease in both symptomatic and asymptomatic individuals.[137-139]

Careful correlation between imaging findings and clinical findings is essential to determine the significance of these abnormalities and to ensure appropriate treatment. Moreover, the findings on magnetic resonance scans are not predictive of the development or duration of low-back pain in the future.[140]

The imaging strategy for patiens with low back pain will vary according to the background of acute or persistent low back pain.[141, 134]

In the large majority of patients with acute low back pain, radiographs are only obtained when the low back pain persists longer than 6 to 7 weeks, because early use of imaging does not appear to affect treatment overall and increases costs significantly.[141, 142] Secondary, MR imaging may be performed in case of worsening and persistence of the clinical symptoms or if a specific low back pain or systemic disease is suspected.

In case of acute low back pain with neurologic complications (e.g. cauda equina syndrome, paresis or palsy), an urgent MR examination is indicated. In acute low back pain with atypical clinical signs, postero-anterior and lateral radiographs of the lumbar spine are required. An additional MR examination is often necessary, even with negative radiographs, especially to evaluate neurologic complications.[141]

In case of chronic low back pain, with a severe socio-professional impact or a planned invasive treatment, plain films of the lumbar spine must be obtained, eventually with additional MRI examination, although some physicians prefer to request MR imaging as first imaging study, without preceding conventional radiography. CT scan is better to depict bony structures (e.g. in osseous spinal stenosis) and may provide similar diagnostic information as MR imaging. Nevertheless, MR is the imaging technique of choice because of its superior depiction of neurologic structures and because no ionising radiation is used.

During the introduction period of MR as a new imaging technique (before 1995), the volume and cost of diagnostic imaging for persistent low back pain increased, because MR imaging was used primarily as an add-on rather than a substitute for other imaging modalities in the evaluation of persistent low back pain.[143, 144] Later, when MR was

more readily available, the cost of preoperative investigation per operated patient decreased by 35% , because of a decreased use of MR imaging as add-on imaging technique and more as immediate second investigation after plain radiography.

Although technically a rapid MR imaging study is possible, rapid MR imaging and radiographs result in nearly identical outcomes for primary care patients with low back-pain. Rapid MR is therefore not recommended to replace radiography of the lumbar spine: it may increase the costs of care because of the increased number of spine operations that patients are likely to undergo.[145]

4.2.3 Trauma

MRI plays a crucial role in spinal cord trauma particularly when multislice CT fails to demonstrate a bone lesion in a trauma patient with neurological deficit.[146, 147] In a retrospective before-and-after study the effectiveness of MRI was demonstrated [146]. The effectiveness analysis showed that time to clearance was significantly shorter in the MRI protocol. For other outcome measures, e.g. the average length of stay in the intensive care unit and in the hospital, the MRI protocol was favoured, although the differences did not reach statistical significance. In another retrospective study on trauma patients with altered mental status, the authors suggested that MRI should be performed whenever initial CT was suggestive of traumatic injury.[148, 149] However when multi-slice CT of the whole cervical spine is normal in obtunded and or "unreliable" patients with blunt trauma, MRI seems not to be indicated although the authors acknowledge that further investigation and a larger prospective study are needed.[150]

One meta-analysis looked at 392 published cases with pediatric spinal cord injuries without radiological abnormality.[151] They recommend MRI whenever CT does not show any significant damage, but, again the authors recognize that a prospective study is needed to substantiate the findings of the meta-analysis.

4.2.4 Malignancy: spinal cord compression

One systematic review, one prospective observational and one retrospective study on suspected spinal cord compression by malignancy were included. In the systematic review the sensitivity and specificity of MRI varied from respectively 44-93% and 90-98% and, although sensitivity and specificity values of CT-myelography were excellent too (sensitivity ranging between 71-97% and specificity 88-100%). MRI is the preferred technique because of the rapidity and non-invasiveness of the technique.[152] In an older retrospective study on 155 patients, similar conclusions were drawn on the superiority of MRI.[153] A prospective study on 280 consecutive patients with suspected malignant spinal cord compression revealed that urgent MRI was indicated in most patients.[154]

Concerning multiple myeloma, an expert opinion was published recommending MRI in all patients with neurological presentation suggestive of spinal cord compression [155]. MRI should also be performed in patients with a solitary plasmocytoma of bone irrespective of site of the index lesion.[155] Although it was recognized that MRI may be considered useful in monitoring of disease, there is still little experience of assessing MRI appearances after therapy.

4.2.5 Malignancy: spinal metastasis

Original articles and reviews indicate that magnetic resonance imaging is accurate in detecting and characterising spinal vertebral metastasis (Se = 83 % - 93 %, Sp = 90 % - 97 %) and more sensitive and specific than plain radiography (Se = 21 %), computed tomography and bone scintigraphy (Se = 74 %, Sp = 95 % - 99 %).[156-159, 134, 160]

In patients with known primary malignancy and suspicion for metastatic spread to the spine, whole spine MR imaging should be the first choice investigation, as it provides maximum benefit to the patient and avoids examination cascades.[158] MR imaging should be performed very early, when weakness and/or sensory problems are noticed, and should not be delayed until pain or paresis appear.[160]

In some instances differential diagnosis with osteoporotic or acute traumatic vertebral fractures may be difficult, but there are some signs allowing differentiation between benign and malignant vertebral fractures, like paraspinal soft tissue mass, pedicle involvement, posterior element involvement, "fluid sign" and a time-intensity curve with rapid contrast wash-in followed by early wash-out, all signs in favour of malignancy.[161-165]

Although conventional spin-echo imaging allows diagnosis in a large majority of cases, in some instances special MR imaging techniques may be helpful.[166-168]

An economic evaluation (cost-benefit analysis) revealed that MR imaging is cost-effective relative to planning without MR imaging in planning irradiation fields in patients with spinal metastasis and leads to savings by avoiding recurrence treatment.[169]

There is currently not enough evidence to support the routine use of "rapid MR imaging" to detect cancer as a cause of low back pain in primary care patients referred for imaging to exclude cancer as a potential cause of their pain.[170]

Key points

- MR imaging is accurate in detecting and characterising degenerative intervertebral disc disease and disc herniation (evidence level 2).
- A wide spectum of imaging findings is found in both symptomatic and asymptomatic individuals (evidence level 2).
- Correlation between imaging findings and clinical symptoms is low (evidence level2).
- Careful clinical correlation is essential to determine the significance of MR imaging abnormalities and to ensure appropriate treatment (evidence level 2).
- In the large majority of patients with acute low back pain, imaging studies are only obtained when the low back pain persists longer than 6 weeks, because early use of imaging does not appear to affect treatment overall and increases costs significantly (evidence level 6)
- Urgent MR is indicated in patients with acute neurologic deficit (evidence level 5).
- Plain radiography, eventually followed by an additional MR imaging is needed only in a selected group of patients (evidence level 2).
- During the introduction period of MR as a new imaging technique, the volume and cost of diagnostic imaging for persistent low back pain may increase, because MR imaging might be used primarily as an add-on rather than a substitute for other imaging modalities, especially CT (evidence level 2).
- A rapid MR technique is not recommended to replace radiography of the lumbar spine, because it increases costs (increased number of spine operations) (evidence level 6).
- Magnetic resonance imaging is accurate in detecting and characterising spinal vertebral metastasis and more sensitive and specific than plain radiography, computed tomography and bone scintigraphy (evidence level 2).
- In patients with known primary malignancy and suspicion for metastatic spread to the spine, whole spine MR imaging should be the first choice investigation (evidence level 2).
- MR imaging is cost-effective in planning irradiation fields in patients with spinal metastasis (evidence level 6).
- There is currently not enough evidence to support the routine use of "rapid MR imaging" to detect cancer as a cause of low back pain in primary care patients referred for imaging to exclude cancer as a potential cause of their pain (evidence level 6).
- In degenerative cervical spine disorders, there is still a role for CT apart from MRI.
- In spinal trauma MRI is indicated whenever CT does not explain the neurological deficit (evidence level 2).
- In suspected malignancy (metastatic or multiple myeloma) with spinal cord compression, MRI is highly indicated (evidence level 2).

4.2.6 Infection

In a case series analysis of 59 patients with thoracic and lumbar spondylodiscitis, it was shown that MRI was indicated to differentiate between spondylitis with an associated abscess and those without.[171] For the follow-up CT was preferred for demonstrating regressive inflammation and increasing osseous consolidation after 5-6 weeks. Because of its intrinsic high resolution in spinal imaging MRI has been recommended in general as the modality of choice in infectious disorders.[172] The sensitivity to differentiate between spondylitis without and with abscess was 85 % for MRI and 69% for CT.

4.2.7 Congenital spinal abnormality

The most common congenital spinal abnormality is lumbosacral spinal dysraphism. In a systematic review, the need for a prospective study was emphasized.[173] The study population consisted of newborns who were suspected of having occult spinal dysraphism. Three groups were analyzed on the basis of disease prevalence. In the low-risk group (0.3%) neonates with an intergluteal dimple and infants from diabetic mothers were included. The intermediate risk group consisted of low and intermediate anorectal malformation (27-33%). The high risk group was associated with high anorectal and cloacal malformations (44-46%). The sensitivity of the diagnostic strategies was estimated to be 95.6% (95% CI 89.8-99.7) for spinal MRI, 86.5% (95% CI 75-88) for US, and 80% (95% CI 80-100) for plain radiographs. The specificity was estimated to be 90.9% (95% CI 75.7-98.1) for spinal MRI, 92.9% (95% CI 84-100) for US, and 18% (95% CI 11-25) for plain radiographs. Based on a cost-utility analysis, the authors found MR to be the modality of choice in newborns at high risk. In newborns at low risk, ultrasound is the most effective approach as it was the most cost saving technique. In the intermediate risk neonate there is no clear cut choice between either ultrasound or MRI.

Key points

- **In spinal infection, MRI plays a role particularly because of its higher intrinsic resolution. Evidence level 2.**
- **In spinal dysraphism, the role of MRI will be defined by the clinical level of suspicion. Evidence level 2.**

5 CARDIAC RADIOLOGY

5.1 ISCHEMIC HEART DISEASE

5.1.1 Myocardial ischemia

The role of MRI in assessing myocardial ischemia is focused either on detecting significant coronary artery stenoses, usually defined as a luminal narrowing varying between 50% and 75% (i.e., *anatomical imaging*), or on assessing the haemodynamic consequences of obstructive coronary artery disease (CAD) (*functional imaging*).

5.1.1.1 Anatomical Imaging

Anatomical imaging of the coronary artery tree with MRI, usually called magnetic resonance coronary angiography (MRCA) is nowadays achieved using three-dimensional approaches in breath-hold or using a free-breathing navigator approach. Three reviews have recently evaluated its role, comparing this technique with multislice computed tomography (MSCT), electron beam tomography (EBT), using catheter-based coronary angiography (CA) as reference standard.

Budoff et al.[174] (2003) compared MRCA, MSCT, and EBT to CA. For MSCT, eight studies were analyzed and for MRCA five studies. For MSCT (4, 8, 16 row scanners), the range for sensitivities was 37% to 85%, with a summary value of 59%; for MRA the sensitivities ranged 40% to 90%, no summary value was provided. The specificities for MSCT ranged 76% to 99% with a summary value of 89%. For MRA the range was 89% to 97% (no summary value was provided).

Danias et al.[175] (2004) compared the diagnostic performance of MRCA to CA (period 1991 to 2004). They analyzed 39 studies (41 separate comparisons). Across 25 studies (27 comparisons) with data on 4620 segments (993 subjects), sensitivity and specificity for detection of CAD were 73% and 86%, respectively. Vessel-level analysis (16 studies, 2041 vessels) showed sensitivity 75% and specificity 85%. Subject-level analyses (13 studies, 607 subjects) showed sensitivity 88% and specificity of 56%. At the segment level, sensitivity was 69% to 79% for all but the left circumflex (61%) coronary artery; specificity was 82% to 91%. Analysis showed considerable between-study heterogeneity, but weighted summary receiver-operating characteristic curves agreed with these estimates. It has to be mentioned that a considerable number of segments (ie, mainly distal parts of coronary artery tree, and side branches) were not evaluable for analysis, while the above-mentioned results were based on the evaluable segments.

Schuijf et al.[176] (2006) compared MRCA and MSCT to CA (1993-2005)(Table 1). They analyzed 51 studies (24 MSCT studies (4,8,16 slice), 32 MRCA studies). MRCA showed a sensitivity of 72%, a specificity of 87%, MSCT showed a sensitivity of 85% and a specificity of 95%. The odds ratio was significantly higher for MSCT (16.9 fold) than MRCA (6.4 fold) ($p < 0.0001$). The specificity for MSCT versus MRCA was better in lower disease prevalence populations. Taking into account the uninterpretable segments, the sensitivity of MRCA was 58%, the specificity 70%.

The most recent improvements in MRCA were achieved using a more-simplified whole heart technique [177], allowing a complete analysis of the coronary artery tree in less than 30 minutes. They studied 39 patients, with CA in 20 of them. MRCA showed a sensitivity of 82%, a specificity of 91%, a positive predictive value of 78% and negative predictive value of 93%. Sommer et al.[178] (2005) evaluated the use of 3.0T to study patients suspected of having coronary artery disease. In 18 patients, they reported a sensitivity of 82% and specificity of 89%.

5.1.1.2 Functional Imaging

In resting conditions the myocardial blood is preserved even in the presence of a high-grade coronary artery stenosis. In conditions of increased myocardial oxygen consumption, 50 to 75% coronary artery stenoses become symptomatic. Detection of functionally important stenoses with MRI is achieved by increasing the myocardial contractility (and thus the oxygen consumption) most often using an incremental dose of dobutamine (10, 20, 30, 40 microgram/kg/min) optionally 0.25 mg fractions of atropine up to a maximal dose 1 mg till the patient develops ischemia-related chest pain, myocardial wall abnormalities occur, or the target heart rate is reached. The second approach is first-pass myocardial perfusion MRI in rest and stress conditions (using dipyridamole or adenosine). A steal-phenomenon to normally supplied myocardium causes myocardium supplied by funtionally significant stenoses to become hypoperfused, visible as dark myocardial areas. Myocardial perfusion analysis is performed visually or semi-quantitatively using the upslope curves of changes in signal-intensity during the first-pass of contrast. Myocardial perfusion reserve indices can be calculated when performing myocardial perfusion in resting and stress conditions.

Dobutamine stress function MRI

Ischemia-related wall-motion abnormalities can be very well depicted with MRI. In a MRI environment, use of dobutamine is more appealing than physical exercise. In contrast to earlier studies (before 1998), nowadays high-dose dobutamine with atropine is recommended to most accurately study CAD patients. Diagnostic results are very good and direct comparison data with dobutamine stress echocardiography have shown superiority of MRI, due to a higher quality imaging (Table 5).[179] Especially in patients with poor echocardiographic image quality, stress function MRI may be the alternative [180]. In a routine clinical setting, this technique proved to be feasible and safe, resulting in a high number (89.5%) of successful diagnostic examinations.[180] High-dose dobutamine stress studies performed in more than 1000 patients has shown to be a safe procedure (Table 6).[181, 182].

This technique can be applied in the diagnosis of CAD, pre-operative risk assessment,[183] in the follow-up after revascularization procedures,[184] as well to forecast myocardial infarction or cardiac death.[185] In a multivariate analysis, the presence of inducible ischemia (hazard ratio 3.3, CI 1.1 to 9.7) or an ejection fraction less than 40% (hazard ratio 4.2, CI 1.3 to 13.9) was associated with future MI or cardiac death independent of the presence of risk factors for coronary arteriosclerosis (level 4)[185].

Table 5: Summary of the dobutamine stress MRI studies (1999-2006) in patients with suspected CAD

Study/Year	N Pts	Sensitivity	Specificity	Reference	Evidence level
Nagel et al. 1999*	208	86 [74]	86 [70]	CA	Level 2
Hundley et al. 1999	153	83	83	CA	Level 2
Schalla et al. 2002	22	88	83	CA	Level 1
Kuypers et al. 2003	211	-	-	CA	Level 3
Wahl et al. 2004	160	89	84	CA	Level 2
Paetsch et al. 2004	79	89	96	CA	Level 2
Total (4 studies)	622	87	86		

Nagel et al. 1999[179], between brackets are shown the values for dobutamine stress echocardiography

Stress Perfusion MRI

Table 6: Summary of the MRI myocardial perfusion studies (2000-2006) in patients with suspected CAD

Study/Year	N Pts	Sensitivity	Specificity	ROC curves	Reference	Evidence Level
Al-Saadi et al. 2000	15	90	83		CA	Level 2
Panting et al. 2001	26	79	83		SPECT	Level 2
Schwitter et al. 2001	48	87	85		CA/PET	Level 2
Ibrahim et al. 2002	25	69	89		CA/PET	Level 2
Sensky et al. 2002	30	93	60		CA	Level 2
Nagel et al. 2003	84	88	90	0.933	CA	Level 2
Ishida et al. 2003	109	90	85	0.888/0.911	CA/SPECT	Level 2
Takase et al. 2004	76	93	85		CA	Level 2
Wolff et al. 2004*	99	93	75	0.90	CA	Level 2
Thiele et al. 2004	32	75	97	0.83	CA/SPECT	Level 2
Plein et al. 2004**	68	88 / 96	83 /83		CA	Level 2
Ishida et al. 2005***	49	88	86		CA	Level 2
Sakuma et al. 2005	40	70	87	0.86/0.84	CA/SPECT	Level 2
Bernhardt et al. 2006***	738	96	87		CA	Level 2
Total (14 studies)	**1447**	**86**	**84**	**0.88**		

Wolff et al. 2004:* dose-ranging study (0.05, 0.10, 0.15 mmol/kg)
*Plein et al. 2004**:* stress perfusion / comprehensive approach (including perfusion-MRCA - wall motion - late contrast enhancement)
****:* comprehensive approach (including perfusion- late contrast enhancement).

Other applications of stress perfusion MRI include the detection of cardiac syndrome X (microvascular disease) [186]. This technique, because of its superior spatial resolution, may be superior to SPECT in the detection of subendocardial hypoperfusion, usually in combination with intense chest pain during the intravenous administration of adenosine.

5.1.1.3 Myocardial infarct and viability imaging

Imaging of acute and chronic myocardial infarction with MRI has gained widespread acceptance since the introduction of the contrast-enhanced inversion-recovery MRI (CE-IR MRI) technique with delayed or late imaging.[187] Studies in animal models have shown an extremely close match between in-vivo CE-IR MRI and ex-vivo histochemical staining (Level 1).[188-191] This technique is significantly better in detecting less extensive (i.e. subendocardial) infarcts than other established techniques such as SPECT imaging.[190] While sensitivities for transmural infarct detection were similar for both SPECT and MRI (i.e. 100%), infarctions with less than 50% transmurality were detected with a sensitivity of 92% for MRI but only 28% for SPECT. Specificities were similar for both techniques, i.e. 97%, (95% CI 0.946-0.987) for SPECT and 98%, (95% CI 0.968-0.998)(Level 2). In 91 patients, 85/181 segments (47%) with subendocardial infarction were not visible on SPECT. On a per patient basis, 13% individuals with subendocardial infarcts visible by MRI had no evidence of infarction by SPECT (Level 2). Similar results were found by Kitagawa et al.[192] (2003) reporting significantly higher values for predicting myocardial viability in patients with acute myocardial infarction for MRI than SPECT (sensitivity 98.0% vs 90.3%, $p < 0.01$; specificity 75.0% vs 54.4%, $p < 0.05$; and accuracy 92.0% vs 81.1%, $p < 0.001$)(Level 2). Contrast-enhanced MRI is significantly better in predicting infarct transmurality than traditionally accepted approaches such as presence of Q-waves on ECG.[193-195] The presence, location and extent of myocardial infarction can be accurately evaluated,[196-198] changes over time traced,[199, 200] impact on regional and global function quantified,[199, 200] as well as concomitant findings ruled out.[201] The pattern of enhancement in acute and chronic myocardial infarction is highly specific, and allows to differentiate from other myocardial diseases such as myocarditis.[202]

Other advantages of the use of MRI in infarct imaging is the unique potential to detect the presence of myocardial edema (T2weighted-STIR imaging), reflecting the extent of the 'area at risk' and thus allowing to detect the culprit lesion [203, 204]. Takahashi et al. reported significantly higher areas under the ROC curves for MRI (0.878) compared to nuclear imaging SPECT techniques (PYP: 0.787 / BMIPP: 0.725 / ^{201}TICI: 0.731, $p < 0.05$) (18 patients) (Level 2). Moreover, combined use of edema-weighted imaging and late enhancement allows to easily differentiate between acute and chronic myocardial infarction.[205, 206]

Presence of microvascular obstruction (i.e. no-reflow) in the infarcted myocardium can be easily and accurately depicted as an hypo-intense area in the infarcted myocardium on first-pass perfusion MRI or on early post-contrast MRI images,[207-211] Microvascular obstruction (on MRI) is an independent prognostic determinant of negative LV remodeling and worse patient outcome (Level 3).[212] MRI is well suited to evaluate the effects of medication on reducing the extent of microvascular obstruction.[213]

MRI has become a well-accepted technique to evaluate the effects of new therapies, such as stem-cell therapy (see table), on changes in infarct size, no-reflow size as well regional and global ventricular function (randomized, placebo-controlled study, confidence level-5) (Table 7).

Table 7: summary of randomized, controlled studies using MRI to evaluate the effects of stem cell therapy in patients with acute myocardial infarction

Author	Year / Journal	n patients	MRI
Britten et al.	2003- Circulation	28	Infarct size - Function
Wollert et al.	2004 - Lancet	60	Infarct size - Function
Janssens et al.	2006 - Lancet	60	Infarct + no-reflow size - Function
Zohlnhofer et al.	2006 – JAMA	114	Function

Assessment of **myocardial viability** in patients with chronic ventricular dysfunction presenting with heart failure is crucial in choosing the best therapeutic pathway. MRI has shown to be an important technique in predicting functional recovery following coronary revascularization.[214, 215] In a recent review paper by Kaandorp et al. 2005, the value of the different approaches (i.e. end-diastolic wall thickness, low-dose dobutamine stress MRI, CE-IR MRI with late enhancement imaging) was compared (Table 8-Table 10). Both end-diastolic wall thickness and late enhancement show a high sensitivity at the expense of specificity, while dobutamine stress MRI has the highest specificity to predict functional recovery post revascularization. Integrated use of particularly dobutamine stress MRI and contrast-enhanced MRI may be preferred for optimal detection of functional recovery. Additionally MRI can provide highly useful and accurate information on left ventricular ejection fraction, volumes, ischaemic mitral regurgitation and LV shape (aneurysms) which can be used to plan the surgical strategy.[216] Evidence level: 3. Comparison of contrast-enhanced MRI and positron emission tomography in the assessment of myocardial viability showed a good agreement between both techniques ($r=0.81$, $p<0.0001$ for quantitatively assessed infarct size on PET and MRI)(31 patients with ischemic heart failure, LVEF: 28± 9%). However, due the better spatial resolution of MRI, 11% of segments defined as viable by PET showed some degree of MRI hyperenhancement (Level 2).[217] Kuhl et al.[218] (2003) studied 26 patients with chronic CAD and LV dysfunction (LVEF: 31±11%) with PET and contrast-enhanced MRI (Level 2). They found an inverse relation between segmental glucose uptake by PET and segment extent of hyperenhancement ($r= -0.86$, $p < 0.001$). By ROC curve analysis, the area under the curve was 0.95 for the differentiation between non-viable and viable segments. At a cutoff value of 37%, segmental extent of hyperenhancement optimally differentiated viable from non-viable segments, yielding a sensitivity and specificity of contrast-enhanced MRI to detect non-viable myocardium as defined by PET of 96% and 84% respectively.[218]

Table 8: Value of end-diastolic wall thickness in predicting post-revascularization functionally recovery [216]

Study	No.of Patients	Segments with Recovery (%)	Sensitivity (%)	Specificity (%)
Baer et al. 1998	43	46	94	52
Klow et al. 1997	17	35	98	19
Schmidt et al. 2004	40	63	100	53
Average Weighted Mean	**33**	**48**	**95**	**41**

Table 9: Value of dobutamine stress in predicting post-revascularization functionally recovery [216]

Study	No. of Patients	Segments with Recovery (%)	Sensitivity (%)	Specificity (%)
Baer et al.	52	50	86	92
Baer et al.	35	52	81	95
Grunning et al.	23	57	50	81
Sayad	10	60	89	93
Baer et al.	43	46	89	94
Sandstede et al.	25	51	61	90
Trent et al.	25	40	71	70
Lauerma et al.	10	66	79	93
Wellnhofer et al.	29	NA	75	93
Average Weighted mean	**29**	**53**	**73**	**83**

Table 10: Value of late or delayed contrast enhancement in predicting post-revascularization functionally recovery [216]

Study	No.of Patients	Segments with Recovery (%)	Sensitivity (%)	Specificity (%)
Kim et al.	41	53	97	44
Lauerma et al.	10	66	62	98
Selvanayagan et al.	52	59	95	26
Wellnhofer et al.	29	NA	90	52
Average Weighted mean	**33**	**59**	**95**	**45**

A recent HTA (*Functional cardiac MRI in the assessment of myocardial viability and perfusion – Health technology literature review – November 2003 – Ontorio – Canada*) yielded a more neutral conclusion, but some of their conclusions need to be modified (see comments in italic):

1) There is some evidence that the accuracy of functional cardiac MRI (see above) compares favourably with alternate imaging techniques for the assessment of myocardial viability and perfusion.

2) There is insufficient evidence whether functional cardiac MRI can better select which patients (who have CAD and severe LV dysfunction (LVEF < 35%)) may benefit from revascularization compared with an alternate non-invasive imaging technology. *However, in the study by Klein and Kuhl, the pre-revascularization LVEF was lower than 35% (28%[217] and 31%[218], respectively).*

3) There is insufficient evidence whether functional cardiac MRI can better select which patients should proceed to invasive coronary angiography for the definitive diagnosis of CAD, compared with an alternative non-invasive imaging technology.

4) There is a need for a large prospective (potentially multicentre) study with adequate follow-up time for patients with CAD and LV dysfunction (LVEF < 35%) comparing MRI

and PET. *The study by Klein and Kuhl, was a MRI – PET comparison but without follow-up.*

5.1.2 Cardiac Masses and Tumors

No systematic reviews on cardiac masses and tumors are available. MRI is particularly helpful in determining the relationship to normal intracardiac structures and tumor extension to adjacent vascular and mediastinal structures, infiltration to the pericardium, surgical planning and tissue characterization. Because of the rarity of cardiac tumors, most papers in literature are case reports, or small patient groups. In 57 patients with ischemic heart disease, Mollet et al.[201] (2002) found 12 ventricular thrombi using the CE-IR MRI (used for myocardial infarct and scar detection), 6 thrombi using the cine MRI technique, and only 5 thrombi using transthoracic echocardiography. In another study, MRI showed to be helpful in differentiating between benign and malignant cardiac tumors.[219]

5.1.3 Myocarditis, Cardiomyopathies, Myocardial Hypertrophy, Heart Transplantation

No systematic reviews are available. The diagnosis of **myocarditis** remains difficult as symtoms are variable and often non-specific. However, several studies have shown a promising role for MRI in the diagnosis of this disease entity.[220, 221, 198, 222, 202] Contrast enhancement is a frequent finding in the clinical setting of suspected myocarditis and is associated with active inflammation by histopathology. Contrast MRI is a valuable tool for the evaluation and monitoring of inflammatory heart disease, typically appearing as a focal disease not infrequently involving the lateral wall. Abtel-Aty et al. (2005) studying 25 patients with suspected acute myocarditis and 23 healthy controls reported 76% sensitivity, 95.5% specificity, and 85% diagnostic accuracy. Although the diagnosis of **hypertrophic cardiomyopathy** is usually made by echocardiography, MRI is indicated to diagnose apical types of hypertrophic cardiomyopathy.[223] Moreover, in a recent comparative study between echocardiography and MRI (48 patients), MRI showed to be capable of identifying regions of LV hypertrophy not readily recognized by echocardiography and was solely responsible for diagnosis of the hypertrophic cardiomyopathy phenotype in an important minority of patients (6%).[224] There is likely a role for MRI toward clinical risk assessment (ventricular dilation/ sudden cardiac death) of patients with hypertrophic cardiomyopathy, based on the extent of hyperenhancement [225]; and also to evaluate the efficacy of treatment (ablation/embolization) in patients with obstructive hypertrophic cardiomyopathy.[226] **Left ventricular hypertrophy** is an important independent risk factor for cardiac events. MRI is the best technique for assessing LV mass,[227] and for its progression over time because of its excellent interstudy reproducibility.[228] **Left ventricular isolated non-compaction** is a recently described clinical entity, in which MRI may have a central role in making the diagnosis. Petersen et al.[229] (2005) reported a sensitivity, specificity, positive and negative predictions of 86%, 99%, 75%, and 99% respectively in distinguishing pathological non-compaction. Besides accurate measurement of left ventricular dimensions and function in patients with **dilated cardiomyopathy** [230], use of contrast-enhanced MRI enables to distinguish dilated cardiomyopathy from LV dysfunction related to coronary artery disease.[231] MRI is very helpful in differentiating between patients with **restrictive cardiomyopathy** and those with constrictive pericarditis. Contrast-enhanced MRI enables depiction of specific myocardial enhancement patterns in patients with cardiac amyloidosis [232] while in patients with myocardial iron deposition (hemochromatosis) , the disease severity can be quantified by means of T2*-weighted MRI techniques. **Arrhythmogenic right ventricular cardiomyopathy or dysplasia (ARVD)** is characterized by focal fibrofatty infiltration and thinning of the right ventricular free wall, leading to focal bulging, regional and global functional impairment, arrhythmias and increased risk of sudden cardiac death. Although the diagnosis of ARVD remains challenging, MRI is generally considered as the reference imaging technique to depict anatomical (thinning, bulging, fatty infiltration, late enhancement in fibrotic areas).[233-236] Diagnosis of **cardiac sarcoidosis** is hampered because of the low accuracy of current diagnostic techniques. Contrast-enhanced MRI, however, typically shows patchy areas of myocardial enhancement. In a recent study

performed in 58 patients (12 patients with final diagnosis of cardiac sarcoidosis), MRI had a sensitivity, specificity, positive and negative predictive value, and accuracy of 100%, 78%, 55%, 100%, and 83% respectively.[237] The current role of MRI in detecting acute rejection in **heart transplantation** in a clinical setting is limited. MRI may be useful to follow-up of the remodelling process with long term use of cyclosporin, and in detecting complications such as pericardial effusions or intracavitary masses (e.g. thrombi).

5.1.4 Pericardial Diseases

No systematic reviews are available. Both MRI and CT are well suited to define anatomic abnormalities of the pericardium including congenital abnormalities (e.g. cyst – absence), pericardial thickening and effusions. MRI has the advantage of being able to depict and quantify the functional abnormalities, which may be associated with pericardial *disease.*[238, 239] For suspected pericardial thickening, MRI and CT are primary imaging modalities, with CT having an advantage for identification of pericardial calcium. However, since up to 20% of patients with surgically proven constrictive pericardial have a normal or near normal pericardial thickness (i.e. < 4 mm)[240], thickness as sole parameter to diagnose constrictive pericarditis may lead to false negative results. A comprehensive MRI approach including assessment of diastolic functional parameters (using velocity-encoded MRI) and assessment of the degree of ventricular coupling[239, 241] may lead to an improved accuracy. Finally the contrast-enhanced MRI as used to depict myocardial infarction and scarring is also well-suited to detect pericardial inflammation.[242]

5.1.5 Valvular Heart Disease

No recent systematic reviews are available. Although transthoracic echocardiography is the primary clinical tool for evaluation of valvular heart disease, this technique is rather poor in quantifying the degree of **valvular regurgitation**, and for quantification of the effects of valvular lesions on ventricular volumes, function and myocardial mass. Velocity-encoded cine MRI allows to accurately depict the degree of valvular regurgitation as well as to quantify (bi)-ventricular function, volumes and mass. . The severity of **valvular stenosis** can be quantified by measuring the gradient through the stenotic valve (using the modified Bernouilli equation) and by measuring the area valve (directly or using the continuity equation for the aortic valve). Although still classified as Class III indication there is growing evidence that MRI may become important in assessing patients with valvular stenosis. In a comparative study in 44 symptomatic patients with severe aortic stenosis, the sensitivity and specifity of MRI to detect aortic valve orifice less than 0.80 cm2 measured by cardiac catheterization was 78% and 89%, of transesophageal echocardiography 70% and 70%, and of transthoracic echocardiography 74% and 67%, respectively [243]. Similar results were found by Friedrich et al. (2002-2004)[244, 245] and Caruthers et al. (2003)[246]. In recent study in 22 patients with suspected or known mitral stenosis, planimetry of mitral valve area with MRI showed a good correlation with cardiac catheterization ($r=0.89$, $p< 0.0001$) and echocardiography ($r=0.81$, $p< 0.0001$), yielding a sensitivity and specificity of 89% and 75% respectively.[247] MRI is ideally to follow-up the ventricular and/or atrial remodelling after valve repair.[248-252] The **pulmonary valve**, because of its retrosternal location, is often difficult to evaluate with transthoracic echocardiography (e.g. postoperatieve tetralogy of Fallot, pulmonary hypertension, post-Ross procedure). Functional disturbances of the pulmonary valve, as well as the impact on right ventricular volumes and function can be accurately assessed with MRI. **Prostethic valves** are no contra-indication for MRI. Flow patterns above/below the valve, as well as dysfunction of the valve can be well assessed with MRI. Image quality in the vicinity of the prosthetic valve however, may be degraded.

5.1.6 Congenital Heart Disease

No recent systematic reviews are available. The strengths of MRI are the diagnosis and (postoperative) follow-up of congenital heart disease, its non invasive nature and the comprehensive approach (combining information on morfology, ventricular and valvular function, patency of grafts, coronary artery anatomy, and myocardial perfusion and viability).[253] MRI is currently the best noninvasive technique to calculate cardiac shunts (e.g. ASD, VSD, PDA), and to depict congenital abnormalities in regions difficulty assessable to echocardiography (abnormal pulmonary venous return in combination with sinous venosus defect; aortic coarctation). The main indication for MRI is postoperative follow-up of cardiac and/or aortic congenital heart disease[254], especially right-sided cardiac pathology (e.g. tetralogy of Fallot patients)[255-258] (e.g. pulmonary homograft stenosis after Ross procedure)[259], assessment of intracardiac baffles and extracardiac conduits [260] in transposition of the great arteries.[242]

Key points

- **Magnetic resonance imaging has emerged as an excellent technique to study the heart, including assessment of cardiac and pericardial morphology, valvular and ventricular function, myocardial perfusion, and myocardial viability (evidence level 1-3).**
- **In contrast to other parts of the human body, the value and contribution of MRI has primarily not been compared to CT but to other established cardiac techniques, such as echocardiography, nuclear medicine, and cardiac catheterization. Thus, it should be emphasized the issue is not how MRI can substitute for CT but can MRI replace one of the above cardiac techniques.**
- **MRI is increasingly used to study the therapeutic impact (evidence level 4) and patient outcome (evidence level 5) in a variety of cardiac diseases.**

6 VASCULAR RADIOLOGY

6.1 CAROTID AND VERTEBRAL ARTERIES

There are 5 systematic reviews and 6 papers in this category.

Digital subtraction angiography (DSA) is the reference standard. Two systematic reviews and one prospective comparative study have compared computed tomography angiography (CTA) to DSA. The remaining publications have looked at magnetic resonance angiography (MRA).

State-of-the-art MRI units are mandatory and MRA without contrast administration is not acceptable for this indication. Therefore two systematic reviews are of limited value as it concerns mainly unenhanced MRA.[261, 262]

There is now sufficient evidence that contrast-enhanced MRA can replace digital subtraction angiography in assessing the carotid and vertebral artery in the diagnostic work-up of a suspected 70-99% stenosis or occlusion. The evidence mainly concerns the carotid artery but to some extent also the vertebral and basilar artery. Sensitivity values for contrast-enhanced MRA range from 75% [263] to 98% [264] and specificity from 62% [265] to 97% [266]. Often ultrasound (US) is used at the same time as MRA and when both techniques agree about the degree of a stenosis, this increases sensitivitiy (90% to 100%) and specificity (81% to 100%).[265, 267-269, 263]

Interobserver agreement was excellent.[264, 266] Kappa-values for DSA and MRA were comparable.[265, 264]

CTA yields similar sensitivity and specificity values compared with MRA.[270, 271] CTA has the advantage of visualising calcified plaques while it has the disadvantage of using ionizing radiation and iodinated contrast agents. CTA is a valuable alternative for MRA, certainly when using the newer multislice CT scanners.

Key point

The combined use of ultrasound and contrast-enhanced MRA can replace digital subtraction angiography in patients with suspected 70-99% stenosis. State-of-the-art MR scanners are mandatory. Evidence level 2.Computed tomography angiography can be used as an alternative for contrast-enhanced MRA, particularly when the newer multislice (16 and 64 slices) scanners are available. Evidence level 2.

6.2 THORACIC AND ABDOMINAL AORTA, VISCERAL ARTERIES AND PERIPHERAL ARTERIES

There is good evidence that Magnetic Resonance Imaging (MRI) and Magnetic Resonance Angiography (MRA) are accurate in the detection and evaluation of acute and chronic thoracic aortic dissection. With surgery, angiography or necropsy as 'gold standard' reported sensitivity varies between 67% and 100%; specificity ranges between 81% and 100%.[272-278] Nienaber and colleagues compared MRI and transesophageal echocardiography (TEE) in 53 patients for the detection of thoracic aortic dissection and found a sensitivity and specificity of 100% for MRI and a sensitivity of 100% and a specificity of 68.2% for TEE. MRI was also more sensitive than TEE in detecting thrombus formation on the false lumen; there were no discrepancies between the two imaging techniques in detecting the site of entry to a dissection, aortic regurgitation, or pericardial effusion.

Computed Tomography (CT) is also a very accurate non-invasive technique for the detection of acute thoracic aortic dissection or intramural hematoma with a sensitivity, specificity and accuracy of 100% in detection these features.[279] For localisation of the entry tear with CT, sensitivity, specificity and accuracy was 82%/100%/84% respectively. Sensitivity, specificity and accuracy was 95%/100%/98% respectively for arch branch

involvement, 83%/100%/91% for pericardial effusion and three times 100% for detecting concomitant aortic arch anomalies. Comparative high accuracy is found in a recent article of Hayter and colleagues, who demonstrated a sensitivity of 99%, a specificity of 100%, an accuracy of 99.5%, a positive predictive value (PPV) of 100% and a negative predictive value (NPV) of 99.7% in detection acute thoracic aortic disorders such as aortic dissection, intramural hematoma, acute penetrating ulcers, new or enlarging aneurysms or acute aortic ruptures.[280]

In the follow-up of aortic dissection treated by means of either surgery, endovascular stent-grafting or medical treatment a high concordance is found between MRI and (contrast-enhanced) (CE) MRA and TEE (r=0.93/0.94 for MRI versus CE-MRA, r=0.84/0.91 for MRI versus TEE and r=0.84/0.92 for CE-MRA versus TEE) [281] and between MRA and digital subtraction angiography (DSA) (r=0.968).[282]

MRI and CE-MRA is accurate in the detection and follow-up of thoracic aortic aneurysms with reported sensitivity varying between 89% and 100% and a specificity varying between 97% and 100%.[273 , 275 , 276]

CT is also been used for the follow-up of aortic aneurysm (thoracic and abdominal) treated with endovascular stent-graft placement with an overall agreement of 97% between CT and TEE in the study of Maffei and colleagues.[283]

There is a high correlation between MRI and with DSA for evaluation of aortic coarctation (r= 0.82-0.90).[284 , 285] According to Parks and his colleagues, MRI is preferred over DSA by surgeons and clinicians as definitive, risk-free procedure, before surgery.[286] Nielsen and colleagues concluded in their study on 35 patients with suspected coarctation that the combination of anatomic and flow data obtained by MRI provided a test with a sensitivity of 95% and a specificity of 82% (PPV: 90%, NPV: 90%) for predicting a catheterization pressure gradient 20 mmHg.[287] Other authors report on the follow-up of treated aortic coarctation and demonstrated a high correlation between CT and MRA in diameter measurements (r=0.79-0.94) [288] and between MRI and DSA (r=0.97) and TEE (r=0.89).[289]

There is some evidence that MRA is highly accurate (accuracy 100%) in the detection of vascular anomalies such as vascular rings and slings.[290] MRA and CTA are reported in small studies to be accurate in the detection of the vascular involvement in Takayasu's arteritis with a sensitivity and specificity of 100%.[291 , 292]

There are some retrospective studies that show that CT is accurate in the detection of traumatic aortic injury.[293, 294] Reported accuracy was 90% in the study of Mirvis and colleagues; sensitivity and specificity for detecting traumatic injury to the aorta was 90% and 99% respectively, while sensitivity and specificity for detecting mediastinal hemorrhage was 100% and 87% respectively.[293] No MRI or MRA studies exist on this subject.

There are other imaging modalities than Magnetic Resonance Angiography for the detection of abdominal aorta aneurysm (AAA). However there are two reasons to perform MRA or Computed Tomography Angiography (CTA) in the clinical setting of AAA: the first is to evaluate endovascular versus surgical treatment of the AAA, mainly based on the proximal neck configuration and on the appearance of the iliac arteries but also on the possible superior mesenteric or renal artery stenosis and second is the follow-up after stent-graft therapy.

There is some evidence that both CE-MRA and CTA are equal in evaluating the proximal extent of the AAA and in measuring all aortic dimensions.[295 , 296 , 297 , 298 , 282] In the study of Thurnher CE-MRA was inferior to CTA in depicting accessory renal arteries and in grading renal artery stenosis [295], while in the study of Walter and colleagues sensitivity of CTA for assessment of renal and visceral artery stenosis was inferior to CE-MRA (0.66, 95% CI: 0.53-1.0 versus 0.83, 95%CI: 0.53-1.0). CE-MRA can also provide preoperative anatomic information that is equivalent to CA for surgical planning.[299]

There is evidence that CTA is a very good method for establishing the presence of endoleaks following treatment of aortoiliac aneurysms with stent-grafts[300] and that CTA is superior to ultrasound for detection of the origin of the endoleak, the outflow vessels

and the detection of complications related to the procedure.[301] CE-MRA is at least as sensitive as uni- or biphasic CTA for detecting endoleaks, but only in patients with stent-grafts with low susceptibility artefacts.[302, 303, 304, 305, 306]

There are contradictory findings about the diagnostic performance of MRA for the detection of renal artery stenosis. Based on a meta-analysis of Vasbinder and colleagues in 2001,[307] there is good evidence that both CTA and CE-MRA are significantly better than all other studied tests (non-gadolinium enhanced MRA, captopril test, ultrasonography), while CTA and CE-MRA had similar diagnostic performance in the detection of renal artery stenosis. In contrast to this meta-analysis Vasbinder and colleagues published in 2004 a prospective study of 356 patients (between 1998 and 2001) that underwent CTA, MRA and digital subtraction angiography (DSA) (gold standard) for the suspicion of renovascular hypertension and found -values ranging from 0.59 to 0.64 for CTA and 0.40 to 0.51 for MRA and a combined sensitivity and specificity of 64% (95% CI, 55% to 73%) and 92% (CI, 90% to 95%) for CTA and 62% (CI, 54% to 71%) and 84% (CI, 81% to 87%) for MRA in detecting clinically significant stenosis [308]. Thus they concluded that CTA and MRA are not reproducible or sensitive enough to rule out renal artery stenosis in hypertensive patients and that therefore, DSA remains the diagnostic method of choice. Possible explanations for this discrepancy between the two studies are suboptimal technique, low overall disease prevalence (20%), a high proportion of patients with fibromuscular dysplasia (FMD) and an imperfect standard of reference.

Most other studies after 2001 demonstrated then again a high diagnostic performance of CE-MRA and CTA versus DSA.[309, 310] Patel and colleagues concluded that 3D CE-MRA is sensitive to detect hemodynamic significant renal artery stenosis (overall sensitivity/specificity/accuracy/PPV/NPV for 3D CE-MRA was 87%/69%/85%/51%/95%) but they found also an overestimation of the significance of moderate renal artery stenosis in 31% of patients.[311]

MRA has a higher accuracy for detection of accessory renal arteries compared to ultrasound [312], but a lower accuracy compared to CTA.[313, 314, 295, 315-317]

Literature on MRA for chronic intestinal ischemia there is scarce, but nevertheless there is some evidence that CE-MRA and CTA have_high diagnostic performance in detecting significant proximal stenosis of the celiac artery and superior mesenteric artery with a sensitivity of 100% and a specificity ranging between 95% and 100%.[313, 318-320] The inferior mesenteric artery is however more difficult to evaluate correctly.

For the diagnostic work-up of peripheral arterial occlusive disease (PAOD) such as intermittent claudication and chronical critical limb ischemia MRA and especially CE-MRA is a robust technique with sufficiently high diagnostic accuracy to replace digital subtraction angiography (DSA).[321, 322, 323, 261] Berry and colleagues concluded in their meta-analysis that if both DSA and MRA are available in the local setting, MRA is more cost-effective than DSA, especially if CE-MRA is available.[261] This meta-analysis could not demonstrate a difference in expected QALYs for MRA and DSA.

In patients with chronical critical limb ischemia CE-MRA can even modify the choice of therapeutic strategy because of its ability to detect significantly more patent arteries than DSA.[324] A small study of Reid et al.[325] on 13 patients (11 patients with intermittent claudication and 2 with rest pain) showed that treatment plans based on MRA and DSA were identical in 71%. For identifying lesions resulting in intervention, MRA had sensitivity of 100% and a PPV of 92%. MRA had a treatment specific predictive value of 88% for each lesion identified, and 95% for lesions identified in patients evaluated for claudication (versus treatment-specific predictive value of 33% for rest pain). If treatment plans were based on MRA only, 46% of patients would have avoided catheter arteriography. Vavrik and colleagues demonstrated not only an accuracy of MRA for the detection of significant lesions comparable to DSA but they concluded also that the number of DSAs can be reduced by three quarters if therapeutic strategy is based solely on the results of the MRA.[326]

There is also good evidence that MRA is superior (more sensitive and specific) to US for diagnosis and pre-interventional work-up of PAOD [322, 327]. Visser reported a pooled sensitivity for MR angiography of 97.5% [95% CI: 95.7%, 99.3%] that was higher

than that for duplex US (87.6% [95% CI: 84.4%, 90.8%]). Pooled specificities were similar: 96.2% (95% CI: 94.4%, 97.9%) for MR angiography and 94.7% (95% CI: 93.2%, 96.2%) for duplex US. In the study of Leiner sensitivity, specificity and accuracy of CE-MRA was 84% (95% CI: 78%, 89%), 97% (95% CI: 95%, 98%) and 94% respectively. For duplex US this was 76% (95% CI: 69%, 82%), 93% (95% CI: 91%, 95%) and 89% respectively.[322 , 327]

In a few prospective studiesMDCTA appeared to be another valuable alternative for DSA (and thus for MRA) in the assessment of aorta and peripheral arteries with a sensitivity and specificity comparable to CE-MRA (Table 11).[328 , 329 , 330 , 331 , 332 , 333 , 334 , 335] The visualisation of calcified plaques may be an advantage in the pre-operative planning, but it may also be a disadvantage for correct determination of stenosis grade in small calibre vessels such as the crural vessels. Other disadvantages are the use of ionizing radiation and iodinated contrast material. A recent Dutch randomized controlled trial comparing CE-MRA and MDCT angiography for diagnostic imaging work-up in PAOD-patients showed a significant higher average cost for diagnostic imaging and non-significant higher therapeutic costs in the MR group.[336] The costs in this study were only calculated from a hospital perspective in stead of a societal perspective.

For the assessment of peripheral arterial bypass grafts, diagnostic accuracy of MRA and CT angiography is in the range of that of PAOD,[337 , 338 , 339 , 309] with a sensitivity and specificity for detecting significant stenosis that ranged both between 90% and 100% for MRA and between 97% and 100% (sensitivity) and 99% and 100% (specificity) for CTA.

Table 11: Lower-limb CTA in comparison with DSA in patients with PAOD

Study	Collimation (channels x mm)	Slice thickness/reconstruction interval (mm / mm)	N of patients	Sensitivity (%)	Specificity (%)	Accuracy (%)
Ofer 2003	4 x 2.5	3.2 / 1.6	18	91	92	92
Martin 2003	4 x 5	5 / 2.5	41	92	97	-
Ota 2003	4 x 2	2 / 1	24	99	99	99
Catalano 2004	4 x 2.5	3 / 3	50	96	93	94
Portugaller 2004	4 x 2.5	2.5 / 1.5	50	92	83	86
Edwards 2005	4 x 2.5	3.2 / 2.0	44	79	93	-
Willmann 2005	16 x 0.75	0.75 / 0.4	39	96	97	97
Fraioli 2006	4 x 2.5	3 / 3	75	96 (50mAs) 96 (100mAs) 98 (130mAs)	94 96 96	95 96 97

Key points

- MRI, MRA and CT are accurate in detection, evaluation and follow-up of congenital and acquired thoracic aortic disease (level 2)
- MRI, MRA and CT are accurate in detection, pre-interventional work-up and follow-up of AAA (level 2)
- In case of high disease prevalence MRA is sensitive in detection of significant renal artery stenosis, but tends to overestimate moderate renal artery stenosis; in case of low disease prevalence CTA and MRA are not reproducible or sensitive enough to rule out renal artery stenosis in hypertensive patients (level 2)
- MRA has higher accuracy for detection of accessory renal arteries compared to US, but a lower accuracy compared to CTA and DSA (level 2)
- CE-MRA and CTA are accurate in detection and grading of significant stenosis of the celiac artery and the superior mesenteric artery (level 2)
- CE-MRA has sufficiently high diagnostic accuracy to replace DSA for detection and grading of stenosis in peripheral arterial occlusive disease (level 2)
- In patients with chronic critical limb ischemia CE-MRA can modify the choice of therapeutic strategy (level 4)
- CTA may be a valuable alternative for DSA in the assessment of aorta and peripheral arteries (level 2)

7 HEAD AND NECK

7.1 SENSORINEURAL HEARING LOSS

The superiority of MRI over CT in the visualisation of acustic neuromas has been recognised early.[340] The detection of these tumors is important, as in large or growing tumors surgical intervention is indicated. The sensitivity and specificity of MRI for this disease is close to 100%. MRI is also superior over CT in detecting numerous other retrocochlear causes of sensorineural hearing loss.[341] However, in many patients presenting with sensorineural hearing loss, no acoustic tumor is present, nor can a specific, potentially treatable etiology be diagnosed. The question is whether all patients suffering unilateral or asymmetric sensorineural hearing loss should undergo MRI, or, given the low prevalence of this tumor, another cheaper screening method can be employed to select patients for imaging.

Another topic on which some studies on the use of MRI and/or CT were found is congenital sensorineural hearing loss and preoperative imaging in patients in whom a cochlear implant is considered. Some patients with congenital or acquired sensorineural deafness can be treated with such a device. This procedure is not commonly performed, but is associated with high costs. Preoperative imaging is helpful in exploring the feasibility of this procedure and determining the optimal implant side.

7.1.1 Screening for acustic neuroma

Auditory brainstem response (ABR) was studied, with MRI as gold standard, as screening tool for patients suffering acustic neuroma in 3 clinical studies. The sensitivity of this technique ranged between 71 and 100%.[342-344] This means that, although it allows to detect the majority of acustic neuromas, some patients with acustic neuroma will pass this test as normal. The specificity of this test is relatively low (49-74%), implying that many patients will need to undergo MRI to exclude acustic neuroma.

No clear conclusion can be made: depending on their study results, some authors recommend MRI as the initial screening method, while others advocate the use of ABR before MRI. ABR reduces costs, but carries the inherent risk of missing acustic neuromas. A practical solution may be to screen patients with MRI, but to apply a shortened, (non-contrast enhanced) high resolution technique, which allows detection of nearly all tumors if meticulously performed and read by experienced radiologists.

Patients in whom an acustic neuroma was diagnosed do not necessarily need to be operated. One clinical study reported that 36% of these tumors show a stable volume over time and can be observed by regular follow-up with MRI (62% were still treated conservatively at the end of the study period).[345]

7.1.2 Congenital hearing loss and preoperative imaging in cochlear implant patients

Five clinical studies were included on this topic. CT as well as MRI can show abnormalities of the inner ear and internal auditory canal in 39-48% of patients with congenital hearing loss; MRI provides supplementary information on the presence/absence of the vestibulocochlear nerve.[346, 347] If also external or middle ear abnormalities are present or suspected, CT is required.[348]

Before cochlear implantation, MRI can show obliteration of the cochlea, and congenital absence or acquired hypoplasia of the cochlear nerve. MRI can not differentiate between fibrosis and calcification of the cochlea (fibrosis may not be a contra-indication to cochlear implantation). CT can show calcification of the cochlea. Patients with congenital absence of the cochlear nerve almost invariably show severe hypoplasia of the internal auditory canal on CT.[349, 350]

There is no unanimity regarding the imaging protocol in patients with congenital sensorineural hearing loss and before cochlear implantation. Some experts recommend MRI;[349, 346, 348] other experts recommend CT, with MRI in second line if needed.[350]

In patients considered for cochlear implantation due to acquired sensorineural hearing loss, MRI is probably necessary to exclude acquired hypoplasia of the cochlear nerve.[346]

Key points

- **Auditory brainstem response (ABR) is cheaper than MRI as screening tool for acustic neuroma in patients with acquired asymmetric sensorineural hearing loss; however, ABR is less sensitive than MRI. A compromise may be to perform a limited, non-contrast enhanced, high-resolution MR study (at lower costs) in this patient group (evidence level 2).**
- **Patients with acustic neuroma may be followed up conservatively, based on the MRI findings (evidence level 3).**
- **CT or MRI can be used in congenital sensorineural hearing loss and before cochlear implantation (evidence level 2).**

7.2 PHARYNGEAL NEOPLASMS

A distinction should be made between nasopharyngeal, oropharyngeal and hypopharyngeal cancer. Nasopharyngeal cancer is always treated by radiotherapy or a combination of radio- and chemotherapy; oropharyngeal and hypopharyngeal cancer may be treated by surgery, with or without postoperative radiotherapy, or (chemo)-radiotherapy, depending on the stage of disease.

Nine clinical studies were included. Pharyngeal neoplasms can be imaged either by CT or MRI. Overall, there is no evidence for superiority of one modality over the other.[351-353] However, in nasopharyngeal cancer, the tumor extent is better defined by MRI.[354-356] It has also been shown that the choice of the imaging modality influences the outcome of the patient with nasopharyngeal cancer: significantly better treatment results in terms of local control, disease-specific survival and overall survival are obtained with the use of MRI;[357-359] the respective hazard ratios for CT versus MRI are 1.96, 1.48 and 1.85.[359] These better treatment results by using MRI are related to a better definition of the tumor extent in this disease. It should be noted that nasopharyngeal cancer is a rare disease in Belgium.

Key points

- **There is no evidence that CT or MRI is a superior imaging modality in imaging oro- and hypopharyngeal cancer (evidence level 2)**
- **The use of MRI in nasopharyngeal cancer allows better definition of the tumor extent, and is associated with a better patient outcome after treatment (evidence level 5).**

7.3 LARYNGEAL NEOPLASMS

Both CT and MRI can be used to visualize and accurately stage laryngeal neoplasms.[360] The discussion whether to use CT or MRI mainly deals with the question which technique is superior to visualize laryngeal cartilage involvement.[361] The prognostic significance of cartilage involvement on CT is questioned.[362]

Three recent clinical studies were included. One of these studies challenges the value of MRI in diagnosing subtle laryngeal cartilage involvement; a sensitivity and specificity of only 67% for detecting cartilage invasion was reported.[363] Another group recently demonstrated the prognostic value of MRI in early glottic cancer.[364, 365] However, the obtained results are not different from those previously reported for CT.

Overall, there is no evidence that MRI is superior over CT in the visualisation of laryngeal cancer.

Key points

- **MRI can be used to stage laryngeal cancer (evidence level 2).**
- **The findings on MRI have prognostic significance for the local outcome after radiotherapy (evidence level 3). These results are similar to what was previously reported for CT; CT is as good as MRI.**

7.4 NECK LYMPH NODES

Assessing the involvement of neck lymph nodes in head and neck cancer is an important issue, as the management and prognosis of the patient is very much influenced by the presence of neck lymphatic metastasis. This can be achieved by ultrasound, CT or MRI. CT and MRI allow staging of the neck and staging of the primary tumor during the same examination. Some neck lymph nodes are not accessible for US examination. Non-invasive identification of neck node metastasis is challenging, as the ideal imaging method should be able to detect small tumoral depositis in non-enlarged nodes, and to differentiate reactively enlarged (inflammatory) lymph nodes from metastastic nodes. Currently, no such ideal imaging method is available. An advantage of US is the possibility to combine the examination with US-guided fine needle aspiration cytology (FNAC) of the lymph nodes; however, this is a time-consuming procedure, which is also difficult from a logistical point of view.

Eight clinical studies were included. Most of these studies report a comparable diagnostic value of CT and MRI for detecting metastatic adenopathies in the neck (CT: negative predictive value=84%; positive predictive value=50% - MRI: negative predictive value=79%; positive predictive value=52%).[366] Some authors slightly prefer CT.[366-369]

Three included studies addressed the value of a specific contrast agent (ultrasmall superparamagnetic iron oxide, USPIO) in MRI to detect metastatic neck adenopathies. From a theoretical point of view, this contrast agent should allow to obtain more reliable results than with gadolinium-enhanced MRI; however, the reported results for neck adenopathies are somewhat variable. In one study, no significant difference between USPIO-MRI and plain MRI (p>0.5) was found [370], while in another study, a diagnostic benefit with USPIO was found (USPIO-MRI: sensitivity=82%, specificity=100%; plain-MRI: sensitivity=52%, specificity=85%).[371] Two studies reported a therapy-change based on USPIO-enhanced MRI; however, in one study no comparison was made with plain or gadolinium-enhanced MRI,[372] and in the other study this change of therapy was only mentioned without providing details.[371] Further improvement of MRI technology may allow to obtain better results with this contrast agent.[370]

One included study reports on the use of diffusion-weighted MRI in detecting metastatic adenopathies in the neck.[373] This is a new application of diffusion-weighted MRI that may have great interest as it is not using an external contrast agent. Currently, no conclusions on the added value of this technique can be drawn.

Key point

CT and MRI have a comparable sensitivity, specificity and accuracy for detecting metastatic neck adenopathies (evidence level 2)

7.5 SINONASAL NEOPLASMS

The added value of MRI in the evaluation of sinonasal neoplasms is related to its better evaluation of possible intracranial tumor extension, its better abilility to discriminate tumoral tissue from retro-obstructive neoplastic disease, and its better ability to detect perineural tumor spread. However, in many cases of sinonasal neoplasms, a dedicated CT study can provide sufficient information for management of these patients.[374] Given the rarity of these lesions, and their complex extension pattern, no data on sensitivity and specificity of CT and MRI for involvement of various maxillofacial substructures is available. It may be more cost-effective to perform MRI only in cases that are carefully selected based on CT-findings; however, given the rarity of sinonasal neoplasms, systematic performance of MRI in these patients may be justified; further economic evaluation is needed to assess this potential justification.

Two recent clinical studies have shown the possibility of MRI to adequately show the extent of inverted papillomas, a relatively common benign sinonasal tumor, and the ability of MRI to predict non-invasively the histology of this tumor. MRI predicted accurately the tumor extent (positive predictive value > 68%, negative predictive value > 93%, depending on the paranasal sinus), and a columnar pattern on MRI was found to be specific for this tumor type (positive predictive value = 95,8%).[375, 376] In these studies no comparison with CT was performed; the clinical importance of predicting this tumor histology is unclear, as tissue sampling is routinely performed in such patients.

Another study dealt with the ability of CT and MRI to predict intra-orbital tumor extension, an important issue as such extension may require orbital exenteration. Imaging has only a moderate accuracy (72%) for predicting such tumor extent,[377] and MRI was not shown to be superior to CT.

Key points

- **In sinonasal neoplasms, MRI has a number of advantages compared to CT, related to a better evaluation of tumor extent (evidence level 2).**
- **Currently, there is no scientific evidence that MRI should be routinely used in all sinonasal neoplasms.**

7.6 SALIVARY GLAND NEOPLASMS

Six clinical studies were included.

In patients presenting with a swelling in the parotid or submandibular region, determining the intra- or extraglandular localisation of the swelling is of primordial importance. Both CT and MRI are very well suited in this regard, MRI performing slightly better. In parotid tumors CT and MRI have a sensitivity of 100%, but MRI is slightly more specific than CT (MRI: 84-100%; CT: 73-94%, depending on evaluated parameter). In submandibular masses, the accuray of CT was reported to be 87%, while that of MRI was 91%.[378, 379]

The precise localisation of a parotid tumor in relation to the facial nerve is important, to predict in malignant tumors the likelihood of facial nerve sacrifice; this can be accomplished both by CT or MRI; no separate analysis for CT and MRI was found.[380]

Certain characteristics of the tumor on imaging studies predict malignancy; overall, MRI is slightly better than CT in such histologic prediction,[381] and in some studies the results with MRI even approach the results obtained by fine needle aspiration cytology (FNAC: sensitivity 67-81%; specificity 79-96% - MRI: sensitivity: 55-87%; specificity 86-94%).[382, 383]

Key points

- **Both CT and MRI are accurate in precisely localising a salivary gland tumor (evidence level 2)**
- **MRI is slightly more accurate than CT in determining the tumor borders and showing infiltration in surrounding structures (evidence level 2)**

7.7 PARATHYROID DISEASE

Primary hyperparathyroidism is treated by surgical resection of the diseased parathyroid. Pre-operative identification of the pathological parathyroid(s) reduces surgical time and allows the introduction of minimally invasive surgery. The imaging methods used for this purpose vary; usually a combination of two or more techniques amongst US, CT, MRI and scintigraphy is being used. The parathyroid glands may be localised ectopically; identification of such ectopic glands is important to avoid persistent hyperparathyroidism after surgery.

Six clinical studies on imaging in parathyroid disease were included. Few information was found on the value of CT, alone or in combination with other techniques,[384] although when using modern equipement, this modality has similar advantages and disadvantages as MRI.

One study reported a relatively high sensitivity (75-82%) and high specificity (99-100%) with contrast-enhanced MRI.[385] These results are much better than what is reported by other authors; it is unclear if the study population consisted out of consecutive patients.

Most studies reported a higher sensitivity with scintigraphy (mainly Tc-MIBI scan, or MIBI/I substraction scintigraphy) (sensitivity 55-86%) than with US (sensitivity 50-71%) or MRI (sensitivity 42-71%) alone.[386-388] Combination of scintigraphy with US (sensitivity of combination 96%) [384] or MRI (sensitivity of combination 94%) [389] yields better results. Practically, based on the reported results, MRI (or CT) should only be performed if scintigraphy shows the presence of ectopic parathyroid glands in the mediastinum, or if US and scintigraphy show negative or equivocal results.

Key points

- **Scintigraphic methods have a better sensitivity for detecting parathyroid gland pathology in primary hyperparathyroidism than US or MRI (evidence level 2).**
- **The combination of scintigraphy with US or MRI provides better results than obtained with each of this techniques alone (evidence level 2)**
- **MRI (or CT) should only be performed if scintigraphy shows the presence of ectopic parathyroid glands, or if US and scintigraphy show negative or equivocal results (evidence level 2)**

7.8 TEMPOROMANDIBULAR JOINT DISORDERS

One systematic review and three recent clinical studies were included. MRI is the best method for visualising internal derangement of the temporomandibular joint.[390]

Apart from visualising disk displacement, MRI also allows evaluation of joint effusion and bone marrow edema, factors which are associated to the occurrence of joint pain.[391] The clinical evaluation can predict disk dislocation without reduction, but is not sufficiently reliable compared to MRI (clinical evaluation had sensitivity of 75% and specificity of 83%, with MRI as gold standard).[392] However, the clinical assessment of the joint remains very important, as the imaging abnormalities are not always associated with clinical symptoms, and also clinical improvement is not clearly correlated to a reduction of imaging abnormalities.[393]

Key point

If imaging in clinically suspected internal derangement of the temporomandibular joint is needed, MRI is the imaging method of choice (evidence level 2). Clinical improvement of the symptomatology is not clearly correlated to a reduction of imaging abnormalities.

8 MUSCULOSKELETAL RADIOLOGY

8.1 LOWER LIMB

8.1.1 Ankle: Osteochondral lesion and osteochondritis dissecans of the talus

MRI can be used to assess osteochondritis dissecans of the talus with a high accuracy in determining lesion stability.[394, 395] In a multimodality study, 17 cases of occult osteochondral fractures were found in 30 patients with normal radiographs and posttraumatic chronic ankle pain. MRI detected all occult osteochondral injuries, bone scanning missed one, and CT missed four.[396] The accuracy of MRI and its ability to stage osteochondritis dissecans of the talar dome have also been assessed in a study of 54 patients who had operative confirmation of the presence and stage of their lesions.[397] MRI may also have a role in monitoring the healing of an osteochondral lesion after surgery.[395, 398]

Radionuclide bone scanning, CT and MRI have been used to assess the ankle joint for osteochondral injuries. Two studies reported that ankle CT is useful in assessing persistent ankle pain after trauma. One study used CT to evaluate 31 consecutive patients with chronic ankle pain after an injury. Thirteen of these 31 patients had normal radiographs but had occult intra-articular or juxta-articular fractures noted on CT.[399] In one study, four of 32 osteochondral lesions of the talus were missed on radiographs but identified on direct coronal CT scanning.[400] Another study reviewed 92 patients with talar osteochondral lesions. Although they did not report the accuracy for occult lesions alone, only 66% of the osteochondral lesions were seen on radiographs, but the sensitivity was 99% with bone scanning and 98% with CT.[401] There have been no reports on the accuracy of CT arthrography for detecting osteochondral fractures in the ankle. However, case reports suggest that CT arthrography can help detect intra-articular loose bodies and assess the stability of osteochondritis dissecans.[402]

Key points

- **MRI can accurately detect osteochondral lesions and osteochondritis dissecans of the talus. MRA can better determine lesion stability.**
- **CTA can be used when MRI is not available.**
- **Multidetector CTA provides a better analysis of the overlying articular cartilage involvement due to the thinner slices, but is more invasive.**

8.1.2 Knee

MR imaging is increasingly used as a non-invasive means of diagnosing knee lesions. Many studies have investigated the sensitivity and specificity of MR for the detection of internal derangement of the knee (i.e. meniscal lesion, cruciate ligament injury, cartilage lesion, collateral ligament injury and a few other types of lesions) [403-430] and others have examined the role of MR in improving diagnostic accuracy and reducing the need for diagnostic arthroscopy.[431, 412, 432]

Original and review articles indicate that magnetic resonance imaging is an accurate method to diagnose and evaluate meniscal tears with sensitivity levels of 80 – 92 % and specificity levels of 87 – 96 % [419, 426]. Levels are different for medial (Se = 87,5 %, Sp = 76 %, PPV = 46,1 %, NPV = 95 %) and lateral meniscus (Se = 69 -75 %, Sp = 96 %, PPV = 85,7 %, NPV = 96 %).[404, 411, 412, 420] For certain subtypes of meniscal tears, like bucket-handle tear, the accuracy is higher (98 %).[414]

The value of MR imaging lies in its ability to reveal details of meniscal tears, including location, morphology, length, depth, and possible stability. This MR imaging information can affect treatment planning by helping to predict meniscal tears that are potentially

reparable or will have to be resected and tears that might not need surgical intervention. However, the sensitivity for detection of repairable lateral meniscus is very low (33%), but has a high accuracy (91%). The sensitivity for predicting irrepairability (larger tear) is very high (90%), with high accuracy (90%).[412]

For diagnosis of retears in postoperative menisci, CT arthrography or MR arthrography (direct or indirect) are methods with a slightly higher accuracy than unenhanced MR.[408, 415, 418, 427]

The specificity and sensitivity of MR decreases as the number of injured structures within the knee increases. In the presence of acute anterior cruciate ligament tears, MR imaging has relatively low sensitivity for detecting meniscal tears due to missed tears in the posterior horn of the lateral meniscus (medial meniscus : Se = 100 %, Sp = 88 %, Acc = 90 %; lateral meniscus : Se =57 %, Sp = 100 %, Acc = 85 %).[422]

MR can accurately detect meniscal contusion, which is often associated with cruciate ligament rupture.[405]

Specificity and sensitivity are also dependent on the reporting radiologist or on the type of meniscal lesion, i.e. tear, contusion or degeneration. A retrospective review of the literature from 1989 through 1999 on MR imaging of the knee in asymptomatic volunteers revealed that starting in the third decade, there is "age-dependent degeneration" of the meniscus with increasing MR signals in the meniscus.[410] By the fourth and fifth decades, significant MR changes are present, especially in the medial meniscus, yet these patients are asymptomatic. These authors urge that "clinicians match clinical signs and symptoms with magnetic resonance imaging before instituting surgical treatment." The diagnosis of meniscal degeneration with signal changes grade 1, 2, or 3 are often misdiagnosed as "tears".[410] These findings are confirmed by other authors who conclude that a meniscal tear is unlikely when MR shows a focus of high signal intensity in the posterior horn of the medial meniscus that does not unequivocally extend to involve the inferior or superior joint surface. An appropriate trial of conservative treatment is recommended in such questionable cases. MR is a useful diagnostic tool however, it should be used selectively, and in conjunction with history and clinical examination in evaluating internal derangements of the knee.[433, 430] Similar findings are confirmed in a study of 40 knees of 20 asymptomatic professional basketball players : there is a higher prevalence of meniscal lesions (20 %) and patello-femoral articular cartilage lesions (47,5 %) in asymptomatic male professional basketball players than previously reported in the literature.[429]

Another study reveals that about 25% of MR examinations of the knee show meniscal degeneration.[423] The majority shows no evolution after 5 years and the correlation with clinical symptoms is poor.[423] After 5 years 76 % show no change, 8 % regress and 16 % progress, usually after 40 y. Clinical symptoms occur in only 18 % of patients.

An abnormal MR finding may not necessarily be the cause of a patients symptoms. Especially, horizontal or oblique meniscal tears are frequently encountered in both asymptomatic and symptomatic knees and may not always be related to symptoms.[432] On the contrary, radial, vertical, complex, or displaced meniscal tears and abnormalities of the collateral ligaments, pericapsular soft tissues, and bone marrow are found almost exclusively in symptomatic knees and are therefore clinically more meaningful.[432] Meniscal tears are highly prevalent in both asymptomatic and clinically osteoarthritic knees of older individuals, but not more painful than in patients without a tear, and meniscal tears do not affect functional status. Therefore the routine use of magnetic resonance imaging for the evaluation and management of meniscal tears in patients with osteoarthritis of the knee is not recommended.[434]

Studies comparing the accuracy of clinical examination versus magnetic resonance imaging in diagnosing meniscal and anterior cruciate ligament pathology reveal that a well-trained qualified surgeon can safely rely on clinical examination for diagnosing meniscal and anterior cruciate ligament injuries in young patients below 40 years with recent sports trauma. Clinical examination is at least as accurate as MR in the skilled orthopaedic surgeon's hand. MR should be reserved for more complicated and confusing cases. The routine ordering of an MR scan of the knee before examination by

a well-trained orthopaedic surgeon is not recommended in young patients with acute knee trauma.[435, 436]

Magnetic resonance imaging is a moderately accurate method to diagnose and evaluate anterior cruciate ligament tears with sensitivity levels of 83 – 95 % % and specificity levels of 77 % - 80 %, a rather low positive predictive value (45 - 67 %), but high negative predictive value (95 %).[420, 425, 428] Partial anterior cruciate ligament tears are missed frequently, up to 75 %.[428] MR imaging is a reliable method to assess anterior cruciate ligament reconstruction and retear, with a sensitivity of > 90 %, a specificity of 86 % and an accuracy of 87 %.[407]

Although MR may be reliable in diagnosing acute posterior cruciate ligament injury, MR is not so reliable in assessing the healing process and evaluating chronic injuries: up to 85 % of posterior cruciate ligaments with a "healed" appearance may show laxity at clinical examination, and the accuracy in diagnosing a chronic posterior cruciate ligament injury is only 57% (40-80%).[409, 424] It is postulated that, in the case of a chronic posterior cruciate ligament injury, healing in continuity may occur, producing an intact but lax ligament. Although MR may be reliable in evaluation of continuity of posterior cruciate ligament reconstruction, there does not appear to be a relationship between clinical stability and findings at MR imaging.[431]

For evaluation of cartilage, MR imaging and CT-arthrography are methods with equal accuracy, especially for deep cartilage lesions (chondromalacia grade 3 and 4), whereas CT-arthrography is more accurate for superficial fraying and fissures.[403, 416] MR can detect cartilage lesions with high accuracy and specificity if dedicated cartilage sequences are used (Se = 75 – 91 %; Sp = 87 - 98 %; PPV = 48 – 96 %; NPV = 74 - 97 %, Acc = 79 – 86 %).[406, 413, 417, 421] Accuracy is higher for deep cartilage lesions (94 %) than for superficial cartilage lesions (70 % in femoro-tibial compartment and 78 % in femoropatellar compartment).[416] Accuracy levels are also lower when interpretations are made by general radiologists than when experienced musculoskeletal radiologists evaluate the MR examination.[433]

Although the most recent MR examination techniques are able to detect and display cartilage lesions adequately, it is still controversial whether MR can replace arthroscopy for the diagnosis of cartilage damages of the knee joint.[421] In view of the high specificity (97%-99%) and the high negative prediction value (97%-98%), MR is suitable for the exclusion of cartilage lesions [421]. When an MR examination reveals no cartilage injury, a cautious attitude towards an operative cartilage treatment is certainly justified.

Most publications on MR of the knee have focussed on accuracy, whereas cost effectiveness has not been extensively evaluated. In 2001 a cost-effectiveness study of MR imaging for investigation of the knee joint has been published.[433] In this study, performed in the United Kingdom, comparing 2 groups of patients, one group with access to MR imaging and another group without access, the central finding in terms of patient health outcomes was that there were no statistically significant differences between the 2 patient groups in all measures of health outcome (diagnostic impact, therapeutic impact and patient outcome; conjoints studies; stated preference survey). However, the use of MR imaging was found to be associated with a positive diagnostic/therapeutic impact because MR significantly influenced clinicians' diagnoses and management plans in patients with knee problems: a significantly smaller proportion of patients in the MR imaging group underwent surgery (p = 0.001). MR has a diagnostic impact in some cases by refuting certain clinical diagnoses and in others by improving clinician confidence in diagnosis. Additionally, the use of MR helps to bring about new, previously unsuspected diagnoses. In terms of changes in the diagnostic and treatment pathways, there is a marked shift away from the use of surgery either for diagnosis or treatment. As a consequence, the overall costs for both the MR and no-MR imaging groups were similar, indicating that the increased cost associated with the use of MR imaging in all patients was offset in full by the reduced requirement for surgery.

Key points

- **The use of MR imaging for evaluation of the knee is associated with a positive diagnostic/therapeutic impact because MR significantly influences clinicians' diagnoses and management plans in patients with knee problems : a significantly smaller proportion of patients in the MR imaging group will undergo arthroscopy or surgery, and this reduce in cost compensates for the expenses for MR imaging (Evidence level 6)**
- **MR imaging information can affect treatment planning by helping to predict meniscal tears that are potentially reparable or will have to be resected and tears that might not need surgical intervention (Evidence level 4)**
- **MR imaging is a useful diagnostic tool in evaluating internal derangements of the knee, however, it should be used selectively, and in conjunction with history and clinical examination because many abnormal findings occur also in asymptomatic individuals and are therefore not necessarily be the cause of a patients symptoms (Evidence level 2)**
- **Magnetic resonance imaging is a moderately accurate method to diagnose and evaluate anterior cruciate ligament tears, especially partial tears are missed if MR is performed in the acute stage (Evidence level 2)**
- **Although MR may be reliable in diagnosing acute posterior cruciate ligament injury, MR is not so reliable in assessing the healing process and laxity of the posterior cruciate ligament (Evidence level 2)**
- **For evaluation of cartilage, MR imaging and CT-arthrography are methods with equal accuracy (Evidence level 2)**

8.1.3 Hip

8.1.3.1 Health technology Assessments

Bone density measurement

One HTA report aims to compare SPA, DPA, SXA, DEXA, US, quantitative CT and quantitative MR for bone density measurement. Studies between 1985 and September 1994 are included. Conclusions are not available yet. Because a reduction in bone density often correlates to an increased risk of fracture, bone density is usually measured in an attempt to establish the risk of fracture. The results from bone density measurement are intended to provide a potential basis for treating osteoporosis. When assessing the value of bone density measurement, the key issues concern the reliability of the various methods (i.e., how accurately they reflect bone density) and whether bone density treatment can actually prevent fracture. The new methods for bone density measurement are based on either the energy/methodology used in ultrasound and magnetic resonance imaging (MRI), or on x-rays. Most methods demonstrate good precision (i.e. repeated measurements yield the same results). However the accuracy of current technologies is substantially lower than their precision, so further research, technical development, and experience are required.[437]

Usefullness of hip arthroscopy

For this report narrative revisions and case series were used. No other observational designs or randomized controlled clinical trials were detected, neither documents that set position on the topic, published by the main national or international orthopedic associations. Two case series of 40 and 102 patients compare hip arthroscopy (HA) with other diagnostic alternatives such as Magnetic Resonance arthrography (MRA), magnetic resonance imaging (MRI) with contrast and anesthetic injection within the coxofemoral joint. In both series the other methods' validity was calculated against HA, which was used as reference test for the possibility it offers to directly explore the

joint. The case series generally report therapeutic indications. In comparison with other diagnostic alternatives, HA is more specific and sensitive than Magnetic Resonance arthrography, MRI with gadolinium and response to intraarticular anesthetics.[438]

Occult fractures

The aim of this study was to assess the cost-effectiveness of using early MRI (within 24 hours of injury) or delayed bone scintigraphy (RBS) (for 48 hours after injury) in the diagnosis of occult hip fractures in patients with clinically suspected hip fractures. Neither health technology was specifically regarded as the comparator since "there is a continuing debate over which of the two imaging modalities can be used in the most cost-effective manner". It is based on a single study with a retrospective cohort of 40 patients. The clinical outcome results were as follows: sensitivity, RBS 90.9% and MRI 100%; specificity, RBS 100% and MRI 100%; accuracy, RBS 95% and MRI 100%; time to diagnosis (days), RBS 2.24 (SD, 1.3) and MRI 0.368 (0.597), ($p<0.0001$), (95% CI: 1.22 - 2.52 for the difference). Using MRI instead of bone scanning shortens the time to diagnosis in patients with suspected hip fractures in institutions performing delayed RBS. Furthermore cost results were substantially lower for MRI. The MRI modality had an estimated cost of $3,050.75 (range: $1,451.25 - $55,094.25) per patient versus $7,543 (range: $1,145 - $215,717) for RBS. Cost analysis covered the costs of diagnostic modalities (technical and professional elements) and hospital stay, 1996 price data were used.[439]

Conclusion HTA reports

There is only one report comparing CT and MRI, it aims to compare a wide range of techniques to evaluate osteoporosis. It is not finished yet. Definitive results are not available. [437]

Two reports compare MRI with other techniques. MRI and MR-arthrography are compared with hip arthroscopy in a wide range of hip joint disorders. For this report narrative revisions and case series were used, it has a low evidence level (1) and low quality. Hip arthroscopy was far more accurate compared with MRI and is advised in patients with occult chronic hip pain since hip arthroscopy revealed a treatable cause in 50% of cases.[438] In another report scintigraphy is compared with MRI for the diagnosis of occult fracture. The quality of this study is good with level 3 evidence. MRI proved to have a higher accuracy and earlier diagnosis at lower cost. It is most cost effective in patients without contraindication for surgery.[439]

8.1.3.2 Systematic reviews

Recent advances in sports medicine

In the past, hip joint abnormality was attributed solely to osteoarthritis, but magnetic resonance imaging (MRI) and hip arthroscopy have shown that labral injuries, chondral injuries, rim lesions, synovitis and tears of the ligament teres are common causes of hip, groin and low-back pain.

X-ray, arthrography and conventional MRI have all been found to be inadequate in diagnosis. In the last decade, gadolinium-enhanced magnetic resonance arthrography has been widely used to detect labral abnormalities, although more recent studies have suggested that the sensitivity of this procedure may be somewhat less than first reported. More recently, fast spin-echo proton-density weighted MRI sequences taken in the plane of the hip joint have been shown to be more accurate.

Hip arthroscopy is both a diagnostic (gold standard) and therapeutic tool, although it is technically more difficult than arthroscopy of other joints. Distraction of the hip of about 10–15 mm is required to access the hip joint, and most complications, such as neuropraxias, are caused by traction.

In a number of case series, arthroscopy has been shown to be of benefit in recent traumatic labral injury, but gives disappointing results in chronic hip pain, which is

probably associated with degenerative change, and chondral lesions of the acetabulum.[440 1021]

Recommendations for the use of new methods to assess the efficacy of disease-modifying drugs in the treatment of osteoarthritis

Recent innovations in the pharmaceutical drug discovery environment have generated new chemical entities with the potential to become disease modifying drugs for osteoarthritis (DMOAD's). Regulatory agencies acknowledge that such compounds may be granted a DMOAD indication, providing they demonstrate that they can slow down disease progression; progression would be calibrated by a surrogate for structural change, by measuring joint space narrowing (JSN) on plain X-rays with the caveat that this delayed JSN translate into a clinical benefit for the patient. The Group for the Respect of Ethics and Excellence in Science (GREES) organized a working party to assess whether new technologies may be used as surrogates to plain x-rays for assessment of DMOADs. An extensive search of the international literature, from 1980 to 2002, a resource document for regulatory authorities is prepared. Magnetic resonance imaging (MRI) is now used to measure parameters of cartilage morphology and integrity in OA patients. While some data are encouraging, correlation between short-term changes in cartilage structure observed with MRI and long-term radiographic or clinical changes are needed. Hence, the GREES suggests that MRI may be used as an outcome in phase II studies, but that further data is needed before accepting MRI as a primary end-point in phase III clinical trials.[441]

Sportsman's hernia

Sportsman's hernia is a debilitating condition which presents as chronic groin pain. A tear occurs at the external oblique aponeurosis which may result in an occult hernia. The definition, investigation and treatment of this condition remain unclear. A systematic Medline search was performed and all literature pertaining to chronic groin pain, groin injury, sportsman's hernia and sportsman's groin from 1962 to 1999 was retrieved for analysis. The costs of computed tomography and magnetic resonance imaging are such that their routine use for assessment of patients with groin pain cannot be justified. They may, however, be employed in difficult cases to help define the anatomical extent of a groin injury. Plain radiography, ultrasonography and scintigraphy should be the usual first-line investigations to supplement clinical assessment. Herniography may help in situations of obscure chronic groin and pelvic pain. There is no consensus view supporting any particular surgical procedure for sportsman's hernia.[442]

Conclusion on Systematic Reviews of the Hip

X-ray, arthrography and MRI (conventional and MR arthrography) have all been found to be inadequate in diagnosis of labral injuries, chondral injuries, rim lesions, synovitis and tears of the ligament teres. Arthroscopy remains the method of choice.[440]

MRI may be used as an outcome in phase II studies to objectify the effect of disease modifying drugs in osteoarthritis, further data is needed before accepting MRI as a primary end-point in phase III clinical trials.[441]

The costs of computed tomography and magnetic resonance imaging are such that their routine use for assessment of patients with groin pain cannot be justified. They may, however, be employed in difficult cases to help define the anatomical extent of a groin injury. Plain radiography, ultrasonography and scintigraphy should be the usual first-line investigations to supplement clinical assessment.[442]

8.1.3.3 Clinical Studies

MRI and MDCT arthrography of articular cartilage in patients with hip dysplasia

The objective was to assess the diagnostic ability of MDCT arthrography for acetabular and femoral cartilage lesions in patients with hip dysplasia.

A disorder of the articular cartilage was evaluated in 20 hips of 18 patients with acetabular dysplasia who did not have osteoarthritis or who had early stage osteoarthritis before undergoing pelvic osteotomy surgery. The findings on fat-suppressed 3D fast spoiled gradient-echo MRI and MDCT arthrography of the hip were evaluated by two independent observers, and sensitivity, specificity, and accuracy were determined using arthroscopic findings as the standard of reference. Kappa values were calculated to quantify the level of interobserver agreement.

The sensitivity and specificity for the detection of any cartilage disorder (grade 1 or higher) were (observer 1/observer 2) 49%/67% and 89%/76%, respectively, on MRI, and 67%/67% and 89%/82%, respectively, on CT arthrography. The sensitivity and specificity for the detection of cartilage lesions with substance loss (grade 2 or higher) were (observer 1/observer 2) 47%/53% and 92%/87%, respectively, on MRI, and 70%/79% and 93%/94%, respectively, on CT arthrography. CT arthrography provided significantly higher sensitivity in the detection of grade 2 or higher lesions than MRI for both observers. Interobserver agreement in the detection of grade 2 or higher cartilage lesions was moderate (kappa = 0.53) on MRI and substantial (kappa = 0.78) on CT.

MDCT arthrography is a sensitive and reproducible method for assessing articular cartilage lesions with substance loss in patients with hip dysplasia.[443]

Subchondral fractures in osteonecrosis of the femoral head: comparison of radiography, CT, and MR imaging

The objective was to compare the sensitivity of unenhanced radiography, CT, and MR imaging in revealing subchondral fractures. Forty-five subjects with stage I and stage II osteonecrosis of the femoral head were included and were evaluated with radiography, CT, and MR imaging 6 and 12 months after surgery. Compared with CT, MR imaging has a sensitivity and specificity of 38% and 100%, and unenhanced radiography has a sensitivity and specificity of 71% and 97%, respectively. CT reveals more subchondral fractures in osteonecrosis of the femoral head than unenhanced radiography or MR imaging.[444]

Inflammatory changes of hip synovial structures in polymyalgia rheumatica

The accuracy of clinical examination compared to magnetic resonance imaging (MRI) in patients with polymyalgia rheumatica (PMR) with pelvic girdle symptoms is evaluated. Secondary end-point was to evaluate the sensitivity and specificity of ultrasonography (US) compared to MRI in the assessment of hip lesions.

Case-control study of 20 consecutive PMR patients and 40 controls with different rheumatic conditions. Both groups were clinically assessed for the presence of hip synovitis, trochanteric, iliopsoas and ischiogluteal bursitis. Both MRI and US detected trochanteric bursitis in 100% of PMR patients, bilateral in 18/20 (90%), and in 12/40 (30%) controls ($p < 0.001$). Hip synovitis was detected in 17/20 (85%) by MRI and in 9/20 (45%) by US ($p < 0.02$) in case-patients and in 18/40 (45%) controls. In PMR, MRI and US showed iliopsoas bursitis in 10/20 (50%) and 6/20 (30%) and ischiogluteal bursitis in 5/20 (25%) and 4/20 (20%) with no differences compared to controls. Clinical examination showed a good accuracy for hip synovitis, trochanteric and ischiogluteal bursitis, while it overestimated the presence of iliopsoas bursitis. US was less sensitive than MRI for the detection of hip synovitis and iliopsoas bursitis (53% and 60%).

A careful physical examination allows to detect all inflammatory lesions excluding iliopsoas bursitis. US is less sensitive than MRI in the assessment of hip synovitis and iliopsoas bursitis.[445]

Hip joint pathology: clinical presentation and correlation between magnetic resonance arthrography, ultrasound, and arthroscopic findings

Twenty-five consecutive hip arthroscopies in patients with chronic low back or hip pain were prospectively studied to determine the range of pathologic diagnoses, clinical presentation, and the correlation between magnetic resonance arthrographic, ultrasonographic, and arthroscopic findings in the hip joint. All of the hips arthroscoped had pathology. The only consistently positive clinical test result was a restricted and painful hip quadrant compared with the contralateral hip. Plain radiographs were normal in all patients. All but 1 patient underwent magnetic resonance arthrography. Although specificity of 100% for MRI was achieved in the study, the sensitivity was significantly lower, with a relatively high number of false negatives. Hip arthroscopy proved the definitive diagnostic procedure for intraarticular pathology.

Clinical signs of a painful, restricted hip quadrant and a positive FABER test result should suggest magnetic resonance arthrography in the first instance, but a negative magnetic resonance image should not preclude hip arthroscopy if there is high clinical suspicion of hip joint pathology.[446]

US assessment of hip joint synovitis in rheumatic diseases. A comparison with MR imaging

The aim of this study is to assess the significance of ultrasonography (US) in detecting hip joint synovitis in patients with rheumatic diseases. Forty patients with rheumatic disease and suspected hip joint synovitis underwent MRI and US of the hip joint. In addition to the throughout MRI evaluation, the anterior collum-capsule distance (CCD) was determined by both MRI and US. Thirteen healthy volunteers were examined with MRI to establish the criteria for normal findings in MRI when classifying hip joints to those with synovitis and those without. MRI was used as a gold standard.

Synovitis was found using MRI in 31 hips of 22 patients (9 patients had bilateral synovitis). The intraclass correlation was 0.61 between MRI and US in measuring CCD. In classifying hip joint synovitis with US, the sensitivity of the method was 87% and specificity 42%, when the CCD criterion for synovitis was determined to be > or = 7 mm. If the cut-off point was raised to 9 mm, the sensitivity decreased to 61% while specificity increased to 94%.

Measurement of CCD with US proved to be a rather inaccurate method to point out synovitis in rheumatic patients when using MRI as a reference. The main reason for this result was the thickened capsule, which US could not differentiate from a thickened synovium.[447]

Magnetic resonance imaging as the primary imaging modality in children presenting with acute non-traumatic hip pain

The role of magnetic resonance imaging (MRI) in children presenting with acute non-traumatic hip pain was evaluated prospectively. MRI is performed in addition to standard investigations (arthrosonography +/- hip radiographs) in 50 children. MRI was performed on an open 0.23T system and comprised gradient echo T1 weighted coronal, fast spin echo T2 weighted coronal and inversion recovery spin echo (IRSE) axial sequences. Sensitivity of MRI was 0.79 (0.68, 0.90, specificity 1.00 (0.89, 1.00), accuracy 0.81 (0.70, 0.92), PPV 1.00 (0.89, 1), NPV 0.36 (0.25, 0.47). Sensitivity of standard imaging was 0.70 (0.54-0.86), specificity 0.57 (0.41, 0.73), accuracy 0.72 (0.56, 0.88), PPV 0.91 (0.75, 1.00), NPV 0.24 (0.08, 0.40). MRI correctly identified all seven children with serious underlying disorder whereas conventional imaging correctly diagnosed only two. Combined with inflammatory markers MRI is the imaging method of choice to determine those children with acute non-traumatic hip pain who require aggressive management.[448]

Magnetic resonance imaging in the evaluation of periprosthetic acetabular osteolysis: a cadaveric study

Periprosthetic osteolysis is a well recognized complication of total hip arthroplasty that leads to implant failure. The ability to accurately assess and visualize the position and volume of periacetabular bone defects is paramount for clinical observation and medical treatment, as well as pre-operative planning of revision surgery. A modified MRI protocol that is useful in detection and quantification of periacetabular bone loss is used to compare MRI to plain film analysis in the assessment of periacetabular bone loss in 3 cadavers. MRI was 95% sensitive in the detection of lesions. Specificity was 98%, and accuracy was 96%. Lesion detection was not statistically dependent on lesion location (p=0.27).

Using conventional radiographic analysis, the overall sensitivity of lesion detection was 52%, and the specificity was 96%. Using plain film analysis, identification of true lesions depended on the location with 83% of ilial lesions, 64% of pubic lesions, 55% of ischial lesions, and 0% of posterior wall lesions correctly identified. The modified MRI technique utilized did allow for accurate visualization of simulated osteolytic lesions, and may provide a suitable noninvasive method to provide serial assessment of clinical periacetabular osteolysis without the use of ionizing radiation.[449]

Fibrocystic changes at anterosuperior femoral neck: prevalence in hips with femoroacetabular impingement

The aim of this study was to retrospectively evaluate if there is an association between juxta-articular fibrocystic changes at the anterosuperior femoral neck and femoroacetabular impingement (FAI). An orthopedic surgeon and a radiologist in consensus retrospectively reviewed the anteroposterior (AP) pelvic radiographs of 117 hips with FAI and compared these images with the AP radiographs of a control group of 132 hips with developmental dysplasia (DD) to determine the prevalence of juxta-articular fibrocystic changes at the anterosuperior femoral neck. The sensitivity and specificity of AP pelvic radiography in the detection of these fibrocystic changes were calculated by using an additional 61 hips with FAI and on the basis of findings at magnetic resonance (MR) arthrography, which was routinely performed for assessment of FAI. In 24 patients who underwent joint-preserving surgery for FAI, the fibrocystic changes were localized intraoperatively and the spatial relation of the region of these changes to the area of FAI was identified. For statistical comparisons, nonparametric tests were performed. According to MR arthrogram findings, the sensitivity, specificity, and positive and negative predictive values of AP pelvic radiography were 64%, 93%, 91%, and 71%, respectively.[450]

Magnetic resonance arthrography versus arthroscopy in the evaluation of articular hip pathology

In this study magnetic resonance arthrography performance is compared with hip arthroscopy findings to assess the diagnostic value in evaluating acetabular labral tears and concurrent articular hip pathology. One hundred one consecutive patients (102 hips) with a clinical diagnosis of acetabular labral tear were assessed after failing to improve with nonoperative treatment. Magnetic resonance arthrography detected 71 of 93 (76%) acetabular labral tears with five false positive studies in 4.9%. Articular cartilage findings diagnosed by magnetic resonance arthrography were confirmed by arthroscopy in 64 hips in 64 patients (62.7%). With respect to labral pathology, magnetic resonance arthrography showed a sensitivity of 71%, specificity of 44% positive predictive value of 93%, negative predictive value of 13%, and accuracy of 69%. With respect to articular cartilage pathology, magnetic resonance arthrography had a sensitivity of 47%, specificity of 89%, positive predictive value of 84%, negative predictive value of 59%, and accuracy of 67%. Although magnetic resonance arthrography is an excellent positive predictor in diagnosing acetabular labral tears and articular cartilage abnormalities, it has limited sensitivity. A negative imaging study does not exclude important intra-articular pathology that can be identified and treated arthroscopically.[451]

MR arthrography of the hip: diagnostic performance of a dedicated water-excitation 3D double-echo steady-state sequence to detect cartilage lesions

The objective this study was to compare the diagnostic performance of a dedicated cartilage MR sequence (water-excitation 3D double-echo steady-state) with a standard MR arthrography sequence (T1-weighted spin-echo) in 50 MR arthrograms of the hip joint obtained in 47 consecutive patients. Sensitivity and specificity for detecting cartilage defects were calculated for those hips that underwent open surgery (n = 21). For the 3D double-echo steady-state and T1-weighted spin-echo sequences, sensitivities and specificities for cartilage lesion detection were 58% and 88% and 81% and 81% for reviewer 1 and 62% and 94% and 62% and 100% for reviewer 2, respectively. Lesion conspicuity was significantly superior (p = 0.036) for the 3D double-echo steady-state sequence (mean grade, 3.4) compared with the T1-weighted spin-echo sequence (mean grade, 3.0). The 3D double-echo steady-state sequence optimized for cartilage imaging improves lesion conspicuity but does not improve diagnostic performance.[452]

MRI diagnosis of tears of the hip abductor tendons (gluteus medius and gluteus minimus)

The purpose of this study was to determine the accuracy of MRI for diagnosing tears of the hip abductor tendons (gluteus medius and gluteus minimus) by retrospective evaluation MRI's of 74 hips (in 45 patients). Fifteen hips had surgically proven abductor tendon tears, and 59 hips were either asymptomatic or had surgically confirmed intact tendons. The accuracy of MRI for the diagnosis of tears of the abductor tendons was 91% (gluteus medius and gluteus minimus tendons) with sensitivity and specificity at 73% and 95%, respectively.[453]

Fatigue stress injuries of the pelvic bones and proximal femur: evaluation with MR imaging

The purpose of this study was to determine the prevalence and the distribution as well as male/female differences in patients with hip or pelvic pain based on MRI results. Three hundred forty consecutive patients (45 women, 295 men) suffering from stress-related hip, buttock or groin pain underwent MR imaging. Radiographic data were available for 215 patients. In MRI 174 stress injuries were diagnosed in 137 patients (32 women, 105 men). The incidence of bone stress injuries in women was significantly higher than that in men (p<0.0001). Thirty-three of the 137 patients (24%) had multiple bone stress injuries, 29 had two bone stress injuries on MRI and 4 patients had three. The sensitivity of radiography was 37%, specificity 79%, accuracy 60%, positive predictive value 59% and negative predictive value 61%. Patients suffering from stress-related hip pain MRI revealed bone stress injuries in 40%; of these, 60% were located in the proximal femur and 40% in the pelvic bones.[454]

Cartilage lesions in the hip: diagnostic effectiveness of MR arthrography

The purpose of this study was to retrospectively evaluate the diagnostic performance of magnetic resonance (MR) arthrography in the detection of articular cartilage lesions in patients suspected of having femoroacetabular impingement and/or labral abnormalities. Forty-two MR arthrograms were obtained in 40 patients with within 6 months open hip surgery. At surgery, most (37 [88%] of 42) cartilage defects were identified in the anterosuperior part of the acetabulum. The sensitivities and specificities of MR arthrographic detection of cartilage damage were 79% and 77%, respectively, for reader 1 and 50% and 84%, respectively, for reader 2.[455]

Conclusion Clinical Studies of the Hip

MR or MR arthrographic detection of cartilage damage has a low sensitivity of 50-79% and higher specificity of 77-100%.[452,455] The accuracy of MRI is far lower compared to MDCT arthrography. [443] Although MR arthrography is a good positive predictor in diagnosing acetabular labral tears and articular cartilage abnormalities, it has limited sensitivity. A negative MR arthrography study does not exclude important intra-articular pathology that can be identified and treated arthroscopically. [451] Clinical signs of a painful, restricted hip quadrant and a positive FABER test result should suggest magnetic resonance arthrography in the first instance, but a negative magnetic resonance image should not preclude hip arthroscopy if there is high clinical suspicion of hip joint pathology.[446]

According to MR arthrogram findings, AP pelvic radiography has a low sensitivity and high specificity to detect juxta-articular fibrocystic changes at the anterosuperior femoral neck in femoroacetabular impingement.[450]

The accuracy of CT to reveal subchondral fractures in known osteonecrosis of the femoral head is higher compared to non-enhanced radiography or MR imaging.[444]

US is less sensitive than MRI in the assessment of hip synovitis and iliopsoas bursitis in patients with polymyalgia rheumatica.[445]

Combined with inflammatory markers MRI is the imaging method of choice to determine those children with acute non-traumatic hip pain who require aggressive management.[448]

The accuracy of MRI for the diagnosis of tears of the abductor tendons was 91% (gluteus medius and gluteus minimus tendons) with sensitivity of 73% and specificity of 95%.[453]

Key points

- **There is only poor evidence comparing CT and MRI. No completed HTA reports are available, no systematic reviews, only two clinical studies, both with level 2 evidence.**
- **MRI is compared with other imaging techniques in 3 reviews with poor quality.**
- **Eleven clinical studies compare MRI with other techniques (arthroscopy, CT, ultrasound, radiograph and bone scintigraphy). Evidence ranges from level 1 to 3.**

Articular Disease

A HTA report uses narrative revisions and case series, it has a low evidence level (1) and low quality. Hip arthroscopy was far more accurate compared with MRI and is advised in patients with occult chronic hip pain since hip arthroscopy revealed an arthroscopic treatable cause in 50% of cases.[438] A review report compares MRI with other techniques. X-ray, arthrography and MRI (conventional and MR arthrography) have all been found to be inadequate in diagnosis of a wide range of hip joint disorders i.e. labral injuries, chondral injuries, rim lesions, synovitis and tears of the ligament teres. Arthroscopy remains the method of choice.[440 1021] Clinical studies discuss the value of MR in articular disease. MR or MR arthrographic detection of cartilage damage has a low sensitivity of 50-79% and higher specificity of 77-100%.[455, 452] Although MR arthrography is a good positive predictor in diagnosing acetabular labral tears and articular cartilage abnormalities, it has limited sensitivity. Also a negative MR arthrography study does not exclude important intra-articular pathology that can be identified and treated arthroscopically.[451] Clinical signs of a painful, restricted hip quadrant and a positive FABER test result should suggest MR arthrography in the first instance, but a negative MRI should not preclude hip arthroscopy if there is high clinical suspicion of hip joint pathology.[446] MRI is still indicated in these patients hence it is able to detect bone disease and soft tissue disease, these patients are excluded from arthroscopic morbidity.

In an other study of patients with known hip dysplasia, MDCT-arthrography showed higher sensitivity and specificity compared to MRI to detect osteo-arthritic cartilage lesions.[443] This is merely a sensitivity matter in low grade cartilage lesions, furthermore there is actually poor clinical/therapeutical consequence regarding these low grade cartilage lesions. Taking into account the radiation exposure and risks linked to the invasive procedure (infection, jodium allergy…) of (MD)CT-arthrography the first choice is MRI.

In a second review MRI is proposed in advantage of radiographs as an outcome in phase II studies to objectify the effect of disease modifying drugs in osteoarthritis. [441] Three clinical studies (level 1 and 2) on synovial inflammation or overall hip pathology with prove higher sensitivity, specificity or accuracy for MRI compared to US. US is less sensitive than MRI in the assessment of hip synovitis and iliopsoas bursitis in patients with polymyalgia rheumatica.[445]

In one clinical study (level 2-3) on acute non traumatic pain in children MRI was better in directing therapy planning compared to XR. Combined with inflammatory markers MRI is the imaging method of choice to determine those children with acute non-traumatic hip pain who require aggressive management.[448]

Soft Tissue Disease

Soft tissue neoplasm and other soft tissue lesions are discussed thoroughly in another part of this report. Two clinical studies specifically discuss soft tissue disease at the hip.

CT and MRI may be employed in difficult cases to help define the anatomical extent of a groin injury. [442] MRI has the advantage of higher contrast resolution at the soft tissues especially if fat suppressed T2-WI is used.

The accuracy of MRI for the diagnosis of tears of the abductor tendons was 91% (gluteus medius and gluteus minimus tendons) with sensitivity and specificity at 73% and 95%, respectively.[453]

Bone Disease

In a clinical study in patients with known avascular necrosis of the hip MRI proved much lower sensitivity to detect subchondral fractures compared to CT and XR.[444] The clinical consequence of this finding is restricted since the prognostic advantage of early diagnosis of subchondral fracture is limited. It is common knowledge that prognosis of AVN depends on assessing the volume and the surface of the femoral head involved and not on the presence of a subchondral fracture line. Assessing the volume and the surface of the femoral head involved is done by MRI. First choice in detection and grading of hip AVN is MRI. This statement is supported by multiple case reports and non-blinded small studies that develop MRI as the method of choice to differentiate bone marrow edema syndrome (BMES) (transient osteoporosis), avascular necrosis and subchondral insufficiency fractures (SIF).

In another report scintigraphy is compared with MRI for the diagnosis of occult fracture. The quality of this study is good with level 3 evidence. MRI proved to have a higher accuracy and earlier diagnosis at lower cost. It is most cost effective in patients without contraindication for surgery.[439]

According to MR arthrogram findings, AP pelvic radiography to detect juxta-articular fibrocystic changes at the anterosuperior femoral neck in femoroacetabular impingement has a low sensitivity and high specificity.[450]

Key points

Articular Disease

- Hip arthroscopy was far more accurate compared with MRI, X-ray and arthrography and is advised in patients with occult chronic hip pain. (Level 1) MR arthrography has limited sensitivity for cartilaginous disease. MDCT-arthrography showed higher sensitivity and specificity compared to MRI to detect osteo-arthritic cartilage lesions for low grade lesions. (Level 2) There is actually poor clinical/therapeutical consequence regarding these low grade cartilage lesions. MRI is still indicated in these patients hence it is able to detect bone disease and soft tissue disease; these patients are excluded from arthroscopic morbidity.
- US is less sensitive than MRI in the assessment of hip synovitis and iliopsoas bursitis. (Level 1)
- Combined with inflammatory markers, MRI is the imaging method of choice to determine those children with acute non-traumatic hip pain who require aggressive management. (Level 2-3)

Soft Tissue Disease

- Preoperatively, MRI may be employed in difficult cases to help define the anatomical extent of a groin injury. MRI has the advantage over CT of higher contrast resolution. (Low level)
- The accuracy of MRI for the diagnosis of tears of the abductor tendons was 91%. (Level 2)

Bone Disease

- CT is more accurate compared to MRI, and MRI more accurate compared to scintigraphy to detect subchondral fractures in AVN. (Level 2) As prognosis of AVN depends on assessing the volume and the surface of the femoral head involved, first choice in detection and grading of hip AVN is MRI.
- MRI is the method of choice to differentiate bone marrow edema syndrome, avascular necrosis and subchondral insufficiency fractures.
- Preoperatively, MRI may be employed in difficult cases to help define the anatomical extent of a groin injury. MRI has the advantage over CT of higher contrast resolution.
- The accuracy of MRI for the diagnosis of tears of the abductor tendons was 91%.
- CT is more accurate compared to MRI, and MRI more accurate compared to scintigraphy to detect subchondral fractures in AVN. As prognosis of AVN depends on assessing the volume and the surface of the femoral head involved first choice in detection and grading of hip AVN is MRI.
- MRI is the method of choice to differentiate bone marrow edema syndrome, avascular necrosis and subchondral insufficiency fractures.

8.2 UPPER LIMB

8.2.1 Shoulder

MRI is currently the procedure of choice for evaluation of occult fractures and shoulder soft tissues, including tendons, ligaments, muscles, and labrocapsular structures. MRI can aid in detecting osseous and soft tissue abnormalities that may predispose to or be the result of shoulder impingement. The soft tissue abnormalities in the supraspinatus tendon, subacromial bursa, and biceps tendon are well seen. The osseous lesions include morphologic abnormalities of the acromion, acromioclavicular joint, and coracoacromial ligament.

8.2.1.1 Rotator cuff tear / shoulder impingement syndrome

Full-thickness tears of the rotator cuff tendons can be accurately identified using conventional MRI with high sensitivity and specificity. Increased signal intensity extending from the inferior to the superior surface of the tendon on all imaging sequences is an accurate sign of a full-thickness rotator cuff tear. Ten percent of rotator cuff tears will only present with morphologic changes. Tendon retraction, muscle atrophy, and fatty infiltration are important prognostic factors. This type of information can be useful for decisions regarding conservative versus operative repair, type of operative repair (open, mini open, or arthroscopic cuff repair; substitute or muscle transfer) and to provide a postoperative prognosis.

If there is any question concerning the distinction between a full-thickness and partial-thickness tear, MR arthrography is recommended. It is particularly helpful if the abnormal signal intensity extends from the undersurface of the tendon.

MRI: Ten studies were first included, most using conventional MRI pulse sequences as opposed to fat-suppressed MRI. For full-thickness tears, overall pooled sensitivities and specificities were high (0.89, 95% CI: 0.86 to 0.92; and 0.93, 95% CI: 0.91 to 0.95, respectively) and the studies were not statistically heterogeneous. For detection of partial-thickness rotator cuff tears, pooled sensitivity estimate was much lower (0.44, 95% CI: 0.36 to 0.51) although specificity again remained high (0.90, 95% CI: 0.87 to 0.92). Where tear prevalence is relatively high, a negative magnetic resonance finding may be sufficient to rule out the presence of a full-thickness tear, but between study heterogeneity means that similar conclusions cannot yet be drawn regarding a positive test result.[456-460] More recently, Teefey and Martin-Hervas compared prospectively MRI and US to surgery and found higher sensitivity and accuracy rates for MRI.[461, 462] A negative MR result would rule out the presence of a tear with more certainty than a negative ultrasound result. For detection of partial tears, although the accuracy was low, MR was more accurate than ultrasound in both studies.

MRA: Six studies investigating the accuracy of MRA were included. The type of MRI, views and contrast used varied considerably between studies, making any conclusions difficult. The pooled results suggest that MRA may be very accurate for detection of full-thickness rotator cuff tears [overall pooled sensitivity 0.95 (95% CI: 0.82 to 0.98) and specificity 0.93 (95% CI: 0.84 to 0.97), both estimates homogeneous]. Its performance for the detection of partial-thickness tears is less consistent. There is also some suggestion that MRA performs better than ultrasound or MRI, but any such benefit must be set against the invasiveness and potential discomfort to patients of the procedure.[456, 463-466] Two studies evaluated both MRI and MRA.[456, 466] Hodler found the accuracy for detection of full-thickness tears to be the same for both methods, but MRA was better at identifying partial-thickness tears. Yagci found MRA to perform better than MRI for all outcomes, although the use of fat suppression for MRA may also have contributed to the increased accuracy.

In a recent review paper, Matava reported that US is a cost-effective diagnostic tool for partial-thickness rotator cuff tears with a sensitivity of 94% and a specificity of 93% but is operator dependant, evidenced by only a 41% detection rate of partial-thickness tears.[467, 468] For MRA, the sensitivity is 84%, the specificity 96% and the accuracy 91% with the significant advantage of MR to diagnose concomitant abnormalities.[469, 468]

Clinical and arthroscopic diagnoses of rotator interval abnormalities and subtle instability patterns of the long head of the biceps brachii tendon are difficult. Understanding of function through the anatomy using MRA is a key in making diagnosis of subtle findings that may otherwise be missed or untreated.[470]

In a retrospective review of Kaplan, both MRI and arthroscopy described posterosuperior labral and humeral cartilage lesions as well as rotator cuff lesions. These findings may be indicative of internal impingement in throwing athletes.[471]

Pfirrmann showed a sensitivity of 90-100% and a specificity of 55-90% for MRA of subscapularis tendon tears in a retrospective study comparing MRA to arthroscopy and open surgery.[463]

Duc analysed in a retrospective study comparing MRA to revision surgery, full-thickness tears after rotator cuff repair with the following results. Sensitivity 86-90%, specificity 59-89%, accuracy 71-90% for supraspinatus tears. Sensitivity 79-100%, specificity 94-100%, accuracy 90-100% for infraspinatus tears. Sensitivity 82-91%, specificity 92-100%, accuracy 92-96% for suprascapularis tears results.[472]

Arthrography was the mainstay of evaluation for rotator cuff tear until the advent of shoulder MRI. It is currently used only as a potential study in patients with suspected rotator cuff disease who have a contraindication to MRI, in regions where shoulder US expertise is not available.

US can be used to evaluate the tendons of the rotator cuff and the biceps. It is operator-dependent and limited in evaluation of the other important deep shoulder structures and bone marrow. It can be used to determine if a partial-thickness or full-thickness rotator cuff tear is present.

According to the systematic review of J Dinnes on the effectiveness of diagnostic tests for the assessment of shoulder pain due to soft tissue disorders, the relative benefits of these technologies for the diagnosis of shoulder pain in terms of accuracy and cost-effectiveness are currently unknown.[473]

Key points

- **Either MRI or ultrasound could equally be used for detection of full-thickness rotator cuff tears.**
- **All the imaging modalities were less accurate for partial-thickness tears but indirect comparison between them suggests that MRA and ultrasound might be more accurate at detecting such tears than MRI**
- **Given the large differential in the cost of MR and US, the implication from current evidence is that ultrasound is the more cost-effective test to use in a specialist hospital setting for identification of full-thickness tears.**
- **There is a need, in the future, for large, well-designed, prospective studies of the diagnosis of shoulder.**

8.2.1.2 Shoulder instability / labroligamentous tears

The shoulder joint is the most unstable joint in the body. Instability can be difficult to diagnose, and the pain produced by the unstable shoulder could be mistaken for that of shoulder impingement, cervical disc disease, acromioclavicular joint disease, and other processes. During the last decade, MRI has allowed for direct visualization of many of the lesions related to instability, aiding in diagnosis as well as therapeutic planning and follow-up. Although high resolution non-enhanced MRI has been shown to have high accuracy rates for demonstrating labral tears, direct MR arthrography with intra-articular injection (MRA) of a dilute gadolinium solution has gained popularity during the last decade because of its ability to distend the joint and outline labral and capsular structures as well as the undersurface of the rotator cuff.

Waldt et al evaluated, in a retrospective study of 104 patients with proved labroligamentous injuries and a control group of 101 patients, the accuracy of MRA in the classification of such injuries using arthroscopy as the reference standard. They reported sensitivites of 88% (82-94), specificities of 91% (85-97) and accuracies of 89% (85-93) and concluded that MRA is an effective method for use in the detection and classification of anteroinferior labroligamentous injuries (in anterior shoulder instability). The results were lower for Perthes lesions.[474]

Mengiardi et al retrospectively compared preoperative MRA of 22 patients with frozen shoulder (treated with arthroscopic capsulotomy) with 22 control subjects. MRA revealed characteristic findings in frozen shoulder with relatively high specificities (95% for the thickening of coracohumeral ligament, 86% for the thickening of the capsule in

the rotator cuff interval, 100% for the complete obliteration of subcoracoid fat triangle.[475]

Oh et al present a decision tree considering the diagnostic choices in a patient with internal derangement of the shoulder and the cost-effectiveness of the diagnostic alternatives (conventional MRI, conventional arthrography and MR arthrography). MRA is more expensive than conventional MRI, but has much greater effectiveness and the cost-effectiveness ratio is significantly higher. The added cost is mitigated as the prevalence of labral tears increases in a population.[476]

MRA can help accurate identification and demonstration of the integrity of the glenohumeral ligaments (GHL), capsule and labrum and help in staging of abnormalities.[477]

MRA and MRI showed glenoid labral tears with greater sensitivity than CTA. MRA was the most sensitive for detecting a detached labral fragment, labral degeneration, lesions of the inferior part of labrum and of the inferior glenohumeral ligament.[478]

According to the american litterature, CT arthrography is a second-line procedure for shoulders with suspected instability or labral disorders, when magnetic resonance arthrography (MRA) and MRI are unavailable or contraindicated.

In our countries, due to the larger availibility of CT arthrography, both examinations are routinely performed.

Plain CT is useful for characterizing fractures if more information is needed pre-operatively. It can demonstrate fracture complexity, displacement and angulation, especially with the use of reformations.

Standard radiographs should include anteroposterior views with both internal and external humeral rotation and an axillary lateral view (scapular Y view) if there is a question of instability or dislocation.

Key points

- **Both MRA and CTA are effective methods for the detection of labrum tears.**
- **More recently, spiral multidetector CTA has offered the advantages to afford thinner slices than with MRA in a shorter time. Studies have not yet been published on the shoulder applications.**
- **MRA has the advantage towards CTA to directly visualize and detect associated capsuloligamentous injuries.**

8.2.2 Elbow

8.2.2.1 MRI in osteochondral injury or intra-articular osteocartilaginous body (IAB)

MRI has been advocated as the initial study for suspected osteochondral fracture or IAB. Regardless of method, detection of an IAB is limited by its size and location within the elbow joint. Detection of IAB is enhanced by the presence of joint effusion.

Plain MRI (wihout contrast) is far better than MR arthrography and CT for detection of occult bone injury.

Direct intra-articular magnetic resonance arthrography (MRA) is preferred to routine MRI for diagnosis of IAB and may also play a role in improving diagnosis of stability of the osteochondral lesion.[479 , 480, 481]

Either method is appropriate, depending on availability, expertise, and local conditions. If effusion is present, MRI without contrast is preferred.

Radiographs are required before other imaging studies and may be diagnostic for osteochondral fracture, osteochondritis dissecans, and osteocartilaginous intra-articular body (IAB).

Tomography, single-contrast (iodinated contrast or air) and double-contrast (iodinated contrast and air) arthrography with or without CT, and CT alone can be used for detecting an osteochondral lesion or IAB. All of these studies have limitations; a small IAB may be obscured by contrast or confused with air bubbles (double-contrast arthrography). A CT air arthrogram can avoid confusion of air bubbles with IABs.[481]

Key points

- **Plain MRI or MRA using appropriate sequences (T2 with fat suppression) have the advantage towards CT arthrography to detect occult bone injuries**
- **CTA is better for the assessment of the thin cartilage of the elbow**

8.2.2.2 MRI in chronic epicondylitis

Epicondylitis--lateral ("tennis elbow") or medial (in pitchers, golfers, and tennis players)--is a common clinical diagnosis, and MRI is usually not necessary. MRI may be useful for confirming the diagnosis in refractory cases and to exclude associated tendon and ligament tear.[482, 483 , 484-487]

Plain MRI may provide important diagnostic information for evaluating the adult elbow in epicondylitis. There is a lack of studies showing the sensitivity and specificity of MRI in many of these cases; most of the studies demonstrate MRI findings in patients either known or highly likely to have a specific condition.[488, 489]

Ultrasound (US) has been shown to be helpful for diagnosing complete and partial tears of the flexor and extensor tendons providing an alternative to MR imaging, if expertise is available.[490-494, 41]

Key points

- **Both US and MRI are reliable methods to detect chronic epicondylitis, but US is more available and far more cost-effective.**
- **MRI may be more helpful in postoperative cases.**

8.2.2.3 MRI in collateral ligament injury

Avulsion of the ulnar collateral ligament at the insertion site on the ulna, source of chronic medial elbow pain in the throwing athlete is best evaluated with a combination of radiographs and coronal MRI.[495] MRI may provide important diagnostic information for evaluating the adult elbow in collateral ligament injury.[496]

With use of appropriate pulse sequences, MRI is an effective tool in the preoperative diagnosis of posterolateral rotatory instability. This includes assessment of the ulnar band of the lateral collateral ligament.[497]

MRA has been advocated to distinguish complete tears from partial tears of the medial collateral ligament.[498]

There is a lack of studies showing the sensitivity and specificity of MRI in many of these cases; most of the studies demonstrate MRI findings in patients either known or highly likely to have a specific condition.

Ultrasound (US) has been shown to be helpful for diagnosing complete and partial tears of the ligaments, providing an alternative to MR imaging.

Radiographs can be useful to identify heterotopic calcification (ossification) of the ulnar collateral ligament.[499] This finding may be associated with partial or complete tears of that structure.

Key points

- **MRA can differentiate complete from partial tears of the medial collateral ligament.**
- **MRI and MRA can detect associated lesions of the tendons and underlying bone structures.**

8.2.2.4 MRI in nerve entrapment

The ulnar nerve is particularly vulnerable to trauma from a direct blow in the region of its superficial location in the restricted space of the cubital tunnel. Anatomic variations of the cubital tunnel retinaculum may contribute to ulnar neuropathy. Axial T1-weighted images have been shown to depict the size and shape of the nerve, and axial T2-weighted or STIR images may show increased signal in the presence of neuritis.[500]

Radial nerve and median nerve entrapment syndromes may also be evaluated with MR imaging.[500]

Although MRI can provide important diagnostic information for evaluating abnormality of the ulnar, radial, or median nerve, there is a lack of studies showing the sensitivity and specificity of MRI in these cases; most of the studies demonstrate MRI findings in patients either known or highly likely to have a specific condition.

Key point

MRI can provide important diagnostic information for evaluating lesions of ulnar, radial, or median nerve.

8.2.2.5 MRI in biceps tendon tear and/or bursitis

Bicipitoradial and interosseous bursitis around the distal biceps tendon is a source of elbow pain that can be assessed with ultrasound or MRI.[501]

MRI also demonstrates the effects of the bursa on adjacent structures including the posterior interosseous and median nerves.

Key points

- **US or MRI (if available) can detect partial and complete biceps tendon tears and/or bursitis.**
- **US is more cost-effective.**

8.2.3 Wrist

8.2.3.1 Chronic wrist pain

The role of imaging in chronic wrist pain remains controversial (especially when comparing the radiologic and orthopedic literature). There is considerable disagreement about which imaging study should be performed.

The imaging evaluation of the painful wrist should begin with standard radiographs, that may establish a specific diagnosis in patients with arthritis, complications of injury, infection, some bone or soft tissue tumors and occasionally in patients with wrist instability.[502, 503]

MRI has proven to be a good diagnostic modality for patients with chronic wrist pain because it provides a global examination of the bone and soft tissue structures. It may be diagnostic in patients with triangular fibrocartilage and interosseous ligament tears, occult fractures, avascular necrosis and many other intraarticular abnormalities.[504, 497, 505, 506]

At the present time, MRI or indirect MRA (MR with intravenous contrast injection) of the wrist is not adequately sensitive or accurate for diagnosing cartilage defects in the distal radius, scaphoid, lunate, or triquetrum.[507] Imaging of articular cartilage will probably improve with development of 3 Tesla MR systems.

8.2.3.2 Ligamentous injuries

Zanetti et al have shown that MRA (MR arthrography with intraarticular contrast injection) can detect ligamentous lesions of the wrist.[508]. Haims et al found that indirect MR arthrography significantly improved sensitivity in the evaluation of the scapholunate (SL) ligament injuries when compared with unenhanced MRI but did not significantly improve the ability to evaluate the central disc of the triangular fibrocartilage complex (TFCC) or the lunotriquetral (LT) ligament.[505]

Hobby et al reviewed 11 studies reporting the diagnostic performance of MRI for tears of the triangular fibrocartilage complex for a total of 410 patients, six studies for the scapholunate ligament (159 patients), six studies for the lunotriquetral ligament (142 patients) and four studies (56 patients) for osteonecrosis of the carpal bones in patients with surgical confirmation and found that MRI is an accurate means of diagnosing tears of the triangular fibrocartilage and carpal osteonecrosis. Although MRI is highly specific for tears of the intrinsic carpal ligaments, its sensitivity is low. The diagnostic performance of MRI in the wrist is improved by using high-resolution T2* weighted 3D gradient echo sequences. Using current imaging techniques without intra-articular contrast, MRI cannot reliably exclude tears of the intrinsic carpal ligaments.[509]

Potter et al found (in a prospective study of seventy-seven patients with wrist pain) that high resolution MRI permits accurate depiction and localization of tears of the triangular fibrocartilage complex. When the appropriate sequence is used, MRI is an accurate and effective method for the noninvasive evaluation of pain in the wrist [497]. In a study of 56 patients who underwent arthroscopic evaluation of the TFC, Oneson et al could conclude that MR imaging is accurate in revealing TFC perforations.[510]

MRI is helpful in diagnosing ulnar-sided pain caused by impaction syndromes[511, 512] and can differentiate them from other causes of ulnar wrist pain including occult fractures and triangular fibrocartilage tears.

Computed tomography post arthrography (CTA) helped to diagnose ligamentous injuries of the wrist with an increased precision and without affecting the sensitivity or specificity of the diagnosis.[513]

According to the cadaver study of Schmid et al, the performance in depiction of palmar and central segment tears of SL and LT ligaments is almost equal for multidetector row CT arthrography and MR imaging, with much higher interobserver reliability for CT arthrography. They conclude that CT arthrography is significantly superior to MR imaging in the detection of dorsal segment tears of SL and LT ligaments.[514]

Wrist arthrography with a radiocarpal injection was commonly used for the diagnosis of tears of the triangular fibrocartilage and interosseous ligaments. Many authors have replaced it by a three-compartment arthrography (with injections into the radiocarpal, midcarpal, and distal radioulnar joints).

Fluoroscopy or video imaging is sometimes recommended to establish the diagnosis of dynamic wrist instability, and it has been suggested that it is a cost-effective method of making this diagnosis.

Key points

- **MRA (better than plain MRI) is able to detect lesions of the TFC and interosseous scapholunate ligament.**
- **Multidetector row CT arthrography is a good alternative for the diagnosis of those lesions due to the higher spatial resolution but is more invasive than MRA.**
- **In both methods, at the present time, correlation studies with surgery are still limited to a small number of patients.**

8.2.3.3 Osseous abnormalities

Dorsay et al showed that immediate MRI for patients with possible occult wrist fractures with a modified screening protocol was nearly equivalent in cost to follow-up with delayed imaging.[515] Herneth et al performed radiography, high-resolution ultrasound and MRI on 15 consecutive patients with suspected scaphoid fractures. Of nine fractures, all nine were present on MRI, while five were detected on standard radiographs and seven on ultrasound. They concluded that high-spatial-resolution US is a reliable diagnostic tool for the evaluation of occult scaphoid fractures and should be considered an adequate alternative diagnostic tool prior to computed tomography or MR imaging.[516]

Nikken et al found that a short MR imaging examination with a low-field-strength system following radiography in initial evaluation of patients with acute wrist trauma has additional value in prediction of treatment need; it does not have value in identification of patients who can be discharged without further follow-up.[517, 518]

Plain CT can be used in the follow-up of complex wrist fractures or distal radioulnar subluxations.

When a patient is clinically suspect of avascular necrosis of the lunate (Kienböck's disease) with normal or equivocal radiographs, MRI is the most appropriate imaging modality to confirm the diagnosis.[504, 509]

CT could be performed only if it is needed to assess the degree of bone collapse and for detection of associated fractures.

Key points

- **MRI is an accurate method for detection of occult wrist fractures**
- **It is the most appropriate imaging modality for diagnosing avascular necrosis of the lunate (Kienböck's disease)**

8.3 BONE MARROW

MR imaging shows a high sensitivity (Se = 85 % – 100 %, Sp = 69 % = 97 %) in finding occult sites of disease in the marrow but its use has been restricted by high cost and limited availability. However, the future of MR imaging in bone marrow evaluation seems assured. Magnetic resonance imaging provides a non-invasive means to evaluate a large fraction of marrow in less than one hour. Marrow disorders produce non-specific changes in marrow signal intensities which primarily reflect changes in proportions of fat and cellular elements. The pattern of these signal changes narrows the differential diagnosis, and the combination of these features with the clinical context allows interpretations which are clinically useful in many ways. These include focal marrow disorders :1) the diagnosis of avascular necrosis (and its distinction from other causes of joint pain), 2) detection of osteomyelitis, and diffuse marrow disorders : 3) differential diagnosis of haematopoietic disorders, 4) staging of lymphomas and myeloma, 5) selection of patients for autologous bone marrow transplant, 6) objective measures of bone marrow response to therapy, 7) detection of leukemic transformation, and 8) improved detection of marrow disease (primary or secondary) in patients with otherwise unexplained bone pain.[519]

Original articles and reviews indicate that MR (regional, spinal or whole body MR) can detect bone marrow infiltration (Se = 85 % – 100 %, Sp = 69 % = 97 %) in multiple myeloma, lymphoma, leucemia, aplastic anemia, myelodysplastic syndrome, neuroblastoma, systemic mastocytosis, marrow storage diseases (e.g. Gaucher, iron,) and metastases, although false negative examinations may occur in low grade multiple myeloma (11 %; NPV = 55 %) and chronic lymphocytic leucemia (41 %).[520-542] Bone marrow biopsy is still the examination of choice in hematologic malignancies. Bone marrow biopsies and bone scans are replaced more frequently by MR imaging for tumors that metastasize into the marrow, except for those from thyroid carcinoma (iodine scan) and multiple myeloma (bone scan is insensitive). In multiple myeloma, lymphoma, leucemia, myelodysplastic syndrome, neuroblastoma, systemic mastocytosis and metastases whole body or full spine MR is superior to plain radiography and computed tomography and may become an alternative for radionuclide scan at the time of diagnosis and during the course of the disease, and a supplement to bone marrow biopsy.[543-546, 532, 534, 547] However, whole body MR is inferior to bone scintigraphy in dectecting bone metastases within the thorax (ribs, sternum and scapulae) and the skull [548]. Plain radiography should be replaced by MR imaging (whole body MRI or combined full spine and pelvic MRI) for staging of multiple myeloma, although MR may be false negative in low grade multiple myeloma (11 %) (Se = 67 %, Sp = 86 %, Acc = 73 %, PPV = 91 %; NPV = 55 %).[549, 542]

MR may be useful to indicate the best site for biopsy in diseases with focal marrow distribution[540] and is recommended in patients with monoclonal gammopathy of undetermined or borderline significance and lymphoma patients with abnormal clinical and laboratory findings with normal blind bone biopsy.[550, 525, 551] MR may prevent understaging of solitary plasmocytoma and change diagnosis to multiple myeloma.[544, 523] MR is the method of choice for quantitative evaluation of lymphoma when a crucial therapeutic decision (i.e. bone marrow transplantation) must be made.

MR can also be used for monitoring the response to therapy in multiple myeloma, aplastic anemia, myelodysplastic syndrome, acute lymphoid leukemia and Gaucher disease[552, 523, 553, 554, 531, 546, 536, 539, 549, 555, 556] and also has a proven prognostic value in multiple myeloma[546, 557], lymphoma[532] and chronic lymphocytic leucemia[527, 530, 556]. The combination of the staging system of Durie and Salmon and MR is highly significant with respect to survival ($P < 0.0001$, log rank analysis) and provides a significant prognostic tool for patients with multiple myeloma.[557]

A new domain in bone marrow imaging is bone bruise and bone marrow edema. Both bone scintigraphy and MR can demonstrate these abnormalities, although MR is more specific.[558]

MR imaging is also a reliable method to detect and diagnose chronic, subacute and acute osteomyelitis (in an early stage, before plain radiographs are positive) (Se = 88 % - 100

%), and to differentiate osteomyelitis from aggressive benign or malignant bone tumours or tumour-like lesions, although edema, fibrovasular scarring, fracture, medullary bone infarction and metastasis may lower the specificity (Sp = 63 % - 89 %).[559-568] The negative predictive value of MR is very high (> 95 %) [564, 569], and contrast medium administration is usually not needed,[566] although dynamic contrast-enhanced MR permits to discriminate between acute and chronic osteomyelitis.[570]

MR can replace bone scintigraphy for detection and diagnosis of acute osteomyelitis, but for chronic osteomyelitis combination of MR with leucocyte scan may be necessary.[560-564]

In spinal cord-injured, paralyzed patients with decubitus ulcers, sinus tracts, fistulae, fluid collections, abscesses and septic arthritis, MR is accurate (Se = 98%, Sp = 89%, Acc = 97%) for diagnosis of osteomyelitis and associated soft tissue abnormalities, to delineate the extent of infection and in guiding limited surgical resection and preserving viable tissue.[571] These findings may alter the therapeutic strategy.

Key points

- **MR imaging has a high sensitivity in finding occult sites of disease in the bone marrow, including avascular necrosis, osteomyelitis, haematopoietic disorders, lymphomas, leucemia, multiple myeloma and bone bruise (evidence level 2)**
- **Bone marrow biopsy is still the examination of choice in hematologic malignancies (evidence level 2)**
- **MR allows to monitor response to therapy in benign and malignant bone marrow diseases (evidence level 3)**
- **MR is superior to plain radiography and CT scan for bone marrow diseases (evidence level 2)**
- **MR may replace bone scintigraphy for metastases although sensitivity is lower for skull, rib and sternal lesions (evidence level 2)**
- **MR imaging is an accurate method to detect and diagnose chronic, subacute and acute osteomyelitis (evidence level 2)**

8.4 BONE TUMOUR

Original articles and reviews indicate that MR imaging proves to be accurate in bone tumour detection and staging, lesion characterisation, longitudinal assessment of tumours during chemotherapy, and detection of local recurrence (evidence level 2).

Magnetic resonance imaging should follow plain films in the imaging analysis of bone tumours and is considered the modality of choice for evaluation of benign musculoskeletal lesions (except non ossifying fibroma and osteoid osteoma)[572] and all malignant lesions (Se = 100 %, Sp = 60 %, Acc = 93 - 95 %, PPV = 93 %, NPV = 100 %).[573-586]

MR imaging is helpful in preoperative evaluation and staging of bone tumours (evidence level 2). It shows good sensitivity in detecting involvement of joint (Se = 100 %), skip metastases (Se = 100 %) and physeal plate invasion (Se = 95 %), and good specificity in identifying the invasion of neurovascular bundle (Sp = 75 % - 100 %) and skip lesions (Sp = 91 %), involvement of joint (Sp = 60 %), physeal plate invasion (Sp = 62 %) and neurovascular invasion (Sp = 100 %). This information, which is only poorly or even not at all visible on other imaging techniques (like plain radiography, CT and bone scintigraphy) may affect surgical planning and lead to a significant change in patient management strategy, e.g. by changing amputation into limb salvage surgery and vice versa (evidence level 4).[576, 577]

The ability of dynamic contrast-enhanced MR imaging to determine response to induction chemotherapy by means of noninvasive monitoring of necrotic fraction with

perfusion MR imaging methods provides useful prognostic information and helps surgical planning and may change management by switching chemotherapy in non-responders (evidence level 2).[587-593]

MR plays only an ancillary role in the diagnosis of osteoid osteoma, which rests on the concomitant use of bone scintigraphy and CT scan (evidence level 2-3).[594-597] However, MRI can provide additional evidence to support the diagnosis of clinically suspected osteoid osteoma when CT scan findings are not conclusive. Osteoid osteomas can be imaged with greater conspicuity by using dynamic gadolinium-enhanced instead of nonenhanced MR imaging (P <.001) and with conspicuity equal to (73 %) or better (27 %) than that obtained with thin-section CT (evidence level 2).[596]

An audit of magnetic resonance imaging of bone and soft tissue tumours reveals that MR exams performed at non-specialised referral centres is often of inferior quality, by omitting longitudinal images in search of skip metastases and no reporting of precise intraosseous and extraosseous extent of tumour and relationship to the neurovascular bundle and adjacent joint.[598]

Quality control should be an important issue before installation of new MR units in peripheral centres.

Key points

- **MR imaging proves to be accurate in bone tumour detection and staging, lesion characterisation, longitudinal assessment of tumours during chemotherapy, and detection of local recurrence (evidence level 2).**
- **An audit of magnetic resonance imaging of bone and soft tissue tumours reveals that MR exams performed at non-specialised referral centres is often of inferior quality, and therefore quality control should be an important issue before installation of new MR units in peripheral centres.**

8.5 SOFT TISSUE NEOPLASM

8.5.1 Introduction, Diagnosis, Grading and Staging

Primary malignant soft tissue tumors are rare, their number for Belgium is calculated at 200 approximately a year, benign soft tissue tumors are 100 times as frequent not taking into account the numerous mass producing tumor-like lesions. Diagnostic imaging plays a key role in the differentiation of malignant and benign lesions. Ultrasound (US) has a role in the initial screening procedure of a soft tissue mass. In case of a confident benign US diagnosis (ie ganglion cysts, seromas, neuromas, neurinomas and subcutaneous lipomas), further diagnostic work up is generally not needed. The next step of the differentiation of malignant and benign lesions is partially done by MRI, in some cases in combination with radiography. MRI is able to make confident characterization of benign lesions (tumors and tumorlike lesions) with typical presentation, i.e. lipoma, lipoma arborrescens, haemangioma and lymphangioma (vascular malformations), synovial chondromatosis, pigmented villonodular synovitis and giant cell tumor of tendon sheath, neurinoma, Morton neuroma, Ledderhose and Dupuytren disease (plantar and palmar fibromatosis), elastofibroma dorsi, myxoma, Xanthoma of tendon, fibrolipohamartoma. Biopsy is done in case of not confident benign diagnosis or suggested malignant diagnosis on MRI. Diagnosis, grading and local spread of a soft tissue tumor are important factors to decide which local treatment is the most appropriate, the extremes are ‘‘leave alone lesions’’, over enucleation and lesions to be broadly resected. To asses the prognosis of malignant lesions also screening for distant metastasis is done, bone metastasis screening is done by bone scintigraphy, lung metastasis screening with CT and brain metastasis are screened with MRI. The gold standard for diagnosis and grading of soft tissue tumors is histology, often complemented with immuno-histochemic typing. Because of its high spatial and contrast resolution at the soft tissues the gold standard for local staging is MRI, CT offers a lower contrast resolution especially at the musculotendinous unit.

8.5.2 HTA reports

There is only one HTA report that compares MRI and CT and both techniques with FDG-PET.[599]

8.5.2.1 HTA concerning Positron emission tomography (FDG) for soft tissue sarcoma (STS)

The questions to be answered in the HTA concerning Positron emission tomography (FDG) for soft tissue sarcoma (STS) [599] were:

1. What is the diagnostic test performance (sensitivity and specificity) of FDG-PET for:

a. distinguishing benign lesions from malignant soft tissue sarcoma

b. distinguishing low grade from high grade soft tissue sarcoma.

2. How does the test performance of FDG-PET compare with conventional anatomic imaging (CT, MRI, etc) among patients with soft tissue sarcoma with respect to:

a. primary diagnosis

b. diagnosing locoregional recurrence

c. diagnosing distant metastasis.

3. A review of studies on changes in patient management or improved outcomes for patients with soft tissue sarcoma with the use of FDG-PET

4. A review of studies on using FDG-PET to determine tumor response to therapeutic interventions for patients with soft tissue sarcoma

a. Primary diagnosis

The second question is of interest in this HTA. Concerning 2.a, the report concludes that there are currently (11-2001) no available data to answer reliably the question of how FDG-PET compares against CT or MRI for the diagnosis of primary STS. Several studies evaluating FDG-PET for the diagnosis of primary lesions stated that part of the inclusion criteria was the CT, MRI, or US result that was suggestive of malignancy, along with the clinical appearance. Even studies that do not specify the prior use of other imaging modalities, are likely to have used some of these imaging modalities as part of the pre-PET work-up in some patients. The substantial variability in the prevalence of soft tissue malignancy among the primary lesion series included in addressing question 1 suggests that these imaging modalities must have been used to various extents before FDG-PET in defining the eligible population.

b. Diagnosing locoregional recurrence

Concerning diagnosis of locoregional recurrence (Question 2.b). Since FDG-PET is selectively performed after suggestive CT or MRI results, rather than in all unselected patients, the currently available data cannot be used to reliably address the comparative accuracy of CT or MRI vs. FDG-PET for primary soft tissue lesions. Similar considerations relate for the most part also to the question of how FDG-PET compares against CT or MRI for the diagnosis of recurrent disease. Again, most studies have been performed in selected patients. Nevertheless, there are two clinical studies that address specifically question 2b.[600, 601]

In Lucas[601], 72 FDG-PET scans were performed on 60 patients. FDG-PET was positive in 14/19 recurrences (sensitivity 74%), while it was positive in only 3/53 non-recurrences (specificity 94%). There were 67 MRI studies performed with an overall sensitivity and specificity of 88% (15/17) and 96% (48/50), respectively. Based on these data, MRI seems to have better sensitivity than FDG-PET, but the difference is not statistically significant, while there is no difference in specificity. Of the three false positive FDG-PET results, MRI also reported false positive in two of them. Of the five false negative FDG-PET results, MRI had been performed in four of them and it was also

false negative in two. The study has several limitations. First, the definition of positive FDG-PET is apparently based on qualitative interpretation of the scans, without exact description of the criteria used to interpret that a scan is positive. Second, the MRI and FDG-PET were not done on exactly the same patients and lesions (a few patients or lesions were examined with only FDG-PET). If the comparison is limited to the 67 cases where both studies were performed, FDG-PET had a sensitivity of 76% (13/17) and specificity of 94% (47/50). There does not seem to be any case where FDG-PET was correct while MRI was wrong, while the opposite occurred in three of these cases. Third, it is unclear if biopsies were performed on all cases; apparently they were performed only when changes in imaging suggested a recurrence. Several patients were classified as negative apparently based on no clinical evolution during follow-up. The authors conclude that "all three methods (CT, MRI, PET) accurately define the extent of disease", but the presented data do not provide additional information that demonstrates the incremental benefit of FDG-PET over MRI for detecting local recurrence.

In Kole[600], only 17 subjects were included who were being evaluated for potential local recurrence. FDG-PET had sensitivity of 93% (14/15) and specificity of 100% (2/2). MRI had sensitivity of 77% (10/13) and gave false positive reading for both benign lesions (scar and Ascaris mass), where FDG-PET had given correct negative readings. Of the three false negative MRIs, FDG-PET was correct in two and was also false negative in one. MRI was not done in two cases. The study suggests that FDG-PET was correct in three cases where MRI was wrong, while the opposite situation was not seen in any case. This study has too few patients to draw reliable conclusions. Moreover, no information was provided about how the MRI was performed and whether a contrast agent was also given or which weighting method was used.

Overall, the limited available data suggest approximately similar diagnostic performance of MRI and FDG-PET for the evaluation of local recurrence. However, modest differences could have been missed due to small numbers or design flaws. Cases are presented where FDG-PET can correct MRI, or MRI can correct FDG-PET, but each phenomenon occurs in about only 3% of the examined cases.

c. Diagnosing distant metastases

There are three studies that address the comparative performance of FDG-PET vs. other imaging modalities for the diagnosis of distant metastasis.[601-603]

In Lucas (1998)[601], 70 FDG-PET scans were performed on 62 patients. FDG-PET was positive in 13/15 lung metastases (sensitivity 87%), while it was not positive in any of the 55 cases without metastasis (specificity 100%). There were also 70 CT scans performed. The sensitivity was 15/15 (100%) and the specificity was 48/50 (96%). Based on these data, FDG-PET seems to have equal diagnostic performance with CT scan for diagnosing lung metastasis. FDG-PET failed to detect two lung metastases that were detected by CT, while FDG-PET gave correct negative readings in two cases where CT scan was falsely positive. FDG-PET also identified 13 metastatic sites other than lung and gave one false positive FDG-PET in a patient who had negative MRI. These data cannot be compared with other imaging modalities, as other imaging was either performed very selectively or not reported.

This study also has several limitations. First, the definition of positive FDG-PET is apparently based on qualitative interpretation of the scans, without exact description of the additional criteria used to state that a scan is positive, once the uptake is found to be higher than the liver uptake. Second, histopathology was not confirmed in all cases. This was limited to cases where there was a suggestion for metastasis, while most patients are classified as negative apparently based on no clinical evolution during follow-up. The authors conclude that "all three methods (CT, MRI, PET) accurately define the extent of disease", but the presented data do not clearly demonstrate that the additional information provided by FDG-PET provided incremental benefit over CT for detecting metastatic disease.

In Lucas (1999)[602], 31 lesions in 30 patients were evaluated. Data on metastatic disease are very sparse. Three patients had distant metastasis at presentation and one had

multiple primaries. FDG-PET correctly identified two of three metastases (alveolar rhabdomyosarcoma, high-grade leiomyosarcoma), but failed to diagnose the presence of multiple bone metastasis in the long bones and spine of a third patient with high-grade leiomyosarcoma. Metastatic lesions were detected by CT (first two patients) and MRI (third patient). FDG-PET correctly identified and graded the multiple primaries in a patient with neurofibromatosis type 1 with malignant nerve sheath tumors. No false positives were obtained. Besides limited sample size, the study has several other limitations. First, it is unclear how many patients had CT or MRI along with FDG-PET and whether they were performed approximately at the same time. Second, diagnosis was evaluated histologically only when imaging was suggestive, while most patients without imaging or clinical evidence were simply evaluated for metastatic disease based on clinical follow-up (potential for verification bias). While the authors conclude that "PET ... may have a role in staging malignant tumors", the study did not demonstrate that FDG-PET provides incremental benefit over the use of CT or MRI.

In el-Zeftawy[603], both CT and FDG-PET scans were performed at baseline for staging purposes in seven of the eight patients with STS. There was full concordance in six cases (no metastatic disease in three, metastases in three). In one patient, FDG-PET found three metastases vs. two with CT. Both CT and FDG-PET were performed on follow-up in three patients with surgery with or without chemotherapy. New lesions were observed in one patient and were detected 2 months earlier with CT than with FDG-PET, but the FDG-PET performed 2 months later also showed adrenal involvement that was not seen on CT. Both CT and FDG-PET were performed on follow-up in four patients treated with additional radiotherapy. There was good concordance between CT and MRI on seven occasions, and in one instance FDG-PET also showed kidney metastasis in addition to lung involvement shown on CT. The study has severe limitations. It is a small retrospective case series. Imaging studies were not performed systematically on all patients. Diagnosis may be subject to verification bias, although this is not clear. The authors avoided concluding that FDG-PET offers an incremental diagnostic benefit over CT or MRI, but they claim that FDG-PET "proved to have an impact on the clinical management." The supporting evidence for this claim is limited.

d. Conclusions

There are no good quality data on the comparative diagnostic performance of FDG-PET against CT or MRI for diagnosis of primary soft tissue lesions, since comparative evidence has been obtained with tests used in series and not in parallel, and even more limited evidence suggesting approximately equivalent performance of FDG-PET and CT scan for diagnosing distant metastatic disease.

There are very limited data on the usefulness of PET in assessing the response of STS to therapy, it is difficult to separate complete from partial response.

Thus, based on the current evidence, it is unclear whether PET can offer any advantage over traditional imaging modalities.

8.5.3 Reviews

8.5.3.1 Staging by MRI prior to surgical resection of soft tissue sarcoma

Retrospective review of 90 patients with STS. Extra-abdominal desmoid and fibromatosis were not considered STS and thus were not included in this series. The goal in performing limb-sparing procedures is to minimize the number of residual microscopic colonies, satellites, or microprojections of neoplasm past the pseudocapsule and to preserve as much functional tissue as possible. On basis of the MRI staging a 99% negative margin rate was achieved in the series, and the 1 patient with a positive margin remained disease free.[604]

8.5.3.2 Effective Follow-Up Strategies in Soft Tissue Sarcoma

Postresection MRI of the primary site was performed annually in 150 patients. Local recurrence occurred in 27 patients (18%) at a median time of 14 months. Annual imaging of the primary site by CT scan or MRI resulted in the detection of only one local recurrence. The authors conclude that the fact that they did not find the routine use of CT scans and MRI to be effective for follow up of the primary site does not mean these modalities should not be used. Significant improvements in technology have occurred since 1982. The role of specific surveillance strategies for recurrence detection for sarcomas of the trunk, head and neck, retroperitoneum, and viscera have yet to be defined.[605]

8.5.3.3 Fibrous tumours in children

Fibrous tumours soft tissue lesions are relatively frequent in childhood. Twenty-five patients with fibrous tumours were evaluated retrospectively. The following tumour types were encountered: desmoid fibromatosis (n=9), myofibromatosis (n=7), fibromatosis colli (n=2), congenital-infantile fibrosarcoma (n=2), adult-type fibrosarcoma (n=2), fibrous hamartoma of infancy (n=1), angiofibroma (n=1) and hyaline fibromatosis (n=1). While some tumours were non-specific in their clinical and radiological manifestation, others such as myofibromatosis, fibromatosis colli, fibrous hamartoma of infancy and angiofibroma exhibited a characteristic pattern which allowed a diagnosis to be made even without histology.[606]

8.5.3.4 Benign fatty tumors in children

This study correlates the magnetic resonance imaging characteristics with the pathologic findings in rare benign fatty soft tissue tumors in four children. Two cases of infiltrating lipoma a case of facial lipomatosis and a case of lipoblastoma have a characteristic presentation. In childhood, when fatty lesions are almost always benign, a morphologic characterization by magnetic resonance may be sufficient basis on which to make critical therapeutic judgements.[607]

8.5.3.5 Conclusion reviews

On basis of the MRI staging a 99% negative margin rate was achieved in the series, and the 1 patient with a positive margin remained disease free.[604]

Some fibrous tumors in children exhibit a characteristic pattern which allowed a diagnosis to be made even without histology.[606]

In childhood, when fatty lesions are almost always benign, a morphologic characterization by magnetic resonance may be sufficient basis on which to make critical therapeutic judgements.[607]

8.5.4 Clinical Studies

8.5.4.1 Assessment of vascular invasion by musculoskeletal tumors of the limbs

Prospective study of the accuracy of contrast material-enhanced magnetic resonance (MR) angiography in the evaluation of vascular invasion by bone and soft-tissue tumors, with surgery serving as the reference standard. Preoperative MR angiograms and MR images of 31 sites in 30 patients with bone or soft-tissue sarcomas (n = 21) or other tumors (n = 9) were assessed for features of vascular invasion. MR imaging had a sensitivity of 64%, a specificity of 95%, a positive predictive value of 88% a negative predictive value of 83%, and an accuracy of 84% in the detection of vascular invasion on the basis of findings of partial or total encasement. MR angiography had a sensitivity of 82%, a specificity of 85%, a positive predictive value of 75%, a negative predictive value of 90%, and an accuracy of 84% in the detection of vascular invasion on the basis of the findings of a stenosis. On contrast-enhanced MR angiograms, findings of stenosis were sensitive and specific in the detection of arterial invasion. MR imaging evidence of partial or total encasement is highly specific in the detection of vascular invasion, while MR

imaging evidence of a gap between the tumor and the vessels excludes an arterial invasion.[608]

8.5.4.2 *Magnetic resonance imaging in the diagnosis of glomus tumours of the hand.*

This paper studies the sensitivity, specificity and predictive values of MRI in the diagnosis of glomus tumours of the hand and investigates the final diagnosis and outcome in cases with false positive or negative imaging tests. A total of 42 cases with the clinical diagnosis of a glomus tumour were included in the study. All lesions were correlated with the final histological diagnosis of the excised lesion. MRI had a sensitivity of 90%, a specificity of 50%, a positive predictive value of 97% and a negative predictive value of 20%. The four cases in which the MRI was negative all proved histologically to be glomus tumours.[609]

8.5.4.3 *Accuracy of MRI in characterization of soft tissue tumors and tumor-like lesions. A prospective study in 548 patients*

The value of MRI in characterization of soft tissue tumors (STT) and soft tissue tumor-like lesions is prospectively assessed in 548 untreated and proven STT or tumor-like lesions. The correlation between the MRI and histological diagnosis and between the radiological and histological phenotype were statistically determined. One hundred twenty-three patients presented with a malignant STT; 425 patients presented with a benign one. Concerning differentiation between malignant and benign lesions (dignity), a sensitivity of 93%, specificity of 82%, negative predictive value (NPV) of 98% and positive predictive value (PPV) of 60% with accuracy of 85% were obtained. Concerning phenotype characterization, if only the first MRI diagnosis was taken into account, a sensitivity of 67%, specificity of 98%, NPV of 98%, PPV of 70% and accuracy of 96% were obtained. For benign lesions, sensitivity of 75%, specificity of 98%, NPV of 98%, PPV of 76% and accuracy of 97% were obtained. The phenotype's definition of malignant STT had a sensitivity of 37%, a specificity of 96%, NPV of 96%, PPV of 40% and an accuracy of 92%. A correct diagnosis compared with histological assessment was proposed in 227(50%) of the 455 histologically confirmed cases.[610]

8.5.4.4 *Characterization of bone and soft-tissue tumors with in vivo 1H MR spectroscopy*

MR imaging was performed in 36 consecutive patients with bone and soft-tissue tumors larger than 1.5 cm in diameter. In vivo 1H MR spectroscopy characterized bone and soft-tissue tumors, resulting in a sensitivity of 95%, specificity of 82%, and accuracy of 89% (P <.001). Choline can be reliably detected in large malignant bone and soft-tissue tumors by using a multiecho point-resolved spectroscopic protocol. 1H MR spectroscopy can help differentiate malignant from benign musculoskeletal tumors by revealing the presence or absence of water-soluble choline metabolites.[611]

8.5.4.5 *MR imaging in the assessment of residual tumour following inadequate primary excision of soft tissue sarcomas*

The purpose of this retrospective study was twofold: firstly, to assess the ability of MR imaging in confirming/excluding the presence of residual tumour following inadequate primary excision of soft tissue sarcomas; and secondly, to assess the accuracy of the original radiologists report as compared with a retrospective review of the scan hard copy in confirming/excluding. A total of 111 cases were identified that fulfilled the inclusion criteria of inadequate primary surgery followed by a MR scan and subsequent wide re-excision of the surgical field. Histological examination revealed residual tumour in 63 (56.7%) cases. The original radiologists reports failed to indicate the presence or absence of tumour in 7 (6.3%) cases. In the remaining 104 cases the diagnostic performance of MR imaging gave a sensitivity of 0.64, specificity of 0.93, positive predictive value of 0.93 and negative predictive value of 0.67. It is suggested that the poor negative predictive value can be attributed more to limitations of the MR scan and not to failures in observation or interpretation by the radiologists. Despite the low

negative predictive value, MR imaging remains useful in planning the re-excision surgery by identifying the site and extent of the original operation and size of major residual tumour.[612]

8.5.4.6 *Osseous invasion by soft-tissue sarcoma: assessment with MR imaging*

Magnetic resonance (MR) imaging signs and overall accuracy of MR imaging for detection of osseous invasion by soft-tissue sarcoma, with histopathologic correlation as the reference standard is retrospectively assessed of 56 osseous sites in 51 patients who underwent bone resection at surgery for soft-tissue sarcoma. MR imaging overall had a sensitivity of 100%, specificity of 93%, PPV of 79%, and NPV of 100% for detection of osseous invasion on the basis of any finding of cortical destruction or cortical or medullary signal intensity change on T1- or T2-weighted images (P <.001). On T1- and T2-weighted MR images, findings of cortical and medullary signal intensity change and cortical destruction were sensitive and specific for detection of osseous invasion by soft-tissue sarcoma.[613]

8.5.4.7 *Dynamic MRI and fine needle aspiration cytology in the evaluation of soft tissue lesions*

The usefulness of dynamic magnetic resonance imaging (DMRI) in the diagnosis of soft tissue tumors is assessed in 33 patients. Early enhancement, predominantly peripheral, and a time-signal intensity (TSI) curve characterized by a steep rise to an early peak followed by a plateau or washout, were considered signs of malignancy. Using two or more DMRI features of malignancy to dichotomize the series, the sensitivity and positive predictive value of the DMRI series were 87% and, the specificity and negative predictive value were 70%.[614]

8.5.4.8 *99mTc-MIBI in the assessment of response to chemotherapy and detection of recurrences in bone and soft tissue tumours of the extremities*

This prospective study is focused on the assessment of tumour response in a group of 28 bone sarcoma patients using (99m)Tc-MIBI scintigraphy. The quantitative changes in MIBI uptake before and after chemotherapy were measured and associated with the pathological evaluation of the degree of tumour necrosis. Besides this, another group of 40 patients with bone and soft tissue tumours was studied in order to evaluate the diagnostic efficacy of (99m)Tc-MIBI scintigraphy versus computed tomography (CT) and/or magnetic resonance imaging (MRI) in detecting the status of the disease and its recurrences. The sensitivity, specificity and accuracy of (99m)Tc-MIBI scan versus CT and/or MRI were calculated and they resulted 93%, 95% and 92% versus 86%, 75% and 84%, respectively. The application of (99m)Tc-MIBI scan in the management of patients treated with chemotherapy may allow an early identification of the non-responder patients and lead to a choice of different strategies (alternative chemotherapy or salvage surgery).[615]

8.5.4.9 *Additional value of magnetic resonance with spin echo T1-weighted imaging with fat suppression in characterization of soft tissue tumors*

Signal intensity (SI) behavior and characterization of soft tissue tumors (STT) on spin echo (SE) T1 weighted images (WI) with fat suppression (FS) is described in 53 histological proven STT. T1-WI with FS has additional value in the characterization of fibrous and hemosiderotic parts from cellular parts of lesions. It gives more confidence in characterization of neurogenic tumors and hemangioma's. Presence of methemoglobin and melanin are clearly discriminated from fatty tissue. Tumor conspicuity and inhomogeneity evaluation is improved. The use of SE T1-WI FS not only improves tumor conspicuity, but as tumor homogeneity and SI are important parameters in staging and characterization of STT, the use of SE T1-WI with FS will certainly be helpful.[616]

8.5.4.10 The value of MRI in distinguishing lipoma from well-differentiated liposarcoma

The objective of this study was to evaluate the diagnostic value of fat-suppressed T2-weighted (FS-T2) images or short tau inversion recovery (STIR) imaging in distinguishing lipoma from lipoma-like subtype of well-differentiated liposarcoma in 60 lipomas and 32 lipoma-like well-differentiated liposarcomas, histologically proven. Employing the presence of hyperintense nodules and/or septa as criteria of malignancy specificity was 76.6% and sensitivity 100%. Overdiagnoses of well-differentiated liposarcoma can occur due to the presence of non-lipomatous areas within lipomas.[617]

8.5.4.11 Magnetic resonance imaging after incomplete resection of soft tissue sarcoma

Review of magnetic resonance imaging was compared with the pathologic review of reexcision specimens from 24 pediatric patients who had initial incomplete resection for soft tissue sarcoma to determine the accuracy of magnetic resonance imaging in detecting residual tumor. The sensitivity of magnetic resonance imaging for detecting residual tumor was 78%, the specificity was 86%, the positive predictive value was 0.78, and the negative predictive value was 0.86. Decisions regarding the need foradditional resection should not be based on magnetic resonance imaging alone.[618]

8.5.4.12 Dynamic MR imaging of soft tissue tumors with assessment of the rate and character of lesion enhancement

The aim of this study was to analyze the diagnostic usefulness of dynamic MRI with determination of the coefficient of enhancement rate and the character of tumor enhancement, and to assess both parameters in the differentiation of malignant lesions. The material consisted of 45 patients (30 sarcomas, 15 non-malignant lesions). Dynamic MRI with determination of the index of tumor enhancement has a sensitivity of 93% and specificity of 73% in the differentiation of malignant and benign lesions.[619]

8.5.4.13 Musculoskeletal tumors: does fast dynamic contrast-enhanced subtraction MR imaging contribute to the characterization?

The value of fast, dynamic, subtraction magnetic resonance (MR) imaging in the characterization of musculoskeletal tumors is prospectively analyzed in 175 consecutive patients with a musculoskeletal mass. The interval between arterial and early tumor enhancement, the pattern (peripheral or diffuse) of enhancement, and the progression of tumor enhancement, as visualized on time-signal intensity curves, were assessed. MR enhancement features were related to the histopathologic diagnoses. Differentiation of benign from malignant soft-tissue masses was possible with a sensitivity of 91% and specificity of 72% based on start of enhancement, a sensitivity of 73% and specificity of 97% based on peripheral or diffuse enhancement, and a sensitivity of 86% and specificity of 81% based on progression of enhancement.[620]

8.5.5 Conclusion Soft Tissue Neoplasms

There are no HTA reports, reviews and clinical studies to compare soft tissue neoplasms on CT and MRI. Current literature discusses the value of MRI and scintigraphic techniques.

8.5.5.1 Primary Detection and Local Staging of Soft Tissue Neoplasms

MRI has a low sensitivity for the detection of small tumors, ie glomus tumors, in these tumors with specific clinical presentation MRI is abandoned.[609]

MRI is a good technique for local staging of vascular invasion of soft tissue sarcomas and metastasis.[608] On basis of the MRI staging a 99% negative margin after surgical resection rate was achieved.[604]

8.5.5.2 *Detection of Recurrence of Soft Tissue Neoplasm*

There is limited evidence suggesting approximately equivalent diagnostic performance of FDG-PET and MRI for diagnosing local recurrence.[599] MRI has a low sensitivity to detect residual tumor. Despite the low negative predictive value, MR imaging remains useful in planning the re-excision surgery by identifying the site and extent of the original operation and size of major residual tumour. Decisions regarding the need for additional resection should not be based on magnetic resonance imaging alone.[618, 612]

MRI and/or CT also have a lower sensitivity, specificity and accuracy in comparison with (99m)Tc-MIBI scan to detect tumor recurrence. The results of this study are not solid since it is not determinded whether MRI scored better compared to CT or vice versa.[615]

8.5.5.3 *Determination of Response to Non-operative Therapy of Soft Tissue Neoplasms*

There is very limited data on the usefulness of FDG-PET in assessing the response to therapy. The evidence suggests that FDG-PET can be used to follow therapeutic responses. There is insufficient evidence to compare the performance of FDG-PET against CT or MRI in this regard.[599]

8.5.5.4 *Determination of Dignity and Characterization of Soft Tissue Neoplasms*

There are no good quality data on the comparative diagnostic performance of FDG-PET against CT or MRI for diagnosis of primary soft tissue lesions.[599] MRI has a role in characterization of soft tissue tumors. MRI has a good sensitivity and acceptable specificity to differentiate between malignant and benign lesions (dignity) (sensitivity of 93%, specificity of 82%, with accuracy of 85%). Concerning phenotype characterization, MRI has a sensitivity of 67%, specificity of 98%, and accuracy of 96%. For benign lesions there is a much better score compared to malignant lesions. A high number of benign lesions have a characteristic MR appearance with confident MRI diagnosis, these lesions do not need further aggressive work up. In lesions with non-characteristic MRI appearance biopsy has to be performed.[610]

This differentiation of malignant and benign lesions is done by using numerous criteria of which some are discussed in clinical studies. Employing the presence of hyperintense nodules and/or septa as criteria of malignancy specificity was 76.6% and sensitivity 100% in lipomas and well differentiated liposarcomas. Overdiagnoses of well-differentiated liposarcoma can occur due to the presence of non-lipomatous areas within lipomas.[617] SE T1-WI with FS has additional value in the characterization of fibrous and hemosiderotic parts from cellular parts of lesions. It gives more confidence in characterization of neurogenic tumors and hemangioma's. Presence of methemoglobin and melanin are clearly discriminated from fatty tissue.[616] Using two or more dynamic enhancement MRI features produced a sensitivity of 73-91% and a specificity of 70-97% to differentiate benign and malignant lesions, it is used as an additional parameter to discriminate malignant and benign.[620, 614] It is of practical use to differentiate tumor recurrency from fibrosis. In children fibrous tumors and fatty tumors are typical benign, the characteristic MR presentation may be sufficient basis on which to make critical therapeutic judgements.[607, 606] In vivo 1H MR spectroscopy is able to improve MR characterization of bone and soft-tissue tumors, resulting in a sensitivity of 95%, specificity of 82%, and accuracy of 89%.[611]

Key points

- Primary Detection and Local Staging of Soft Tissue Neoplasms
- MRI has a low sensitivity for the detection of small tumors, ie glomus tumors, in these tumors with specific clinical presentation MRI is abandoned. Evidence level 2
- MRI is indicated for local staging of soft tissue neoplasms. Evidence level 2-3

Detection of Recurrence of Soft Tissue Neoplasm

- There is equivalent diagnostic performance of FDG-PET and MRI. Decisions regarding the need for additional resection should not be based on magnetic resonance imaging alone. Evidence level 2.
- MRI and/or CT have a lower accuracy in comparison with (99m)Tc-MIBI scan. Evidence level 2.

Determination of Response to Non-operative Therapy of Soft Tissue Neoplasms

- There is insufficient evidence to compare the performance of FDG-PET against CT or MRI in this regard. HTA
- Determination of Dignity and Characterization of Soft Tissue Neoplasms
- There are no good quality data on the comparative diagnostic performance of FDG-PET against CT or MRI for diagnosis of primary soft tissue lesions. HTA
- MRI has a role in characterization of soft tissue tumors. MRI has a good sensitivity and acceptable specificity to differentiate between malignant and benign lesions. A high number of benign lesions have a characteristic MR appearance with confident MRI diagnosis, these lesions do not need further aggressive work up. In lesions with non-characteristic MRI appearance biopsy has to be performed. Evidence level 2-3

8.6 SOFT TISSUE INJURY

8.6.1 Systematic Review

8.6.1.1 The effectiveness of diagnostic tests for the assessment of shoulder pain due to soft tissue disorders: a systematic review

The objective is to evaluate the evidence for the effectiveness and cost-effectiveness of the newer diagnostic imaging tests as an addition to clinical examination and patient history for the diagnosis of soft tissue shoulder disorders.

Studies were identified that evaluated clinical examination, ultrasound, magnetic resonance imaging (MRI), or magnetic resonance arthrography (MRA) in patients suspected of having soft tissue shoulder disorders. In the included studies, the prevalence of rotator cuff disorders was generally high, partial verification of patients was common and in many cases patients who were selected retrospectively because they had undergone the reference test. Sample sizes were generally very small. Reference tests were often inappropriate with many studies using arthrography alone, despite problems with its sensitivity. For clinical assessment, 10 cohort studies were found that examined either the accuracy of individual tests or clinical examination as a whole: individual tests were either good at ruling out rotator cuff tears when negative (high sensitivity) or at ruling in such disorders when positive (high specificity), but small sample sizes meant that there was no conclusive evidence. Ultrasound was investigated in 38 cohort studies and found to be most accurate when used for the detection of full-thickness tears; sensitivity was lower for detection of partial-thickness tears. For MRI, 29 cohort studies were included. For full-thickness tears, overall pooled sensitivities and specificities were fairly high and the studies were not statistically heterogeneous;

however for the detection of partial-thickness rotator cuff tears, the pooled sensitivity estimate was much lower. The results from six MRA studies suggested that it may be very accurate for detection of full-thickness rotator cuff tears, although its performance for the detection of partial-thickness tears was less consistent. Direct evidence for the performance of one test compared with another is very limited.[473]

8.6.2 Clinical Studies

8.6.2.1 Rupture of posterior tibial tendon: CT and MR imaging with surgical correlation

Computed tomography (CT) and magnetic resonance (MR) imaging were performed in 32 cases of clinically suspected chronic tears of the posterior tibial tendon. Surgery was performed in 22 patients (69%). The sensitivity and specificity of CT were 90% and 100%, respectively, while those of MR imaging were 95% and 100%. The accuracy in detecting ruptures was 91% for CT and 96% for MR imaging. The overall accuracy, which reflected the percentage of cases correctly diagnosed as well as those correctly classified, was 59% for CT and 73% for MR imaging. Although the differences between the CT and MR imaging parameters were not statistically significant (possibly due to the small population), the results suggest that MR imaging is the method of choice for detecting ruptures of the posterior tibial tendon. MR imaging provided greater definition of tendon outline, vertical splits, synovial fluid, edema, and degenerated tissue. CT was superior to MR imaging in showing associated bone abnormalities such as periostitis, subtalar osteoarthritis, and subtalar dislocation.[621] Partial rupture of the proximal Achilles tendon: a differential diagnostic problem in ultrasound imaging.

The aim of this prospective study was to determine whether ultrasound can correctly visualise partial ruptures of the proximal Achilles tendon seen at three centres in Germany from 1998 to 2003 were screened. All patients with clinical and/or sonographic signs of abnormalities were included in the analysis. Each of these cases was evaluated by ultrasound following an assessment protocol. Patients with ambiguous ultrasound findings and/or clinical signs were additionally assessed by magnetic resonance imaging (MRI). Sensitivity was 0.5, specificity was 0.81, and the overall agreement of the ultrasound examination was 61.5%. Ultrasound is a useful tool for evaluation of proximal Achilles tendon complaints. However, ultrasound is not sufficiently reliable for diagnosis of all pathologies, especially partial ruptures of the Achilles tendon. Thus, the definitive diagnosis must be established by MRI.[622]

8.6.2.2 Fatty atrophy of supraspinatus and infraspinatus muscles: accuracy of US

The accuracy of ultrasonography (US) in depicting fatty atrophy of the supraspinatus (SSP) and infraspinatus (ISP) muscles, with magnetic resonance (MR) imaging as the gold standard is prospectively studied in SSP and ISP muscles of 65 consecutive patients with possible rotator cuff tears were evaluated with US in two planes. The accuracy of US in depicting fatty atrophy of SSP muscle was 72-75%, sensitivity was 89-100% and specificity was 68-73%. The accuracy of US in depicting fatty atrophy of ISP muscle was 80-85%, sensitivity was 58-63%, and specificity was 87-96%. US is moderately accurate in the diagnosis of substantial fatty atrophy of the SSP or ISP muscle.[623]

8.6.2.3 Extended field-of-view sonography in Achilles tendon disease: a comparison with MR imaging

Twenty-three symptomatic tendons were examined by conventional grayscale sonography, EFOVS and MRI, which served as the gold standard. EFOVS had a sensitivity of 87.5 % and specificity of 100 % for detecion of tendon lesions. The additional usage of conventional grayscale sonography improved sensitivity to 95.8 %. The sensitivity and specificity of EFOVS for the detection of a paratenonitis were 63.6 % and 66.7 %, respectively. Corresponding values for the detection of a bursitis were 68.8 % and 28.6%. The additional usage of conventional grayscale sonography improved the specificity to 85.7%. The combination of EFOVS and grayscale sonography has the potential to challenge MRI as the preferred imaging method in diagnosing symptomatic

Achilles tendon disease, especially with respect to saving time and cost and the absence of any contraindications.[624]

8.6.2.4 *Value of sonography after rotator cuff repair: a comparison with MRI and clinical results*

Ultrasound- and MR-imaging of the afflicted shoulder on 40 patients who were surgically managed for isolated tear of the tendon of supraspinatus was performed at least 24 months after intervention. Based on the clinical result, sensitivity and specificity for the two imaging procedures was determined. Ultrasonography demonstrated a good specificity (90.3%) yet a poor sensitivity (33.3%). Based on the clinical result, MR-imaging showed sufficient specificity (87.1%), yet also a poor sensitivity (44.4%). Based on clinical findings, postoperative MR-imaging shows a slightly higher sensitivity than ultrasonography. Despite this, both radiographic methods do not allow deductions concerning the clinical outcome. The postoperative ultrasound and MRI should therefore be interpreted with utmost care. Symptoms and functional results are of high clinical relevance in the assessment of the postoperative shoulder.[625]

8.6.2.5 *Posterior tibialis tendon tears: comparison of the diagnostic efficacy of magnetic resonance imaging and ultrasonography for the detection of surgically created longitudinal tears in cadavers*

The purpose of this study was to investigate the utility of ultrasonography (US) and MR imaging in the detection of surgically created posterior tibial tendon tears in cadavers. Sixteen fresh cadaveric foot and ankle specimens were prospectively studied with both US and MR imaging before and after the surgical creation of 64 variable length longitudinal tears of the PTT. Sensitivity, specificity, and accuracy of MR imaging in the diagnosis of PTT tears were 73%, 69%, and 72%, respectively. Dynamic US interpretation yielded values of 69% sensitivity, 81% specificity, and 72% accuracy. Static US interpretation was less reliable than dynamic interpretation, and the only significance of static imaging was a high specificity (94%) for detection of longitudinal tears. The positive predictive value (PPV) for MR imaging and US was 88% and 92% respectively, and the negative predictive value (NPV) was 46% for both MR imaging and US. The results suggest that US and MR imaging perform at the same level for the detection of surgically created longitudinal PTT tears in a cadaveric model. US has a higher specificity compared with MR imaging.[626]

8.6.2.6 *The efficacy of magnetic resonance imaging and ultrasound in detecting disruptions of the forearm interosseous membrane: a cadaver study*

The midportion of the forearm interosseous ligament was longitudinally incised in 19 fresh-frozen cadaver arms. The specimens were imaged with MRI and US. Magnetic resonance imaging showed a 96% accuracy rate, a 100% positive predictive value, a 93% negative predictive value, 93% sensitivity, and 100% specificity. Ultrasound showed a 94% accuracy rate, a 94% positive predictive value, a 100% negative predictive value, 100% sensitivity, and 89% specificity. There was no statistical significance between the accuracy of MRI and US. MRI and US imaging should both be considered when forearm interosseous membrane integrity is in question.[627]

8.6.2.7 *Comparison of sonography and MRI for diagnosing epicondylitis*

The affected elbows of 11 patients with suspected epicondylitis were examined sonographically, and the contralateral (normal) elbow was also examined for comparison. In 10 of these patients, the affected elbow was also examined with MRI. In addition, both elbows of 6 volunteers without epicondylitis were examined sonographically. Sensitivity for detecting epicondylitis ranged from 64% to 82% for sonography and from 90% to 100% for MRI. Specificity ranged from 67% to 100% for sonography and from 83% to 100% for MRI. Sonography is as specific but not as sensitive as MRI for evaluating epicondylitis. Used as an initial imaging tool, sonography might be adequate for diagnosing this condition in many patients, thus allowing MRI to be reserved for patients with symptoms whose sonographic findings are normal.[493]

8.6.2.8 *Finger pulley injuries in extreme rock climbers: depiction with dynamic US*

Sixty-four extreme rock climbers with finger injuries were examined by using dynamic US and compared with magnetic resonance imaging. US depicted 100% of 16 complete A2 pulley ruptures, 100% complete A4 pulley ruptures. The sensitivity of US for depiction of finger pulley injuries was 98%, and specificity was 100%. Dynamic US allows excellent depiction of finger pulley injuries in extreme rock climbers.[628]

8.6.2.9 *Sonography and MR imaging of posterior tibial tendinopathy*

Fifteen healthy volunteers and 31 patients (44 tendons) who were clinically suspected of having posterior tibial tendinopathy were prospectively evaluated with MR imaging and sonography including power Doppler. When compared with MR imaging, the sensitivity and specificity of sonography for diagnosing tendinopathy were 80% and 90%, respectively, and for diagnosing peritendinosis were 90% and 80%. Sonography can be useful as the initial imaging study in evaluating abnormalities caused by posterior tibial tendinopathy.[629]

8.6.2.10 *Arthrography, ultrasound and MRI in rotator cuff lesions: a comparison of methods in partial lesions and small complete ruptures*

Forty patients suffering from subacromial impingement syndrome for at least three months and who were selected for surgery, underwent ultrasound, double-contrast arthrography and MR imaging. Patient preselection focused on partial and small complete tears.

Arthrography, ultrasound and MR imaging yield a sensitivity for complete tears of 91%, 69% and 92% with a specificity of 100%, 93% and 93%. For partial tears sensitivity was 50%, 69% and 69% with a specificity of 100%, 79% and 86%. Arthrography is not helpful in detecting partial tears. Ultrasound and MR imaging yield comparable accuracy. MR imaging has advantages concerning better evaluation of extent, location and classification as well as for the detection of associated pathologies.[630]

8.6.2.11 *Comparison of sonography and magnetic resonance imaging for the diagnosis of partial tears of finger extensor tendons in rheumatoid arthritis*

Twenty-one RA patients with finger extensor tenosynovitis for more than 12 months underwent ultrasound, MRI and surgical inspection. For partial tears, sensitivity and specificity were 0.27 and 0.83 for MRI, and 0.33 and 0.89 for ultrasound, respectively. Accuracy was 0.69 for MRI and 0.75 for ultrasound. For visualization of partial finger extensor tendon tears in RA patients, ultrasound performs slightly better than MRI, but both techniques are at present not sensitive enough to be used in daily practice.[631]

8.6.2.12 *Conclusion clinical studies*

There is only one study that compares CT and MRI, it is an old study with obsolete CT and MRI equipment that scores tears of the posterior tibial tendon. Although not statistically significant the overall accuracy was much higher for MRI, 59% for CT and 73% for MR imaging.[621]

Other studies compare MRI and ultrasound, in these studies MRI, and not pathology or surgery, is often the gold standard. In these overdiagnosis of intratendinous partial tears on MRI is not excluded, indeed displacement of tendon fibres due to edema, mucoid degeneration and new matrix formation with collagen type 3 content may present as high intratendinous signal. In a study on partial Achilles tendon tears sensitivity of ultrasound was 50% and specificity was 81% with MRI as gold standard. Ultrasound is a useful tool for evaluation of proximal Achilles tendon complaints. The conclusion of the authors that, ultrasound is not sufficiently reliable for diagnosis of all pathologies, especially partial ruptures of the Achilles tendon and that a definitive diagnosis must be established by MRI is not based on a solid gold standard. [622] The combination of

extended field of view sonography (EFOVS) and grayscale sonography has the potential to challenge MRI as the preferred imaging method in diagnosing symptomatic Achilles tendon disease, especially with respect to saving time and cost and the absence of any contraindications.[624]

There are recent case reports and small studies that discuss the vascularization that is found on power Doppler ultrasound in tendon disease but no qualitative clinical studies, that calculate its altered accuracy.

US and MR imaging perform at the same level for the detection of surgically created longitudinal posterior tibial tendon tears in a cadaveric model. US has a higher specificity compared with MR imaging.[626] When compared with MR imaging, the sensitivity and specificity of sonography for diagnosing tendinopathy of the posterior tibial tendon in clinical circumstances were 80% and 90%, respectively, and for diagnosing peritendinosis were 90% and 80%. Sonography can be useful as the initial imaging study in evaluating abnormalities caused by posterior tibial tendinopathy.[629]

Sonography and MRI both have high sensitivity and specificity for evaluating epicondylitis. Sonography is as specific but not as sensitive as MRI. Used as an initial imaging tool, sonography might be adequate for diagnosing this condition in many patients, thus allowing MRI to be reserved for patients with symptoms whose sonographic findings are normal.[493]

There was an high sensitivity, specificity, accuracy and no statistical significance between the accuracy of MRI and US in a cadaver model with tear of the forearm interosseous membrane. MRI and US imaging should both be considered when forearm interosseous membrane integrity is in question. [627]

Dynamic US allows excellent depiction of finger pulley injuries in extreme rock climbers with MRI as gold standard.[628]

Arthrography and MR imaging yield a high sensitivity for small complete tears of the rotator cuff, ultrasound a good sensitivity. The three techniques yield a high specificity. Arthrography is not helpful in detecting partial tears of the rotator cuff. Ultrasound and MR imaging yield comparable accuracy. MR imaging has advantages concerning better evaluation of extent, location and classification as well as for the detection of associated pathologies.[630]

Based on clinical findings, postoperative rotator cuff MR-imaging and ultrasonography show good specificity but low sensitivity for tears. Both radiographic methods do not allow deductions concerning the clinical outcome. Symptoms and functional results are of high clinical relevance in the assessment of the postoperative shoulder.[625]

US is moderately accurate in the diagnosis of substantial fatty atrophy of the SSP or ISP muscle if MRI is used as gold standard.[623]

For visualization of partial finger extensor tendon tears in RA patients, ultrasound performs slightly better than MRI, but both techniques are in 2000 not sensitive enough to be used in daily practice.[631] It is my personal experience that advances in ultrasound technology since 2000 resulted in significant improvement of ultrasound accuracy.

8.6.2.13 General Conclusion Soft Tissue Injury

There is poor comparative study on CT and MRI of soft tissue injury. There is only an old study that compares CT and MRI that scores tears of the posterior tibial tendon. Although not statistically significant the overall accuracy was much higher for MRI.[621] In radiological daily practice also the newly developed multidetector CT is not used for soft tissue injury.

Soft tissue injury is generally evaluated by ultrasound and/or MRI. Indeed some studies compare MRI and ultrasound, although in the majority of these MRI, and not pathology or surgery, is the gold standard. Ultrasound generally has a lower to comparable sensitivity and comparable specificity. In cadaver models US and MR imaging perform at the same level for the detection of posterior tibial tendon tears and forearm membrana interossea lesions.[627, 626]

Most studies investigate the rotator cuff, this resulted in one systematic review. [473] The results suggest that clinical examination by specialists can rule out the presence of a rotator cuff tear, and that either MRI or ultrasound could equally be used for detection of full-thickness rotator cuff tears, although ultrasound may be better at picking up partial tears. Ultrasound also may be more cost-effective in a specialist hospital setting for identification of full-thickness tears.[473] Ultrasound combined with radiography is accepted as the primary investigation in shoulder impingement and suspected partial and full-thickness rotator cuff tear.

Dynamic execution of ultrasound is a major advantage over MRI.[628] However ultrasound has the disadvantage of its operator dependency leading to variable results in daily practice, its poor iconographic quality and impracticability to perform second opinion on hard copies.

Ultrasound is also used as an initial tool for evaluation of non-rotator cuff soft tissue complaints (achilles tendon, posterior tibial tendon, finger tendons, epicondylitis, finger pulley…), MRI is reserved for patients with symptoms whose sonographic findings are normal. [628, 493, 629]

Based on clinical findings ultrasound and MRI do not allow deductions concerning the clinical outcome on postoperative rotator cuff.[625]

Key points

- **Soft tissue injury is generally evaluated by ultrasound and/or MRI. Ultrasound generally has a lower to comparable sensitivity and comparable specificity.**
- **Most studies investigate the rotator cuff. The results suggest that clinical examination by specialists can rule out the presence of a rotator cuff tear, and that either MRI or ultrasound could equally be used for detection of full-thickness rotator cuff tears. Ultrasound may be better at picking up partial tears. Ultrasound also may be more cost-effective in a specialist hospital setting for identification of full-thickness tears. (Evidence level 3) Ultrasound combined with radiography is accepted as the primary investigation in shoulder impingement and suspected partial and full-thickness rotator cuff tear.**
- **Ultrasound is also used as an initial tool for evaluation of non-rotator cuff soft tissue complaints (achilles tendon, posterior tibial tendon, finger tendons, epicondylitis, finger pulley…), MRI is reserved for patients with symptoms whose sonographic findings are normal. (Evidence level 1-Evidence level 3)**
- **Based on clinical findings ultrasound and MRI do not allow deductions concerning the clinical outcome on postoperative rotator cuff. (Evidence level 2)**

8.7 SOFT TISSUE INFECTIONS/INFLAMMATIONS

8.7.1 HTA reports

No relevant HTA reports are available.

8.7.2 Systematic Reviews

No relevant systematic reviews are available.

8.7.3 Clinical Studies

8.7.3.1 Magnetic resonance tomography in the diagnosis of nonorganic bulky masses of the retroperitoneal space. Cysts, abscesses and flegmons

The paper considers the diagnostic capacities of magnetic resonance imaging (MRI) in detecting non-organic bulky masses of the retroperitoneal space. It was based on the analysis of findings in 23 patients with non-organic cysts of the retroperitoneal space and 27 patients with its abscesses and phlegmons. Comparison of the data of MRI and pathomorphological analysis of operation materials has yielded the rates of sensitivity, specificity, and accuracy of the method, which are equal to 100, 88.5, and 94.2% for non-organic cysts and 100, 87.1, and 93.5%, respectively. The authors note the lower efficiency of MRI in recognizing hydatid cysts and foreign bodies than ultrasound study and X-ray computed tomography and show it necessary to take into account clinical information in making a radiological conclusion.[632]

8.7.3.2 Correlation of imaging techniques to histopathology in patients with diabetic foot syndrome and clinical suspicion of chronic osteomyelitis

The role of ultrasound in the diagnosis of osteomyelitis in the diabetic foot is compared with magnetic resonance imaging (MRI), bone scintigraphy (BS), and plain film radiography (PFR) and histopathology after metatarsal resection. 19 consecutive diabetic patients with clinical suspicion of bone infection of the foot were investigated blinded and prospectively. Ultrasound showed a sensitivity of 79% (PFR, 69%; BS, 83%; MRI, 100%), a specificity of 80% (PFR, 80%; BS, 75%; MRI, 75%), a positive predictive value of 92% (PFR, 90%; BS, 91%; MRI, 93%), and a negative predictive value of 57% (PFR, 50%; BS, 60%; MRI, 100%). The data indicate that ultrasound might have a better diagnostic power for detecting chronic osteomyelitis in the diabetic foot than PFR and has similar sensitivity and specificity as BS. MRI is superior to the other three methods. It is concluded that the use of ultrasound in the management of the diabetic foot is worthy of further investigation.[633]

8.7.3.3 Retrocalcaneal bursitis in spondyloarthropathy: assessment by ultrasonography and magnetic resonance imaging

Nineteen Achilles tendons with severe enthesitis and 9 normal tendons of 14 patients' spondylarthropathy were examined by MRI and US. Using MRI as the gold standard, US showed 50% sensitivity and 100% specificity for retrocalcaneal bursa involvement and lacked sensitivity for superficial bursitis.[634]

8.7.4 Conclusion Soft Tissue Infections

MRI yielded good accuracy in detecting non-organic bulky masses of the retroperitoneal space. There is lower efficiency of MRI in recognizing hydatid cysts and foreign bodies than ultrasound study and X-ray computed tomography.[632] CT is still the method of choice to study retroperitoneal infection.

Ultrasound might have a better diagnostic power for detecting chronic osteomyelitis in the diabetic foot than radiography and has similar sensitivity and specificity as bone

scintigraphy. MRI is superior to the other three methods.[633] MRI is the method of choice to detect, stage and follow up osteomyelitis in diabetic feet and other locations.

US has a lower sensitivity and 100% specificity compared to MRI for retrocalcaneal bursa involvement and lacked sensitivity for superficial bursitis in spondylarthropathy.[634] Imaging diagnosis of spine and peripheral joint involvement in spondylarthropathy is discussed in an other part of this HTA. Investigation for bursal involvement is done on clinical indication, US with power Doppler technique is used as primary tool in clinical practice to study bursal infection and inflammation.

Key points

- **CT is still the method of choice to study retroperitoneal infection. (Level 3-4)**
- **MRI is the method of choice to detect, stage and follow up osteomyelitis in diabetic feet and other locations. (Level 3-4)**
- **Investigation for bursal involvement is done on clinical indication, US with power Doppler technique is used as primary tool in clinical practice to study bursal infection and inflammation. (Level 1)**

9 ABDOMEN

9.1 UPPER ABDOMEN

9.1.1 Liver

9.1.1.1 General involvement

Multifocal hepatic steatosis can cause misleading findings in the differential diagnosis when using ultrasound and computed tomography and can be misdiagnosed as metastatic disease. MRI is able to establish the correct diagnosis using T1-weighted gradient echo and T2-weighted sequences with spectral fat suppression.[635] Out of phase imaging is used to depict small amounts of lipids in the liver.[636] However, non of the imaging modalities being US, CT and MRI were able to distinguish NASH (non alcoholic steatohepatitis) from non alcoholic fatty liver disease.[637] Only the severity of the steatosis was reflected in these radiological modalities.

Quantification of liver iron concentration can be crucial in the management of patients suffering from pathologies producing iron overload, for instance hemochromatosis. Compared to biomagnetic liver susceptometry, MRI has equivalent precision. The results from both techniques showed a significant linear correlation.[638]

One group estimated the iron concentrations with MRI and managed to obtain thresholds when used, leading to a positive and negative predictive value of 100% for hemochromatosis. MRI is therefore considered a useful and noninvasive diagnostic tool for quantification of hepatic iron concentration.

In the cirrhotic liver, the equilibrium phase contrast enhanced MRI study can be helpful to distinguish between regenerative and dysplastic nodule.[639]

MR and, to a lesser extent, CT can depict the underlying nodular and fibrotic changes in patients with cirrhosis, particularly when siderotic nodular regeneration is present.[640]

Despite being present pathologically in all cirrhotic livers, regenerative cirrhotic nodules are seen in a minority of patients on CT and in about half of the patients on MRI.[640]

9.1.1.2 Benign lesions

MRI does not depend on patient factors such as obesity and air interposition for visualization of focal lesions and has therefore an intrinsic benefit over ultrasound (US). Also, the unique tissue characterization capacities of MRI even without the use of gadolinium can be exploited in lesion diagnosis.

FLAIR-HASTE imaging is proven to be useful for distinguishing hepatic hemangioma from hepatic cyst even without the use of contrast-enhanced MR images.[641]

Small hemangiomas typical show atypical appearances at CT. Two phase helical CT does not improve sensitivity but does improve specificity for differentiating hemangiomas from hypervascular malignant tumors.[642]

Without the use of any contrast, a specificity in distinguishing liver hemangiomas from liver malignancies up to 98-100% can be reached with MRI.[643]

A statistically significant difference is found between CT and MRI in the detection of benign lesions, with an advantage of unenhanced MRI over enhanced CT: 94% of the lesions were seen at unenhanced MRI, where only 85% was demonstrated at enhanced CT.[644]

Focal nodular hyperplasia is the second most common benign liver tumor after hemangioma. The sensitivity and specificity of MRI was found to be higher compared to ultrasound and computed tomography.[645]

Gd-BOPTA-enhanced MRI is found to be significantly better than ferumoxide-enhanced MRI for the identification and characterization of FNH.[646]

SPIO-enhanced MR imaging and 16-MDCT showed similar diagnostic accuracies for detection and differentiation of liver metastases from cysts, but sensitivity of SPIO-enhanced imaging in the detection of liver metastases was superior to that of 16-MDCT.[647]

9.1.1.3 Malignant masses and primary liver tumors:

MR provides superior characterization of liver masses to CT. It is critical to have a multi-phase gadolinium enhancement including a properly timed arterial phase. Lipid and/or iron content of the lesion can be assessed.[648]

Gadolinium enhanced MRI is superior to T2 unenhanced MRI with and without fat suppression for the detection of focal hepatic masses.[649]

Hepatocellulary carcinoma (HCC) is the most common primary tumor of the liver. In 53 hepatocellulary carcinomas, the diagnostic performance of contrast enhanced MRI was compared to 16-MDCT. The sensitivities of contrast enhanced MRI for all observers were significantly higher than those of MDCT for all the lesions and for lesions 1 cm or smaller. However, for lesions larger than 1cm, the sensitivities of both techniques were similar,[650] leading to no significant difference of overall accuracy when compared with MDCT. The equilibrium phase contrast enhanced MRI study can be helpful to distinguish between regenerative and dysplastic nodule.[639]

9.1.1.4 Metastasis

MRI is an excellent diagnostic tool for the detection and characterization of liver metastasis. The most characteristic finding is the peripheral ring enhancement on immediate post gadolinium images.[651]

Unenhanced MRI was able to show more metastasis then enhanced CT.[644]

Another group compared mangafodipir-enhanced liver MRI with whole body FDG-PET in patients with known metastases from adenocarcinoma of the colon and the pancreas and concluded both imaging modalities were comparable in the detection of liver metastasis. However, significantly more and smaller liver metastases were detected on MRI compared to FDG-PET.[652]

Mangafodipir trisodium is another T1-shortening MR contrast agent, which also has a potential as a hepatobiliary agent. Researchers who have compared this agent with standard gadolinium reported no observable differences in terms of the detection and characterization of liver metastasis.[653]

Researchers that compared the detect abilities of contrast enhanced CT and SPIO enhanced MRI for malignant hepatic tumors including metastasis, reported sensitivities of 71.7-75.3% and 79.8-97.1%, respectively [653]. While some have reported the superiority of gadolinium enhanced MRI over SPIO enhanced MRI for the detection of hepatic tumors, others disagree. For liver metastases, sensitivities of 63% to 43% are reported for gadolinium and SPIO enhanced MRI respectively.[653]

Key points

- **Although non of the imaging modalities being US, CT and MRI are able to distinguish NASH (non alcoholic steatohepatitis) from non alcoholic fatty liver disease, MRI can be used to correct misdiagnosis (pseudo lesions) from US and CT in focal steatosis.**
- **MRI is considered a useful and noninvasive diagnostic tool for detection of hepatic iron concentration (evidence level: 2).**
- **Regenerative cirrhotic nodules are better seen on MR compared to CT (evidence level: 2).**
- **MR provides superior characterization of liver masses than CT. Significantly more and smaller liver metastases are detected on MRI compared to FDG-PET and CT (evidence level: 2).**
- **Gadolinium enhanced MRI is superior to T2 unenhanced MRI with and without fat suppression for the detection of focal hepatic masses (evidence level: 2).**

9.1.2 Spleen

New MR imaging techniques have increased the role of MR imaging in detection and characterization of splenic diseases. MR imaging is an excellent tool for diagnosis and evaluation of focal lesions and pathologic conditions of the spleen. The additional benefit in detection and differential diagnosis of peri- and intrasplenic tumors by use of an super paramagnetic iron oxide contrast agent (SPIO) was demonstrated in malignant tumors.[654] Results indicate that a combination of SPIO and gadolinium enhanced MRI might be superior in detection and characterization of splenic tumors.[654]

Key point

MR imaging is an excellent tool for diagnosis and evaluation of focal lesions and pathologic conditions of the spleen.

9.1.3 Biliary ducts

MRCP is considered in the literature as a non-invasive screening tool for common bile duct stones, appropriately selecting candidates for preoperative ERCP and sparing others the need for an endocopic procedure with its associated complications.[655]

MRCP is the method of choice for non-invasive assessment of the pancreatic duct [656], has a sensitivity to predict common bile duct stones of 94% and may even demonstrate stones not seen on ERCP.[655]

A recent article published in Radiology in 2006 states that MRCP is superior to ERCP for delineation of the main pancreatic duct and that overall sensitivity, specificity and accuracy values of MRCP for pathology was 88%, 98% and 91% [657] and that use of ERCP tends to result in overestimation of the caliber of the main pancreatic duct, while MRCP can enable accurate evaluation of the condition of the pancreatic duct and its changes in patients with chronic pancreatitis.[657]

The sensitivity and specificity of MRCP were 87.5% and 96.6% for the detection of common bile duct stones and 90.5% and 87.5% for etiologic diagnosis. The corresponding values for endoscopic US were 86.4% and 91.3% for etiologic diagnosis and 93.8% and 96.6% for visualization of choledocholithiasis.[658] In case of mild to moderate suspicion of choledocholithiasis, the accuracies of endoscopic sonography and MRCP are similar. Because of the noninvasive character of MRCP, it may be preferred for this indication.[658]

The sensitivity of EUS, MRCP and helical CT-cholangiography are 100%, 88% and 88%. False negative cases for MRCP and HCT-C had a common bile duct stone smaller than 5mm in diameter. When examination can be scheduled, MRCP or HCT-C will be the first choice because they are less invasive than EUS. MRCP and HCT-C had similar detect ability but the former may be preferable considering the possible allergic reaction in HCT-C, while MRCP can be performed without any contrast administration.[659] When MRCP is negative, EUS is recommended to check for small common bile duct stones.[659]

While MRCP may supersede the diagnostic role of ERCP for the patients with choledochal cyst, it showed limited capacity to detect minor ductal anomalies or small choledochocoele.[660]

MR is considered a useful method for establishing the changes in biliary ducts specific to primary sclerosing cholangitis and for identifying long standing cases complicated with cirrhosis.[661]

The image quality and overall accuracy of MRI was evaluated in malignant hilar obstruction. Overall MR accuracy for the assessment of tumor status, periductal infiltration and lymph node metastases was 90%, 87% and 66%, provided single shot thick-slab technique was combined with multisection MRCP.[662] With newer imaging techniques endoscopic retrograde cholangiopancreatography is evolving into a predominantly therapeutic procedure, MRCP is excellent for identifying the presence and the level of biliary obstruction.[663]

Key points

- **MRCP is considered in the literature as a non-invasive screening tool for common bile duct stones, appropriately selecting candidates for preoperative ERCP and sparing others the need for an endocopic procedure with its associated complications. Since MRCP is performed without radiation and contrast administration, it is definitely preferred over HCT-C (evidence level 2).**
- **MRCP may supersede the diagnostic role of ERCP for the patients with choledochal cyst and is considered a useful method for establishing the changes in biliary ducts specific to primary sclerosing cholangitis (evidence level 2).**
- **MRCP is excellent for identifying the presence and the level of biliary obstruction in malignant invasion (evidence level 2).**

9.1.4 Gallbladder

Ultrasound (US) is the primary imaging modality for assessment of acute right upper quadrant pain: it is both sensitive and specific in demonstrating gallstones, biliary dilatation and features that suggest acute inflammatory disease.[664] Occasionally, additional imaging modalities are indicated. CT is valuable to confirm the nature and extent of the complications of acute cholecystitis, while MRCP is helpful in complicated ductal disease, when more detailed diagnostic information is required for treatment planning, whereas ERCP is used when biliary intervention is required for the treatment of choledocholithiasis.[664]

MR findings in gallbladder wall thickening are characteristic in chronic and acute cholecystitis, adenomyomatosis and gallbladder carcinoma. Such gallbladder patterns based on T2 findings led to a positive predictive value of 73% or higher, sensitivity of 92% or higher and a sensitivity of 95% or higher).[665]

In the evaluation and staging of gallbladder carcinoma, CT is traditionally used. Three dimensional CT cholangiography with MIP can be a strong competitor with MRCP , because it gives equivalent information with regard to the level of ductal obstruction in gallbladder carcinoma.[666]

Key points

- **Ultrasound (US) is the primary imaging modality for assessment of acute right upper quadrant pain and as such for the detection of acute cholecystitis.**
- **CT is valuable to confirm the nature and extent of the complications of acute cholecystitis and in staging of gallbladder carcinoma.**
- **MRCP is helpful in complicated ductal disease and as a preoperative exam for anatomical evaluation (treatment planning) (evidence level 2).**
- **ERCP is used when biliary intervention is required for the treatment of choledocholithiasis**

9.2 THE RETROPERITONEUM

9.2.1 Adrenals

Accurate characterization of adrenal masses has been a focus of medical imaging for many years. Adrenal masses are detected with an increasing frequency as an incidental finding during CT or US. MRI provides the unique ability to detect and specify adenomas with chemical shift imaging, without using gadolinium, which makes it a very patient friendly imaging modality.

A large patient study including 138 adrenal lesions lead to the conclusion that, when using the sensitivity index based on signal intensities on in-phase and opposed-phase imaging, no overlap in indexes was found between adenomas and metastatic tumors, while the accuracy in distinguishing adenomas from metastasis was 100% if the cutoff value of this signal intensity index was properly selected.[667]

This index was as such found to be the most reliable evaluation for differentiating adrenal adenomas from metastases and adrenal tumors.[667]

The benefit of chemical substraction MRI was also demonstrated by another group [668], where the mean signal intensities of adenomas and metastasis were again significantly different. There was even no overlap between signal intensities between adenomas and metastatic tumors. Quantitative results corresponding to 100% specificity were observed, with similar sensitivity, [668] confirming the high confidence level in distinguishing adrenal adenomas from adrenal metastases.

Retrospective study in 34 patients with primary hyperaldosteronism resulted in a calculated sensitivity and specificity for detecting aldosterone-producing adenoma of 85-87% and 82-93% for CT and 83% and 92% on MRI: both imaging modalities show similar performances in the detection of aldosterone-producing adenoma.[669]

However, another group including 36 patients confirms the unique high specificity of MRI for the diagnosis of adenoma using chemical shift imaging, but mentions a lower sensitivity of 89% for chemical shift imaging.[670]

Key point

The lack of ionizing radiation combined with a very high sensitivity and specificity of chemical substraction MRI in the differential diagnosis between adrenal adenoma and metastasis or primary adrenal tumors is unique, which makes MRI the first choice modality for adrenal evaluation (evidence level 2).

9.2.2 Pancreas

9.2.2.1 Congenital disease

MR cholangiopancreatography (MRCP) is the technique of choice for detecting pancreas divisum non-invasively.[656]

9.2.2.2 Pancreatitis

Contrast enhanced multi-detector row CT is the method of choice to assess the extent of the disease in acute pancreatitis [656]. In acute pancreatitis, the role of MRCP is mainly limited to finding bile duct stones in patients with suspected biliary pancreatitis.[656]

Although MDCT shows the subtle calcifications in chronic pancreatitis, inflammatory pseudotumor and groove pancreatitis are very difficult to distinguish from pancreatic cancer. In these cases, multiple imaging techniques such as MDCT, MRI and endosonography including biopsy may be used.[656]

MRCP also detects peripancreatic edema and inflammatory changes consistent with acute pancreatitis in 70%.[655]

Also, MRCP can be used to select patients with biliary pancreatitis who require ERCP.[671]

9.2.2.3 Adenocarcinoma

In a consecutive series of 48 patients who were found to bear pancreatic adenocarcinoma and where surgery was performed, for tumor detection, the sensitivity of EUS was superior to MRI and PET (98 vs. 87.5 and 87.5%, respectively, p = 0.13). MRI best assessed loco-regional staging, i.e. arterial involvement. For the detection of distant metastases, the sensitivity of all preoperative examinations taken separately, was low. MRI can be recommended as the first examination in patients bearing pancreatic tumors, complemented by EUS if the findings on MRI are non-conclusive. For detection of distant metastasis, only the combination of all preoperative examinations proved to be more accurate than a single technique.[672]

Helical CT is very effective in detection and staging of adenocarcinoma, with a sensitivity of 76-92% for detection and an accuracy of 80-90% for staging, but it has limitations in the detection of small cancers (<=2 cm).[656]

9.2.2.4 Neuroendocrine tumors

Neuroendocrine tumors are mostly hypervascular. Diagnosis of insulinoma is a challenge: they are <2 cm in 90% of cases and mostly hypervascular at CT or MRI. A combination of contrast-enhanced MDCT, MRI, endosonography, and/or somatostatin receptor scintigraphy is used to detect these small tumors [656].

9.2.2.5 Cystic pancreatic tumors

Differentiating cystic neoplasm from pancreatic adenocarcinomas is important, since the prognosis for malignant cystic neoplasms is better than that for ductal adenocarcinomas. Hence, accurate preoperative characterization of the lesion aids in prognostication and guides therapeutic decision making. Imaging is indispensable in the evaluation of patients with cystic pancreatic lesions. CT allows thin-scanning of the pancreas and has become the preferred imaging modality for both initial detection and characterization of pancreatic cysts, while MRI and MRCP accurately depicts the morphologic features of the cyst and has the advantage of demonstrating the relationship of the cyst to the pancreatic duct.[673]

CT and MRI imaging are excellent modalities for the initial detection as well as the characterization of cystic pancreatic lesions; however endoscopic ultrasound has the added advantage of allowing aspiration of the cyst contents and sampling of the cyst wall and septa or mural nodules. The sensitivity, specificity and accuracy of endoscopic

ultrasound for detecting malignant mucinous tumors have been reported as 40%, 100% and 55%, respectively.[673] Consequently, endoscopic US has been recommended as the technique of choice for the aspiration of cyst fluid and for fine-needle aspiration biopsy of cystic pancreatic lesions.[673] For the intraductal papillary mucinous tumor, sensitivity and specificity and accuracy for detection of malignancy where 70%, 87% and 76% on CT and 70%, 92% and 80% with MRCP.[674]

Key points

- **MR cholangiopancreatography (MRCP) is the technique of choice for detecting pancreas divisum non-invasively (evidence level 1).**
- **In acute pancreatitis, the role of MRCP is mainly limited to finding bile duct stones in patients with suspected biliary pancreatitis. MRCP can be used to select patients with biliary pancreatitis who require ERCP (evidence level 2).**
- **Although MDCT shows the subtle calcifications in chronic pancreatitis better, MRI can be useful in distinguishing inflammatory pseudo tumor and groove pancreatitis from pancreatic cancer.**
- **A combination of contrast-enhanced MDCT, MRI, endosonography, and/or somatostatin receptor scintigraphy is used to detect small neuroendocrine tumors.**
- **MRI can be recommended as the first examination in patients bearing pancreatic tumors, MRI best assessed loco-regional staging, i.e. arterial involvement (evidence level 2).**
- **CT is preferred for initial detection and characterization of pancreatic cysts, while MRI and MRCP depicts the morphologic features of the cyst and the relationship of the cyst to the pancreatic duct more accurately. For aspiration of cyst fluid and for fine-needle aspiration biopsy of cystic pancreatic lesions endoscopic US is the modality of choice.**

9.3 KIDNEY

9.3.1 Renal masses

Distinguishing renal cysts from solid renal lesions remains a challenge. Contrast enhanced MRI was used to depict malignancies in 74 patients with a sensitivity of 100%.[675] The percentage of enhancement after 2-4 minutes was prescribed to 15% for cysts with a 6% false-positive rate. Autosomal recessive polycystic kidney disease in children can be diagnosed with MRI and RARE-MR-urography as microcystic dilated water-filled collecting tubes.[676]

9.3.2 Acute pyelonephritis

Experimental studies in a pig model indicate that MRI is equally sensitive and reliable for the detection of acute pyelonephritis than ^{99m}TC-DMSA SPECT and spiral CT examinations (Se=89.5%, Sp=87.5%).[677] Power Doppler US is significantly less accurate.

9.3.3 Chronic medical nephropathies

In 33 patients with chronic renal disease and renal insufficiency, a good correlation between morphological features of the kidney and serum creatinine values was found.[678] In patients with chronic renal failure dynamic MRI shows both morphological and functional changes. The functional changes seem to differ in vascular from glomerular nephropathies.

9.3.4 Living Renal Donors

Preoperative CT and MR Angiography (MRA) of the renal arteries in 35 renal donors demonstrated supernumerary arteries with substantial agreement (kappa=0.74). [679] The interobserver disagreement between CT and MRI angiograms is related to 1-2 mm diameter vessels.

9.3.5 All-in-one approach

64 Patients were examined with an all-in-one examination on MRI ((a) T1- and T2-weighted imaging; (b) 3D contrast-enhanced MRA, including the renal arteries, renal veins, as well as renal perfusion; and (c) 3D contrast-enhanced MR urography (MRU) in the coronal and sagittal plane).[680] The renal parenchyma, the vascular supply, and the collecting system were adequately visualized in all cases. Nevertheless, one infiltrating urothelial cancer was missed and there was one false-positive urothelial malignancy. Continuous refinement of the applied MRI techniques and further improvements in spatial resolution is needed to expand the actual imaging possibilities.

Key points

- **MRI can be used as a problem solver in the differentiation of suspected renal masses (evidence level 2)**
- **Acute pyelonefritis can be detected on SPECT, CT and MRI (evidence level 2)**
- **Morphological changes are correlated with the degree of renal insufficiency and not with the type of nephropathy (evidence level 1).**
- **Different MRI techniques can be combined to assess diseases which affect the kidneys and urinary tracts (evidence level 1)**

9.4 RETROPERITONEUM

9.4.1 Neoplasms

MRI is widely used for nodal imaging in lymphoma. An older study of 1991 including 74 patients demonstrated that retroperitoneal lymph nodes were correctly assessed in 97% of cases if MRI was compared with lymphography.[681] Primary retroperitoneal neoplasms are a rare but diverse group of benign and malignant tumors that arise within the retroperitoneal space but outside the major organs in this space. Dynamic enhancement patterns can reflect the vascularity of masses and may be useful in diagnosis, especially in differentiating benign from malignant soft-tissue masses.[682]

Key point

MRI has an important role in evaluating soft-tissue masses of the extraperitoneal spaces and can limit the differential diagnosis (evidence level 2).

9.5 WHOLE BODY MRI

In a large patient study, the diagnostic capacity of PET-CT was compared to MRI. The differentiation between benign and malignant lymph nodes was made with a sensitivity of 98% and a specificity of 83% for PET-CT and with 80% and 75% for whole body MRI. Malignant and benign distant lesions were detected with a sensitivity/specificity of 82% for PET-CT and 96/82 for whole body MRI. Accuracy for correct TNM staging was 96% for PET-CT and 91% for whole body MRI. This lead to the conclusion that both whole body MRI and PET-CT are reliable imaging modalities for tumor staging. While whole body MRI is higher sensitive in detecting distant metastasis, PET-CT is superior in lymph node staging.[683]

Key point

While whole body MRI is higher sensitive in detecting distant metastasis, PET-CT is superior in lymph node staging (evidence level 2).

9.6 PELVIS

9.6.1 Intestinal

9.6.2 Crohn's disease

Conventional enteroclysis is considered as the method of choice in the diagnosis of inflammatory bowel disease. However its sensitivity in detecting extraluminal disease is low. MDCT -enteroclysis and -enterography has a high resolution and can depict early changes in the small bowel wall, with a sensitivity of 100% and a specificity of 95%.[684, 685] In a trial of 84 patients the sensitivity in diagnosing inflammatory bowel disease was 85.4% for conventional enteroclysis and 95.2% for MRI, and the specificity was 76.9% for conventional enteroclysis and 92.6% for MRI.[686] The enhancement of lymph node ranks identified on MR enteroclysis were strongly correlated to disease activity in a study of 19 patients.[687] The simultaneous display of the small and large bowel by MRI is feasible by rectal application of water.[688]

9.6.3 Colorectal cancer

The prognosis of patients with colorectal carcinoma is dependent on the depth of tumor invasion into the colorectal wall (T) and regional lymph node involvement (N). Contrast-enhanced multi–detector row CT colonography was an accurate technique for preoperative local staging of colorectal tumors in 41 patients.[689]

The challenge for preoperative imaging in rectal cancer is to determine subgroups of patients with different risks for recurrence after surgery. Preoperative radiation therapy depends on the TNM-staging of rectal cancer. So far, there is no consensus on the role of diagnostic imaging: endorectal ultrasonography (EUS), CT or MRI.[690]

A meta-analysis; including 90 relevant articles published between 1985 and 2002 compared EUS , CT, and MRI in rectal cancer staging; found that endoluminal US was most accurate for evaluation of local invasion.[691] A study of 49 patients concluded that MRI seems to be more useful than EUS for preoperative identification of clinically occult advanced disease.[692] Nevertheless, MRI has a role in the assessment of local lymph nodes, which can not be seen with EUS. Large studies are being performed to further evaluate the role of MRI in the staging of rectal cancer. The use of USPIO has shown promising results in differentiating nodes that contain tumor.

9.6.4 Pelvic floor

Fluoroscopic x-ray defecography has been shown to aid in detection of functional and morphologic abnormalities of the anorectal region. MRI can more easily visualize the complex anatomy of the pelvic floor. The supine position in a closed magnet is not a natural way to look at functional disorders of the pelvic floor. Nevertheless, a study with 38 patients showed that dynamic supine MRI before and after rectal contrast agent administration appears to be an alternative to sitting MR defecography performed with an open-configuration unit for diagnosis of clinically relevant pelvic floor abnormalities.[693] When MRI findings were graded and clinically irrelevant MR findings were excluded, sensitivity increased to 100% for depiction of bladder descents and anterior rectoceles and to 96% for depiction of rectal descents.

9.6.5 Anal fistulas

High-spatial-resolution MRI is accurate for detecting anal fistulas. MRI provided important additional information in 21% of 56 patients with anal fistulas. In patients with Crohn disease, the benefit was 40% (six of 15). The sensitivity and specificity for detecting fistula tracks were 100% and 86%, between patients with or without Crohn disease respectively. MRI is recommended in the preoperative work-up of patients with anal fistulas.[694] Contrast-enhanced MRI shows well the activity of the fistula.

Key points

- **MDCT and MRI with oral contrast administration have value in the investigation of small bowel diseases (evidence level 2).**
- **The accuracy of MRI, EUS, and CT for staging the lymph nodes is disappointing.**
- **USPIO might help staging rectal carcinoma.**
- **MR- defecography shows effectively pelvic floor abnormalities (evidence level 2).**
- **MRI for anal fistulas has a positive effect on the patient outcome (evidence level 2).**

9.7 PROSTATE

9.7.1 Cancer

Accurate staging of prostate cancer is important because treatment options are mainly based on the local extend and on the presence of metastatic disease. PSA is the most accurately marker to screen prostate cancer. In a study with 38 patients, prostatic MRI with an endorectal surface coil using the dynamic technique detected tumor localization, capsular penetration, seminal vesicle invasion, and neurovascular bundle involvement more accurately than other imaging methods, such as transrectal ultrasound. The sensitivity and specificity of tumor detection was 81% and 79% for peripheral zone cancers and 37% and 97% for transition zone cancers, respectively on MRI.[695] It is not yet conclusively determined whether preoperative MR staging is appropriate, but results of decision analysis suggest that MR staging is cost-effective for men with moderate or high prior probability of extracapsular disease.[696]

Key point

MRI of the prostate is still in exploratory phase and an endorectal coil should be used to accurately stage the tumor.

9.8 CERVIX

9.8.1 Cancer

Cervical cancer is staged according to the International Federation of Gynecology and Obstetrics (FIGO). 41 Patients were assessed for parametrial invasion, vaginal invasion and lymph node metastases.[697] MRI had an accuracy of 95, 83, and 86%, respectively. In determining stage of disease and differentiating operable (stage IIA) from advanced disease (stage IIB), MRI had an accuracy of 82.9 and 93%. Node staging in 35 patients with cervical carcinoma resulted in sensitivities of 0.91 with FDG-PET and 0.73 with MRI and specificities of 1.00 with FDG-PET and 0.83 with MRI.[698] Dynamic enhanced MRI and pharmacokinetic analyses in 26 patients with cervical cancer proved that radiation therapy is more effective in well-enhanced tumors, resulting in improved local control.[699]

Key point

MRI should be used in tumor that is clinically suspected to be stage II disease (evidence level 2)

9.9 UTERUS

9.9.1 Leiomyoma

MRI helps choosing the appropriate therapy for symptomatic fibroids. MR imaging was useful for evaluation of changes in fibroleiomyoma volume in 18 patients with 32 leiomyomas 2 and 6 months after uterine arterial embolization. MR imaging characteristics of fibroleiomyomas before embolization can help predict subsequent response to treatment.[700]

9.9.2 Adenomyosis

MRI can diagnose and differentiate adenomyosis from other gynecologic disorders, and can help in the planning of appropriate treatment. Although the typical MRI findings are well established, adenomyosis actually varies widely in terms of histopathologic features, growth patterns, responses to hormonal activity, and responses to treatment.[701] The accuracy of transabdominal and transvaginal sonography and MRI for the diagnosis of adenomyosis was compared in 120 patients.[702] Sensitivity, specificity, and positive and negative predictive values of MRI were 77.5, 92.5, 83.8 and 89.2% respectively. Transvaginal sonography is as efficient as MRI for the diagnosis of adenomyosis in women without myoma, while MRI could be recommended for women with associated leiomyoma.

9.9.3 Congenital anomalies

MRI is the most accurate modality for identifying uterine anomalies. MRI allows accurate morphologic demonstration and classification of uterovaginal anomalies, thereby indicating the appropriate treatment. Associated pelvic lesions or renal anomalies can be depicted.[703] At this time, magnetic resonance imaging is the study of choice because of its high accuracy and detailed elaboration of uterovaginal anatomy. Laparoscopy and hysteroscopy are reserved for women in whom interventional therapy is likely to be undertaken.[704]

9.9.4 Endometrial cancer

Contrast-enhanced MRI performs best in the pretreatment evaluation of myometrial or cervical invasion, compared to ultrasonography, CT, or nonenhanced MRI. The overall costs and accuracy are similar to those of the current methods of staging, including intraoperative gross dissection of the uterus. In addition, results of MRI might decrease the number of unnecessary lymph node dissections.[705] MRI can help to distinguish most polyps from endometrial carcinomas on the basis of morphologic features. In 35 patients the accuracy of MRI in distinguishing endometrial polyps from endometrial carcinomas was a sensitivity of 79%, specificity of 89%, accuracy of 86%, positive predictive value of 82%, and negative predictive value of 88% for diagnosis of carcinoma.[706]

Key points

- **MRI can accurately diagnose size, number and location of leiomyomas**
- **MRI is an accurate noninvasive modality for diagnosis of adenomyosis (evidence level 2)**
- **MRI is currently used as a problem solving modality in inconclusive cases of congenital malformations of the uterus**
- **MRI is the modality of choice for preoperative staging of endometrial carcinoma (evidence level 2)**

9.10 OVARY

9.10.1 Benign conditions

The main role of MRI in evaluating ovarian abnormalities is that of tissue characterization. Mature cystic teratomas, cysts, endometriomas, leiomyomas, fibromas, and other lesions can be accurately diagnosed. Endovaginal US is the most practical modality for assessment of ovarian tumors because it is readily available and has a high negative predictive value. MRI is better reserved for problem solving when US findings are nondiagnostic or equivocal.[707]

9.10.2 Cancer

In 93 patients MRI correctly characterized malignant and benign tumors in 89% of cases versus 85% by ultrasound.[708] The site of the primary tumor was correctly diagnosed in 94% of cases by MRI vs. 90% by ultrasound. For US, the positive predictive value was 85%, the negative predictive value 73% vs. 92% and 89% for MRI. MRI was superior in the diagnosis of malignant ovarian masses though US, too, performed well at lesion detection and characterization. For tumor staging, MRI is used as a problem-solving modality. In 280 patients - of which 118 with malignant ovarian cancer - US, CT, and MRI were compared for diagnosing and staging of the disease. In the peritoneum, MRI and CT were more accurate than US. MRI and CT were more sensitive than US (95%, 92%, and 69%, respectively) for peritoneal metastases. MR imaging was more accurate than CT for detection of lymph node metastases.[709]

It is difficult to accurately distinguish between primary and secondary ovarian malignancies with MRI or US.[710]

Key points

- **MRI is superior to US for demonstrating the origin of a lesion as well as in lesion characterization, and should be used as a problem solver.**
- **CT stays the imaging modality of choice for preoperative staging of ovarian carcinoma (evidence level 2).**

9.11 PEDIATRIC ONCOLOGY

9.11.1 Neuroblastoma and Wilms' tumour

The most commonly encountered abdominal tumours in children are the Wilms' tumour and the neuroblastoma. Most other tumours are much less common and the literature on MRI in these rare tumours mainly consists of case reports or short case series. There are no systematic reviews.

Generally speaking, the use of MRI in the paediatric population is even of greater importance because CT is the greatest source of diagnostic radiation in children. One important disadvantage of MRI in this population is the need for adequate sedation, usually general anaesthesia, in children younger than 6-7 years.

Concerning neuroblastomas, there has been one multicenter prospective cohort study on 96 children who were suspected of having neuroblastoma on the basis of conventional radiographic and sonographic findings.[711] The sensitivity of CT for detection of stage 4 disease was 43% and of MRI 83%. The specificity of CT was 97% and of MRI 88%. CT and MRI performed poorly for local tumour staging. The authors recognized that both CT and MRI aid in over- and understaging of neuroblastoma and that there is still considerable room for improvement of the imaging mathods used to assess disease extent in patients with neuroblastoma.

The most common renal tumour in children is the Wilms' tumour. In a recent opinion article the authors state that the absence of ionizing radiation and the multiplanar acquisition are important advantages of MRI compared to CT. MRI is helpful in planning nephron-sparing surgery. On MRI it was possible to recognize all contralateral nephrogenic rests, identified subsequently at surgery.[712] However, the choice of abdominal CT versus MRI in the staging of Wilms'tumour remains questionable because of the lack of evidence comparing the specificity of both modalities.

A recent review paper on MRI in abdominal masses in children claims the following specific advantages of MRI: (1) assessment of resectability of hepatic tumours, (2) staging neuroblastoma in the bone marrow, lymph nodes, liver and spinal canal (3) response of bilateral Wilms' tumour and nephroblastomatosis and (4) detection of pelvic tumours and peritoneal tumours.[713]

9.11.2 Non-palpable testis

In the diagnosis of non-palpable testis in childhood, a positive MRI locates the testis reliably, whereas a negative finding always needs further exploration because the testis might have been missed (no false positive findings, 32% false negative findings).[714]

9.11.3 MR urography

Static and dynamic MR urography showed the morphology of the urinary tract and excretion with sufficient diagnostic imaging quality, and the results where in diagnostic compliance with scintigraphy. Compared to scintigraphy, the higher spatial resolution of MR provides additional important information, improving the management of the pediatric patients without the application of radioactive tracers.[715] In children, MR urography may replace conventional uro-radiological methods [716] and functional

isotopic imaging. However the need for sedation in young children remains a clear disadvantage of the method.

9.11.4 MR enterography

In pediatric patients with Crohn's disease, contrast enhanced mannitol-MR contributes significantly to the identification of disease extension, severity and intestinal complications with adequate diagnostic accuracy. This technique could also be useful as the first line diagnostic exploration in young patients with suspected Crohn's disease.[717] Because of the absence of ionizing radiation, MR enterography should become the gold standard in pediatric patients in patients with known or suspected Crohn's disease.[718]

Key points

- **Although MRI has clear advantages over CT in pediatric abdominal oncology there is at present no evidence in the literature that MRI is superior to CT.**
- **In the diagnosis of non-palpable testis in childhood, a positive MRI locates the testis reliably**
- **In children, MR urography may replace conventional uro-radiological methods and the results where in diagnostic compliance with scintigraphy**
- **Because of the absence of ionizing radiation, MR enterography should become the gold standard in pediatric patients in patients with known or suspected Crohn's disease.**

10 MAGNETIC IMAGING RESONANCE OF THE BREAST

10.1 GENERAL INDICATIONS

Dynamic Magnetic Resonance Imaging (MRI) of the breast has become an important complementary examination in breast cancer management, thanks to the high sensitivity of 98% for invasive carcinomas and 54-100% for in situ carcinomas.[719] Due to low specificity, with extremely variable reported rates of 37-97%,[720] it may only be performed for selected indications. Interpretation of MR images is based on morphology of enhancement and dynamics of enhancement.

Two guidelines have specified the indications for MRI of the breast:

- The recommendations of the Institute for Clinical Systems Improvement (ICSI)
- The guidelines of the EORTC

10.1.1 Recommendations of the Institute for Clinical Systems Improvement (ICSI) in "Diagnosis of breast disease" [721] (86 references)

MRI does not replace mammography. Presently, MR breast imaging is being used for:

- Staging existing cancer
- Detecting occult breast cancer (e.g., positive axillary lymph node with negative mammogram)
- Distinguishing postoperative scar vs. tumor recurrence
- Screening in high-risk patients with a breast cancer gene mutation
- Monitoring response to neo-adjuvant chemotherapy
- Determining close or positive surgical margins (if not found on pathology report)
- Evaluating integrity of breast implants including rupture

In women at high genetic or familial risk of breast cancer, MRI has high sensitivity (up to 94%) for the detection of breast cancer when used as an adjunct to mammography. This increase in sensitivity may lead to an earlier diagnosis of malignant breast lesions. The development of better targeted contrast agents will advance the implementation of breast MR imaging. MR imaging provides an accurate map of the extent of cancer within an affected breast.

The guidelines were based on different sources (86):

- Non-randomized trials with concurrent or historical controls
- Case-control studies
- Studies of sensitivity and specificity of a diagnostic test
- Population-based descriptive studies
- Meta-analyses
- Systematic reviews
- Decision analyses
- Cost-effectiveness analyses

10.1.2 EORTC guidelines [722]

The indications for an MRI investigation are (in order of specificity)

1. Staging of tumor extent within the breast and exclusion of multicentricity in the same or contralateral breast
2. Assessment of scarring after breast-conserving therapy (preferentially 18 months after radiation therapy)
3. Evaluation after silicon implant
4. Problem solving early after surgery
5. Monitoring of neoadjuvant chemotherapy
6. Search for primary tumor when the primary tumor is unknown and breast cancer is suspected

Key points

- **MR mammography is very sensitive, but has a low specificity.**
- **MR may be performed only in selected indications. (Evidence level 3)**

10.2 STAGING OF TUMOR EXTENT WITHIN THE BREAST AND EXCLUSION OF MULTIFOCALITY, MULTICENTRICITY IN THE SAME OR CONTRA LATERAL BREAST

In the majority of breast cancer patients diagnosed today, disease-free and overall survival are similar after **breast conserving therapy** when compared with mastectomy. Breast cancer recurrence after breast conserving surgery is reported in 3 to 19% of patients and is mostly due to incomplete resection or multifocality. Furthermore, **breast tumor recurrence** is a risk factor for distant metastasis and mortality. Therefore, good preoperative staging before planning breast conserving surgery is important.

Reports have demonstrated that MR detects **multifocal/multicentric** carcinoma in up to 37% of breast cancer patients. However, of the enhancing lesions detected on MR only, 20% false positive lesions are reported (table 1).

A literature search performed by the Blue Cross and Blue Shield Association Technology Evaluation Center (TEC)[1] identified studies using contrast-enhanced breast MRI in patients with localized breast cancer.[723]

They considered 18 studies (n=1401) confirming that MRI has a better sensitivity for identifying breast tumors. The 18 studies confirmed that MR has a better sensitivity for identifying multicentric breast tumors compared to conventional staging (sensitivity of 75-100%), but due to the moderate specificity (82-100%) and relatively low PPV (50-100%), presurgical biopsy of additional lesions should be performed before changing conservative therapy to mastectomy.

Approximately 2% to 15% of women who appear eligible for breast conserving therapy have multicentric disease, detected on MRI. The presence of multicentric disease appears somewhat higher in patients with ductal carcinoma in situ (DCIS) (20-28%) or infiltrating lobular carcinoma (ILC) (17-40%). Studies demonstrated sensitivity of 75-

[1] Since 1985, the Blue Cross and Blue Shield Association's Technology Evaluation Center (TEC) has been recognized for its leadership in evidence-based healthcare technology assessment. Its mission is to provide healthcare decision makers with timely, objective and scientifically rigorous assessments that synthesize the available evidence on the diagnosis, treatment, management and prevention of disease.

100% and specificity of 82-100% for multicentric tumor foci and a PPV of 50-100%, the 3 most representative studies had a PPV of 67-100%.

They stated that there is no direct evidence that mastectomy would improve health outcomes compared to conserving surgery with radiation therapy and that there is insufficient evidence to determine the overall prognostic significance of multicentric breast tumors found on MR alone. Therefore, they concluded that MRI for preoperative staging does not meet the TEC criteria (Box 1).

Box 1: Technology Evaluation Center Criteria

The Blue Cross and Blue Shield Association uses the five criteria below to assess whether a technology improves health outcomes such as length of life, quality of life and functional ability:

1. The technology must have final approval from the appropriate governmental regulatory bodies.

This criterion applies to drugs, biological products, devices and any other product or procedure that must have final approval to market from the U.S. Food and Drug Administration or any other federal governmental body with authority to regulate the technology.

Any approval that is granted as an interim step in the U.S. Food and Drug Administration's or any other federal governmental body's regulatory process is not sufficient.

The indications for which the technology is approved need not be the same as those which Blue Cross and Blue Shield Association's Technology Evaluation Center is evaluating.

2. The scientific evidence must permit conclusions concerning the effect of the technology on health outcomes.

The evidence should consist of well-designed and well-conducted investigations published in peer-reviewed journals. The quality of the body of studies and the consistency of the results are considered in evaluating the evidence.

The evidence should demonstrate that the technology can measure or alter the physiological changes related to a disease, injury, illness, or condition. In addition, there should be evidence or a convincing argument based on established medical facts that such measurement or alteration affects health outcomes.

Opinions and evaluations by national medical associations, consensus panels, or other technology evaluation bodies are evaluated according to the scientific quality of the supporting evidence and rationale.

3. The technology must improve the net health outcome.

The technology's beneficial effects on health outcomes should outweigh any harmful effects on health outcomes.

4. The technology must be as beneficial as any established alternatives.

The technology should improve the net health outcome as much as, or more than, established alternatives.

5. The improvement must be attainable outside the investigational settings.

When used under the usual conditions of medical practice, the technology should be reasonably expected to satisfy TEC criteria #3 and #4.

However, the results of more recent clinical studies, performed to determine the role of MR in preoperative staging, showed again the superior role of MR to detect additional lesions occult on other imaging methods (table 1). A large prospective, multicenter trial involving 426 women with confirmed breast cancer was performed at

15 institutions in the US, Canada, and Germany.[724] Women underwent mammography (MX) and MRI prior to biopsy of the suspicious index lesion. MRI had a significantly higher yield of confirmed cancer incidental lesions than MX: (0.18 (95%CI: 0.142-0.214) for MRI versus 0.072 (95%CI: 0.050-0.100) for mammography). They concluded that consideration needs to be given to the integration of breast MRI into the pretreatment evaluation of women seeking breast conservation therapy.

MRI is more accurate than mammography in determining **invasive tumor size** and in **detecting and estimating the extent of extensive DCIS around a carcinoma** (extensive intraductal component = EIC + tumours). Studies of the role of MR in detection of in situ carcinoma and in assessment of extent of EIC + cancers were performed. Four of them contained between 11 and 25 patients, 2 larger studies contained respectively 68 and 59 patients.[725, 726, 720, 727-731]

Synchronous bilateral breast cancer accounts for 3-6% of breast cancers. The reported rates of MR-demonstrated but mammographically and clinically occult contralateral breast cancer varies between 5.7-24%.

Due to its growth pattern, **invasive lobular carcinoma** is often difficult to detect on clinical examination, MX and US. Moreover, patients with invasive lobular carcinoma (ILC) are reported to have a relatively high frequency of multifocal, multicentric or bilateral breast cancer (14-31%).[732, 733] Even if one ILC in a patient is detected, additional lesions may potentially be occult on the routine imaging examination. Seven studies of the role of MRI in ILC are published, the number of patients varied between 20 and 32. The conclusion was that MR is superior to mammography in determining the extent of ILC, including the presence of multifocal/multicentric disease (16-50%).[734, 732, 733, 735-738] If breast conservation therapy is planned for an ILC, it is important to perform MRI to detect eventually multifocal or multicentric foci, given the limitations of mammography and ultrasound to detect ILC.

A few studies of small numbers of patients (3-9) are published of **Paget disease** of the nipple. The authors concluded that MRI can detect foci of carcinoma within the breast and can help in choosing the most reasonable and conservative treatment in these patients (66-88%).[739, 740]

One study compared **CT** and MRI for evaluating the extent of breast cancer in 50 patients and concluded that CT can provide good information about the spread of the cancer.[741] The sensitivity, specificity, and accuracy of 3D CT in detecting intraductal spread or DCIS were 71.9%, 83.3%, and 76.0%, respectively, and those of 3D MRI were 87.5%, 61.1%, and 78.0%. Overestimations numbered three (6.0%) on CT and seven (14.0%) on MRI, and underestimations numbered nine (18.0%) on CT and four (8.0%) on MRI.

As recurrence of breast cancer is mostly due to tumor left in the breast, rate of recurrence may be lower for patients who had preoperative MRI. One study reported on the **influence of preoperative MR on recurrence rate**. The recurrence rate in the group of the patients with preoperative MR (n=121) was 1.2%, compared to 6.8% in the patients without preoperative MR (n=225). Contralateral cancer was detected within follw-up for more than 20 months in respectively 1.7% and 4%. This difference was statistically significant.[742]

Moreover, thanks to the superior role of MR in assessment of extent of a carcinoma, definitive surgical resection can be performed in 1 time.

If patients will not be treated with radiotherapy, preoperative staging is of utmost importance.

To ensure optimal use of this new diagnostic tool high technical standards, proper expertise on the part of the examining radiologist, and effective cooperation among the involved disciplines (radiology, pathology, surgery) must be guaranteed. If on MRI additional lesions are identified, biopsy should be performed before important therapy change is done.

Key points

- **MR is superior to MX and US in detection of multifocal/multicentric and bilateral carcinoma and in assessment of diameter and extent of a carcinoma. Evidence level 2.**
- **Up to 37% extra lesions are detected.**
- **Due to the low specificity, false positive enhancing lesions can lead to unnecessary wider surgery.**
- **MRI is especially useful in patients with invasive lobular carcinoma or dense breasts. Evidence level 2.**

10.3 DISTINGUISHING POSTOPERATIVE SCAR VS. TUMOR (RECURRENCE)

Breast MRI is useful in the evaluation of patients with a high clinical suspicion of local recurrence within the irradiated conserved breast. It is a **sensitive method for detecting or excluding recurrence of malignant disease,** with reported sensitivities of 93 %-100%.[720, 743, 744]

A TEC report has been published of the effectiveness of MRI to detect or diagnose primary or recurrent breast cancer. A part of the work was on the detection of cancer in patients who have breast characteristics limiting the sensitivity of MX, i.e. dense breasts, implants or scarring after treatment. In the group of patients with prior history of breast cancer and limited sensitivity of MX, they included 7 studies (n=535, 2 prospective). The studies suggested that MRI may offer higher sensitivity and similar or better specificity than conventional methods in detecting breast cancer recurrence, with a PPV generally above 20%.

Another part reviewed 5 studies (n=422; 1 prospective) of patients treated for breast cancer, with low suspicious findings on conventional imaging. Sensitivity and NPV of MR were 100% and specificity of MR was higher than of conventional imaging. In the prospective study, sensitivity of combination of MX and CE was also 100%. The specificity of adjunctive MRI was significantly higher than combined conventional testing alone (93% and 67% respectively). TEC concluded that the use of MRI for both groups of patients (i.e. breast cancer patients with breast characteristics limiting the sensitivity of MX or with nonsuspicious lesions) has not be demonstrated.[723]

A thirth part reported on 10 studies (n=1021; 6 prospective) that evaluate the adjunctive use of MRI for diagnosis of recurrent disease in patients with suspicious lesions referred for biopsy. MRI had a sensitivity of 91-100%, specificity of 67-100%, NPV from 67-100%. The potential harm of failing to diagnose breast cancer or to delay diagnosis of breast cancer in patients with false negative MRI is of significant concern. The potential benefit of sparing patients from unnecessary biopsy does not outweigh the potential harm of a missed or delayed diagnosis of breast cancer. MRI is not an adjunctive test for diagnosis of a suspicious lesion in order to avoid biopsy.[723]

Davis reported on 5 studies that reviewed the sensitivity and specificity of MRI to detect recurrent breast cancer in 158 women after radiation therapy, of whom 123 women had conservative surgery. The ability of MRI to detect recurrent local breast cancer was nearly 100% and the specificity was 98%.[745]

MR must be performed 12-18 months after stop of radiotherapy to avoid false positives.

Key points

- **MRI can detect recurrent local breast cancer. Evidence level 2.**
- **If a suspicious lesion is seen on MX, a negative MRI may not delay biopsy. Evidence level 2.**

10.4 PROBLEM SOLVING EARLY AFTER SURGERY

In most staging studies, MR is performed prior to excisional biopsy. It has been demonstrated that MR imaging can be used for breast cancer staging after excisional biopsy when there are positive margins of resection. These preliminary results have shown that **residual or multifocal cancer can be detected on MR images obtained after excisional biopsy** with an accuracy for the diagnosis of residual disease of 64% - 88%. Orel et al. reported on the accuracy for the diagnosis of residual disease of 64% for MR compared to 7% for mammography, if the MR examination was performed within a mean time of 18 days after surgery.[746-750]

However, **there are limitations to MR after excisional biopsy**. In the performed studies, the false-negative rate was 27% and the false-positive rate was 19%. Scheduling patients with positive resection margins no earlier than 28 days after initial surgery for evaluation of residual cancer using MR imaging of the breast is recommended bei Frei et al. The time interval between lumpectomy and MR imaging of the breast had the greatest influence on the specificity and negative predictive value of MR imaging, increasing progressively over time. A plateau of highest values of 75% specificity and 86% negative predictive value was reached at 28 and 35 days after surgery, respectively.[751]

Key points

- **Residual or multifocal cancer can be detected on MR images obtained after excisional biopsy. Evidence level 2.**
- **There are limitations: false-negative rate of 27% and false-positive rate of 19% are reported**

10.5 AFTER SILICONE IMPLANT

One **meta-analysis is published on the radiographic diagnosis of breast implant rupture.**[752] Results of this retrospective analysis, corroborated by a review of the literature, revealed that MX with US constitutes the most cost-effective initial study, followed by MRI if MX and US are equivocal. MRI however, is the most sensitive and specific study to evaluate breast implant rupture (sensitivity 74-96% and specificity 94-98%).

This is confirmed by Pfleiderer, who concluded in a **review article** that MRI, in comparison to other imaging modalities, has the highest specificity and sensitivity in the diagnosis of implant defects but that, due to its high costs, it is not suitable as a screening tool and should only be used in cases of sonographic suspected rupture or after radical mastectomy. In these cases MRI is the method of choice.[753]

In a **large study of 1626 single lumen silicone gel-filled implants** imaged with MR, the sensitivity for rupture was 74% and the specificity was 98%.[754]

Another study consisted of a **meta-analysis of 18 published studies of 2036 implants** in 1039 women, who underwent both MRI and subsequent implant removal. Most studies involved women with symptomatic implants. Assuming that sensitivity and specificity were independent parameters, the summary sensitivity was 78% (95% confidence interval: 71-83) and the summary specificity was 91%. Using ROC meta-analysis methodology, the odds ratio describing the overall accuracy of the test was 40.1 (range, 18.8-85.4). There was substantial heterogeneity across studies. Studies using breast

coils, those with convenience samples, larger studies, and studies of lower report quality tended to report higher levels of accuracy. The quality of study reports was generally poor. The authors concluded that, among symptomatic women, PPV was fairly high and MRI is moderately accurate in detecting silicone breast implant rupture. In most of the studies, MRI was involved in the decision to undergo breast implant removal, which may lead to a substantial bias. It is likely that the accuracy of MRI is insufficient to be useful as a screening tool among asymptomatic women for the purpose of detecting implant rupture or as a test to estimate the prevalence of implant rupture among asymptomatic women. Therefore, MRI should remain a confirmatory diagnostic test and should not be used to screen asymptomatic women.[755]

However, MRI seemed to be the best imaging method on its own for the evaluation of rupturing among asymptomatic patients in a more recent clinical prospective study of 44 asymptomatic women who subsequently had implants surgically removed. Eighty-three implants were evaluated by both MX and US and 77 implants were evaluated by MR. Sensitivity and specificity of MX was 20% and 89%; of US, 30% and 81%; and of MRI, 64% and 77%.[756]

Another study reported on forty-one implants in 25 patients that were analyzed by MRI before surgical removal and in which 2 breast cancers were detected. The sensitivity for detection of implant rupture was 86.7% with a specificity of 88.5%. The positive and negative predictive values were 81.3 and 92.0%, respectively. Magnetic resonance imaging revealed two lesions with suspicious contrast enhancement (one carcinoma, one extra-abdominal fibromatosis). They concluded that magnetic resonance imaging is a reliable and reproducible technique for diagnosing both implant rupture and malignant lesions in women after breast augmentation and reconstruction.[757]

Key points

- **MR has a high sensitivity of 74-78% for implant rupture and a specificity of 91-98%.**
- **MX and US are the most cost-effective techniques for the initial diagnosis of breast implant rupture, evidence level 2.**
- **MR is indicated if MX and US are equivocal and in symptomatic women, evidence level 2.**

10.6 MONITORING OF NEOADJUVANT CHEMOTHERAPY

Neoadjuvant chemotherapy is used for locally advanced breast cancers but also for operable cases in an adjuvant setting. After neoadjuvant chemotherapy, breast conserving surgery can be performed more often if the tumor has shrunk centrally and a survival benefit can be predicted if chemotherapy achieves pathological complete response.[758]

Reduction in size occurs late in the course of chemotherapy; however, **tumor vascularity decreases** relatively early in responsive tumor. Contrast enhancement on MR is related to tumor vascularity, thus, reduction in enhancement is a measure of early response to chemotherapy. Enhancement on MR correlates well with vital tumor.

A systematic review study is performed by the Technology Evaluation Center.[723] They included eighteen studies (total n=558) that evaluate the use of MR after neoadjuvant therapy. Moreover they reviewed 4 studies that described the preoperative use of MR to identify tumor involvement of the chest wall, skin or nipple. Nine of the reviewed studies compared MR with conventional imaging. All the reviewed studies were peer reviewed, used human subjects and reported diagnostic performance characteristics for MRI and alternative tests when appropriate or effect of MRI on health outcomes.

No randomized, controlled trials that assess the effects of breast MRI on breast cancer related morbidity or mortality have been published. The best available evidence is from studies that report the diagnostic performance of MR to define extent and response of

the tumor after neoadjuvant chemotherapy, using comparison with pathology as gold standard.

Other clinical studies are reported.

One of the main roles of neoadjuvant chemotherapy for breast cancer is to shrink large tumors to increase patient eligibility for breast conserving surgery. Two shrinkage patterns of a tumor are described: a concentric shrinkage pattern and a dendritic shrinkage pattern. The cases with concentric shrinkage were good candidates for breast conserving surgery, but tumors showing dendritic shrinkage often had positive margins necessitating mastectomy in a study of Nakamura et al. on 25 patients. MR is a useful modality for evaluating whether breast conserving surgery can be safely done in the neoadjuvant setting.[759]

Accurate presurgical evaluation of residual disease appears essential for successful clinical outcome in patients with breast cancer who are undergoing chemotherapy.

High correlation is seen between measurements of residual disease obtained on MR images and those obtained at pathology, while clinical examination can be false negative.[760] However, whenever MR is used to judge the response of breast cancer to chemotherapy, the reader must be aware that therapy-induced changes may cause significant over- or underestimation of tumor size on MRI. High precision is reported when there was either no response - according to histological criteria - or when the tumor had regressed completely.[761] Other investigators reported that MR proved very reliable in determining the size in patients whose tumors showed only slight response to chemotherapy, while determination of residual tumor size is unreliable in carcinomas exhibiting significant response to chemotherapy, leading to false-negative results. In patients whose tumors displayed significant (PR) or complete response (CR), the size of the residual tumor was underestimated in 8 of 12 cases. During chemotherapy, intensity of contrast medium uptake decreased in 88.2% of patients with PR and in all patients with CR.[762]

The most important use of MR would be to reliably identify those patients whose tumors do not respond. If these non-responders could be identified early during treatment, they could potentially benefit from either a change in therapy or earlier surgery, rather than continuing completion of the planned course of treatment.

MR is a sensitive technique to monitor response or to detect insufficient response in time.[763] MR assesses response to neoadjuvant chemotherapy better than traditional methods of physical examination and mammography.[764] However, one study showed that patients who failed to show a response on MR after 2 cycles of neoadjuvant chemotherapy may still go on to have at least a partial response. This means that the early appearance on MRI is not a reliable predictor of final tumor response [762]. However, a review article of Beresford et al. concluded that reduction in enhancement appears to be a good predictor of eventual response.[765] Martincich et al. found an accuracy of 93% in identifying tumors achieving a pathologic complete response, if there was a reduction both in tumor volume and enhancement ratio.[766] Padhani et al. found that after 1 cycle of chemotherapy, a change in size of the tumor on MRI was more predictive of response, but that after 2 cycles predictive value of change in volume and enhancement were equivalent.[767] A study of Ah-See et al. of 28 breast cancer patients showed that a change in enhancement could predict pathologic nonresponse with a sensitivity of 100% and a specificity of 72%.

The Technology Evaluation Center (TEC) report concluded that MR appears to be better than conventional presurgical clinical staging methods at determining extent and size of residual tumor. However, it cannot be used as a replacement for histopathologic assessment.[723]

There is insufficient evidence to permit conclusions on the effect on health outcomes of using MRI to provide an early prediction of the response to neoadjuvant chemotherapy.

Key points

- **MR is better than conventional techniques at determining extent and size of residual tumor after neoadjuvant chemotherapy. Evidence level 2.**
- **A combination of measuring reduction of volume on MR in combination with reduction of enhancement could potentially play a role in the identification of nonresponders. Evidence level 2.**

10.7 SEARCH FOR PRIMARY UNKNOWN TUMOR WHEN BREAST CANCER IS SUSPECTED

Occult primary breast cancer represents in less than 1% of breast cancers. In only 1/3, MX identifies a primary tumor.

In a retrospective review of 10 patients with occult primary breast cancer and unknown metastatic lymphadenopathy, MR identified the primary site in 8 (80%) and excluded it in 2.[768] In another study of 22 patients with axillary node metastases and negative CE and MX, MR depicted a primary breast cancer in 19 (86%) and 2 patients had false negative findings. In these patients, MR imaging offers potential not only for cancer detection but also for staging the cancer within the breast, which may be useful for treatment planning.[769]

In another study of 14 patients presenting with metastatic disease, who had no evidence of tumor on MX and US, MR revealed suspicious lesions in 9, 6 of which were carcinomas. In 5 patients with normal MRI, follow-up to 1 year after initial treatment revealed no breast cancers in these 5 patients.[770]

The Technology Evaluation Centre reviewed 6 studies (n=113), 2 of which were prospective, of patients with axillary nodal adenocarcinoma and negative mammogram. Combining these studies, 68 of 72 primary breast cancers identified at surgery but missed on conventional imaging, were identified by MR. Overall sensitivity was 94%, specificity 94-100% and estimated PPV was 90% or greater. They concluded that MR will improve the net health outcome and that the use of MRI can guide breast conserving treatment instead of presumptive mastectomy.

Key point

In patients with metastatic disease of unknown primary, MRI of the breast depicts the primary breast cancer in up to 94% of cases with normal conventional evaluation. Evidence level 3.

10.8 SCREENING OF HIGH RISK WOMEN

Breast cancer is associated with or due to a genetic predisposition in 5-10% of the cases. Women with a strong family history of breast cancer are more likely to develop the disease in at a young age, when breast density is higher. Mammography is less reliable, as sensitivity is lowered due to breast density. Additionally, the mean growth rate of a tumour slows down to half in each successive 10 years-older group. A high sensitive test that can be performed frequently is necessary in this group of patients.

Four reviews are published; two of them are systemic reviews. The conclusion is that MR may not be used for population screening but that it has a better sensitivity than mammography in screening high risk women. It can detect otherwise occult cancers.[771-773]

A large study of 1909 women performed in 6 centres (MRISK study)[774] showed that cancers detected in high risk women are smaller than those in control groups and that

less patients had involved lymph nodes. Another prospective multicentre cohort study in 649 women of 22 centres also learned that the sensitivity of MRI was significantly higher than for mammography (Sensitivity MRI (77%, MX 40%, MRI + MX 94%. Specificity MRI 81%, MX 93%, MRI + MX 77%. BRCA1 carriers (13 cancers; sensitivity MRI 92%, MX 23%).[775]

Other studies came to the same conclusion.[776-780]

hIn their report of December 2003, the Technologic Evaluation Center concluded after review of the literature that MRI of the breast in screening women considered being at high genetic risk of cancer meets their criteria. Women are considered at high genetic risk of cancer because of

1. confirmed presence of Breast Cancer 1 (BRCA1) or Breast Cancer 2 (BRCA2) mutation or

2. high risk of BRCA1 or BRCA2 due to known presence of the mutation in relatives or

3. pattern of breast cancer history in multiple first-degree relatives, often occurring at a young age and with bilaterality, consistent with a high probability of harbouring BRCA mutations or other hereditary breast cancer.[723]

Key points

- **Screening women at high risk is a good indication. Evidence level 2.**
- **Cancers detected by screening with MR are smaller and have less lymph node involvement**

10.9 OTHER

10.9.1 Nipple discharge

Orel et al. published a study of 23 patients with nipple discharge, 15 of them underwent escisional biopsy and 8 were followed. In 73%, MR findings correlated with pathology. Six of the 7 malignant lesions were suspicious on MR, the 7th appeared benign.[781] They concluded that MR potentially offers a noninvasive alternative to galactography. Another study compared ultrasonography, galactography and MRI in 55 patients with nipple discharge [782]. The conclusion was that MR demonstrates the location and distribution most clearly, especially in cases of ductal carcinoma in situ (DCIS). Krämer et al. evaluated MRI alone and in combination with MX and galactography in 48 women with pathologic nipple secretion. Thirty five patients underwent surgery and 16 patients had a papilloma and 6 of these had a carcinoma without papilloma. For papillomas, sensitivity of galactography was 94% and specificity 79%, while only 1 carcinoma was detected. MRI had a sensitivity of 89% (8/9) for malignant lesions. They concluded that MX in combination with galactography remains the primary diagnostic tool. The addition of MRI permits exclusion of malignant disease with a high degree of certainty; thus expectant management in individual cases with negative findings appears justified [783].

Key points

- **MR demonstrates location and distribution of lesions. Evidence level 2.**
- **Addition of MR permits exclusion of malignant lesions with a high degree of certainty. Evidence level 2.**

10.9.2 Diagnosis of breast lesions

A TEC report has been published on the use of MRI in the diagnosis of low suspicious findings on conventional imaging (follow up suggested). In their review of published studies, they did not find a study on this type of lesions without a prior history of breast cancer. They reviewed 3 mixed retrospective studies. All 3 studies reported 100% sensitivity, specificity ranged from 63-85%, NPV=100% and PPV ranged from 10-56%. It would be important to ensure that the PPV of MRI would be in line with current biopsy techniques. Therefore, they concluded that the use of MRI for the diagnosis of low suspicion findings does not meet the TEC criteria [723].

In the same report, they studied the role of MR in diagnosis of suspicious breast lesions (biopsy suggested). They reviewed 25 prospective studies and 14 retrospective studies and 10 studies that evaluated the adjunctive use of MR for diagnosis of recurrent disease. Their analysis of diagnostic performance was based on 7 prospective studies (n>150 patients) (total n=2279 patients). Sensitivity of MR ranged from 91-99%, NPV from 56-99% and specificity from 31-91% [723]. The conclusion was that the use of MRI as an adjunctive test does not meet the TEC criteria for diagnosis of a suspicious lesion in order to avoid biopsy.

A meta-analysis was published in1999 and included 16 studies. Sensitivities ranged from 63-100% and specificities from 21-100%. A maximum joint sensitivity and specificity of the summary ROC curve was 89% (95% CI: 82-93%). At a sensitivity of 95%, specificity was 67%. When test performance values were applied to a previous cost-effectiveness analysis, the cost-effectiveness of preoperative MR imaging relative to that of excisional biopsy was confirmed, but its cost-effectiveness relative to that of needle core biopsy varied widely. The authors concluded that, for MR imaging to be a cost-effective alternative to excisional biopsy for diagnosis of suspicious breast lesions, its diagnostic test performance must be equal to or better than the best results in recently published studies [784].

Key points

- **Diagnosis of a breast lesion is not a good indication for MRI of the breast. Evidence level 3.**
- **MRI can not avoid biopsy of a suspicious lesion. Evidence level 3.**

Part 2: Financing mechanisms for MRI in Belgium

LUK CANNOODT

11 INTRODUCTION

The Belgian Minister of Social Affairs and Public Health recently decided to increase the number of MRI-units to be installed in Belgian hospitals, according to certain programming criteria.

At the same time, the budget of those hospitals will increase to pay for the additional expenses related to the acquisition of these units and the basic operating costs. The Minister placed his decision in the following context: There are problems with the process of applying the guidelines of good medical practice (as worked out by the Consolium Radiologicum Belgicum). The ratio of MRI/CT is considered too low. The waiting lists of MRI-examinations should be reduced. Simultaneously, the Minister announced some specific measures to raise the MRI/CT ratio and to contain the overall CT+MRI-activity level.

Given the current financing system and the proclaimed existence of waiting lists in the MRI-field, there is a real possibility that the MRI-activity will increase significantly with the enlarged supply without a noticeable decrease in CT-activity.

The first part of this part describes the current financing system of both the MRI and CT in Belgium.

In the second part an overview is presented of some relevant issues relating to financing mechanisms in health care (with special attention towards MRI and CT)

The third part focuses on the supply and utilisation of MRI and CT in Belgium. The following part puts this in an international perspective, using both a quantitative (benchmarking) and a qualitative (expert opinion) approach.

Finally, some conclusions are drawn from these analyses and observations with the focus on what we can learn from it to develop a financing system that helps promoting a more optimal supply and utilisation of both technologies in Belgium.

Given the policy context and the research time available, the focus of this part is on the MRI- and CT-fields. This is not to say that the financing system of other medical imaging technologies (such as ultrasound) is not worth studying, with the same intention to optimalise the use of medical imaging in the Belgian health care.

12 CURRENT FINANCING MECHANISMS OF MRI AND CT IN BELGIUM + RELATION WITH COST-STRUCTURE

12.1 FINANCING MRI'S IN BELGIUM

The current financing system consists of a fixed as well as a variable part. The fixed part is split up in different sections.

12.1.1 Part A3 of the hospital budget

For each accredited MRI-unit, the hospital receives in the yearly budget (in the so-called PART A3) an amount of 148.736,11 € (index February 2002) to reimburse the equipment over a period of 7 years. The Belgian legislation requires a replacement or an upgrading of at least 50 % of the purchasing value of a new MRI-unit within 10 years of the initial purchase (Koninklijk besluit van 25 april 2002 betreffende de vaststelling en de vereffening van het budget van financiële middelen van de ziekenhuizen, *B.S.* 30 mei 2002). MRI-units that do not comply with this rule, lose their fixed reimbursement per year for MRI investment costs.

The cost of a new unit may vary from about 1 tot 1.5 million €, depending on the various options and appliances that go with the unit. In other words, the amount of Part A3 may be sufficient to cover the capital costs of the MRI-equipment, depending on the policy of the hospital to choose for the more sophisticated equipment or not. The 50 % upgrading requirement is not an overestimation of the real costs either. The upgrading and updating relates to the hardware as well as the software. According to COCIR an upgrading of the hardware after 5 years is to be recommended if one wants to keep up with the medical advancements.[785] The updating of the software is a more on-going process that usually starts already in the first years of the acquisition of the unit. Together with the hardware upgrading this may result in expenses that approach the same level as the original acquisition cost. In other words, here too it depends largely on the hospital policy what the magnitude of these costs will be.

From personal communications with experts in neighbouring countries, it can be concluded that the MRI-equipment usually is depreciated over a period that varies from 5 to 8 years, depending on the country.

In summary, the fixed amount of part A3 presents a good picture of the depreciation costs involved if the focus is on standard models without additional options.

Article 11 of the above mentioned Royal Decree of 25-04-02 mentions that the Part A3 includes both the acquisition costs of the MRI-unit as well as the building adjustments needed to install these units. The instalment costs turn out to be a large investment that may cost as much as 30%-50% of the acquisition cost of the MRI. Under conditions further specified in the same Royal Decree, the real costs of the instalments can be fully recuperated, according to the general rules concerning the immovables.

12.1.2 Part B3/B7 of the hospital budget

The second section of the fixed part of the financing system relates to the so-called B3 of the hospital budget. Article 14 of the same Royal Decree specifies that this includes: maintenance of the equipment and the facilities, consumable goods, general costs, costs of nursing personnel and qualified technicians as well as the administrative costs. There is no mentioning of the indirect costs that should be allocated to this service unit.

For each accredited MRI-unit an amount of 220,641.46 € is allocated to public hospitals and 220,218.95 € in private hospitals (index February 2002). A small number of MRI's are being accredited as "university MRI-s". For these MRI-units, the hospital budget provides an amount in the so-called B7 as determined in earlier legislation. This includes both the costs elements assigned to the A3 and B3 of the other MRI-units.

More information and research as well as the collaboration of a representative sample of hospitals are needed to calculate how many operating costs an MRI-unit in standard working conditions (4000 - 5000 scans a year) would generate. Benchmarking with other countries may also be comparing apples with oranges as it is unclear what costs are included or not. (e.g. in Belgium are the costs related to contrast material reimbursed via the pharmaceutical circuit). A sound methodological approach would require the Activity Based Costing technique with close interaction between the different partners who provide the data. This cannot be realised within the time-schedule of this study.

Some "quick and dirty" calculation work raises serious doubts about the assumption that the amount that is designated in the B3 to cover the costs of the MRI as described by the Royal Decree of 25-04-2002 would be sufficient. In the Netherlands there are some freestanding MRI-centres operating. All their costs are therefore exclusively related to MRI-activity. One such a centre (with 3 locations) realises together about 22.000 MR-scans a year with 3 MRI-units. The cost of the non-medical staff alone (management not included) amounts to an estimated 900,000 € or about 200,000 € for a workload of 5000 scans. In an ongoing study at U.Z.Leuven, where it is attempted to allocate operating costs to the different medical imaging activities, it was found that the non-medical staff related to the daily operation of the 3 clinical MRI's costs over 750,000 € per year, or about 250,000 € per MRI-unit. Demaerel et al calculated a cost of 245,000 € (data from 1998) for radiographers, registrars and secretary personnel (6,785 examinations).[786]

In summary, the 220,000 € of the B3 is estimated to reimburse solely the direct personnel costs of the MRI-units. Costs for maintenance contracts, consumable goods and other operating costs are together at least of the same magnitude, if not higher. Most of these costs as well as the indirect costs are also fixed costs that have to be paid currently via the physician reimbursement system.

12.1.3 Physician reimbursement: the fixed part

The N.S.I.I.I. has developed a system to value all kinds of medical activities (called The Nomenclature) and to reimburse physicians accordingly. Most of these values are intended to also pay the equipment, the non-medical staff, etc.. related to that medical activity and don' t therefore reflect the exact income level of the physicians involved. This is certainly also the case for most medico-technical activities where medical equipment is used to perform diagnostic procedures. A growing portion of this payment system becomes more fixed in nature as there is no longer a one to one relationship between the payment fee and a specific procedure or activity of the physician. In the medical imaging field, for instance, various flat fees have been created that have no direct link with a given medical activity related to a specific patient.

The medical imaging activities are in part reimbursed by a **"consultance honorarium" per admission** that is reserved for radiologists to reimburse them for their activity as consultant to help the treating physician by determining the diagnosis. A second fee called **"forfaitair honorarium inzake medische beeldvorming per opneming"** is also paid for each patient admitted to the hospital but the value depends on the case-mix of the hospital and differs therefore from hospital to hospital (see appendix 5).

Both fees have no direct relationship with the number of MRI-scans performed. They are related to the activity-level of the hospital in general and its case-mix.

12.1.4 Physician reimbursement: the variable part

The fees just described relate to the patients that are admitted to hospitals. However, 85 % of the MRI-activity relates to **ambulatory patients**. For this activity too a **"consultancehonorarium**" is created. This fee can be charged **for each prescription**, but only once a day. As for the "forfaits" described above, this fee is also meant to avoid that too many examinations are done where simultaneously different types of examinations are examined (e.g. a MRI-scan as well as a CT-scan for the same patient at the same time), but of course, this will not guarantee that all prescriptions are appropriate. From personal communications, it is learned that CT-scans may also be

prescribed because the results will be known sooner than the results of a MRI-examination, although the guidelines may not support this. One fee per prescription per day will not stop the asserted tendency to overprescribe MRI- nor CT-scans. In that sense the fee per prescription can be classified rather with the variable type of reimbursement than the fixed one. As the tendency for prescribing MRI-diagnostics increases, the amounts spent on these diagnostic procedures also will increase.

As already explained above (see table 13) , certain codes of the nomenclature relate to each scanning activity performed by a MRI-unit. The more scans, the higher the amount that is reimbursed to the hospital. The amount that is reimbursed as a **fee per activity** is the same whether patients stay in the hospital or are scanned on a ambulatory basis. The more fees, the higher the workload of the physician, but also the higher the variable costs, such as consumable goods (medical material), administrative activities, etc…. No information is available concerning how the values are determined, but there is a general perception that most values are considerably higher than the variable costs related to the activity (As mentioned earlier, the fees are also used to reimburse a considerable amount of fixed and semi-variable costs).

As indicated in a recent note of the N.S.I.I.I. concerning the amount reimbursed for medical imaging activity through the system of the nomenclature, the fees per activity form 67 % of the total amount. These fees, together with the insufficient financing of the fixed and semi-variable costs of MRI-activity, don't encourage hospitals and providers to limit the activity level to what is considered appropriate (according to the guidelines already mentioned above).

Questions are also raised about the degree to which each type of MRI-activity as described by the nomenclature, is sufficiently homogeneous. In an ongoing study at U.Z.Leuven, for instance, the MRI-activity is divided into those cases that need 25, 30, 40 and 45 minutes of scanning time. As it turns out, it is not possible to relate the different scanning times to the various types of nomenclature. Also, the workload for the radiologist can differ from e.g.10 minutes to e.g. one hour for the same code of the nomenclature. The characteristics of the MRI-activity may be such that it may never be possible to create homogeneous groups, however the variation in workload appears to be so wide that it may stimulate some providers to be selective to focus primarily on the simple cases and referring the more complex cases to other institutions.

12.2 FINANCING CT'S IN BELGIUM

Contrary to the MRI-financing, the hospital budget does not finance the acquisition nor depreciation of the CT-equipment, nor some of the operating costs. (As mentioned earlier the CT-units are no longer programmed in Belgium). The CT-costs (including the indirect costs) ought to be financed completely from the N.S.I.I.I. nomenclature system.

As mentioned earlier about 2/3 of the amounts reimbursed in radiology come from fees per activity. Yet, the general cost structure of the CT-technology does not differ that much from the MRI-technology. The large majority of the costs can be considered fixed when the CT-scanner is in full service during the normal working hours. The purchase price of a CT-scanner used to be less than an MRI-unit. Since a few years the CT-market shifted almost completely toward multi-slice CT-units. The newest versions can also cost about 1 million € or more. When the unit is in operation, the technicians (radiographers) also need to be present constantly. Maintenance contracts are also expensive in the CT-field.

From a financial perspective the main differences between MRI and CT are fourfold:

1. Building adjustments and upgrading costs related to the MRI-units are much higher than for the CT.
2. On average CT-scanning demands more often the use of contrast material. This is undoubtedly a variable cost. But most of these costs in Belgium are financed through a different circuit (pharmaceuticals);
3. CT-scans are more often conducted for hospitalised patients. The percentages vary among hospitals based on their case-mix, but

nationwide the percentage is 34 % for CT versus 15 % for MRI. Hospitalised patients are less mobile, they need extra personnel to accompany them to and from the radiological department. This should also be taken into account when comparing costs for the non-medical staff of MRI versus CT.

4. The CT-scanning time per patient is only a few minutes (max. 5 minutes) whereas the average scanning time for an MRI is about half an hour. It is especially this last argument that is used to defend the difference in the financing method for both technologies.

Especially the last point is rather an argument against a financing primarily based on a fee for service system for the CT-activity. As the turn-over of patients is much higher, the potential financial gains for overusing the technology are much stronger for the CT than for the MRI. This is of course not to suggest that these financial incentives are the sole reason for the alleged overuse of CT's. There is also an upward trend in CT-use in other countries, where the financial system does not encourage more CT-scans than necessary. It is also not to suggest that there are no financial gains in overusing the MRI-technology.

This observation does support the argument that the financing system should be shifted towards a payment system that is more in line with the underlying cost-structure than is the case now.

Key points

- **The current financing of the MRI-equipment and activity in Belgium is considerably different from that of the CT. The cost structure of both technologies is not that different (mostly fixed and semi-variable costs).**
- **The turnover of patients is much higher for the CT than for the MRI. The potential financial gains for overusing the technology are, therefore much stronger for the CT than for the MRI.**

13 SYSTEMS OF REIMBURSING HEALTH CARE ACTIVITY: A GENERAL OVERVIEW

13.1 INTRODUCTION

This part of the study focuses on the way MRI-examinations should best be financed, or more specifically reimbursed. As reviewed above, physicians often have a choice between using the MRI- or the CT-technology as an instrument in the medical management of their patients. Aside from aspects such as benefit/risk assessments, accessibility, supply factors, etc., the extent to which these examinations are financed, as well as the specific reimbursement modalities, might influence this choice. Therefore, it is considered worthwhile to analyse this topic for both types of examinations.

The reimbursement schemes of health care activity have several features upon which their appropriateness and/or feasibility can be judged. These features represent different, sometimes conflicting, goals. None of the schemes scores high on all these features. Therefore, the aim is often to reach a satisfactory level of success for most of the goals (satisficing) rather than reaching the highest level (maximising) for all the intended objectives. One should, however, continuously strive for a more optimal mix of all these features. This can only be realised when one is conscious about the intended effects as well as unintended side-effects of existing reimbursement schemes, and the need for changing these schemes to account for changes in medical practice or other factors.

The purpose of this first part of the part is to provide a framework to analyse the different features of existing schemes in health care. It is not the aim to present a complete overview of all possible modes of reimbursement for all aspects of health care delivery. This exceeds the purpose of this study. Rather, the focus is on a selection of reimbursement schemes and features that are most relevant for the provision of acute health care in general and medical imaging in particular.

More attention will be oriented towards the following features:

- The extent to which the financing is retrospective versus prospective in nature ;
- The degree to which the reimbursement scheme is earmarked to reimburse specific medical activity (such as MRI- or CT-activity) ;
- Built-in incentives for efficient use of the diagnostic technology ;
- Built-in incentives to assure quality of care of diagnostic services ;
- The degree to which cost structure characteristics are incorporated ;
- The administrative workload ;
- The degree to which innovation is encouraged.

13.2 RETROSPECTIVE VERSUS PROSPECTIVE REIMBURSEMENT SCHEMES

Each reimbursement scheme can be placed somewhere on a scale from completely retrospective to completely prospective in nature. At the one extreme, totally retrospective schemes, all costs related to the activity are completely reimbursed. No questions are asked about the appropriateness of any given medical activity, assuming the legal conditions for reimbursement are met (to avoid that the system is being abused).

In the other extreme a fixed amount is budgeted in advance to repay the expenses incurred for a defined period of time in the future, no matter what the activity level will be in that period.

In the retrospective system all the care delivered is considered to be appropriate and should therefore be reimbursed, there is no cap or ceiling set. Providers will have no incentive to spend the money wisely. On the contrary, they may well benefit from the care that is delivered inappropriately (see further). Consumers (patients) too have no incentive to be cost-conscious as they don't bear the financial consequences of higher medical expenses, at least not directly.

The financing body has no control over spending levels, and will have to look for additional sources of financing for the care delivered, when it turns out that the collected taxes and/or contributions are insufficient.

On the longer run, this system is bound to collapse as taxes and contributions cannot be increased indefinitely.

When providers have a financial interest in higher activity levels or even when they are indifferent about the activity-levels, this might result in overuse of medical activity what can result in unacceptable health risks to some patients. Patients may be treated unnecessary for false positive results (with risks for iatrogenic diseases, etc…). For CT-scans, for instance, real concerns are expressed about the health risks from unnecessary exposure to radiation.

At the other extreme, individual providers, groups of practitioners, hospitals, etc… are faced with a fixed budget and income level, no matter what the actual activity level. This way, they are encouraged to spend the money wisely. But their cost-consciousness might induce them to cut on services delivered to the extent that some services are underused or delivered at a suboptimal level of quality, that may result in unacceptable health risks to some patients. On the other hand, it can be argued that providers faced with fixed budgets might be more interested in quality of care to avoid costly treatment complications. Measures in hospital hygiene for instance are said to be their money's worth as they reduce infection rates and therefore also lengths of hospital stay.

It should be noted that a fee for service system does not guarantee high quality of care either. The pressure to realise a high activity level, may also tempt providers to use less qualified personnel that is readily available, or to shorten the scanning time to a degree that quality of care can no longer be realised. A MRI-unit, that operates on an average of 3 or more patients an hour, is considered to be excessive, unless only the simplier procedures are selected.

For diagnostic services, such as medical imaging, the same arguments can be formulated. When more tests, examinations, scans means higher revenues, chances are that the diagnostic technology might be overused. A fixed budget system may result in insufficient use, or the use of production processes of lower quality.

In short, open ended reimbursement systems, such as fee for service tend to result in an overspending, while fixed budget systems might result in rationing of health services. The effect on quality of care is less clear. Whatever financing system is introduced, one needs to address the quality of care issue explicitly.

13.3 THE DEGREE TO WHICH THE REIMBURSEMENT SCHEME IS EARMARKED TO REIMBURSE SPECIFIC MEDICAL ACTIVITIES

Any existing reimbursement system can also be placed on a scale from "all in" on the one end to the financing of each specific diagnostic procedure or each specific treatment intervention.

Hospitals can be paid for all activity (including physician remuneration) relating to the patients admitted to the hospital (one-day treatments and outpatient department included or not) for the whole year, per month, per diem, etc…; they can be paid one amount for each Diagnosis Related Group (to account for difference in case-mix), etc…

Physicians working in the hospital can also be paid separately from the rest of the hospital budget. In that case, several options remain possible ranging from lump-sum salary-payments to fees per admitted patient, per patient day or per medical activity.

Physicians in an ambulatory setting (e.g. G.P.'s) can be paid on a capitation basis, depending on the number of patients registered in their (solo or group) practice, for each consultation or visit at home, etc.

Concerning the diagnostic services an important distinction can be made whether this activity is reimbursed separately, or whether this is included in the total revenues of the hospital, of the provider of the services or even of the prescriber of the services. As it needs a specific registration, fee for service systems usually provide more information on what diagnostic services are being delivered, what the trends are in these activities, what variation can be observed in the use of these activity, by provider, by prescriber, by hospital, by area, etc… It has the advantages as well as the risks related to all fee for service systems.

One argument to include the diagnostic services in the total amount reimbursed per type of patient is that the diagnostic tests are no more than an instrument in the medical management of a patient. It is then considered up to the treating physician to judge whether the extra information of these diagnostic activity is worth its cost. Arguments against this might be that the prescribers may not have sufficient knowledge about the value of each test / examination to make the right choice based on benefits/ risks / costs for each diagnostic tool. Here too, the specific modalities of charging the prescribers for the diagnostic services they order may influence their behaviour and may result in under- or overuse of certain diagnostics.

13.4 BUILT-IN INCENTIVES FOR EFFICIENT USE OF THE DIAGNOSTIC TECHNOLOGY

Aside from the general discussion of the impact of open- versus closed-ended reimbursement schemes upon the efficient us of health care services, specific measures of the payment system might either encourage or discourage efficient use of diagnostic technology. When hospitals receive subsidies to acquire diagnostic equipment, regardless of the volumes needed to appropriately treat the patients, chances are that this equipment will not be used most efficiently. When providers are rewarded rather than penalized for conducting multiple scans that provide overlapping information, inefficiency is bound to occur.

There are plenty of possible measures to increase efficiency (or decrease inappropriate use). One example is the rule that certain activities do not generate a reimbursement fee in the Belgian system of nomenclature, when at the same day, certain other activities are also delivered (e.g. the BOLD-technique in the MRI can only be charged once a day for the same patient: nomenclature codes 459535 and 459546). Rather than attempting to present here an exhaustive list of these measures, it appears to make more sense, to discuss the efficiency issue when concrete measures relating to the reimbursement of MRI or CT-scans are being proposed later on in this report.

13.5 BUILT-IN INCENTIVES TO ASSURE QUALITY OF CARE OF DIAGNOSTIC SERVICES

In order to protect the population from health risks due to the provision of suboptimal quality of care, public authorities can take a mix of regulatory measures. One is to set minimum quality criteria to certify hospitals, medical services, equipment, etc… Another is to define what types of providers can deliver what kinds of care, can prescribe what kinds of drugs, diagnostic procedures, etc… These measures will not be further discussed in this project.

Some may argue that there is no need to reimburse diagnostic activity separately. Once providers are paid for the treatment they deliver, they will do whatever is possible to include the most appropriate diagnostic procedures in their case management so that the best care is delivered in the most efficient way. If an MRI-examination gives better results than a CT-scan, or other radiological techniques, so that the patient can be treated more effectively, chances are his length of stay will be reduced, multiple consultation visits or readmission to a hospital can be avoided, etc…

However, it can also be argued that providers, faced with all-in payment schemes, would tend to skim the market and avoid to treat the bad risks (from an economic perspective), they may transfer those patients to other institutions (e.g. university hospitals), etc… Therefore, it can be considered worthwhile to introduce (aside from other regulatory efforts to promote quality of care) , specific measures in the financing system that assure quality of care, or at least avoid suboptimal quality of care levels.

Payment schemes to reimburse physicians can distinguish between those physicians who can demonstrate their participation at continuous education activities related to their professional performance, who follow evidence based guidelines, etc…. Certain medical activities are only reimbursed if the physician has the required certificate of specialisation (e.g. radiologist), or when the diagnostic procedure is conducted in an environment that meets certain quality criteria.

13.6 THE DEGREE TO WHICH COST STRUCTURE CHARACTERISTICS ARE INCORPORATED

The most important issue here is to what extent the reimbursement system takes into account the degree to which the costs incurred to deliver a medical activity can be described as fixed, semi-variable or variable. In other words what are the cost-drivers of a medical activity such as a diagnostic procedure. Fixed costs are for instance the instalment costs to start an activity and the depreciation of the machines that can generate diagnostic activity.

Semi-variable costs are costs that are fixed within certain boundaries of activity levels. They increase stepwise, when the scale of activity rises. Qualified personnel that operates the radiological equipment is a good example.

One needs to have a minimum amount of personnel on the spot to operate the equipment, no matter what the activity level. The efficient use of this personnel increases when the activity level increases within these boundaries. Once the top of that level is reached additional manpower is needed and the costs will increase disproportionately.

Variable costs are extra costs incurred for each additional unit of activity.

When the proportion of fixed costs and semi-variable costs are high relative to the variable costs, and the provider and/or his hospital is paid on a fee for service basis, they have any interest to reach at least the activity-level that compensates for the fixed costs and the first level of semi-variable costs. Once this level is reached, surplus can easily be earned by a further increase in activity level. Both MRI and CT-units are technologies with a relatively low percentage of variable costs. Yet, the current reimbursement system for MRI and CT is primarily based on a fee per act, for CT more so than for MRI (see further).

When the provider and/or his hospital is paid a lump-sum no matter what activity level is reached; there is, on the contrary, rather an interest to keep the activity at the lowest possible level. Other forces, peer pressure, medico-legal consequences, competitions, … will also have to be active to move the activity level to the most appropriate level.

When the financing system reflects the cost structure characteristics, it is less likely that overconsumption or underconsumption is rewarded. Unfortunately, economies of scale and scope or diseconomies of scale, disturb the feasibility to reach a well-balanced financial system that is universally applicable.

13.7 THE ADMINISTRATIVE WORKLOAD

Every reimbursement system has its own administration. The administrative costs may vary widely. A lump-sum payment system, where for instance the hospital gets an all-in yearly budget, may require considerably less administration than a fee-for-service system, where every procedure (or even parts of it) is charged separately. When the system includes a co-payment part from the patient and when the fees are negotiated separately between individual providers and health insurance companies the invoicing

becomes even more complicated and expensive. When third party payers are involved, it is logic that they are concerned that the money is spent properly.

A budget system based on some input-parameters (such as number of hospital beds or number of patients treated) scores well on administrative simplicity and low administrative costs, but is bound to score low on distributional equity. Providers who have a more severe case-mix are often not paid properly for their higher workload per case. So, the budget system should at least account for differences in case-mix, which also means more administration to register the case-mix (in terms of medical procedures, homogeneous diagnostic categories, nursing workload, etc…) and extra administrative activity to control for possible abuses of the registration (e.g. DRG-creep).

Fee-for-service systems, whether for direct treatment or diagnostic activity, are supposed to account for differences in case-mix, but in reality this is far from optimal. For any given fee, there is considerable variation in the amount of work, depending on the type of patient. In additional, medical practice is changing continuously. As a consequence, current fee-schedules may no longer reflect difference in workload of the providers concerned. This again calls for recalculating the weights of each fee.

With the rapidly changing CT- and MRI-technology, it should be of no surprise that this issue is also relevant here.

13.8 THE DEGREE TO WHICH INNOVATION IS ENCOURAGED

Reimbursement systems differ in the extent to which they discourage rather than encourage promising innovation. Innovation is encouraged in per diem rates, but also in payments per case or even in more global budget systems. In the later case this is to the extent that the financing system promotes the efficient use of resources, in other words when the new technology improves the productivity of the medical treatment and/or diagnostic activity. When the new technology is subsidised explicitly and sufficiently by the authorities, of course this could play a major role in the dispersion of this technology throughout the health care scene.

When innovation allows for detecting morbidity that could previously not be detected, for treating new patients that could previously not be treated, or for improving the quality of diagnosis and/or treatment but at a higher cost, all-in reimbursement systems might well discourage the use of the more expensive new technology.

Fee-for-service systems could encourage the introduction of new technology when they reimburse explicitly this new technology.

Obviously, other regulatory measures, such as the programming and certification of this new technology have a significant impact on the pace that this innovation is implemented on a large scale.

Key points

- **Each reimbursement scheme of health care activity has a set of features upwhich it can be judged, such as the degree to which efficiency, quality of care and innovation are encouraged, the amount of administrative work it provokes, to what matter it reflects the cost structure characteristics of that technology, etc….**
- **None of the existing schemes scores high on all features together. The aim is to strive for a more optimal mix of them than is the case now.**

14 MRI AND CT-SCANS IN BELGIUM

As explained above, the financing system (and other regulations such as programming and accreditation) may influence both the supply and utilisation of medical technologies. Before comparing the Belgian MRI- and CT-scene with other countries, it is considered worthwhile to describe some trends in supply and utilisation of MRI's and CT's in Belgium, as well as the most recent situation for which data are available.

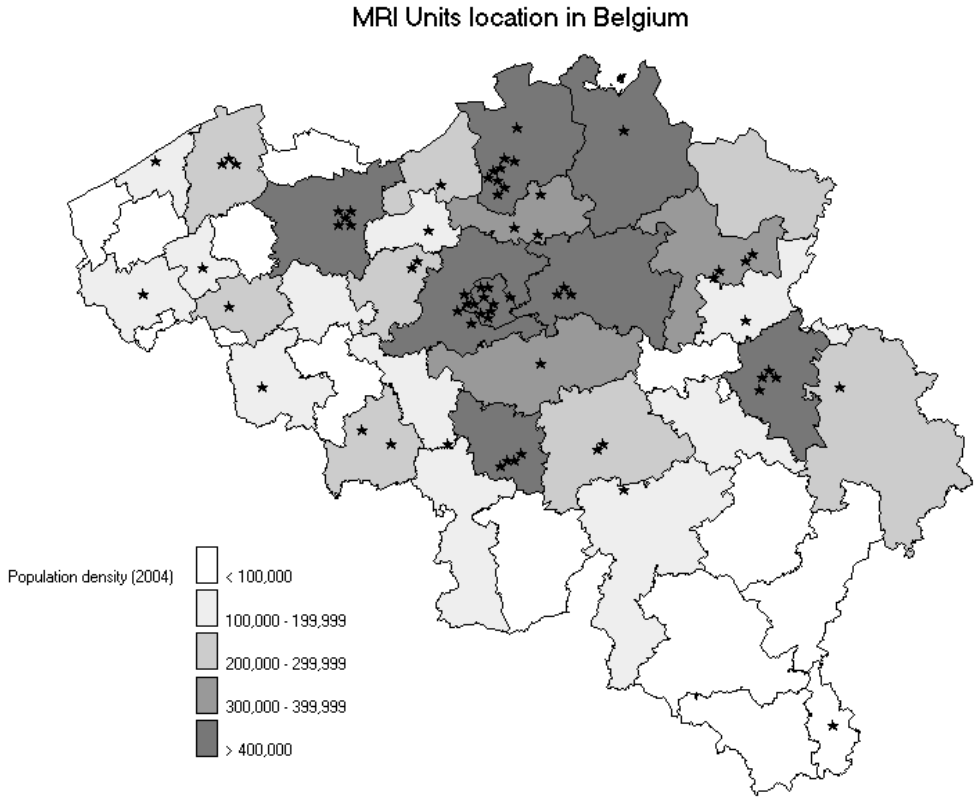
14.1 SUPPLY OF MRI- AND CT-UNITS IN BELGIUM

In Belgium, MRI-units are currently only allowed to be installed in hospitals. In order to operate an MRI-unit, any given hospital has to meet certain accreditation criteria set by the federal government to get subsidies from the government and reimbursement by third party payers in the context of the mandatory health insurance system.

In addition, the federal government also has programmed the total number of MRI-units for each region (Flemish, Brussels and Walloon region).

Therefore, one would expect that there is no doubt about the number of MRI-units existing in Belgium. The Federal Public Services for Health, Food Chain Safety and Environment reports that there are 68 accredited MRI-units in Belgium as of February 2006. This means: 6.5 units per million population. The OECD-statistics (2002) and Philips Medical Systems (2006) both report the same number of MRI-units for Belgium. The geographical distribution of these 68 scanners is presented in Figure 1.

Figure 1: Geographical distribution of MRI scanners in Belgium



However, other sources show different pictures of the number of MRI-units, which suggests that the number of approved MRI scanners does not reflect the actual situation. According to the COCIR (European Coordination Committee of the Radiological and Electromedical Industries) Belgium has 92 hospital based MRI-units.[785] Data from a survey performed by the Consilium Radiologicum (Prof. Struyven, chairman) suggests that there are 85 MRI-units in operation in Belgium, of which 79 are

for clinical practice and 6 for research purposes. The later are all operating in university settings; the financing of their acquisition, instalment and activity has to come from other sources than the health care financing described above.

The Minister of Social Affairs and Public Health, has recently decided to allow and finance another 40 MRI-units. These units are planned to operate within the next 2 years. Assuming the 68 units are an accurate count, these extra units will bring the ratio up to 10.4 units per million population.

Contrary to the MRI, there is no limit set by the government on how many CT-units can be accredited. Hospitals can buy as many CT-scanners as they wish. We have found no data from the government as to the number of CT-units in Belgium. The OECD reports 298 CT-scanners (2002), COCIR counts 294 units, of which 244 hospital based units (December 2001) and Philips Medical Systems reports 260 units (2006). Leading radiologists in Belgium count 252 CT-units in Belgian Hospitals.

Based on the OECD-data, there are 4.4. CT-units in Belgium for each accredited MRI-unit. With the additional 40 units announced by the Belgian Minister of Social Affairs and Public Health and assuming that the CT-supply remains stable, this comes down to a ratio of 2.8 CT-units / MRI in the near future. From the database of some Belgian radiologists a ratio of 3.2 can be derived.

Not to be ignored from a quality perspective is the age distribution of the units in operation.

In an article published by COCIR on their website (Age Profile Medical Devices) they calculate that 25 % of the MRI-units are 6 – 10 years old, none are > 10 years old.[785] Given the current financing regulation, units cannot be subsidised by the government when they are 10 years old and not upgraded during that period. CT-scanners emerged earlier on the health care market, and there is no regulation sanctioning CT-units that are considered too old.

The same COCIR- article reports for Belgium that 41 % of the CT-scanners are 6-10 year old (situation December 2001) and another 7 % is even more than 10 years old. In other words only about 52 % of the units is 5 years old or less. According to their golden rule, at least 60 % of the installed equipment should be 5 years or less, while not more than 10 percent can be tolerated to be more that 10 years old. No scientific evidence is cited to support this statement. Given the figures they present, Belgium fails to meet their golden rule for the CT-equipment, and barely makes their rule for the MRI-equipment.

14.2 ACTIVITY LEVELS OF MRI AND CT IN BELGIUM

14.2.1 Total activity MRI + CT

Apart from the scientific activity, all MRI- and CT-examinations are registered as the national health insurance system is paying a fee for each service delivered, assuming the administrative procedures are followed properly.

In the midst of 1999, MRI-examinations are registered separately from the CT-examinations. Before, the MRI-activity was integrated in the CT-nomenclature. This means that starting from 2000 it is possible to follow both the yearly evolution of the MRI-activity as well as the CT-activity, nationwide.

The National Sickness and Invalidity Insurance Institute (N.S.I.I.I.) has forwarded the total volume of reimbursed MRI and CT-scans from 1999 to 2004. During that period the total volume is increased from 1.079 to 1.891 million examinations (CT + MRI). The total Belgian population is increased slightly during that period. The activity per 1000 population is increased from 105,4 to 181,0 or an increase with 72 % (see Table 12).

Table 12:Total activity MRI + CT for Belgium : 1999 - 2004

	1999	2000	2001	2002	2003	2004
Total volume	1,078,951	1,394,619	1,606,749	1,582,243	1,714,398	1,890,835
per 1000 people	105.4	135.9	155.9	152.8	164.9	181.0
INDEX (2001=100)	67.6	87.2	100	98.0	105.8	116.2

Between 1999 and 2000 alone, activity increased with 29 %; between 2000 and 2001 there was again an increase of 15 %. The following three years the activity levelled off somewhat, with an increase of only 16 % in three years.

A possible explanation for the increase from 1999 to 2001 could be that in 1999 the Belgian government decided to increase the number of MRI-units from 32 accredited MRI-units to 68 MRI-units, spread over two years. Unfortunately, there is no information about the evolution of MRI-activity versus CT-activity nationwide between e.g. 1998 and 2000. It is therefore not possible to measure the exact effect of the increase of MRI-supply on the MRI- and CT-activity. Given the sharp increase of total activity MRI + CT from 1999 to 2000 and the further increase in 2000 it is almost impossible that this increase is solely due to an increase in MRI-activity, nor that the increased MRI-capacity resulted primarily in a shift from CT- to MRI-activity.

As a matter of fact, the CT-activity per 1000 population increased further from 2000 to 2001, although not as sharp as the MRI-activity in that year. (see Table 13).

Table 13: Trends of activity per 1000 population: Belgium 2000 -20004: MRI versus CT

	2000	2001	2002	2003	2004
MRI	21.4	31.8	35.1	39.0	42.9
INDEX 2000=100	100	149	164	182	200
CT	114.5	124.1	117.7	125.9	138.2
INDEX 2000=100	100	108	103	110	121

After 2000 the number of examinations continues to increase nationwide, both for CT's as MRI's, despite the fact that total capacity of accredited MRI's did not change in that period (data on the evolution of CT-capacity could not be found).

The number of reimbursed CT-scans per 1000 population increased with 11.4 % between 2001 and 2004. The number of reimbursed MRI-scans per 1000 population increased with 34.8 % between 2001 and 2004. Again, the increase of the MRI-activity is not at the expense of the CT-activity. Both types of examinations continue to increase.

This is an important observation in the lights of the recent decision to again increase the accredited MRI-capacity in Belgium with 40 units. Given the current policies and prescription behaviour related to medical imaging, it is quite possible that the increase of MRI-capacity will not result in an decrease of CT-activity, and that therefore the total activity of CT + MRI would further increase.

One could argue that the increase of CT and MRI-examinations is justifiable because it may reflect the increasing need of health care (e.g. due to the aging of the population) or because it would result in a more efficient medical management overall. It might be that the desired substitution of MRI for CT (from a medical quality perspective) is realised simultaneously with a desired substitution of CT-scans for other diagnostic techniques. With the transmitted N.S.I.I.I.-data it is not possible to provide sufficient

evidence to support or reject this argument. However, there are indications that the CT and MRI-examinations may not always be appropriate.

A study of Van Breuseghem and Geusens [787] reports that about 25 % of the requested radiological examinations for referred out-patients are not in concordance with the guidelines as developed by a group of radiological experts in Belgium (The Consilium Radiologicum). The study was conducted on a small scale. It consisted of 1000 out-patient referrals to a radiological department of one university hospital, of which about 50% were CT- and MRI-requests. The results are not necessary valid for the whole country, but they confirm what is perceived among experts in medical imaging that the questions raised about the appropriateness of prescribing practices in the field of medical imaging are not marginal. The study also analysed specific modalities of medical imaging. Out of 371 requested MRI-examinations, 88.8 % were labelled as conform to the developed guidelines. Out of 140 requested CT-examinations only about 60 % were labelled conform to the developed guidelines related to the CT-technique.

It is to be recommended that an effort similar to the one presented by the above mentioned article, should be made on a much larger scale (see further). Awaiting such a study, it remains useful that the trends in CT- and MRI-activity be reported in greater detail. The following statistics might also help in judging the appropriateness and feasibility of specific proposals to change the current financing system for MRI- and CT-activity.

14.2.2 MRI and CT-activity per type of activity

The reimbursement system for the MRI determines 8 types of MRI- and 7 types of CT-examinations. Each type as two codes, one for out-patient activity, one for in-patient activity (= patients who are at the time of scanning admitted in the same hospital where the MRI- / CT-scanner is located). In order to facilitate the description of the results, the various types of MRI and CT-codes of the nomenclature, are given a short anatomic specification (see Table 14). A full description is presented in the Appendix 5.

Table 14:Transforming codes of nomenclature of CT and MRI into types of examinations, based on anatomic specifications

	Code of Nomenclature		Anatomic index
CT	458673	458684	brain + sinuses
	458732	458743	skull base
	458813	458824	thrunk (+neck)
	458835	458846	spine one level
	458850	458861	spine more levels
	458872	458883	limbs
	458894	458905	joints
MRI	459395	459406	Head
	459410	459421	thrunk (+neck)
	459432	459443	MRA body
	459454	459465	cardiac
	459476	459480	mammo
	459491	459502	spine
	459513	459524	limbs
	459535	459546	functional

From the 8 MRI-types, three represent over 81 % of the reimbursed activity in 2004, the fourth adds another 11 % to the count (see Table 15).

Table 15: Activity per 1000 population per type of activity MRI + Frequency distribution: 2004

Type of MRI activity	Scans per 1000 population	Percentage
Head	11.5	26.7 %
Thrunk	4.9	11.4 %
MRA-body	2.1	4.9 %
Cardiac	0.2	0.5 %
Mammo	0.9	2.1 %
Spine	13.1	30.5 %
Limbs	10.3	24.0 %
Functional	0.0	0.1 %
Total	**42.9**	**100 %**

From the 7 CT-types, three represent almost 90 % of the reimbursed activity in 2004. If one wants to closer monitor the prescription of these diagnostic procedures, it is recommended to start with these 3 CT-types.

Table 16: Activity per 1000 population per type of activity CT+ frequency distribution: 2004

Type of CT-activity	Scans per 1000 population	Percentage
Brain/sinuses	39.1	28.3 %
Skull base	4.2	3.0 %
Thrunk	60.2	43.6 %
Spine one level	0.8	0.6 %
Spine more levels	24.1	17.4 %
Limbs	7.3	5.3 %
Joints	2.6	1.9 %
Total	**138.2**	**100 %**

As mentioned earlier, the supply of the MRI-units remained stable between 2001 and 2004. Per type of activity, the trend during the same period, is different (see Table 17), going from 26% to 72% increase for most types of examinations. Two MRI-types with a very small volume increased considerably faster.

Table 17 : Percentage increase 2001-2004 per type of activity

MRI		CT	
Type of activity	Percentage increase	Type of activity	Percentage increase
head	26 %	brain/sinuses	1 %
thrunk	48 %	skull base	10 %
MRA-body	72 %	thrunk	27 %
cardiac	282 %	Spine one level	-7 %
mammo	72 %	Spine more levels	5 %
spine	32 %	limbs	-2 %
limbs	42 %	joints	132 %
functional	125 %		

The activity changes between 2001 and 2004 were quite different for the CT-scans. Some types show no significant increase or even a small decrease, others increased considerably.

One of the most important questions related to the financing issue is the degree to which MRI-scans replace CT – scans. To measure this it is more accurate to compare specific types of scans than to compare the evolution of the total MRI-activity with that of the CT-activity (see Table 18).

Table 18: Trends in comparable tests MRI versus CT 2001 - 2004

Type of activity	Number of scans		Absolute increase	Percent increase
MRI head	95,323	119,913	24,590	25.8 %
CT head	445,070	451,514	6,444	1.5 %
MRI thrunk	34,082	50,587	16,505	48.4 %
CT thrunk	495,810	629,171	133,361	26.9 %
MRI spine	103,588	136,361	32,773	31.6 %
CT spine	248,666	259,082	10,416	4.2 %
MRI limbs	76,044	107,707	31,663	41.6 %
CT limbs/joints	89,477	103,345	13,868	15.5 %

If substitution indeed occurs, one could expect a reduction of CT-head (brain/sinuses and skullbase) when MRI-head increases. Between 2004 and 2001, the volume of MRI-head increased with 26 %, but we also notice a (small) increase of the comparable CT-activity, namely 1.5 %.

During the same period, the volume of MRI-thrunk increased with 48 %, but the volume of CT-thrunk increased too, namely with 27 %. In absolute terms the increase in CT-thrunk is far stronger than the one for MRI-thrunk. As a matter of fact, the volume of the CT-thrunk increased between 2001 and 2004 more than the total increase of all MRI-examinations during that period.

For MRI-spine and MRI-limbs there was an increase of 32% and 42%, but the comparable CT-activity also increased with 4% and 16%.

In summary, the supply of MRI-units more than doubled during the years 1999 and 2000. It is likely that this sharp increase in supply has helped in responding to the growing demand of MRI-examinations in the following years (+ 35 % from 2001 to 2004). There is however no evidence that the growing MRI-activity resulted primarily in a substitution from CT-scans to the relevant MRI-examinations. In absolute numbers, the CT-activity rose more than the MRI-activity between 2001 and 2004.

14.2.3 MRI and CT-activity : inpatient versus outpatient

Generally speaking, MRI-examinations are performed more on an out-patient basis than on patients staying in the same hospital where the MRI-unit is located. In 2004 in-patient cases represent only 15.5% (16% in 2000) of the total MRI-activity (see Table 20).

Table 19: Percent in-patient: MRI versus CT :2000 -2004

	2000	2001	2002	2003	2004
MRI	16.1 %	15.7 %	16.0 %	15.6 %	15.5 %
CT	35.4 %	34.8 %	35.1 %	34.0 %	33.6 %

For the CT, about 2 out of 3 examinations are performed on an out-patient basis. Overall, the ratio out-patient versus in-patient for CT- as well as MRI-scans remains rather stable in recent years. Here too, we have significant differences between types of activity (see Table 20).

Table 20: Percent in-patients per type of activity in 2004: MRI - CT

MRI		CT	
Type of activity	Percent in-patient	Type of activity	Percent in-patient
Head	28.7 %	Brain/sinuses	45.6 %
Thrunk	22.0 %	Skullbase	16.2 %
MRA-body	33.4 %	Thrunk	39.9 %
Cardiac	39.4 %	Spine one level	15.8 %
Mammo	1.9 %	Spine more levels	11.2 %
Spine	9.8 %	Limbs	14.2 %
Limbs	2.0 %	Joints	3.3 %
Functional	9.7 %		

MRI-Mammo and Limbs are seldom done for in-patients (only 2 %). For the second highest volume type (MRI-Head) the ratio of in-patients is almost 30 %. The ratio of some lower-volume types vary between 30 and 39 %. The highest volume types of the CT-scans (Brain/sinuses and Thrunk) have respectively 46 % and 40% in-patient cases in 2004. The in-patient ratio's for the rest of the CT-types vary between 3 % and 16 % in 2004.

In summary, some types of CT-scans as well as MRI-examinations are more related to in-patient activity than others. Compared to the outpatient activity, they will be easier to link to the existing MKG/RCM dataset (based on APR-DRG registration), and eventually to a hospital financing system that accounts for case-mix differences, where the diagnostic activity is included.

14.2.4 MRI and CT-activity: Regional variation

For each MRI and CT code of the nomenclature, The National Sickness and Invalidity Insurance Institute transferred also the identification of the province where the activity took place, for each year from 1999 to 2004. In the context of this study, it appears less interesting to analyse what the trends of the CT- and MRI-activity are for each province individually. A cross-sectional analysis of the total MRI- and CT-activity per 1000 population per province might provide further inside as to the variation of prescribing patterns. It is assumed that the characteristics of the patients (such as morbidity) treated in the different provinces can hardly explain why the CT or MRI-activity would be significantly higher in some provinces than others or why the CT/MRI ratio would be different. The financing system is identical in each province, so that cannot be an explanation for differences in prescription rates either.

If variation is observed, it is therefore assumed that this is primarily due to prescription behaviour patterns, which of course might be linked to the availability of MRI- and CT-units.

The volume of activity per 1000 population is the highest in the region of Brussels, for CT as well as MRI. As observed in other studies about hospital utilisation, the catchment area of the hospitals in Brussels as a group is considerably larger than the boundaries of the region of Brussels. Using the population of Brussels as denominator therefore overestimates the activity level. On the other hand, the most neighbouring provinces (Vlaams Brabant and Brabant Wallon) realise the lowest utilisation rates for both MRI and CT-scans. Part of their population travel to Brussels for hospital care. The Brussels region and these two other provinces are therefore excluded from further analysis.

Table 21 presents the results of the other provinces.

Table 21: Activity of MRI and CT per 1000 population by province: 2004

	MRI		CT	
Province	**Activity per 1000 Population**	**Ranking**	**Ranking**	**Activity per 1000 population**
Limburg	51.7	1	8	107.1
Oost-Vl.	51.0	2	4	138.6
Antwerpen	49.8	3	6	129.9
West-Vl.	47.7	4	7	128,9
Liège	42.2	5	2	169.6
Hainaut	37.3	6	1	170.2
Namur	33.4	7	3	151.0
Luxembourg	18.1	8	5	132.1

Two important observations can be derived from this:

- The variation between the other 8 provinces remains considerable. For the MRI-examinations the average varies from 18.1 per 1000 population in one province to 51.7 per 1000 population in another. The variation for the CT-scans go from 107.1 per 1000 population one province to 170.2 per 1000 population in another.
- The provinces that rank relatively high in terms of CT-activity tend to rank lower in terms of MRI-activity. On the contrary, the province with the highest MRI-activity per 1000 population has the lowest CT-activity per 1000 population.

Given these observations, it is no surprise to find that the ratio of CT- to MRI-activity varies considerably, namely from 2.07 to 7.30 (see Table 22).

Table 22: Ratio CT/MRI scans

Province	Ratio CT / MRI scans
Limburg	2.07
Antwerpen	2.60
West-Vlaanderen	2.70
Oost-Vlaanderen	2.72
Liège	4.02
Namur	4.52
Hainaut	4.56
Luxembourg	7.30

The variation in percentage out-patient activity is less wide from province to province. For the MRI this fluctuates from 81.5 to 87.6 %. This variation is higher in the CT-area: from 60.7 % to 75.4 % (see Table 23).

Table 23: Percent out–patient scans MRI – CT: 2004

Province	MRI	CT
Hainaut	87.6	70.0
Limburg	87.1	65.9
Antwerpen	86.9	63.9
Luxembourg	85.6	75.4
Oost-Vlaanderen	84.6	68.0
Liège	84.3	66.5
Namur	83.4	68.9
West-Vlaanderen	81.5	60.7

14.2.5 MRI and CT-activity : types of prescribers

The N.S.I.I.I. also transferred for each code of nomenclature and for each year (1999 – 2004) the number of cases per type of prescriber. These prescribers are divided in 164 different codes. They are grouped in 6 groups: General Physicians (including Family Practitioners and Dentists), Physicians in Training, Specialists, Specialists in two or more fields, Specialists who can cumulate general practice locally, and Physicians in the Functional and Professional Revalidation. The last group contains also some Family Practitioners.

As a large number of specialists are specialised in two or more fields, and a large number of the CT and MRI-activity is related to these specialists, the dataset does not really allow for calculating the activity level of each type of specialist.

Moreover, a considerable part of the MRI - and CT-cases have been assigned as prescriber the code '999', which is not further explained in the document provided. The proportion of these prescribers varies for the CT-activity from 31 % in one province to 0 % in some other provinces. For the MRI the proportion per province varies from 0 tot 74 %. Overall this group makes out 16 % of all MRI-examinations prescribed and 6 % of all CT-examinations prescribed. Excluding these group of '999' codes, the group of General Practitioners represents less than 0.01 % of the CT- as well as the MRI-prescriptions. For all these reasons, this parameter is considered insufficiently reliable for further analysis.

Key points

- The supply of MRI- and CT-units differs, depending on the source of information. The increase in MRI-supply during 1999 and 2000 has not resulted in a decrease of CT-activity in the years after that.
- The number of accredited MRI-units in Belgium more than doubled in 1999-2000 (from 32 to 68 MRI-units). The supply of CT-units is estimated to be between 250 and 300 units.
- The activity level of MRI-examinations doubled from 2000 to 2004. During the same period the activity level of the CT-scans increased with 21 %.
- The activity trends differ considerably depending on the type of examination. In general, the number of MRI-examinations increased faster than the CT-scans.
- The absolute number of the group: CT's of the Neck, Thorax and Abdomen increased more than all the MRI-examinations together (between 2001 and 2004).
- The percentage inpatient CT-scans is more than double that of the MRI-exams :33.6 % versus 15.5 % (2004).
- There is considerable regional variation in utilisation rates MRI- versus CT-scans. The provinces with relatively high CT-scans per 1000 population score relatively low on MRI's per 1000 population.

15 INTERNATIONAL COMPARISON

15.1 SUPPLY OF MRI- AND CT-UNITS

As already mentioned for Belgium (see 2.1.), the supply statistics of MRI- and CT-units differ depending on the source of information. As the field of MRI-applications is still expanding, some of the differences that will be reported hereafter, may be explained by the degree to which the data are up-to-date.

15.1.1 OECD-statistics

Among other statistics, the OECD presents on his website data concerning the number of MRI-units as well as CT-units per 1000 population (*O.E.C.D. Health data 2005)*. Table 24 gives an overview of these data (in most cases the data refer to the situation as of 2003).

Table 24: MRI versus CT per million population in 2003 + ratio CT / MRI-supply

Country	Per million population		Ratio CT / MR
	MRI-units	CT-units	
Iceland	17.3	20.7	1.2
Switzerland	14.2	18.0	1.3
Austria	13.5	27.2	2.0
Finland	12.8	14.0	1.1
Italy	11.6	24.0	2.1
Luxembourg	11.1	26.7	2.4
Denmark	9.1	14.5	1.6
Spain	7.3	13.0	1.8
Belgium	6.6	28.8	4.4
Germany	6.6	14.7	2.4
U.K.	5.2	5.8	1.1
Canada	4.5	10.3	2.3
Portugal	3.9	12.8	3.3
Australia	3.7	-	-
New Zealand	3.7	11.5	3.1
France	2.7	8.4	3.0

From this table it can be concluded that:

- Contrary to many other high-tech applications in health care, the current Belgian capacity of accredited MRI-units is rather low. Even after the instalment of the extra 40 units that will be accredited and financed by decision of the Belgian government, the capacity will not be excessive compared to several other countries in Western-Europe.
- None of the countries in table 23 scores as high as Belgium concerning the capacity of CT-units per 1000 population.
- The ratio of CT to MRI - units is more than 4 to1 for Belgium, which is by far the highest ratio. Several other countries have a CT/MRI ratio of less than 2 to 1.

In summary, this comparison suggests that Belgium tends to have an overcapacity of CT. This cannot be concluded from the MRI-units, even after the expansion with 40 units.

15.1.2 INAHTA-survey

INAHTA is an international network of Health Technology Assessment organisations, currently consisting of 43 member agencies in 21 countries. Via the coordinating agency, a limited survey was sent to each member asking information about the supply of MRI- and CT-units in their country, about some activity levels related to it, the number of radiologists, and the financing system relating to MRI- and CT-activity. (Questionnaire: see appendix)

Eleven members, representing nine countries, have returned the questionnaire with most or all of the questions answered. Some have limited their answers to a specific region or subgroup (e.g. Department of Veterans Affairs for the U.S.A.) of their nation's population. Others focus on their country as a whole. Three members of France have sent a combined response.

As far as the supply statistics are concerned, this gives the following results:

Table 25: INAHTA survey 2006: MRI units versus CT-units per million population + ratio CT / MRI

Country or region	Per million population		Ratio CT/MR
	MRI-units	CT-units	
Andalusia	2.1	6.5	3.1
Denmark	10.5	13.9	1.3
France	5.9	12.0	2.0
Latvia	2.5	14.9	6.0
Mexico	0.3	0.9	3.0
Quebec	6.4	13.5	2.1
Spain	14.3	21.2	1.5
Sweden	11.1	17.8	1.6
U.S.A (V.A.)	12.6	26.4	2.1

This survey confirms the conclusions based on the OECD-data.

15.1.3 Data from the industry

Data were also provided from the Philips Medical Systems and COCIR (see above).

There are some differences with the statistics of the O.E.C.D., but similar conclusions can be drawn from it.

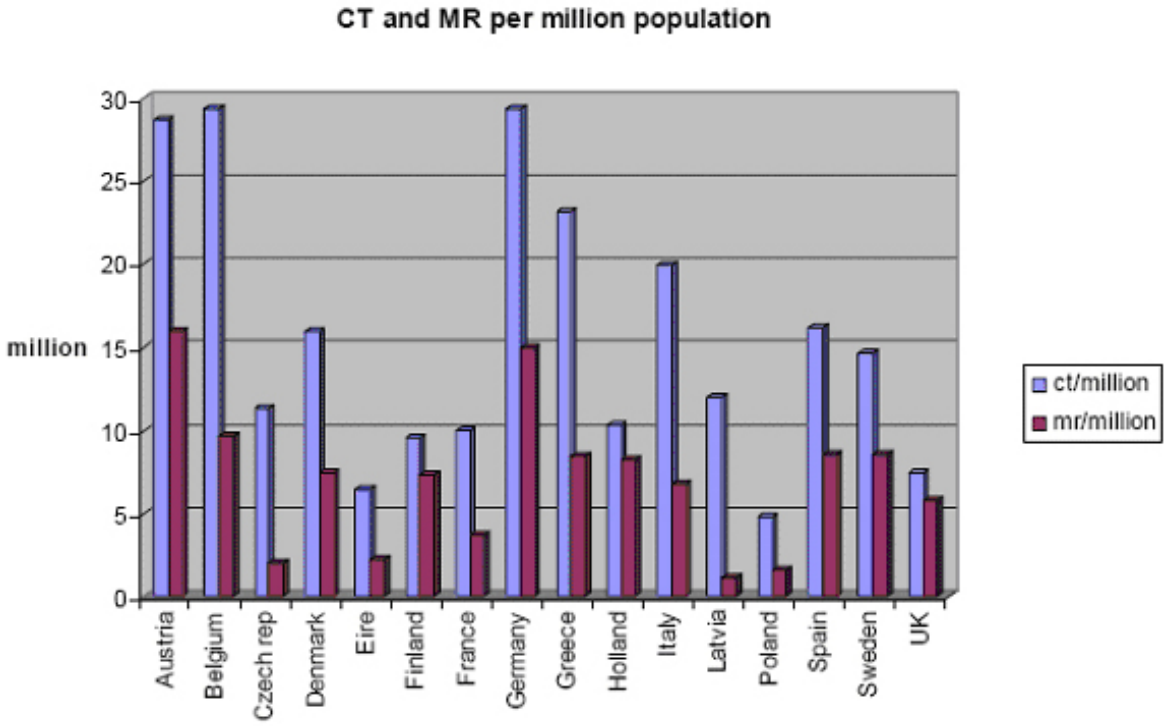
Table 26: Ratio CT-units / MRI-units : sources from the industry

	Ratio CT / MRI	
	Source Philips 2006	COCIR 2001
Austria + Switzerland	1.2	-
Belgium	3.8	3.0
Finland	-	1.3
France	1.9	2.8
Germany	1.5	2.0
Italy	3.0	3.0
The Netherlands	1.1	1.3
Spain	-	1.9
Sweden	-	1.7
U.K.	-	1.3

15.1.4 E.A.R./U.E.M.S.-data

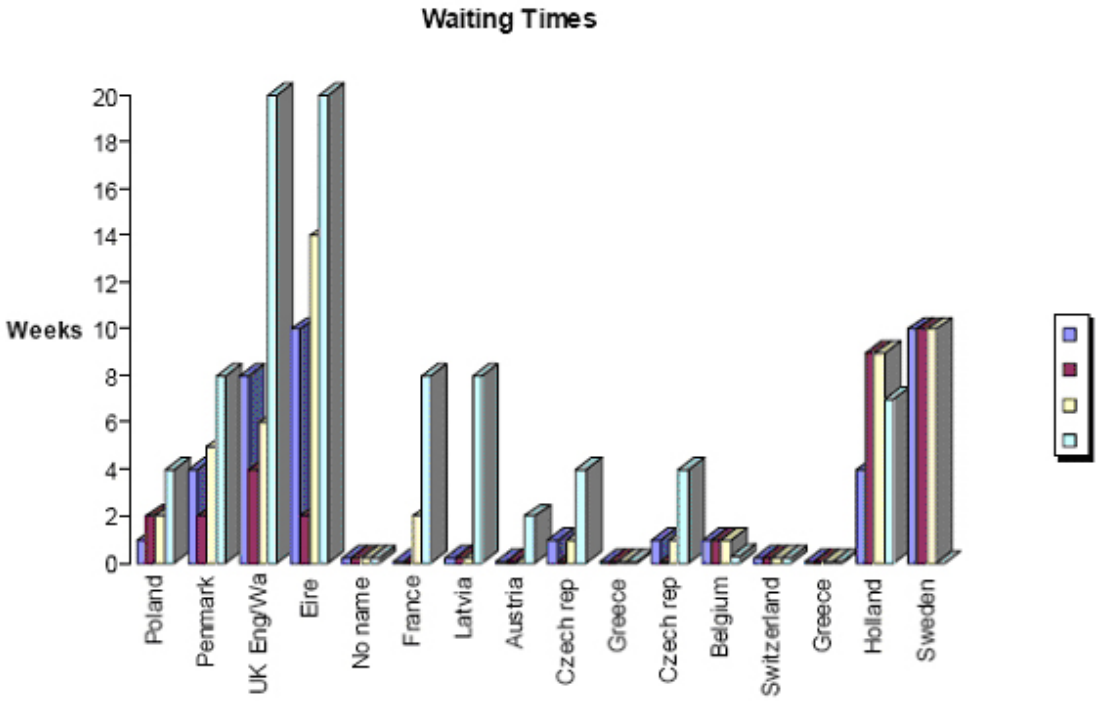
The European Association of Radiologists has, together with the European Union of Medical Specialists embarked on a benchmarking process in 2002, partially based on the data from COCIR.[788] According to those statistics Belgium has the highest density of CT-scanners (together with Germany). With the unofficial MRI-units count of COCIR, Belgium ranks third as far as the MRI-density is concerned (see graph 1).

Graph 1: EAR/UEMS benchmarking 2002: Number of CT and NMR-units per million population



With the large variation in density of CT- and MRI-capacity in different countries, it should not be a surprise that the waiting times vary widely. According to the E.A.R.-survey the average waiting time is only one week for a CT in Belgium and even less for an MRI-examination (see graph 2). The figures are from some years ago. It should be taken into account that the volume of MRI-examinations rose with 35% in Belgium beween 2001 and 2004 while the capacity did not increase during that period. Still, the existing waiting times in Belgium remain marginal when compared with e.g. Ireland and the U.K. (20 weeks) and Denmark, France and the Netherlands (7 to 8 weeks).

Graph 2: EAR/UEMS benchmarking 2002: Average waiting time per type of medical imaging technique



Yellow : CT Light blue : MRI

15.1.5 Location of MRI - and CT- units

Table 27 shows that the large majority of MRI's are located in hospitals. Mobile units are rare.

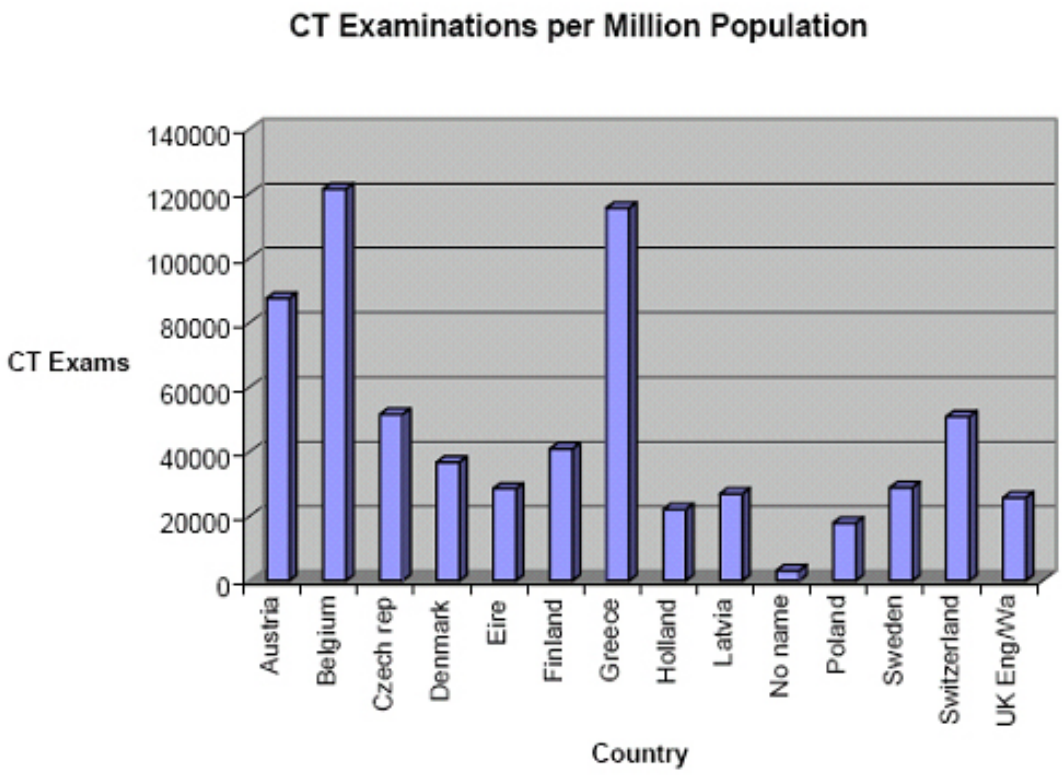
Table 27: INAHTA survey 2006: Location of MRI- and CT-units

Location	MRI						CT					
	Hospital based		Freestanding		Mobile		Hospital based		Freestanding		Mobile	
	#	%	#	%	#	%	#	%	#	%	#	%
Andalusia	16	100 %	-	-	-	-	49	100 %	-	-	-	-
Denmark	53	93 %	4	7 %	-	-	73	97 %	2	3 %	-	-
Latvia	3	50 %	3	50 %	-	-	35	85 %	6	15 %	-	-
Mexico	27	100 %	-	-	-	-	90	95 %	5	5 %	-	-
Quebec	33	69 %	14	29 %	1	2 %	93	92 %	8	8 %	-	-
Spain	630	100 %	-	-	-	-	923	99 %	-	-	10	1 %
Sweden	99	99 %	1	1 %	-	-	149	93 %	10	6 %	1	1 %

15.2 VOLUME OF MRI- AND CT- ACTIVITY IN OTHER COUNTRIES

The EAR-study also reports data for the CT-activity per million population. Belgium has the highest utilization rate, more than two times higher than most other countries (See graph 3).

Graph 3: EAR/UEMS Benchmarking 2002: Number of CT-scans per million population



Some participants of the survey also completed the questionnaire relating to the number of scans registered per year (in 2004, for Sweden and Denmark for 2004). For Quebec only the scans from publicly owned MRI and CT-units were available. Assuming the private units have a similar average production level, the total volume is adjusted accordingly.

Other sources provide also data for The Netherlands and Belgium.

Table 28: INAHTA survey: Activity per 1000 population

Country	MRI	CT	CT/MRI
Denmark	17.4	33.9	2.0
Quebec	19.5	92.4	4.7
Spain	21.4	57.0	2.7
Sweden	38.9	88.9	2.3
USA (V.A.)	45.9	135.2	2.9
The Netherlands	25.0	41.3	1.7
Belgium	43.0	138.3	3.2

The activity levels of Belgium are comparable with those of the Veterans population of the U.S.A. It should be realised, however, that the population of the Veterans in the U.S. are not representative for the whole population, neither for the age-distribution nor for the general health status. The ratios for The Netherlands (data from the Netherlands association of radiologists) are comparable with Quebec and Spain for the MRI and rather with Denmark for the CT. The ratio of CT to MRI-scans varies from 1.7 to 2.9 except for Belgium, where the ratio is above 3.0, and Quebec (4.7).

Together with the supply data, the data of activity levels allow for calculating the average number of examinations per MRI- or CT-unit. The average "productivity" varies considerably between the countries and regions concerned. For Quebec, this data was only available for the public sector.

As can be seen from table 28 the productivity ranges from around 1000 scans a year per MRI-unit in Mexico and 1500 scans in Spain to about 3500 in Sweden and the U.S.A.

For the CT this ranges from about 2500 scans a year per unit in Denmark to about 5000 in Sweden and the U.S.A. and over 6000 in Quebec.

Table 29: INAHTA survey: Average activity level per unit per year

	MRI	CT
Denmark	1,672	2,448
Mexico	4,056	4,486
Quebec	3,043	6,862
Spain	1,498	2,690
Sweden	3,500	5,000
U.S.A. (V.A.)	3,652	5,117
Belgium	6,584* / 5,740+ / 4,867$	5,772# / 4,810§
The Netherlands	3,000	4,467

* based on 68 approved MRI scanners (source: Ministry Public Health), + based on 78 MRI scanners for clinical purposes (source: survey Struyven, Consilium Radiologicum), $ based on 92 hospital based MRI scanners (source: COCIR; including scanners used for research purposes), # based on approximately 250 CT scanners (source: Consilium Radiologicum), § based on approximately 300 CT scanners (source: OECD and COCIR).

Data from other sources show that the average in the Netherlands is somewhat in between the range of the data from the INATHA-survey.

As mentioned above, there is uncertainty about the exact number of MRI and CT-units operating in Belgium. Whatever the reported supply figures used, the Belgian "productivity" per unit is higher than the data available from most other countries. The Belgian activity levels per unit mentioned in table 29 are based on the total volume reimbursed by the N.S.I.I.I. in 2004, divided by the number of units reported by different sources: Ministry of Public Health, Belgian radiologists (survey organised in 2005 by Prof. Struyven, president of the Consilium Radiologicum), industry and OECD. Even with the highest supply-figures of the industry, an average of 4,867 is calculated.

The average production per CT-unit in Belgium is also higher than most other countries. Here too there are doubts about the exact number of CT-units in Belgium. Based on the data reported by OECD and COCIR, the average reimbursed scans per unit would be around 4,810 per year.

The case mix of types of examination for MRI and CT show some remarkable similarities as well as differences for certain types (See Table 30 and Table 31).

Table 30: INAHTA survey types of examination - MRI (percentage)

	Neuroradiology/ Head and Neck	Abdominal	Musculo-skeletal	Thorax	Cardiac	Other
Denmark	30	9	59	1	<1	<1
Latvia	81	5	6	<1	7	1
Quebec	41	6	49	1	-	3
Spain	25	-	65	-	-	-
Sweden	50	10	35	-	3	2
U.S.A.	74	5	21	-	<1	<1

The abdominal examinations range beween 5 to 10% for the MRI and between 20 and 26% for the CT in all countries and regions that provided data.

Table 31: INAHTA survey types of examinations – CT (percentage)

	Neuroradiology/ Head and Neck	Abdominal	Musculo-skeletal	Thorax	Cardiac	Other
Denmark	48	22	8	21	-	1
Latvia	63	20	2	-	14	2
Quebec	46	23	14	13	-	4
Spain	45	-	-	-	-	55
Sweden	50	20	10	20	<1	1
U.S.A.	50	26	22	-	<1	2

The group Neuroradiology/Head and Neck usually makes out 45 – 50% of all CT-scans, the variation is much wider for the MRI's of that type. There is a wide variation in the proportion of Musculoskeletal MRI's. Thorax MRI's are marginal. The group of Musculoskeletal + Thorax CT's usually represents about 30%.

Finally, Table 32 presents some data of the proportion of MRI- and CT-scanning production for hospitalised patients. Only four participants could deliver these data. In all cases this proportion is higher for CT than for MRI, but the difference in percentage tend to be smaller than is the case for Belgium.

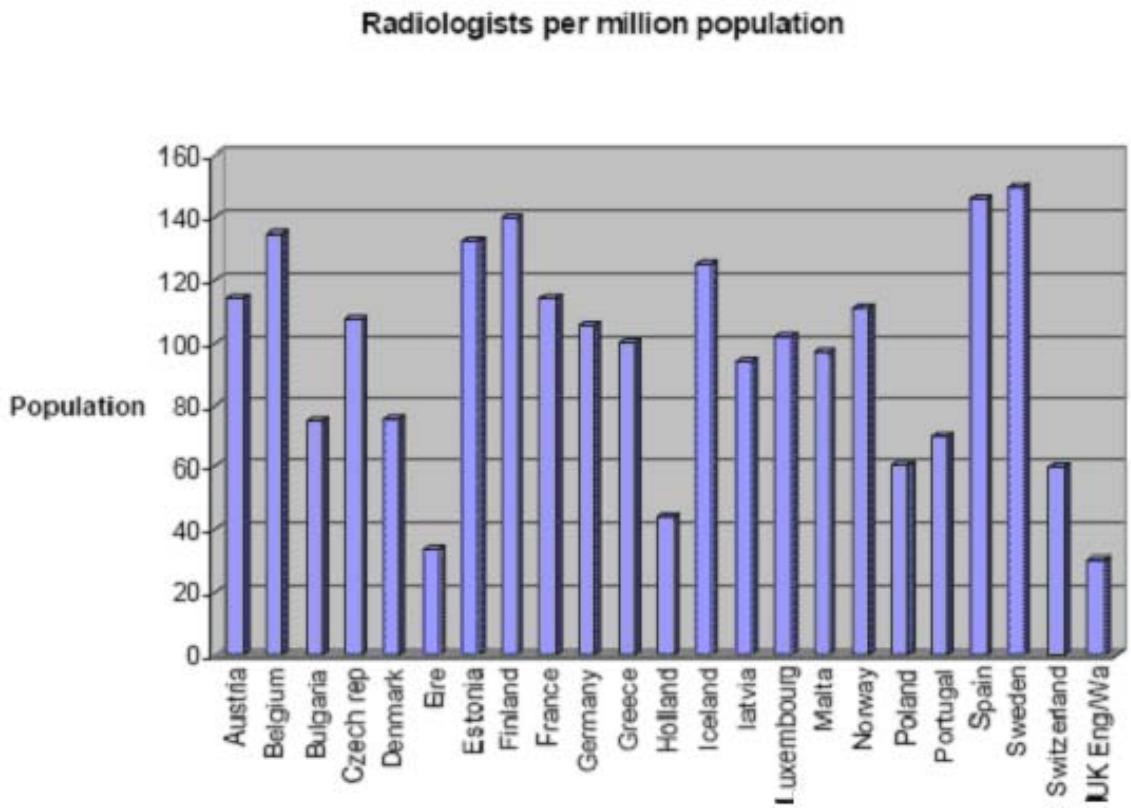
Table 32: INAHTA survey in-patient examination (percentage)

	MRI	CT
Latvia	29.4	32.3
Quebec	12.0	19.0
Spain	29.3	38.6
U.S.A.	17.0	25.0
Belgium	15.5	34.6

15.3 NUMBER OF RADIOLOGISTS IN OTHER COUNTRIES

The benchmarking study of the EAR/UEMS[788] reports the number of radiologists per million population in 23 countries of Europe. As can be seen in graph 4, Belgium scores at about 135 qualified radiologists per million population. Only Spain, Sweden and Finland have a higher density of radiologists. Recent data from the Federal Public Services of Public Health show that Belgium has 1623 or 156 per million population. This would place Belgium at the top of the supply of this specialism.

Graph 4: EAR/UEMS benchmarking 2002: Number of qualified radiologists per million population



15.4 FINANCING SYSTEMS IN OTHER COUNTRIES

Almost all participants of the INAHTA-survey indicate that the financing systems for reimbursing the MRI and CT are the same in their country (see Table 33).

Table 33: INAHTA survey financing system for reimbursement of MRI- and CT-activities

Financing system	Number of regions / countries	
	MRI	CT
No separate reimbursement (within hospital budget)	6	6
Separate financing of the apparatus	5	4
Separate financing of operating costs	1+(3)	1+(3)
Separate financing of radiologists - Fee for service - Others	 2+(1) -	 2+(1) -

Several mention that both the acquisitions of MRI-units and CT-units are paid separately from the other hospital expenses. For the rest, the operating costs for the MRI- and CT-activity usually are included in the general budget of the hospital. A few countries/regions mention that there are differences within the country or region itself.

In Table 32 the exceptions from the general rule of a country/region are counted within brackets. In Quebec there is only a separate reimbursement of operating costs for the

first year of operation of the MRI. In private clinics the patients pay the total costs. In Mexico the financing system differs between the public and private hospitals.

In France, the imaging procedure for hospitalized patients is included in the cost of the hospital stay. For ambulatory patients in hospitals or in private settings, the examination is reimbursed in 2 parts: 1) A technical fixed price ("forfait technique") including amortization of the equipment and operating costs (price variable according to date of installation, class of equipment, geographical location, reduced above a certain threshold of activity); 2) remuneration of the radiologist.

From all the INAHTA-responses, only France and Quebec have a fee for service system to reimburse the radiologists.

Key points

- Compared to other countries, Belgium scores very high on the supply of CT-scanners per million population, on CT- and MRI-activity per unit, on the ratio of CT versus MRI (both supply and activity), and on the supply of radiologists.
- While the supply ratio of CT / MRI-units in most countries lies between 1.1 and 2.4, for Belgium this is more than 3.0 to 4.4 , depending on the source of information.
- Average waiting times in Belgium (both CT and MRI) tend to be very short compared to some neighbouring countries (< 2 weeks versus 2 months and more). These figures are somewhat outdated.
- The activity level of CT-scans per 1000 population is higher in Belgium than in every country from where data are available.
- The average MRI- and CT-activity per unit in Belgium is among the highest of the country from where data are available.
- The number of radiologists per million population in Belgium is among the highest of the country from where data are available.
- For most other countries/regions from where data are available, the financing system for the CT- and MRI-technology is the same. In most cases, the costs of both are to be financed by the annual budget of each hospital. For the acquisition of the MRI- and CT-activity, the hospitals may receive a separate budget.

16 INTERNATIONAL COMPARISON: SITE VISITS

In order to better understand how supply, organisation and financing mechanisms interact with each other, it was intended to visit 4 or 5 countries from Western Europe, as close as possible to Belgium. Via several sources (INAHTA, radiologists with an international reputation, professional contacts from earlier studies) several countries were contacted to ask whether they would cooperate with a site visit initiative. The purpose was to collect more information and insight than would be possible with written communication.

For a few countries, experts from different disciplines (radiologists, civil servants, economic advisors) could be interviewed. From other countries, none of the attempts to make appointments were succesful.

Eventually, three countries were visited: Denmark, The Netherlands and France. This part of the Part summarises the interviews and complement these with data made available locally.

16.1 DENMARK

Denmark (5.5 million people) is about to make a major reform of their government structure, which will also have a drastic effect on the organisation and financing of their hospital care.

Starting next year, 98 municipalities will replace the existing 271. The current 14 counties + the Copenhagen area will be abolished and five regions will be created. These 5 regions will take over the authority from the counties to regulate and finance the public hospitals. Private hospital care is marginal in Denmark.

Contrary to the counties, the new regions will have no taxation powers. They will receive a regional budget from the national government, coming from general revenue taxation, to pay for acute health care (mostly hospital care). The amount each region will receive, depends on several parameters. It is meant to finance about 75% of the costs from the hospitals located in that region. Another 10% is paid by the municipalities of that region. Together these amounts form the fixed part of the hospital budget. Each hospital receives a share of it, based on its case-mix.

The remaining 15% is also financed by the national government (5%) and the municipalities (10%). The 10% coming from the municipalities is linked to the number of admissions of their population to that hospital. If a municipality realises to reduce the admission rate (by keeping the population healthy – they are responsible for preventive health care) they have to pay less than 10%.

The national 5% is linked to the activity level of the hospitals. They have to prove that they reached a predetermined activity level. With each activity, the hospital earns DRG-points. For example, each MRI-examination earns 300 points while each CT-examination is worth 200 points. Once a total amount of points is exceeded in a given year, the hospital receives only 50% extra of this variable part of the budget. If the hospital does not reach the activity level set in advance, it will receive only half of the DRG-related share of the budget.

As an MRI-examination brings in more DRG-points then a CT, it may result in a shift from CT towards MRI. However, it is calculated that an MRI-examination also costs that more, so the hospital has no incentive to produce more MRI's nor CT's than necessary.

Three other factors explain why the DRG-type of financing will not result in overuse of the MRI- and CT- technology.

1. The revenues received from the fixed and variable part of the budget are not sufficient to purchase MRI- and CT-scanners. Each hospital has to ask the regional authority extra money (coming from the 85% fixed budget allowances that the region receives) to purchase a MRI- or CT-scanner. As there will then be less money available for the other hospital activities the regional authority might be reluctant to subsidise additional MRI- and CT-units. As the demand for these diagnostics increase, this will result in a longer waiting list for MRI- and CT-examination.
2. However, when a patient has to wait more than 2 months for a scan, he has the right to be treated in whatever hospital (even outside the region) in a private facility or, as a last resort, outside the country. The regional authority is required to reimburse the cost incurred. The rate is set at 323 € for a MRI-scan, and 211 € for a CT-scan.
3. The number of radiologists in Denmark is insufficient to meet the increasing demand for MRI and CT-scans.
4. Also, radiologists are paid a monthly salary (depending on the hospital where they work). They work 37 hours a week and will only accept to work overtime if they are paid for it, additionally.
5. The hourly rate of overtime hours can be up to 300% of the average amount for normal working hours.
6. Each hospital receives a fixed budget and a variable portion related to the activity level. The hospital distributes this further to the various departments. There is no guarantee that an increased activity level of the radiological department will result in a higher share of the hospital revenues allocated to that department.

In summary, there are in Denmark little or no financial incentives to conduct more MRI- or CT-scans than necessary.

Miscellaneous issues

While conducting the interviews some other issues that are relevant to this study have been addressed.

Concerning the referral patterns, it is not known what percentage of the MRI-examinations is prescribed by GP's, ambulatory specialists and hospital bound specialists nationwide.

At the Herlev Site of the university hospital of Copenhagen 23 % of the MRI-activity is requested by ambulatory specialists and also 23 % by other hospitals. Referrals by GP's are limited. Most requests come from specialists working in the same hospital.

The radiological department organises daily conferences with the prescribers to discuss the appropriateness of the requests and the results. It is believed an important factor to avoid unnecessary prescriptions.

In order to limit further inappropriate use of the MRI- and CT-technology, the prescriber is required for every request to provide information about the diagnostic tests already conducted before, the symptoms of the patient, the reasons why the scan is demanded and what type of scan is requested.

Since May 2000 the head of each radiological department is required to refuse any request for a scan that is considered inappropriate. Also, each radiologist may decide to switch to another type of diagnostic procedure (e.g. a MRI instead of a CT-scan) if he considers this more appropriate with the medical data of the patient available. After judging the appropriateness of the request for a CT or MRI it is the radiological department who makes an appointment with the patient concerning supply and demand. Both are increasing in Denmark, despite the serious constraints discussed above.

Given the observed shortages in supply, the national Government decided, exceptionnally, to earmark separate loan funds for both 2005 and 2006 to pay for the acquisition of extra MRI-, CT- and PET-units. This budget includes money for extra training of radiologists and radiographers and subsidies for building adjustments for the MRI-units. A competitive bidding procedure was set up to get the most units out of this budget. For 2005 this resulted in an extra supply of 7 MRI-, 5 CT- , 1 PET- and 2 PET/CT scanners + the replacement or upgrading of 3 MRI-units and 9 CT scanners. For 2006 there will be an additional acquisition of 5 MRI-units, 7 CT- and 2 PER/CT scanners + the replacement or upgrading of 3 MRI-units and 5 CT- scanners.

The demand for MRI-exams also is increasing rapidly, exact data of this trend could not be delivered. The CT-activity increases too. Especially in the CT-field it is mentioned that there is an ongoing shift from CT's for diagnostic purposes to CT's to follow-up drug and other treatments, especially in the field of oncology.

Concerning quality control, the regional authorities are required by law to hire physicists to control the CT-equipment periodically. For MRI-equipment there is no external quality control system. An accreditation system is being setup.

16.2 THE NETHERLANDS

Last year, the Netherlands started implementing major reforms in the financing system of health care in general as well as the hospital services.

The hospital financing shifts gradually from a fixed budget system towards a DRG-type system. Each patient treatment (including ambulatory care) in the hospital is classified into a DBC (Diagnosebehandelcombinatie). For 10% of the DBC's the hospitals can negotiate with the insurance companies to get a reimbursement based on all costs involved. For each DBC the average direct costs of every activity has been calculated as well as the average frequency of this activity for this DBC.

For example, the average costs of the different types of MRI-examinations were calculated. The average number of each type of MRI-scans was calculated for each DBC.

Multiplying both gives the average cost per type of MRI-examinations. This cost varies from 203 € to 280 € depending of the type of MRI, including the remuneration of the physician (usually 64 €).

The same amounts are charged to private MRI-centers for each scan conducted. These costs do not include depreciation of large investments (such as building facilities), capital costs, general administration, etc…

The one private MRI-centre that was visited has an average cost of about 310 € per MRI-scan.

As in Denmark, there is a long waiting time to get a MRI-examination. Insurance agencies who compete for clients may guarantee them that they can get an MRI-scan within e.g. one week. They make arrangements with private MRI-centers to reimburse these scans.

The "MRI-Centrum" has developed a fee schedule with 40 different rates depending on the scanning time and the time of analysis.

Hospitals too may have an interest in referring patients to those centers. For 90% of the current DBC's, the private MRI-centre has to accept the fee set by the government as mentioned above. The number of private centers is growing, but the large majority of the scans are still conducted in hospitals.

As mentioned above, the hospitals are still primarily operating within a fixed budget per year.

For paying the salaries of their specialists, they receive a lump-sum amount each year. This is further distributed among the specialists based on certain agreed upon salary-levels that may differ depending on the specialty. For that salary, the specialist has to perform a yearly activity-level. Neither the hospital nor the specialist has an interest in

increasing activity above that level. The hospital would then have to pay the extra variable costs, why the specialist has to work harder for the same salary. This dynamic may change as the hospital would be financed more when the share of payments per DBC increases considerably. This is not to be expected in the first years to come.

In summary, the current financing mechanisms do not, generally speaking, encourage hospitals nor their radiologists to overuse the MRI-units or to increase their productivity.

At the same time, there certainly isn't an oversupply of radiologists in the Netherlands.

Yet, the demand for MRI-scans as well as CT-scans is growing, resulting in waiting times that may become months rather than weeks.

Miscellaneous issues

Concerning quality control, the professional associations play a major role in the health care scene in The Netherlands. The Royal Society of Medicine organises an accreditation programme where each specialist has to comply with every five years to be able to continue practising. This includes the radiologists.

Physical and technical controls are usually done by the company that sold the MRI-unit.

The association of radiologists in the Netherlands organises site visits to the radiological department of each hospital. Each department is visited at least once every five years. It receives a report with recommendations to optimise quality of care.

In the past requests from General Practitioners for MRI-examinations where strongly discouraged. This tends to change now. The "MRI-Centrum" of Rotterdam and Amsterdam (a private centre) reports that 30% of the 22.000 examinations a year come from patients referred by G.P.'s. Every request is screened thoroughly in advance and refused if considered inappropriate (about 20% of the cases). Only if the request is accepted, an appointment with the patient is set up.

16.3 FRANCE

As in several other countries, the hospital financing system in France is also in a transitional period. France is moving gradually towards a financing by DRG's. In such a system, the reimbursement is not earmarked for specific diagnostic procedures. Hospitals may benefit financially from extra MRI- or CT-examinations, when this result in faster treatments and thus shorter lengths of stay. But they may also gain by shifting some diagnostics currently conducted for hospitalised patients to ambulatory care, that is reimbursed separately from the DRG-system. This assumes that the hospital invests sufficiently in MRI-units to treat those ambulatory cases. If they don't, the waiting time becomes too long, and patients would choose care in other public hospitals or private units.

Radiologists working in hospitals do not gain directly from an increased MRI-activity as they are paid on a salary-basis.

According to Prof. Frija (French Society of Radiologists) about 40% of the MRI's are done in private settings. These units are allowed a fixed fee depending on the type of unit. A unit of 1,5 tesla for instance is reimbursed 220 € for the "technical" part and 69 € for the physician remuneration. Physicians who have no agreement with the National Health Insurance Agency are allowed to charge more. Hospital radiologists normally have such agreement for which the 69 € is the fixed fee.

The "technical" part includes the costs for acquisition, building adjustments, salaries, etc… The fee is reduced gradually once a certain activity level is reached (e.g. 5000 MRI-scans per unit). In comparison, the basic fees for CT-scans are respectively 104 € for the technical part and 30 € for the remuneration of the physician. In the private sector, the patients have to pay 30% of the physician fee.

In France the depreciation period for MRI- as well as CT-units is set at five years.

Miscellaneous issues

The average waiting time for MRI-examinations in France is 25 days. Recently a national cancer plan was launched. One aspect of this plan is to increase the number of MRI-units so that the waiting time can be reduced to an average of 15 days.

Regulations concerning quality assurance in MRI-units hardly exist. Suppliers of MRI-units conduct their own controls via the maintenance contracts.

A process of external quality control is being developed by the professional association of radiologists in France. Aside from the already existing guidelines, they are developing standards of good medical practice per indication of MRI-activity.

Prof. Frija is convinced that the first priority now is to develop a registration system that allows to calculate the proportion of inappropriate prescriptions (according to the guidelines) and the proportion of inadequate examinations (according to agreed upon standards of care).

It is common practice in France that the prescriptions are first read by a radiologist and if necessary refused, before an appointment is set up with the patient.

17 IMPROVING THE FINANCING SYSTEM: SOME REFLECTIONS

What can we learn from the above described observations and analyses?

Is there any evidence that the current ratio of MRI- versus CT-supply and/or MRI- versus CT-activity is suboptimal?

To what extent could this be linked to the existent financing system? Does the international comparison shed some further light on this issue?

Is the current financing system of MRI and CT compatible with the principle of a balanced mix of features that is necessary to promote the appropriate use of both technologies? (see key points of section 14.)

It was the purpose of this part to provide some answers to these questions, if not full-proof than at least partially. With the existing information, it is not possible to prove that the current financing system causes inappropriate use, but the information available certainly helps in better understanding current utilisation practices. Based upon it some reflections are made that can further be used in the policy-making process. Concrete policy recommendations will be presented in an attachment to this report.

17.1 REFLECTIONS ABOUT SUPPLY AND UTILISATION

As observed in this part, the supply of CT-scanners in Belgium (per million population) and the screening activity per CT-scanner is among the highest in the world. It is quite possible that this can be explained by the lack of programming criteria for the CT's combined with the current CT-reimbursement scheme, based primarily on a fee per activity.

On the contrary, several other countries have more MRI-units per million population than Belgium, even if the extra 40 MRI-units will be installed. However, the current activity-level per MRI-unit is quite high (compared to that of other countries from which data are available). This raises concerns that overutilisation of MRI might not be marginal either and may further increase when supply constraints are reduced and certainly when the MRI-propgramming is abolished without changing the reimbursement system.

Although some substitution from inappropriate use of CT-technology to a more appropriate use of the MRI-technology is likely to occur when the supply of MRI-units is increased and spread over a larger number of hospitals, there is no evidence that such an increased of MRI-supply has in the past resulted in a reduction of the total volume of CT-activity in Belgium.

The ratio of CT- to MRI-supply as well as activity appears to be considerably higher in Belgium than abroad. This calls for measures to correct this imbalance.

17.2 FINANCING SYSTEM AND COST STRUCTURE

As described above the cost structure of the MRI-technology differs somewhat from that of the CT-technology (e.g. use of contrast material, upgrading costs) but the differences are too small to justify the current duality, where the total costs related to the CT-scanning are financed via the physician remuneration system, while part of the MRI-related costs are financed via the hospital budget. It is to be recommended that the financing systems for both technologies are harmonised, as is the case in almost all other countries of which information is made available.

Not a single financing system is to be preferred above all others. Every system has its limitations. Yet, some options have more potential that the resources are spent appropriately.

A first option is the integration of MRI, CT and all medical imaging costs into a DRG-type of financing. This option is already being implemented in some countries (e.g. The Netherlands), which illustrates that it is feasible. It is also consistent with the opinion

that medical imaging techniques, as well as other diagnostics, are in the first place instruments to realise the most efficient treatment for patients, depending on their medical conditions.

There are some limitations with this option too. First, 85 % of the MRI-examinations are done on an ambulatory basis. Contrary to the hospitalised patients, there is no national registration system in Belgium that could classify each request for an MRI or CT into a Diagnosis Related Group. Whatever the benefits of a DRG-system might be, it will take time and further research before this option can be implemented. Secondly, as the financing would no longer be earmarked for specific radiological procedures, it might induce some to cut down on services or postpone necessary investments. There will remain a need to monitor the likelihood of these side-effects and, if necessary, to take specific measures to assure quality of care.

As most costs related to the MRI-activity are not variable in nature, it would not be wise to adapt the current MRI-financing to the current CT-financing as the latter is more based on a fee per activity than the current MRI-reimbursement.

On the contrary, there is a need to reduce the percentage that is paid on a fee per activity basis and to increase the percentage that is paid either via the "forfaits per patient" or via the hospital budget (A3, B3, B7) or both. Whatever the options chosen, there is also a need to refine the current system of paying some MRI-expenses through the hospital budget. The current regulation creates confusion as to what types of costs are covered by the A3 and B3-parts of the hospital budget and what types are paid via the physician reimbursement system.

For instance, the current financing system related to the B3 for the MRI appears to pay only for the direct cost of MRI-personnel. If this is the case, Artikel 8, c) of the Royal Decree of 25/04/02 should clarify this. Assuming this interpretation is accepted, it is to be recommended that the fixed amount for direct (non-medical) staff is adjusted based on workload-differences. The current B3-amount is one lump-sum amount that does not differentiate hospitals based on the working hours nor the labour intensity related to certain types of MRI-examinations (e.g. number of sequences, coronary imaging, non-invasive angiography, virtual endoscopic techniques, interventional procedures) and types of patients (intensive care patients, children, patients under general anaesthesia, patients staying in the hospital, etc..).

For several reasons, it might be better to install less MRI-units that are also in operation during evenings and even the weekends, than to install more MRI-units in the same location, that operate only during the normal working hours. It enhances the efficient use of an expensive technology with a high portion of investments, building construction costs and other fixed costs; It avoids that many patients need to take time off from work to have a MRI-examination or for other reasons have difficulty in coming to the scanning unit during the normal working hours; etc…

The question is whether these advantages are sufficiently captured by the current fee for service system or whether correcting the B3 for differences in the opening hours of the unit might not be a better solution? Whatever options are chosen, it remains necessary to take measures that the MRI-technology is used appropriately.

17.3 RESPONSIBILITY OF THE PRESCRIBER AND THE RADIOLOGIST

Radiologists often argue that the prescribers are the driving force for the increase of MRI- and CT-examinations. Some suggest that up to 30 % of the requests may well be inappropriate. There is little empirical evidence available on this topic. One publication, mentioned above , shows that the inappropriate CT-requests may be up to 40 % , while the inappropriate MRI-requests were about 11 % (Van Breuseghem and Geusens[787]), but that study was only based on a small sample of requests related to one hospital. The results need to be validated by a study on a larger scale.

One way to contain the upward trend is to make the prescriber financially responsible for the MRI- and CT-requests (s)he makes. A problem with this approach in Belgium is that there is little information per prescriber about the medical conditions (case-mix) of his/her ambulatory clients. Some may prescribe more because the medical

characteristics of their patients are such that they require more treatments, and more diagnostic tests before treatment, just because they are sicker. Letting these prescribers pay for their higher than average prescription activity would merely punish those who treat the sickest patients and risks to create tendencies to focus on the healthier clients in order to avoid financial loss.

An alternative could be that the appointment system for MRI and CT-examinations in Belgium is adapted to what is common practice in other countries (from which data were available). In these countries the radiologist has the right to deny or change a request that is considered inappropriate because it does not comply with the existing guidelines. Such a system can hardly be implemented with the current practice in Belgium that first arrangements are made by the prescriber to fix an appointment for the patient to get a MRI or CT, and that only after the patient arrives at the department of radiology (after maybe some weeks of waiting) it becomes clear that the request is not the most appropriate. At that time it is difficult to make a new appointment with the patient for e.g. a MRI-examination instead of the CT-scan requested.

17.4 REFLECTIONS CONCERNING QUALITY ASSURANCE

As described above, financing mechanisms might provide positive or negative incentives to assure quality of care, but none of these are sufficient to warrant optimal quality of care. In Belgium, apart from voluntary internal quality control measures, little attention is given to the quality assurance, except from the regulation in relation to the radiation levels in the CT-field.

During the site visits in some other countries, the quality assurance issue has been addressed explicitly. They may provide inspiration for developing quality assurance programmes in Belgium as well.

For instance, In the Netherlands a system of site visits is installed where all hospitals with a MRI and/or CT-unit are visited (e.g. once every five years) to check whether they are meeting certain quality standards. Those who don't comply may lose their accreditation.

In Denmark a national programme to train radiologists and/or technicians (radiographers) was set up, in the first place oriented towards the hospitals who start with their first MRI-unit. In Denmark too, some hospitals organise regularly conferences between providers and prescribers of MRI and CT-scans to discuss the appropriateness of the requests, the quality of the information provided on the standard request, the accuracy of the diagnoses, etc… The requests and reports are compared with the data from the discharge abstracts and/or follow-up data, etc…

In summary, the data and analyses presented in part 2 are not sufficient to provide full-proof scientific evidence of the degree to which inefficient use of the selected medical imaging techniques exist in Belgium. But they provide plenty of information that tend to confirm that the current financing system may well result, at a macro-level, in a significant overuse of the CT-technology. They support the concerns that the decision to increase the MRI-supply may well result in a growing overutilisation of both the CT- and MRI-technology as well, if no further measures are taken to stimulate the appropriate use of these technologies.

Part 3: Short Health Technology Assessment: Mobile Magnetic Resonance Imaging

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18 INTRODUCTION

Mobile MRI systems have been introduced on the market in the late 80ies in the US as an alternative to fixed systems. Early 90ies the technology became available in Europe. Mobile MRI systems are built in special trailers or vans, which travel from hospital to hospital. Two systems exist: mobile MRI systems in trailer or re-locatable MRI. The re-locatable are semi-fixed MRI systems that provide more space within the operating and imaging room but are less easily transportable. This short HTA focuses on the mobile MRI systems in trailers.

Mobile MRI may be useful and has been used worldwide for different reasons:

- Tackling waiting lists
- Insufficient case load for one fixed MRI
- Structural alterations or renewal of fixed MRI equipment
- Ensuring access to MRI to patients in remote areas
- Lower investment costs

In Belgium, mobile MRI is currently used when structural alterations are needed or if existing fixed MRI equipment needs to be renewed. They are typically used as a temporary solution a temporary out-of-service fixed MRI.

The Belgian government envisages the licensing of 40 additional MRI scanners in 2006. The possible place of mobile MRI scanners in this picture is yet unclear. In this short Health Technology Assessment, we examine the potential role of mobile MRI in Belgium.

19 TECHNOLOGY DESCRIPTION

Mobile MRI scanners are compact scanners built in a trailer of a truck. They can be transported via regular highways.

Mobile MRI scanners are technologically identical to fixed MRI scanners, although the technological possibilities in terms of field strength of the MRI scanners are somewhat less in mobile systems than in fixed systems. Mobile systems are limited to high-end systems of 1.5 Tesla, whereas in fixed MRI higher field strengths are possible. The quality of the images appears to be identical between the mobile and the fixed systems,[789] but no literature could be found to confirm this finding.

The scanning room and operating room are smaller in mobile MRI trailers than in fixed MRI sites. Figure 2 and Figure 3 show the exterior and interior of a mobile MRI.

Figure 2: Mobile MRI on truck



Figure 3: Inside view of control and imaging room



There are three rooms in the MRI trailer: a technical room with all the technical equipment for cooling etc., a control room with the imaging computers and the MRI room. The rooms are small due to legal limitations imposed to the size of the truck. Its limited size allows the trucks to circulate on regular European roads without additional specific legal approvals (mobile MRI trucks are not categorized as 'exceptional vehicles'). Some but not all trailers are equipped with a changing room for patients.

Magnetic shields are integrated in the side and rear walls of the trailer and in the floor of the mobile MRI trailer to prevent a leakage of magnetic activity around the vehicle. Such leakage may interfere with the function of pacemakers of passer-bys (both during operation near a hospital and during transport) and should therefore strictly be avoided. This influence was found in a study with a mobile MRI scanner of 1.5 Tesla and for a distance between the pacemaker and the vehicle of less than 90 cm.[790] The results of this study may no longer be applicable to current mobile MRI systems, as the static magnetic field measured on the side wall of the trailer in this study was of 48mT, while current systems report a magnetic field of less than 0.5mT outside the trailer wall (measured at the wall).

Temperature and humidity in the trailer are maintained at an appropriate level during transport and operation to guarantee the good functioning of the imaging equipment. The technological advances in the constitution of the trailer considerably diminished the siting requirements for mobile units, compared to earlier mobile MRI trailers.

The trailer is equipped with a lift for and a ladder. The lift can be used for patients who are unable to walk or confined to bed.

The mobile MRI requires a power supply of 380 Volts, 115 kA. The hospital wishing to install a mobile MRI should thus be able to provide this electrical supply at the location of the trailer. In addition, sufficient parking space is needed near the electrical outlet. Direct access from the hospital to the trailer through a bridge is preferred, for safety and comfort of the patient and the personnel working with the MRI. Safety issues relate to patients requiring e.g. gadolinium chelates injections for MRI. Some risk is associated with such injections, sometimes requiring reanimation of the patient. Especially if there is no changing room within the trailer, a bridge is required for the comfort of the patient.

Mobile MRI scanners usually already have run through the procedures of inspection and quality control before they are installed near a hospital. It takes about 1 hour to install a mobile MRI unit near a hospital.

With a mobile MRI scanner, about 25 scans can be performed per day, assuming working days of 10 hours.

Key points

- **The MRI scanners installed in a mobile trailer are technologically identical to the fixed MRI scanners of the same field strength.**
- **Mobile MRI scanners are yet limited to 1.5 Tesla.**
- **Image quality is the same for fixed and mobile MRI systems of 1.5 Tesla.**
- **Limitations to the size of the trailer imply limited working surface within the trailer.**
- **Mobile MRI trailers are equipped with shields in the walls to preclude magnetic leakage around the vehicle.**
- **Installation of a mobile MRI requires a certain amount of logistics: adequate power supply, easy access to the hospital, sufficient parking space for the trailer.**

20 METHODS

A literature search was performed in Medline (OVID), Embase (OVID), Econlit (OVID), CINAHL (OVID), NHSEED, DARE and the HTA Database.

The search string used in Medline (OVID) was:

([exp Magnetic Resonance Imaging/] or (Magnetic resonance imaging or MRI).mp) and ([exp Mobile Health Units/] or (mobile or portable or shared).mp. [mp=title, original title, abstract, name of substance word])

We used a slightly adapted search string in Embase:

('nuclear magnetic resonance imaging'/exp OR 'magnetic resonance imaging':mn,de,tn,ab,ti OR mri:mn,de,tn,ab,ti) AND ('portable equipment'/exp OR portable:mn,de,tn,ab,ti OR mobile:mn,de,tn,ab,ti OR shared:mn,de,tn,ab,ti) AND [embase]/lim

Medline and Embase searches were limited to 'humans' and articles or reports published after 2000. The search was done on January, 30th, 2006. The flow chart for the literature search is presented in Appendix. Eventually, only two relevant articles[791, 790] and two reports[789, 792] were retained.

Apart from the published literature, we organised several meetings with the industry, including producers of mobile MRI equipment, mobile MRI trucks and a service provider for mobile MRI and with a Belgian centre with experience with mobile MRI. We visited a functional mobile MRI in a Belgian centre and talked with the people working with the mobile system about their experiences.

Based on the information retrieved from literature and personal communications, we attempted to assess the potential role of mobile MRI in Belgium.

21 RESULTS

21.1 IMPLEMENTATION MODELS AND COST STRUCTURE OF MOBILE AND FIXED MRI SYSTEMS

Technologically, mobile and fixed MRI scanners are identical. The demand for mobile MRI in other countries was mainly based on cost arguments [789] or arguments of increased waiting lists. Two HTA reports reported on the cost structure of mobile MRI compared to fixed MRI.[789, 792]

The Canadian Coordinating Office for Health Technology (CCOHTA) published in 1995 a report where fixed MRI was compared with mobile MRI in Canada. Some issues (e.g. resistance to extremely low temperatures) are not relevant for Belgium and are hence not discussed in this part.

Costs of mobile and fixed MRI scanners encompass fixed, semi-fixed and variable costs. From the perspective of the hospital, the cost of mobile MRI highly depends on the implementation model chosen to use a mobile MRI.

Possible implementation models are:

- Purchasing a mobile MRI by an association of hospitals and keeping the mobile scanner in own management
- Renting a mobile MRI unit for a specific period of time from a service provider
    - Full service (the entire service, including transportation, technical staff, radiologists)
    - Partial service (trailer and driver or trailer, driver and technical staff but no radiologists)
- Leasing a mobile MRI unit: this is a special case of the renting option.

In case of subcontracting, i.e. renting a mobile MRI unit from a service provider, different types of contracts are possible:

- fee per patient: in this case, the fee depends on the number of patients seen per day
- fee per day: in this case, the fee is independent of the number of patients

Upgrade of the equipment is guaranteed by the service provider and is included in the price.

The financial implications for the hospital of each organisation form are different and hence the financing of services provided on mobile systems will vary between the implementation models and between the mobile and the fixed MRI units.

Table 34 gives a brief overview of the different cost elements from the perspective of the hospital. For mobile MRI, the cost structure depends on the implementation model chosen. Either the mobile MRI is purchased, or it is rented from a service provider. In case of rental, different possibilities exist: the service provider can provide the full service, including medical and paramedical staff, or can provide only the driver and the equipment.

Table 34: Fixed and variable cost items of mobile and fixed MRI scanners

	Fixed MRI	Mobile MRI		
Implementation model		**In ownership**	**Rented**	
Type of service			**Full service, including staff, maintenance**	**Partial service**
Fixed costs	Equipment Building Staff* Maintenance	Equipment Trailer Staff* Maintenance	All costs semi-fixed in case of fee per day	Staff (radiologist and/or technical staff)* + semi-fixed costs in case of fee per day
Variable costs	Consumables	Consumables Driver	All costs variable in case of fee per patient	Consumables + variable costs per patient in case of fee per patient
Indirect costs	Patients' travel	Patients' travel	Patients' travel	Patients' travel

* in a university hospital setting.

The initial capital costs are higher for fixed MRI scanners than for mobile MRI scanners. Installing a fixed MRI implies the preparation of a building suitable for MRI scanning as well as the installation of the MRI equipment. Specific requirements are imposed upon MRI rooms. These are regularly inspected. Buying a mobile MRI implies lower capital costs but is still more expensive in terms of capital investment than renting a mobile MRI from a private company.

Variable costs are usually higher for a mobile MRI than for a fixed MRI. If a mobile MRI is bought by a hospital, the hospital has to pay the driver and the fuel to move the mobile MRI from one location to another. If rented from a service provider or producer of mobile MRI systems, either the rent is variable per patients or per day.

Operating costs, which may be fixed per year, are higher for mobile than for fixed MRI scanners. In case of mobile MRI, both the MRI equipment and the trailer need regular maintenance.

21.2 COSTS OF MOBILE VERSUS FIXED MRI IN PARIS

The French "Comite d'Evaluation et de Diffusion des Innovations, Technologiques" (CEDIT) compared the costs of fixed MRI with the costs of mobile MRI. The study was commissioned by the "Assistence Publique-Hôpitaux de Paris" (AP-HP). AH-AP groups 36 hospitals in and around Paris. The objective was to study the different options for high-field MRI units before acquiring one device especially intended for the patients of their 20 geriatric facilities. Three possibilities were considered: a mobile unit, a fixed unit or referrals to existing units counting on future MRI planning in France and updating leading to a higher throughput. The main motivations for this request were the reduced mobility of the geriatric patients and their specific needs, the constant technologic evolution, and a saturated MRI offer in hospitals equipped with a MRI service. The report was issued in 2002.

The constraints identified for a mobile unit were:

- necessity for an examinations planning,
- required availability of a specialized team,
- maintenance and quality control of the equipment,
- site preparation (including the space, communication and electrical connections and safety issues).

The main choice criteria were the investment and operating costs and the distance between associated hospitals, with the possibility of a short stay in the hospital equipped with the MRI unit.

The economic evaluation was performed from the hospital's perspective. Clinical equivalence between fixed and mobile MRI was assumed, which justifies a cost-minimization analysis. Assumptions included a 7-year depreciation of a 1.5 T unit. Initial investment costs of equipment go from €1,220,000 to €1,800,000 for a fixed MRI and from €1,920,000 to €2,610,000 for a mobile MRI with trailer (€1,700,000 to €2,310,000 without trailer). The baseline analysis used an investment cost of €1,500,000 for a fixed unit and €2,015,000 for a mobile unit with trailer. Maintenance costs were fixed around 8 to 10% of the purchase price due beyond a one-year guarantee. Materials range from € 121,000 (4,000 examinations a year) to € 181,000 (6,000 examinations a year). For the mobile unit, the option chosen was a rental contract for the truck and the driver. The staff includes 1 physician, 2 technicians, 1 general supervisor, 1 secretary and 1 assistant.

Table 35 displays the different cost items included in the study. From our information from the industry, costs are similar in Belgium.

Table 35 : Baseline costs in Paris (2002)

	Fixed	Mobile
One shot (subject to 7-year depreciation)		
1.5 T MRI investment	€ 1,500,000	**€ 2,015,000**
Additional equipment	€ 100,000	€ 100,000
Site preparation	n/a	**€ 180,000**
Building costs	**€ 305,000-460,000**	n/a
Operating costs (Yearly)		
Maintenance MRI *	(€0) €150,000	(€0) €150,000
Maintenance additional equipment***	€ 8,000	**€40,000**
Maintenance trailer **	n/a	**(€25,000) € 50,000**
Materials (incl. contrast medium) (6,000 exam.)	€ 152,000	€ 152,000
Truck rental (incl. driver)	n/a	**€ 30,000**
Staff	€ 288,300	€ 288,300

* Maintenace MRI: First year free - ** first year 50%=€22,500 - ***depends on the number of hospitals involved.

The results of the comparisons are shown in Table 36.

Table 36 : Costs of acquisition of a fixed MRI versus a mobile MRI

	Fixed	Mobile		Difference mobile – fixed	
Nb of hospitals involved		5	10	5	10
Year 1 - 4,000 exam.	€720,000	€1,041,000	€1,276,000	€321,000	€557,000
(with transport included) *	(€ 862,000)			(€ 179,000)	(€129,000)
Year 2 to 7 - 6,000 exam/year	€930,000	€1,251,000	€ ,486,000	€321,000	€1,165,000
(with transport included) *	(€1,122,000)			(€129,000)	(€365,000)

* shown only as example.

With five hospitals involved, 4,000 examinations the first year and 6,000 examinations the following years, the mobile option would lead to a total cost equal to €1,041,000 in year one and €1,251,000 per following year (respectively €1,276,000 and €1,486,000 for ten hospitals due to a multiplication of additional equipments). The same scenario with a fixed unit would save €321,000 each year. The higher the number of sharing hospitals is the higher the savings are, especially from the second year onwards.

The mobile unit was thus more expensive than the fixed one, especially due to the higher fixed costs. The results do not take the fuel of the truck into account, nor the potential costs associated with a ride trough Paris' narrow streets. No discounting was applied on the 7 years period (no global calculations on the whole period were made anyway).

Though, there are two financial advantages of a mobile unit from a hospital perspective. The first one is the cut of the patient transportation costs (indirect costs). In the example of the French geriatric hospitals, those costs are a hospital charge. As an important part of the magnetic resonance imaging is done in an ambulatory setting (85% in Belgium in 2004), transportation costs for the patient may be high. The second one is the possibility to divide the initial investment between different hospitals.

The existing facilities and staff can also influence the costs if the unit is mobile and hospitals prefer to employ their own staff (e.g. to facilitate communication inside the hospital). This is not the case if the staff of the mobile unit is permanent.

In 2002, 8 mobile units were in function (or in buying process) in France.

21.3 COST OF FIXED VERSUS MOBILE MRI IN CANADA

The Canadian Coordinating Office for Health Technology Assessment (CCOHTA) compared in 1995 the costs of mobile MRI with fixed MRI (1.0 Tesla). The cost information is somewhat outdated. Nowadays, more performant mobile MRI systems exist. Moreover, Canadian conditions are not entirely applicable to Belgium. For instance the calculation of patients' travel costs to a centre with a fixed MRI is assumed to be on average 240 kilometers, whereas the travel distance to a mobile unit would be on average 60 kilometers. In Belgium it is unlikely that patients would have to travel more than 30 kilometers to a centre with a fixed MRI scanner, certainly if the location of the 40 fixed MRI scanners that will be approved in 2007 will be located at places where the access to MRI scanners is still relatively limited.

The results of the cost calculation are presented in Table 37.

The total fixed costs of a 1.0 T mobile MRI was estimated at CA$2,210,000 to CA$3,215,000. This range fell completely within the range of the estimated fixed costs of fixed MRI, which was CA$ 2,085,000 to 4,130,000.

Annual operating costs are higher for the mobile MRI than for the fixed MRI (Table 37).

Table 37 : Baseline costs in Canada (1995)

	Fixed	Mobile (3 sites)
Fixed costs (total)	CA$ 2,085,000-4,130,000	CA$ 2,210,000-3,215,000
- 1.0 T MRI investment (configuration dependent)	CA$ 1,650,000 – 2,150,000	CA$ 1,650,000 – 2,150,000
- Mobile trailer	n/a	CA$ 350,000 –500,000
- Tractor	n/a	CA$ 105,000 – 115,000
Site preparation	n/a	CA$ 35,000-CA$50,000 OR CA$ 100,000-150,000
Building costs		
- New	CA$ 900,000-1,800,000	
- renovative	CA$ 350,000-650,000	
- radio frequency field	CA$ 85,000-110,000	
- Magnetic shield	CA$ 0-70,000	n/a
Operating costs (Yearly)	CA$ 705,000-810,000	CA$ 725,000-828,000
Maintenance facilities	CA$ 20,000-30,000	CA$ 5,000-8,000
Maintenance additional equipment (cryogens and magnet)	CA$ 35,000-40,000	CA$ 35,000-40,000
Service contract	CA$ 120,000-140,000	CA$ 155,000-180,000
Materials	CA$ 230,000-270,000	CA$ 230,000-270,000
Van driver and gasoline	n/a	CA$ 40,000-60,000
Staff	CA$ 150,000-180,000	CA$ 150,000-180,000
Equipment upgrades	CA$ 150,000	CA$ 150,000

The same organisation compared the estimated costs of a fixed MRI scanner in one hospital with a mobile MRI scanner for 3 hospitals with the same throughput of 2,080 scans per year (i.e. based on 1 scan per hour, 8 operating hours/day and 5 days/week). The results are presented in Table 38.

Table 38: Total cost of a fixed versus mobile MRI solution in Canada for a throughput of 2080 scans per year

	Fixed	Mobile (3 sites)	Difference mobile – fixed
Total fixed costs	CA$ 2,420,000	CA$ 2,700,000	CA$ 280,000
Total operating costs	CA$ 790,000	CA$ 890,000	CA$ 100,000
Travel costs patients	CA$ 329,000 (based on average of 240 km one way)	CA$ 83,000 (based on average of 60 km one way)	- CA$ 246,000

With a throughput of 2,080 scans per year, the additional fixed cost per scan is CA$135 higher for mobile MRI scanners than for fixed MRI scanners and the additional operating cost is CA$48 higher.

In Canada, it is especially the patients' travel costs that make the mobile solution attractive from the patients' perspective. A saving of CA$118 per scan in travel costs could be realised with the mobile solution compared to the fixed solution. In Belgium, it is unlikely that similar savings could be realised, given the much smaller geographical area and the shorter distances to fixed MRI scanners in Belgium.

Key points:

- **The management and service of a mobile MRI scanner can either be outsourced to a service provider (with or without technical and/or medical personnel) or kept by a single or consortium of hospitals. The financial implications for the hospital depend on the implementation model chosen.**
- **The initial investment costs are higher for fixed than for mobile MRI systems.**
- **Yearly operating costs are higher for mobile than for fixed systems.**
- **In Paris, the yearly total cost of mobile MRI is higher than the yearly total cost of fixed MRI.**

21.4 THE BELGIAN CONTEXT

Part 2 explained the current availability of (fixed) MRI services in Belgium. In view of the 40 planned additional licenses, a critical analysis of the potential role of mobile MRI scanners would be useful to guide decisions about the allocation of the additional MRI scanners. Hospitals that will not be eligible for a fixed MRI, for instance, might be eligible for a mobile MRI solution, when involved in an association with other hospitals that are not eligible for a fixed MRI (e.g. because of insufficient case load). The case load for the association may be sufficient to justify one additional MRI. In principle, this can still be one fixed MRI, but this does only make sense if the hospitals are geographically clustered.

The questions that need to be answered is how feasible it is to provide MRI services in virtually all Belgian hospitals and how desirable such a situation would be. The review of the possibilities of substitution of CT for MRI may help in answering these questions.

There are currently 164 approved CTs in Belgium, based in 116 hospitals. Elements that may be important are the extent to which existing equipment in the nearest hospital may guide the imaging procedure performed, rather than the most effective procedure. Moreover, for the patient there may be a crucial difference between CT and MRI, besides the quality of the imaging. In CT the patient is exposed to radiation, whereas MRI operates with a magnetic field. For MRI, one potential patient issue may be the contrast agent that is injected. This agent is, however, quite safe. A second patient issue is that MRI cannot be performed in patients with ferro-magnetic implants as magnetic fields influence the proper functioning of these devices.

Key points:

- **The main issue for Belgium is whether mobile MRI would increase efficient use of MRI and CT services.**
- **A large number of hospitals in Belgium already have a fixed MRI. The question is whether addition of mobile units in order to provide MRI in virtually all Belgium hospitals would improve effectiveness of care.**

21.5 ADVANTAGES AND DISADVANTAGES OF MOBILE MRI

Although fixed MRI and mobile MRI scanners are technologically identical, some advantages and disadvantages of mobile MRI scanners can be identified.

21.5.1 Advantages of mobile MRI

From the perspective of the hospital, an advantage of a mobile MRI solution is that the initial installation takes less time. While for the installation of a fixed MRI special rooms or buildings need to be constructed, mobile MRI scanners on trailer can be placed outside the hospital and connected to an energy source in about 1 hour. This may offer an advantage in case of acute (excess) demand for MRI at a specific site. This advantage disappears, however, in the long term, once a fixed MRI is installed.

Costs and services can be shared between hospitals. If one hospital has an insufficient case load for running a fixed MRI at full capacity, the costs of a fixed MRI may be too high to justify the installation of a fixed MRI scanner.

Mobile MRI systems allow a flexible planning of scanning services of different hospitals in function of volume requirements. Rapid response can be given to temporary excess demand for MRI services. We note that coordination of planning may at the same time be a disadvantage, for instance, if two or more hospitals have a simultaneous increased acute need for MRI capacity.

An advantage of mobile MRI from the patient perspective is that travel time and costs may be further reduced. In the Belgian context, where there is already a wide geographical distribution, the operation of mobile MRI would make access even easier.

21.5.2 Disadvantages of mobile MRI

From the hospital perspective, a possible disadvantage of a mobile MRI solution is that the MRI is not always located at the site and is therefore not available for emergencies. This applies only to hospitals that do not use a mobile system to temporarily capture excess demand on their fixed MRI.

A second disadvantage may be that a hospital without a fixed MRI does not permanently have the appropriately qualified staff available to run the mobile MRI or to read the images. Staff requirements for running a MRI service are imposed by the Belgian law[2]. Service providers have responded to this potential problem by offering an all-in formula,

[2] Art.46 van de wet van 27 april 2005 betreffende de beheersing van de begroting van de gezondheidszorg en houdende diverse bepalingen inzake gezondheid, B.S. van 20.05.2005.

where the mobile MRI scanner is rented with staff. However, reading magnetic resonance images often requires specific skills, especially for specialised indications. For a hospital that uses a mobile solution as the sole solution to provide MRI, it may not be feasible to hire sufficiently qualified staf permanently.

The operating costs of a mobile MRI are higher than the operating costs of a fixed MRI. This is related to the costs associated with the transport of the MRI (driver, fuel, insurance) and maintenance. Mobile MRI systems also require more frequent servicing, because transport may cause some vibration that may impact upon the functioning of the MRI. Quality assurance ckecks must be performed more frequently.

Additionally, the required logistics may pose a problem. On the one hand, the trailer needs to be placed at a sufficiently isolated location, e.g. on a parking space, because passage of haulage (heavy trucks) may distort the images. On the other hand, the trailer should be placed sufficiently near the hospital to allow electrical supply and the building of a bridge between the hospital and the trailer. Stand alone mobile MRI systems, i.e. where a bridge is not possible, have major disadvantages: imaging is not safe in patients requiring gadolinium chelates injections or in hospitalised patients and if there is no changing room stand-alone MRI involves a major discomfort to the patient[3].

Due to the limitation of 1.5T scanners in mobile systems, mobile MRI cannot be used for certain emerging indications that require a 3.0T MRI (e.g. in neuroradiology). It is to be expected, however, that – if the indications for 3.0T MRI increase – the possibility of building 3.0T systems in a mobile trailer will be investigated, if there is a sufficiently large market for mobile MRI. As of yet, it is neither feasible nor useful from a clinical point of view to expand the use of 3.0T MRI scanners. They are currently used only in specialised centres.

From the patient's perspective a possible disadvantage of mobile MRI systems is the increased incidence of claustrophobia. The interior space of a mobile unit is smaller than that of fixed units. The incidence of claustrophobia in mobile and fixed MRI scanners was found to be up to 10% in mobile MRI units compared to 1-4% in fixed units.[793]

Key points

- **Advantages of mobile MRI systems from the hospital perspective are shorter installation times, lower initial investment, (potential) rapid response to acute excess demand for MRI services and cost sharing between hospitals. From the patient perspective, travel time may be shortened when mobile MRI is provided in the nearest hospital.**
- **Disadvantages of mobile MRI from the hospital perspective are potential unavailability of MRI for emergencies (when no fixed MRI is available in the same hospital), potential unavailability of qualified staff and higher operating costs. Scanning in a mobile MRI leads to more discomfort to both patients and personnel.**

21.6 FINANCING

Initial investment costs of fixed MRI scanners are reimbursed by the government by means of a fixed fee per year for a period of 7 years. The Belgian law requires a re-investment of 50% of the initial purchasing price within the 10 years of the purchase to update the technology.(Koninklijk besluit van 25 april 2002 betreffende de vaststelling en de vereffening van het budget van financiële middelen van de ziekenhuizen, *B.S.* 30 mei 2002) MRI units that do not comply with this rule, lose their fixed reimbursement per year for MRI investment costs. Units that do re-invest 50% of the initial purchasing price within the period foreseen, get a fixed reimbursement for another 7 years.

In order to guarantee good quality of the MRI services, the rules for updating the equipment within successive periods of 7 years should also apply to mobile MRI

[3] in some cases, the lift will be used as the basis for building a changing room. In this case, patients in a wheelchair or confined to bed cannot enter the trailer.

equipment. In case of outsourcing MRI services to a third party, the service provider takes care of the replacement of old equipment.

Depending on the implementation model that is chosen (mobile MRI in own management or rented), the financial risk shifts. With a mobile unit kept in own management the financial risk lies entirely with the hospital (and the government who actually finances part of the equipment through the reimbursement mechanism). With a rented mobile MRI unit, the private company carries the risk. This risk is obviously calculated in the prices charged for rental of a mobile unit.

Purchased mobile MRI kept in own management by one or a consortium of hospitals implies a specific cost structure than the cost structure of fixed MRI systems. Consequently, the financing of such solutions should be different. Investment costs are lower, but yearly maintenance costs are higher for mobile MRI solutions. The variable cost component is hence larger for mobile MRI than for fixed MRI systems. This should preferably be reflected in the reimbursement system to ensure efficient use of resources.

Also rented mobile MRI solutions would require a different financing system than the financing of fixed MRI, due to the differences in cost structure. The reimbursement system would have to rely more on variable reimbursement than on reimbursemend of fixed costs (through the hospital budget) + variable costs (fee for service).

Key points

- **Mobile MRI solutions would require a revised reimbursement system compared to the current reimbursement of fixed MRI.**
- **A larger component of the total reimbursement will be variable for mobile MRI than for fixed MRI.**

Part 4: General conclusions and recommendations

22 GENERAL CONCLUSIONS

22.1 CLINICAL EFFECTIVENESS

In this project, the purpose was to assess the clinical efficacy of MRI in daily practice using a well-defined search strategy. For most subspecialisms, comparisons between CT and MRI were retrieved from the literature, but occasionally digital subtraction angiography or non radiological diagnostic procedures were compared to MRI.

Overall, MRI provides high-quality images showing the visually impressive technical capability of the technique. The technical improvements have led to an increase in the potential indications. However, quantitative rigorous assessments of the clinical effect of MRI in large case series or well-controlled comparison trials are still missing. Most studies suggest more research to investigate the benefits of MRI.

The known high quality of MRI and the widespread use of MRI make it more difficult to set up such studies. It is generally considered difficult to measure the effect of MRI on patient management and outcome.

One difficulty is the rapid technological advance. It is therefore not uncommon to find literature findings to be outdated while having been published only 4 or 5 years ago.

One could therefore even argue that the findings in this report may not be contemporary enough to be useful for clinicians.

Despite the general lack of evidence that MRI affects patient management and outcome, recommendations can probably be put forward for a limited number of applications, based on the literature findings and expert opinions. This would mean a change in part of the currently available guidelines.

With the additional announced 40 MRI units, Belgium will be ranked among the countries with a high number of MRI units/million people, but there are other Western-European countries with higher supply rates. Belgium has a very high number of CT units and the volume of CT examinations increased more than the volume of MRI examinations between 2001 and 2004. The ratio of CT/MRI examinations is 3.2, which is among the highest reported in the literature.

22.2 FINANCING OF MRI IN BELGIUM

The financing systems of MRI and CT activity differ considerably in Belgium without a clear explanation. Harmonisation of the financing systems is recommended but more research is necessary prior to the implementation. In the meantime, improvements to the current financing system can be performed.

22.3 MOBILE MRI

Although mobile MRI scanners are technololgically identical to fixed MRI scanners of the same field strength, working with mobile MRI scanners has a number of disadvantages: working surface within the trailer is limited leading to more discomfort to personnel and patients, there are a number of logistic requirements, MRI may be unavailable for emergencies and operating costs are higher. The advantages of mobile MRI solutions are the lower Initial investment costs, the increased accessibility to MRI services in regions with limited or no supply of fixed MRI scanners, the potential rapid response to acute excess demand and the possiblility of cost sharing between hospitals. The advantages and disadvantages of mobile MRI in the Belgian context need to be balanced before decisions about the appropriateness of mobile solutions in Belgium can be taken. There is insufficient evidence to conclude the advantages outweigh the disadvantages or otherwise.

23 POLICY RECOMMENDATIONS

23.1 ADAPTATION OF EXISTING IMAGING GUIDELINES

An update of the "Belgian Guidelines for Efficient Use of Radiology and Medical Imaging" based on the evidence for Magnetic Resonance Imaging (MRI) provided in this Health Technology Assessment report is recommended. An update is needed in terms of the indications for which medical imaging should be used and in terms of the optimal imaging technique for each indication.

The RIZIV/INAMI takes care of the distribution of these referral guidelines. The latest version dates from 2004 (http://inami.fgov.be/care/nl/doctors/promotion-quality/guidelines/index.htm and http://inami.fgov.be/care/fr/doctors/promotion-quality/guidelines/index.htm). As radiology is a fast evolving field of medicine, further bi-annual updating and scientific validation of the guidelines is recommended.

Although quantitative rigorous assessments of the clinical impact of MRI in well-controlled comparison trials are still missing, there is evidence in the literature that supports the use of MRI in the diagnostic work-up of a number of indications. To stimulate substitution of Computed Tomography (CT) by MRI a number of indications can be listed for which MRI is the modality of choice and CT should no longer be performed, even if MRI is not available in the hospital or if there is a waiting list for MRI. In some of these indications an emergency MRI can be needed (e.g. suspicion of spinal cord compression).

For the following examinations MRI is the preferred imaging technique. CT should in general no longer be performed in these cases:

NEURORADIOLOGY

- clinical suspicion of demyelinating pathology (multiple sclerosis)
- partial complex seizures
- acute low back pain with neurological alarm symptoms (e.g. cauda equina syndrome, paresis or palsy)
- clinical suspicion of spinal cord lesion or spinal cord compression
- spinal metastasis in patients with known primary malignancy (detection; differentiation from fracture, osteoporosis; planning irradiation)
- cranial nerve palsy (except n. VII and VIII)

HEAD AND NECK RADIOLOGY

- nasopharyngeal cancer
- clinically suspected internal derangement of the temporomandibular joint

MUSCULOSKELETAL RADIOLOGY

- detection and grading of avascular necrosis of the hip
- peripheral nerve disease or entrapment (e.g. ankle impingement syndrome, tarsal tunnel syndrome)
- osteomyelitis
- soft tissue infection and fistulae
- bone marrow diseases
- local staging and follow-up of bone and soft tissue tumours
- postoperative carpal tunnel syndrome

- game keeper injury (thumb metacarpophalangeal ulnar collateral ligament injury)

ABDOMINAL RADIOLOGY

- To correct the misdiagnosis from CT and US in focal liver steatosis
- Detection of hepatic iron (hemochromatosis, hemosiderosis)
- Detection of common bile duct stones
- Preoperative exam before gallbladder resection
- Visualization of choledochus cysts
- Establishing changes in the biliary ducts in primary sclerosing cholangitis
- Identifying the presence or the level of obstruction in malignant invasion of the biliary tracts
- Evaluation of anal fistulas
- Determination of the loco regional extent in rectum carcinoma
- Congenital anomalies of the uterus where US is inconclusive
- Staging cervix carcinoma (loco-regional extent of tumour)

Key points

- **The Belgian guidelines for medical imaging need to be revised according to up-to-date evidence on the appropriateness of MRI in different indications.**
- **Revision of the guidelines every two years is recommended.**
- **For some indications there is strong evidence that MRI is superior to CT. In these cases, CT should no longer be performed.**
- **The absence of an MRI scanner in a hospital or waiting lists for MRI does not justify non-compliance with the guidelines for appropriate use of medical imaging, certainly not for elective indications.**

23.2 IMPLEMENTATION OF REFERRAL GUIDELINES

Existing referral guidelines (ref. Consilium Radiologicum) were disseminated by post to all Belgian physicians by RIZIV/INAMI in 2004 to be used voluntary by the referring physicians. Legislation at the European and national level (directive 97/EURATOM and K.B. 20 July 2001) imposes the use of referral guidelines in order to reduce the exposition of patients to radiation. However, major implementation problems exist and the impact of these guidelines on prescription behaviour is very limited as these guidelines were not mandatory and not accompanied by supportive measures to guarantee a more stringent use.

For practical implementation of the abovementioned imaging referral guidelines (for optimal use of MRI, and radiology in general), the broad implementation of an expert computing system for requesting radiological examinations would be a powerful instrument. Such software could suggest to the requesting physician which radiological exam to order according to the guidelines given a suspected diagnosis, thereby avoiding unnecessary exams and inefficient use of resources. Such intelligent ordering systems exist at Harvard University and are routinely used in Brigham and Women's Hospital and other hospitals affiliated with the Harvard University (Massachussetts General Hospital). When referring physicians order inappropriate examinations, the system suggests a better exam or proposes to contact a radiologist.

Such a system would also allow a feedback of the "requesting profile" and the percentage of examinations requested according to the guidelines at e.g. an annual base.

Giving feedback on individual referral patterns and prescription profiles is a soft and slow approach to the implementation of guidelines. In the long run, however, convincing prescribers to systematically use referral guidelines may turn out to be a cost-effective implementation approach. Universities have a major role to play in changing attitudes of medical doctors in training. They should familiarize medical students much more with existing guidelines. Also in continuing medical education programs, appropriate use of medical imaging should become a priority.

Key points

- **European en national legislation for radioprotection impose the use of referral guidelines**
- **An expert computing system, incorporating the referral guidelines, would be a helpful tool for prescribers to select the most optimal radiological examination for a given suspected diagnosis. This system would allow yearly feedbacks of individual referral patterns and prescription profiles.**
- **Medical students should be trained in using the referral guidelines during their basic training. Appropriate use of medical imaging should become a priority in continuing medical education.**

23.3 QUALITY ASSURANCE

Apart from voluntary internal quality control measures, little attention is given to quality assurance in medical imaging, except for the regulation in relation to the radiation levels in the CT-field. Several measures could be introduced to promote quality assurance.

First, a system of site visits could be installed where all hospitals with MRI and/or CT-units are visited (e.g. once every five years) to check whether they are meeting certain quality standards. Criteria for quality assessment may include the number of scans done per hour (the daily average should not exceed 6 per 2 hours of examination time), the degree to which requests are consistent with the guidelines, the quality of the technicians, the technical quality of the equipment, etc…Units that do not comply with these criteria may lose their accreditation. The abovementioned referral guidelines were previously developed at the European level, mainly as a measure for radioprotection. A visitation commission should be composed of the currently competent governmental bodies with involvement of some of the foremost experts in radiology, possibly foreigners. A quality assurance system solely based on peer review by radiologists is bound to have a limited impact.

Second, a national training programme for radiologists and/or technicians (radiographers) could be set up by university faculties in their continuing professional development programs, in the first place oriented towards the hospitals that start with their first MRI-unit. Support by radiologists with a large experience in MR imaging should be encouraged, especially for reporting and diagnosis with MRI. Systems such as teleradiology with expert centres, or local advice by experts travelling from one starting centre to the other, may be useful.

Third, in each hospital a system of regular (e.g. weekly) conferences could be organised between providers and prescribers of MRI and CT-scans to discuss the appropriateness of the requests, the quality of the information provided on the standard request, the accuracy of the diagnoses, etc… Some large hospitals already organise these conferences, but it might be more difficult to enforce them in smaller hospitals. The requests and reports can be compared with the data from the discharge abstracts and/or follow-up data, etc…

Fourth, concrete quality assurance measures could be legally enforced. For example:

- Allowing the installation of high quality MRI scanners (1 Tesla or higher) only. Exceptions include a second MRI scanner, scanners for intensive care MRI or surgical use.
- Limiting the installation of dedicated MRI scanners (e.g. cardiac only/head only/knee only MR unit) to centres that already have a total body MRI scanner.
- Limiting certain "difficult" exams to expert centres, such as
    - Cardiac and functional MRI (only to be performed in centres with more than 1 MRI unit and/or a department of neurosurgery/interventional cardiology to guarantee the link with therapy)
    - Follow-up of tumour pathology, especially after treatment of bone and soft tissue sarcomas and head and neck tumours
    - Exams under general anaesthesia (only to be performed if there is an adequate MRI compatible monitoring system)
    - MR spectroscopy

The main allocation criterion for these specialised examinations should be the link between the quality of the imaging procedure and interpretation of the results and the available multidisciplinary therapeutic expertise in the hospital.

Key points

For quality assurance, different measures could be taken:

- **MRI and CT site visits could be organized by a visitation commission to check for compliance with quality standards.**
- **Experienced radiologists could train and support radiologists and/or radiographers in diagnosing with MRI and reporting of findings, especially in hospitals installing a first MRI scanner.**
- **Regular, e.g. weekly, conferences could be organized in each hospital between providers and prescribers of CT and MR examinations to discuss the appropriateness of referrals for MRI.**
- **Installation of full body and dedicated MRI scanners could be regulated: allowing the installation of high quality MRI scanners (field strength of at least 1 Tesla, apart from some exceptions) and limiting the installation of dedicated MRI scanners to hospitals that already have a total body MRI scanner.**
- **Certain difficult examinations could be limited to expert centres, based on the available multidisciplinary expertise in the hospital.**

23.4 FINANCING OF MRI IN BELGIUM

23.4.1 Recalibration of the nomenclature

It is recommended to reconsider certain values of the existing nomenclature codes for MRI based on workload and within the budgetary restraints. The reimbursement needs to be increased for certain very time consuming and logistically complex MR examinations such as MR under general anesthesia, MR of extremities or MR of primary bone and soft tissue tumours or tumour simulating lesions, and whole body MRI for specific diseases such as multiple myeloma, neurofibromatosis and other multi-organ systemic or congenital diseases. Other reimbursement codes could likewise be reduced, e.g. MRI spine.

What type of codes ought to be used, and what the value of these codes should be, is to be negotiated within the RIZIV competent bodies. The same recommendation applies to the CT-nomenclature. However, it is not to be expected that such a recalibration alone will lead to a more efficient use of technology from the health insurance point of view. Structural changes in the financing system and planning of MRI may be needed to improve efficiency in resource allocation for MRI.

23.4.2 Planning of MRI supply

Cost containment and pursuing efficient use of MRI and CT may urge decision makers to control supply of technology or at least to restrain the number of scanners financed.

In the short run, decisions on the number of scanners needed and their allocation cannot be based on case-mix parameters for ambulatory patients, as data on case-mix for ambulatory patients are simply not available (yet). Alternative allocation parameters should be considered. The number of scanners in the hospital, the number of examinations currently performed per scanner and the number of patient contacts in ambulatory care are obviously bad parameters. They would perpetuate possibly existing disequilibria or create incentives for over-use.

Instead of looking at the number of patient visits, the number of patients ("number of heads") coming to the hospital for specialty consultations could provide a proxy for local needs and attractiveness of the hospital. Patients visiting the hospital only for imaging or other diagnostic procedures or for an emergency should not be taken into consideration as this would bias the parameter as a proxy for need and attractiveness. The scanner(s) can hence be allocated according to the number of patients treated in the hospital. Other proxies for a rational distribution of technology based on population density and geographical proximity can possibly be found.

Currently, compared to other countries, there is a clear oversupply of CT scanners in Belgium. An equitable distribution of MRI and CT should take into account the ratio of CT/MRI. In those areas where the ratio exceeds the national average, an MRI should only be financed conditional upon closure of CT scanning facilities.

23.4.3 Structural changes in the financing system

Not a single financing system is to be preferred above all others. Each system has its limitations. Therefore, the following alternatives are described as options for policy makers. Yet, some options have more potential to stimulate appropriate use of resources.

23.4.3.1 Harmonising CT and MRI financing

As described in chapter 2, the cost structure of the MRI-technology differs somewhat from that of CT-technology (e.g. the use of contrast material, upgrading costs, examination time) but the differences are too small to justify the current duality in financing of CT and MRI. The total costs related to CT-scanning are currently mainly financed via the physician remuneration system, while part of the MRI-related costs is financed via the hospital budget. It is to be recommended that the financing systems for

both technologies are harmonised, as is the case in almost all other countries for which information was available in this study.

23.4.3.2 Financing fixed costs of equipment

Financing fixed costs of equipment (investment costs, capital costs and general operating costs) through a lump sum as part of the hospital budget can be considered for scanners allocated to hospitals according to, for instance, the number of patients visting the hospital, as suggested above. A similar approach is already applied to other medical imaging techniques such as Positron Emission Tomography (PET) scanners.

23.4.3.3 Financing variable costs of imaging

Variable costs of imaging include costs of consumables and physicians' fees. Financing fixed costs through the hospital budget and variable costs trough the "nomenclature" seems to be the option that is most in line with the cost structure of both CT and MRI.

The current fee-for-service system for radiologists and lack of financial responsibility of prescribers for CT- and MRI-examinations, however, preclude the development of incentive mechanisms to stimulate appropriate use and discourage inappropriate use of medical imaging procedures.

With a fee-for-service reimbursement of physicians a financial incentive persists to increase the number of examinations. In a setting without shortage of supply, a system that combines a lump sum and a fee-for-service gives no clear incentive towards appropriate use of technology. In countries where radiologists receive a financing less dependent on the number of examinations this problem is much less striking. Therefore, other incentive mechanisms for appropriate use of technology should be sought that fit in the Belgian context. A distinction between reimbursement for hospitalised and ambulatory patients is inevitable, as the information that may serve to guide the reimbursement available for hospitalised patients is much more elaborate than for ambulatory patients.

For **hospitalised** patients (including one-day treatments in hospital), an (all-in) DRG-based financing system may be an option. This system turned out to be feasible in other countries. DRG-financing is consistent with the idea that medical imaging procedures, as other diagnostic procedures, are in the first place meant to find the most efficient treatment for a patient. A potential disadvantage of a DRG-financing of MRI and CT is that the financing is no longer earmarked for specific radiological procedures. This might induce providers to cut down on expensive services or postpone necessary investments. It can lead to waiting lists if no market-driven incentive (e.g. competition between hospitals) is present. If financing of fixed equipment costs is separated from the financing of variable costs and physician's fees (as suggested in 1.4.3.2), fixed imaging costs should obviously be excluded from the DRG calculations.

Case mix-based (all-in) financing can, however, not easily be applied to MR imaging performed on an **ambulatory** basis – about 85% of the total number of MRI-examinations. For ambulatory patients, no registration of diagnoses is currently done in Belgium. If a DRG-based financing is considered for hospitalised patients, other financing mechanisms should be worked out for ambulatory patients. If decision makers want to reform the financing of ambulatory imaging based on case-mix, the mandatory registration of established as well as suspected diagnoses or syndromes will be inevitable. Piloting and implementation of imaging related registration systems will take several years, however, and the acquired data will always lag behind new indications for MRI, that sometimes can replace other (invasive and/or sometimes more expensive) techniques (e.g. invasive angiography, endoscopy, conventional radiography, scintigraphy, etc.)

An additional issue for ambulatory imaging is that patients are referred to a MRI centre by a prescriber who has no reason to rationalise his prescriptions for MRI in the current system. The radiologist, who is paid a fee-for-service, rarely refuses to do an MRI as prescribed. This is due to (1) the practical organisation of MR imaging for ambulatory patients and (2) the financial incentive induced by the fee for service system.

It is hardly thinkable that a radiologist would send a patient back home if he believes the prescription is inappropriate for this patient. This would frustrate the patient, who may have been waiting for weeks to get his MRI and is against the personal financial interest of the radiologist.

The radiologist receives a consultancy honorarium over and above his regular fee-for-service. This additional honorarium is in principle meant to evaluate the appropriateness of a prescription. In the current situation, it can be concluded that the consultancy honorarium in general is not meeting its objective. The consultancy honorarium could, however, be used more effectively and modulated to stimulate the appropriate use of MRI and CT. Whenever a prescription for MRI or CT falls outside the referral guidelines, as defined by the Consilium Radiologicum (cfr infra), and the imaging is nevertheless performed, no consultancy honorarium can be charged. For procedures that comply with the guidelines or procedures that are refused by the radiologists because they are deemed inappropriate, a consultancy honorarium is allowed. This system will stimulate feedbacks to prescribers by the radiologists (cfr 1.5) but can only work if both prescriber and radiologist have ready access to updated guidelines. and comply with them. Given the (limited) existing waiting lists for ambulatory patients, early evaluation of the request would allow early annulation of possible appointments, thereby avoiding frustration of the patients.

This leaves the question open what to do with the hospitals that do not have a MRI-unit. It is very likely that in these hospitals patients will not benefit from the increased number of MR units in Belgium and still undergo inappropriate CT examinations, with its negative radiation effects. Furthermore, referring physicians might not always be aware of the technologies available in nearby hospitals. Before making any policy-proposals, more information about the utilisation and referral patterns in those hospitals is needed. More specifically, it is recommended that an analysis is made of the ratio of CT-scans performed on request by the specialists working in a given hospital without an MRI divided by the number of referrals by these specialists to other institutions in order to perform an MRI-examination by type of scan.

Key points

- **The value of some CT and MRI nomenclature codes needs to be revised. Reimbursement of specific complex and time-consuming procedures should be upgraded while others should be downgraded.**
- **Efficient use of expensive medical imaging procedures calls for appropriate and controlled allocation of technology supply, taking into account local needs, attractiveness of hospitals and the ratio of CT/MRI in the geographical area.**
- **Financing mechanisms for CT (mainly financed by physician remuneration) and MRI (partly financed by the hospital budget) should be harmonized.**
- **The current fee-for-service system for radiologists and lack of financial responsibility of prescribers for CT- and MRI-examinations preclude the development of incentive mechanisms to stimulate appropriate use and discourage inappropriate use of medical imaging procedures.**
- **One option that can be considered is to finance fixed costs through the hospital budget and variable costs by case-mix financing for hospitalised patients and by fee-for-service for ambulatory patients.**
- **In the long run, if case-mix financing for ambulatory examinations would be considered, diagnostic registration systems for ambulatory patients should be developed.**

23.5 RESPONSIBILITY OF THE PRESCRIBER

Radiologists often argue that the prescribers are the driving force behind the increase of MRI- and CT-examinations. Increases in the number of CT and MRI scanners will however also lead to more supplier-induced demand. Both phenomena in combination with weak cost-containment will lead to rising health care costs.[794] One option to contain the upward trend is to give the prescriber full financial responsibility for his/her MRI- and CT-requests. A problem with this approach in Belgium is that a whole rethinking of the current referral and financing system would be needed. Furthermore, there is currently little information per prescriber about the medical conditions (case-mix) of his/her ambulatory clients. Some may prescribe more because the medical characteristics of their patients justify them to do so.

Due to the rapid developments in imaging technology (e.g. diffusion imaging, diffusion tensor, functional MRI, virtual endoscopy, spectroscopy, etc.) many physicians (GPs and specialists) might not really be up to date about all the implications of the examination they have requested (risk of false positives, false negatives, etc…). The utility and possible impact on patient management of an MRI (and CT) also highly depends on the pre-test probability.

A second option to increase appropriate use of CT and MRI is to delegate the choice of the imaging procedure to the radiologist. In this approach, the prescriber indicates on a standardised request form the clinical specifications and the suspected diagnosis and refers the patient to a radiologist. The radiologist decides on the most appropriate imaging technique for confirmation of the diagnosis, based on the referral guidelines.

A third option to regulate prescription behaviour is to restrict certain types of tests to physicians with specific qualifications. For instance, referral for a cardiac MRI could be restricted to cardiologists. The advantage is that the requesting physician in principle better understands the results of the test he/she has ordered and often there will be a direct link with therapy. However, there are several arguments against this. Little is know about the prescribing qualities of different specialty groups when it comes to MRI- and CT-technologies. There is a perception that not all physicians know and regularly consult referral guidelines. Further research is needed before making policy statements in this area.

Rather than denying the right to prescribe MRIs to any group of physicians, an alternative option is to link the ambulatory imaging referral procedure more explicitly to the national referral guidelines. Derogation from a referral guideline is possible but should be motivated based on the clinical condition of the patient. In this scenario, the use of the referral guidelines is made mandatory. Co-responsibility of the prescriber as well as the radiologist is needed in the Belgian context. The following implementation issues should be envisaged:

- Updated referral guidelines should be readily available both in a handy booklet and electronically for all prescribers.
- On the prescription form, the prescriber clearly describes the clinical condition that justifies the appropriateness of the imaging referral outside the guidelines
- In his report, the radiologist confirms or adds that the imaging was performed outside guideline indications including a feedback on the appropriateness of the referral. In addition, the radiologist codes the suspected and established diagnoses allowing peer review and auditing.
- At the local level, communication possibilities between prescribers and radiology departments should be present and easily accessible, allowing the prescriber to ask the advice ('consultancy') of the radiologist before sending the patient to the radiology department. Especially for referrals outside guidelines, this would also permit to arrange substitution between CT and MRI and vice versa.

In order for such a system to have some impact, capacity building for dissemination and feedback, peer review and auditing are necessary preconditions. Possible financial

consequences should be clear. Many partners are involved: RIZIV/INAMI, the Consilium Radiologicum, radiologists' and other speciality associations, radioprotection authorities, etc… Reluctance and resistance from both the prescriber and radiologist side is to be expected.

Key points

- **Updated referral guidelines should be readily available both in a handy booklet and electronically to all prescribers and radiologists.**
- **Different options exist for stimulating appropriate use of CT and MRI. Either the prescriber refers to the radiologist, who choses the most appropriate imaging for a specific suspected diagnosis following the guidelines, or standardised referral forms are used for imaging requests, allowing the radiologist to verify compliance with the referral guidelines.**
- **Imaging referrals outside the guidelines should be justified by the prescriber. The radiologist should confirm or reject the appropriateness of the referral according to the guidelines. In addition, the radiologist codes the suspected and established diagnoses allowing peer review and auditing.**
- **Communication between prescribers and radiology departments and advice ('consultancy') from the radiologist before referral should be fostered. This communication would also permit to substitute CT for MRI and vice versa.**

23.6 MOBILE MRI

Assessment of the need for mobile MRI in Belgium should be guided by the following considerations:

- What might be the advantages in terms of productive efficiency: can economies of scale be fully exploited, and can this better be done with mobile than with fixed MRI systems? In other words, are some fixed MRI systems sub-optimally used? Here the (expected) internal demand for MRI should be taken into account. The break-even point, where average total costs of mobile MRI are equal to the costs of fixed MRI, has been calculated to be in the region of 1600 to 2600 MRI scans per year, depending on the cost of mobile provision, and the average cost of fixed MRI. This means that if the excess demand of the MRI centre of that order of magnitude, or the demand in a hospital without an MRI is less than 1600 MRI scans per year, there are stronger arguments for a mobile MRI than for a fixed MRI. With a larger (excess) demand for MRI, it is better to chose for a fixed MR solution from a cost point of view.
- Can economies of scope be fully exploited when mobile MRI solutions are installed? That is, do all hospitals in an association for mobile MRI have the qualified staff to ensure appropriate use of the mobile MRI scanner (imaging in different indications) and to guarantee efficient use of the equipment during the days/weeks the mobile system is installed near the hospital?
- Does mobile MRI increase the patient accessibility to MRI services in Belgium? A relevant question to be posed is whether there is a sufficient geographical spread of fixed MRI scanners so that all patients have access to MRI within a radius of 20 kilometres.

23.6.1 Economies of scale

Some hospitals with an MRI are faced with waiting lists, given the current number of fixed MRI scanners in Belgium. Approval of an additional 40 MRI scanners is planned in

2006. The likely impact of this increasing capacity is that waiting lists will initially diminish or disappear to return in due time: indications will expand and substitution of CT for MRI may continue.

The operating costs of a mobile MRI scanner are higher than those of a fixed MRI scanner. If fixed MRI scanners are expected to be fully occupied in the future, it may be economically more sound to chose for fixed solutions instead of mobile solutions. In the long term, mobile systems are more expensive than fixed systems.

23.6.2 Economies of scope

It is questionable whether all hospitals have sufficiently qualified staff to perform MRI scanning for all indications. Especially for smaller hospitals that currently do not have a MRI scanner, this problem may arise.

23.6.3 Accessibility

The geographical spread of fixed MRI is sufficiently large in Belgium to guarantee good access to services, except in the region of Luxemburg, where access to a fixed MRI is not guaranteed within a ray of 20 kilometres for all inhabitants.

If the introduction of mobile MRI scanners is considered, approval should be linked to associations of hospitals. A single hospital should not be allowed to install a mobile MRI for de facto permanent use. Such a situation is economically sub-optimal.

There are, however, a couple of arguments in favour of mobile MRI. First, mobile MRI may be useful for patients that cannot be moved and that are hospitalised in a centre without MRI. However, these cases are rare and cannot justify the high cost associated with running a mobile MRI. The case load would be insufficient to use the mobile system efficiently.

Second, mobile MRI may be useful as a temporary solution when a fixed MRI is being rebuilt.

Key points

- **Elements that need to be taken into account in considering mobile MRI in Belgium are the minimal scale (volume) required to let a mobile unit function optimally, the scope of services that can be provided with the available staff and the accessibility to MRI services in Belgium.**
- **No strong arguments on one of these elements can be found in favour of introduction of mobile MRI systems in Belgium.**
- **Mobile MRI should be reserved as temporary solutions if a fixed MRI is temporary out-of-service.**

APPENDICES:
Health Technology Assessment of Magnetic Resonance Imaging

APPENDIX 1: LEVELS OF EVIDENCE

Efficacy is defined as the probability of benefit from a medical technology to individuals in a defined population under ideal conditions of use [795]. In other words: can the diagnostic test work? This is not the same as effectiveness, which assesses the test's ability to work in the real world: does it work in clinical practice? Finally, in efficiency the test's financial implications are considered: is it worth it? [796]

The model is characterized by a change in perceived goals. It is hierarchical: on one extreme are endpoints describing only the technical performance of the test, on the other extreme are endpoints pertaining to the value of the diagnostic technology to society. If a test performs poorly at one level, it is unlikely to perform well at a higher level. The reverse, however, is not true: increases in the technical performance of a test will not necessarily guarantee improvement at a higher level, for example effect on patient outcome.

A diagnostic test does not necessarily have to demonstrate effectiveness at each level before it can be used in clinical practice [797], but the possible gain and remaining uncertainty on the test's efficacy is clearly presented by this approach.

LEVEL 1: TECHNICAL EFFICACY

The technical efficacy of a test refers to the ability to produce usable information.

The *test's feasibility* and *operator dependence* refer to in what circumstances and by whom the test can be performed.

The *analytical sensitivity* is the ability to detect small quantities of the measured component. This should be distinguished from the diagnostic sensitivity, the ability of a test to detect disease.

The precision or *reproducibility* of results is the ability to obtain the same test results on repeated testing or observations. It is influenced by analytical variability and observer interpretation. Analytical variability consists of inaccuracy and imprecision. Inaccuracy implies systematic error, such as calibration error. Imprecision implies random error. Agreement between two continuous test methods can be expressed in a regression analysis or Bland & Altman plots [798]. A correlation coefficient does not provide information on agreement. The agreement between two observers (interobserver) or the same observer on different occasions (intraobserver) can be expressed with a kappa statistic.

It is often assumed that the technical efficacy does no longer need to be evaluated once a test is being used in clinical practice.

LEVEL 2: DIAGNOSTIC ACCURACY

This level refers to the test's ability to detect or exclude disease in patients compared with a criterion standard or reference test. Test characteristics are sensitivity, specificity, predictive values, likelihood ratios and ROC curves. Definitions of these and other terms are provided in appendix.

Sensitivity and specificity are the most widely used outcome measures, but are sensitive to spectrum bias. Spectrum bias may occur when the study population has a different clinical spectrum (more advanced cases, for instance) than the population in whom the test is to be applied [799, 800]. If sensitivity is determined in seriously diseased subjects and specificity in clearly healthy subjects, both will be grossly overestimated relative to practical situations where diseased and healthy subjects cannot be clinically distinguished in advance[801, 802]. This design has been called 'inappropriate case-control design' in the pilot assessments.

Predictive values, with the positive predictive value being the proportion of patients with a positive test result that actually has the disease and the negative predictive value

the proportion of patients with a negative test result that does not have the disease, are dependent on disease prevalence in the study sample. For example, in a situation where disease prevalence is very low, say 1%, the negative predictive value of the test will be easily over 95% as already 99% of the population do not have the disease. Prevalence and the setting in which patients were recruited should be noted to reflect on this.

The *likelihood ratios* show how a test result alters the pre-test probability into a post-test probability, using Bayesian reasoning. The pre-test probability depends on the prevalence of the target condition and the results of previous tests, for example history, clinical examination, imaging or laboratory tests.

Another outcome measure which is sometimes used, is the *number needed to diagnose*, analogous to the number needed to treat in intervention studies. However, using this measure it is assumed that diagnostic testing is always done to rule in a target condition, to diagnose the target condition, while in clinical practice tests are also used to rule out a target condition.

Finally, test accuracy can be illustrated using an *ROC curve*. The ROC curve graphs test sensitivity versus 1-specificity for various cut-off points. The area under the curve provides a summary measure of the test performance. It also allows comparison of two different tests by testing the two areas under the curve or by testing partial areas under the curve in which the test is most useful.

Clearly, the first level of diagnostic efficacy, technical efficacy, contributes to the diagnostic accuracy. But it also becomes apparent that there may be a point beyond which improvement in technical performance no longer improves diagnostic accuracy. Assuming therefore that diagnostic accuracy can be estimated on the basis of technical accuracy studies is not correct.

LEVEL 3: DIAGNOSTIC THINKING

This level of diagnostic efficacy is concerned with assessment of the effect of test information on diagnostic reasoning and disease categorization. Studies on diagnostic thinking serve as a proxy for estimating the effect of a test on patient care. Patients' outcome can not be influenced by the diagnostic technology unless the physician is led to do something different than would have been done without the test information.

Using the *likelihood ratio* and calculating the post-test probability, this change in diagnostic thinking can be computed. However, the pre-test probability of a disease is not always available in clinical practice and depends not only on setting, but also on patient characteristics and other selection processes, such as referral and the results or previous tests. Clinicians who wish to apply the Bayesian properties of diagnostic tests require accurate estimates of the pre-test probability of target disorders in their area and setting. These estimates can come from five sources personal experience, population prevalence figures, practice databases, the publication that described the test or one of a growing number of primary studies of pre-test probability in different settings[803].

An alternative are studies that empirically test the *change in the physician's subjective assessment* on the probability of disease. In these studies, physicians are asked to estimate the probability of disease before knowing the test result, and estimating it again after the test result has been disclosed. Efficacious tests are those that significantly increase or lower pre-test probabilities assumed by the physician or computed by likelihood ratios using Bayesian reasoning.

One major difficulty with this level of diagnostic efficacy is that it is not always known what post-test probability of disease should be used as a threshold. Which probability of disease is low enough to exclude disease, which is high enough to treat the patient? These thresholds will differ according to the target condition and the treatments that are available [804].

LEVEL 4: THERAPEUTIC IMPACT

The most efficacious tests at this level are those that lead to the institution of a new management strategy. Studies can assess this empirically by comparing the intended management before the test result is known with that after the test result has been disclosed. In what *proportion of patients did the information change the intended management*? In some cases, management changes are considered not only in the patient himself, but also in other persons, for example prophylactic measures in case of an infectious outbreak. These prospective case-series, however, can be subject to bias such as selection bias. The lack of a concurrent control group may lead to confounding, as there is no information on those patients not enrolled in the study and therefore not receiving the new technology. These considerations underscore the need for randomized controlled trials. But, in the absence of RCT's they do play an important role as an intermediate.

LEVEL 5: PATIENT OUTCOME

The ultimate goal of health care is to improve patient outcome. For diagnostic tests that are expensive, dangerous or widely used, knowledge about patient outcome efficacy seems particularly important. It is at this level that expected harm, such as burden, pain, risk, can be weighed directly against its expected benefit, such as improving life expectancy, quality of life, disease related morbidity, etcetera.

The *randomized controlled trial* is the study design the least prone to bias to estimate these risks and benefit. However, it is not always feasible to perform an RCT for ethical, financial or other reasons. In those cases, case-series collected before and after the introduction of a new test technology or case-control studies may provide some of the answers.

A methodological difficulty with this level is that the independent contribution of test technology to patient outcomes may be small in the context of all the other influences and therefore very large sample sizes may be required. But, in spite of these difficulties, RCT's on diagnostic tests are feasible. Various designs are possible, according to the specific research question [805].

Some tests, however, will never be able to prove a change in 'objective' patient outcomes such as mortality or morbidity, simply because there is no treatment available at this moment that has an impact on these outcomes. This is the case in for example dementia or Amyotrophic Lateral Sclerosis (ALS). A diagnostic test will therefore never produce a difference in mortality, but may improve *quality of life measures* by giving the patient (and the carer) an affirmative diagnosis and providing an explanation for the signs and symptoms the patient experiences.

LEVEL 6: COST-EFFECTIVENESS ANALYSIS

This level goes beyond the individual risks and benefits, but assesses whether the cost for use of a given test is acceptable for society. Is the price for the positive effect on patient outcome worthwhile? Resources can not be allocated twice; money spent on one technology can not be spent on another.

Cost-effectiveness studies compute a cost per unit of output. Any of the measures of the previous levels can be used as input, for example cost per surgery avoided, cost per appropriately treated patient, cost per life year gained or cost per quality adjusted life year gained. Final outcomes, such as life years gained or QALYs gained, are preferred over intermediate outcomes in economic evaluations, as they allow comparisons across a broader range of health interventions, e.g. diagnostic and therapeutic interventions. Because data on these outcomes and costs of the diagnostic and subsequent therapeutic paths are not routinely available from observations, modelling becomes inevitable to examine the cost-effectiveness of diagnostic tests. The validity of the model input parameters is crucial for the credibility of the model. The values of all input variables must be based on solid evidence obtained from literature or observations. Sensitivity

analyses can illustrate the robustness of the conclusions, by demonstrating the sensitivity of the results to changes in the values of remaining uncertain input parameters.

Cost-effectiveness models can only upgrade the level of evidence if level 5 evidence was available on the outcomes used in the model (be it life years gained or procedures avoided) and if this evidence was actually used in the model. More specifically, models that base their outcome estimation on non-MRI related evidence (e.g. on the survival after surgery, regardless of the diagnostic work up prior to the treatment decision) can not upgrade the level of evidence from, for instance, 4 to 6. There must be at least level of evidence 5 for MRI to reach level 6 with cost-effectiveness models.

For rare diseases, it is again more difficult to reach higher levels of evidence, as the patient numbers that can be included in a clinical trial are small. As a consequence, it is more difficult to reach statistical significance.

APPENDIX 2: LITERATURE SEARCH STRATEGIES

NEURORADIOLOGY

Brain

Date	
Database	Medline (Pubmed) + Embase (OVID)
Date covered	1.1.2000 until 31.1.2006
Search Strategy	MeSH terms or similar EMTREE keywords: X-ray, computed tomography" AND "magnetic resonance imaging" AND "brain diseases" OR "cranial nerve diseases" OR "central nervous system neoplasms" OR "nervous system malformations" OR "spinal cord diseases" OR "spinal diseases" (MeSH terms, limited to "human"). Magnetic resonance imaging AND X-ray, computed tomography AND brain diseases OR cranial nerve diseases OR central nervous system neoplasms OR nervous system malformation: MEDLINE: 25444 EMBASE: 1300 **Clinical queries:** Magnetic resonance imaging AND brain diseases: syst.rev 35, diagn narrow 242, broad 3425 Magnetic resonance imaging AND cranial nerve diseases: syst.rev 2, diagn narrow 14, broad 225 Magnetic resonance imaging AND central nervous system neoplasms: syst.rev 1, diagn narrow 45, broad 827 Magnetic resonance imaging AND nervous system malformation: syst.rev 0, diagn narrow 8, broad 243 Magnetic resonance imaging AND orbital disease: syst.rev 0, diagn narrow 3, broad 5 Magnetic resonance imaging AND eye diseases: syst.rev 1, diagn narrow 13, broad 259
Note	From all these hits, 241 were printed to read more details. Finally 64 were analysed in detail

Epilepsy

Date	13/03/2006
Database	Medline (Pubmed)
Date covered	No restrictions
Search Strategy	Search option Clinical Queries: diagnosis, broad sensitive MeSH terms: "Magnetic Resonance Imaging"[MeSH] AND "Tomography, X-Ray Computed"[MeSH] AND "Epilepsy"[MeSH])
Note	all articles: 788 reviews only: 95, limited to 'English language' and 'humans', resulted in 73 articles

Date	17/02/2006
Database	Embase (OVID)
Date covered	2000-2006
Search Strategy	'mri'/mj AND ([article]/lim OR [review]/lim) AND [english]/lim AND [humans]/lim AND [embase]/lim AND ['epilepsy'/exp/mj AND ([article]/lim OR [review]/lim) AND [english]/lim AND [humans]/lim AND[2000-2006]/py: 211

Multiple Sclerosis

Database	Medline (Pubmed)
Date covered	No restrictions
Search Strategy	"Magnetic Resonance Spectroscopy"[MAJR] OR "Magnetic Resonance Imaging"[MAJR] OR "Diffusion Magnetic Resonance Imaging"[MAJR]) AND ("Tomography, Spiral Computed"[MAJR] OR "Tomography, X-Ray Computed"[MAJR]) AND ("Multiple Sclerosis"[MAJR] OR "Multiple Sclerosis, Chronic Progressive"[MAJR] OR "Multiple Sclerosis, Relapsing-Remitting"[MAJR])
Notes	Result: 23 publications, of which one was a review [Moseley 1983 #1]. Exclusion of non-English articles: German [Hornig 1984 #1], Slovak [Mihale 2000 #1] Spanish [Diaz de la Fe 1999 #1]. Exclusion of case reports [Saloway 1988 #1, Guthling 1989 #1, Rusin 1995 #1, Riaz 1998 #1, Mujic 2002 #1, Di Patre 2003 #1, Akiyama 2005 #1]. An article from 'Neurology India' [Mani 1999 #1] did not yield any information on the comparison between CT and MRI in MS patients, and was excluded.

Spine and spinal cord

Magnetic resonance imaging AND spinal disease: syst.rev 3, diagn narrow 29, broad 314

Magnetic resonance imaging AND spinal cord disease: syst.rev 3, diagn narrow 15, broad 260

Published HTA reports were retrieved by using the web sites of health technology assessment (HTA) agencies (CRD database).

Degenerative Lumbar spine

3 searches:

1st search for intervertebral disk degeneration in embase (combining embase and pubmed)

2nd search for low back pain and MRI in Pubmed

3rd search for low back pain, MRI and CT in Pubmed

4th search: 2 additional references were found via reference list from an article found in previous searches

Date	17 Feb 2006
Database	EMBASE (OVID)
Date covered	2000-2006
Search Strategy	'intervertebral disk degeneration'/exp/mj AND ([article]/lim OR [review]/lim) AND [humans]/lim AND 'nuclear magnetic resonance imaging'/exp/mj: 31
Note	31 articles; 11 relevant

Date	23 feb 2006
Database	Pubmed (NCBI - UGent)
Date covered	1996-2006
Search Strategy	("Magnetic Resonance Imaging"[MeSH] AND "Low Back Pain"[MeSH]) AND specificity[Title/Abstract]
Note	21 articles; 11 relevant; 7 witheld

Date	15 March 2006
Database	Pubmed (NCBI - UGent)
Date covered	1993-2006
Search Strategy	("Low Back Pain"[MeSH] AND "Tomography, X-Ray Computed"[MeSH] AND "Magnetic Resonance Imaging"[MeSH]) AND (sensitiv*[Title/Abstract] OR sensitivity and specificity[MeSH Terms] OR diagnos*[Title/Abstract] OR diagnosis[MeSH:noexp] OR diagnostic *[MeSH:noexp] OR diagnosis,differential[MeSH:noexp] OR diagnosis[Subheading:noexp])
Note	168 results; 17 seemed relevant after quick manual filtering based on title/abstract. Nine were witheld

Date	25 March 2006
Database	Medline (Pubmed)
Date covered	2001-2006
Search Strategy	Search by investigator via references of article found in previous searches
Note	Provided 2 articles not found in previous searches 1, 2 and 3

Malignancy: Spinal metastasis and osteoporosis

3 searches

1st search for spinal metastasis in embase (combining embase and pubmed)

2nd additional search for spinal metastasis in Pubmed at later date

3rd search in embase for osteoporosis (combining embase and pubmed)

Date	17 Feb 2006
Database	EMBASE (incl. Medline)
Date covered	2000-2006
Search Strategy	#17. 'nuclear magnetic resonance imaging'/exp/mj AND ([article]/lim OR [review]/lim) AND [humans]/lim AND [2000-2006]/py AND 'spine metastasis'/exp/mj : 13
Note	13 articles; 8 relevant

Keywords	Spine, lumbar vertebrae, neoplasm metastasis, magnetic resonance imaging
Date	19 March 2006
Database	Medline (Pubmed)
Date covered	1990-2005
Search Strategy	"Spine"[MeSH] AND "Neoplasm Metastasis"[MeSH] AND "Magnetic Resonance Imaging"[MeSH]
Note	31 results; 5 were relevant; 1 was already in previous search

Keywords	nuclear magnetic resonance imaging, osteoporosis
Date	17 feb 2006
Database	EMBASE (incl pubmed)
Date covered	2000-2006
Search Strategy	'nuclear magnetic resonance imaging'/exp/mj AND 'osteoporosis'/exp/mj AND ([article]/lim OR [review]/lim) AND [humans]/lim AND [1990-2006]/py: 23
Note	23 articles; 3 relevant

HEAD AND NECK

1/ Search for HTA publications on magnetic resonance imaging for specific topics on head and neck radiology, via the website of the Centre for Reviews and Dissemination (http://www.york.ac.uk/inst/crd/). None were found.

2/ A search was conducted in the Pubmed and Embase databases using the below defined search strategies. The MeSH terms were exploded. A search was conducted both for systematic reviews and clinical studies. The search for clinical studies in Pubmed was limited to studies related to diagnosis, using a sensitive ('broad') search strategy. Only clinical studies published in 2000 or later, including at least 15 patients, in English, French or German, and displaying an abstract in Pubmed were considered. In some instances, older key-articles were also considered.

Date	19-2-2006
Database	Pubmed
Date covered	2000-2006
Search Strategy	"Magnetic resonance Imaging" (MeSH) and "Hearing Loss" (MeSH)
Notes	128 articles; 9 relevant

Date	17-02-2006
Database	Pubmed
Date covered	2000-2006
Search Strategy	"Magnetic resonance Imaging" (MeSH) and "Pharyngeal Neoplasms" (MeSH)
Notes	266 articles; 9 relevant

Date	19-2-2006
Database	Pubmed
Date covered	2000-2006
Search Strategy	"Magnetic resonance Imaging" (MeSH) and "Laryngeal neoplasms" (MeSH)
Notes	47 articles; 3 relevant

Date	9-3-2006
Database	Pubmed
Date covered	2000-2006
Search Strategy	"Magnetic resonance Imaging" (MeSH) and "Lymphatic diseases" (MeSH) and "Head and neck neoplasms" (MeSH)
Notes	75 articles; 3 relevant

Date	9-3-2006
Database	Pubmed
Date covered	2000-2006
Search Strategy	"Magnetic resonance Imaging" (MeSH) and "Nose neoplasms" (MeSH)
Notes	209 articles; 3 relevant

Date	22-2-2006
Database	Pubmed
Date covered	2000-2006
Search Strategy	"Magnetic resonance Imaging" (MeSH) and "Salivary neoplasms" (MeSH)
Notes	126 articles; 6 relevant

Date	19-2-2006
Database	Pubmed
Date covered	2000-2006
Search Strategy	"Magnetic resonance Imaging" (MeSH) and "Parathyroid disease" (MeSH)
Notes	79 articles; 6 relevant

Date	19-2-2006
Database	Pubmed
Date covered	2000-2006
Search Strategy	"Magnetic resonance Imaging" (MeSH) and "Temporomandibular joint disorders" (MeSH)
Notes	153 articles; 3 relevant

Date	13-3-2006
Database	Embase
Date covered	2000-2006
Search Strategy	All above mentioned search strategies
Notes	110 articles; 5 relevant

MUSCULOSKELETAL

Lower limb

Knee

8 searches:

1st search for knee injuries and osteoarthritis in Pubmed

2nd search knee, meniscal lesions in Pubmed

3rd search for knee, cruciate ligament injuries in Pubmed

4th search for knee injury in Embase

5th search for knee, osteoarthritis in Embase

6th search for knee CT and MRI in Pubmed

7th search for knee CT and MRI in Pubmed, with 3 filters

8th search for knee cartilage in Pubmed

Keywords	nuclear magnetic resonance imaging, knee joint, knee injuries, osteoarthritis
Date	24 March 2006
Database	Medline (Pubmed)
Date covered	1990 - 2006
Search Strategy	"Magnetic Resonance Imaging"[MeSH] AND AND ("Knee"[MeSH] OR "Osteoarthritis, Knee"[MeSH] OR "Knee Joint"[MeSH] OR "Knee Injuries"[MeSH]) Option systematic reviews
Note	18 articles

Keywords	nuclear magnetic resonance imaging, knee, meniscus
Date	7 Feb 2006
Database	Medline (Pubmed)
Date covered	1990 - 2006
Search Strategy	"Magnetic Resonance Imaging"[MAJR] AND "Menisci, Tibial"[MAJR] NOT "Letter"[Publication Type] NOT "Comment"[Publication Type] NOT "Editorial"[Publication Type] NOT "Case Reports"[Publication Type] AND "humans"[MeSH Terms] AND ("2000"[PDAT] : "2006"[PDAT])
Note	76 articles

Keywords	nuclear magnetic resonance imaging, knee, cruciate ligament
Date	7 Feb 2006
Database	Medline (Pubmed)
Date covered	2000 - 2006
Search Strategy	"Magnetic Resonance Imaging"[MAJR] AND ("Posterior Cruciate Ligament"[MAJR] OR "Anterior Cruciate Ligament"[MAJR]) NOT "Letter"[Publication Type] NOT "Comment"[Publication Type] NOT "Editorial"[Publication Type] NOT "Case Reports"[Publication Type] AND "humans"[MeSH Terms] AND ("2000"[PDAT] : "2006"[PDAT])
Note	74 articles

Keywords	nuclear magnetic resonance imaging, knee injury
Date	17 Feb 2006
Database	Embase (OVID)
Date covered	2000 - 2006
Search Strategy	'mri'/exp/mj AND 'knee injury'/exp/mj AND ([article]/lim OR [review]/lim) AND [english]/lim AND [humans]/lim AND [embase]/lim AND [2000-2006]/py/: 107
Note	107 articles

Keywords	nuclear magnetic resonance imaging, knee osteoarthritis
Date	17 Feb 2006
Database	Embase (OVID)
Date covered	2000 - 2006
Search Strategy	'mri'/exp/mj AND 'knee osteoarthritis'/exp/mj AND ([article]/lim OR [review]/lim) AND [english]/lim AND [humans]/lim AND [embase]/lim AND [2000-2006]/py: 52
Note	107 articles

Keywords	nuclear magnetic resonance imaging, computed tomography, knee joint
Date	24 March 2006
Database	Medline (Pubmed)
Date covered	1988 - 2006
Search Strategy	("Magnetic Resonance Imaging"[MeSH] AND ("Tomography, Spiral Computed"[MeSH] OR "Tomography, X-Ray Computed"[MeSH]) AND ("Knee"[MeSH] OR "Knee Joint"[MeSH])) AND specificity[Title/Abstract]
Note	144 articles

Keywords	nuclear magnetic resonance imaging, computed tomography, knee joint
Date	24 March 2006
Database	Medline (Pubmed)
Date covered	1990 - 2006
Search Strategy	("Magnetic Resonance Imaging"[MeSH] AND ("Tomography, Spiral Computed"[MeSH] OR "Tomography, X-Ray Computed"[MeSH]) AND ("Knee"[MeSH] OR "Knee Joint"[MeSH])) AND (predict*[tiab] OR predictive value of tests[mh] OR scor*[tiab] OR observ*[tiab] OR observer variation[mh]) options: Broad (sensitive), diagnosis, clinical prediction guides
Note	16 articles

Keywords	nuclear magnetic resonance imaging, knee joint, cartilage
Date	24 March 2006
Database	Pubmed
Date covered	2000 - 2006
Search Strategy	"Magnetic Resonance Imaging"[MAJR] AND ("Knee"[MAJR] OR "Knee Joint"[MAJR]) AND "Cartilage"[MAJR] NOT "Letter"[Publication Type] NOT "Comment"[Publication Type] NOT "Editorial"[Publication Type] NOT "Case Reports"[Publication Type] AND "humans"[MeSH Terms] AND ("2000"[PDAT] : "2006"[PDAT])
Note	145 articles

Hip

Keywords	MRI AND Hip AND Tomography, Spiral Computed
Date	18/05/2006
Database	Medline CRD databases (DARE, NHS EED and HTA)
Date covered	No limits
Search Strategy	((("magnetic resonance imaging"[TIAB] NOT Medline[SB]) OR "magnetic resonance imaging"[MeSH Terms] OR MRI[Text Word]) AND ("hip"[MeSH Terms] OR hip[Text Word]) AND ("spiral computed tomography"[Text Word] OR "tomography, spiral computed"[MeSH Terms])) AND systematic[sb]
Note	No hits

Keywords	MRI AND Hip AND Tomography, X-Ray Computed
Date	18/05/2006
Database	Medline CRD databases (DARE, NHS EED and HTA)
Date covered	No limits
Search Strategy	((("magnetic resonance imaging"[TIAB] NOT Medline[SB]) OR "magnetic resonance imaging"[MeSH Terms] OR MRI[Text Word]) AND ("hip"[MeSH Terms] OR Hip[Text Word]) AND ("x-ray computed tomography"[Text Word] OR "tomography, x-ray computed"[MeSH Terms] OR Tomography, X-Ray Computed[Text Word])) AND systematic[sb]
Note	3 hits, 1 relevant[442]

Keywords	MRI AND Ultrasonography AND Hip
Date	18/05/2006
Database	Medline CRD databases (DARE, NHS EED and HTA)
Date covered	No limits
Search Strategy	((("magnetic resonance imaging"[TIAB] NOT Medline[SB]) OR "magnetic resonance imaging"[MeSH Terms] OR MRI[Text Word]) AND ("ultrasonography"[Subheading] OR "ultrasonography"[MeSH Terms] OR Ultrasonography[Text Word]) AND ("hip"[MeSH Terms] OR Hip[Text Word])) AND systematic[sb]
Note	4 hits, 2 relevant[442, 806]

Keywords	MRI AND Hip AND Echography AND Tomography AND 'spiral computer assisted tomography'
Date	18/05/2006
Database	Embase
Date covered	No limits
Search Strategy	'nuclear magnetic resonance imaging'/exp/mj AND 'hip'/exp/mj AND ('echography'/exp/mj OR 'tomography'/exp/mj OR 'spiral computer assisted tomography'/exp/mj AND [review]/lim
Note	4 hits, none relevant

Keywords	MRI AND Hip AND Tomography, Spiral Computed
Date	18/05/2006
Database	CRD databases (DARE, NHS EED and HTA)
Date covered	No limits
Search Strategy	((("magnetic resonance imaging"[TIAB] NOT Medline[SB]) OR "magnetic resonance imaging"[MeSH Terms] OR MRI[Text Word]) AND ("hip"[MeSH Terms] OR Hip[Text Word]) AND ("spiral computed tomography"[Text Word] OR "tomography, spiral computed"[MeSH Terms])) AND specificity[Title/Abstract]
Note	1 hit, 1 relevant[443]

Keywords	MRI AND Hip AND Tomography, Spiral Computed
Date	18/05/2006
Database	Cochrane Library
Date covered	No limits
Search Strategy	((("magnetic resonance imaging"[TIAB] NOT Medline[SB]) OR "magnetic resonance imaging"[MeSH Terms] OR MRI[Text Word]) AND ("hip"[MeSH Terms] OR Hip[Text Word]) AND ("spiral computed tomography"[Text Word] OR "tomography, spiral computed"[MeSH Terms])) AND specificity[Title/Abstract]
Note	No hits

Keywords	MRI AND Hip AND Tomography, X-Ray Computed
Date	18/05/2006
Database	CRD databases (DARE, NHS EED and HTA):
Date covered	No limits
Search Strategy	((("magnetic resonance imaging"[TIAB] NOT Medline[SB]) OR "magnetic resonance imaging"[MeSH Terms] OR MRI[Text Word]) AND ("hip"[MeSH Terms] OR Hip[Text Word]) AND ("x-ray computed tomography"[Text Word] OR "tomography, x-ray computed"[MeSH Terms] OR Tomography, X-Ray Computed[Text Word])) AND specificity[Title/Abstract]
Note	6 hits, 2 relevant[444, 443]

Keywords	MRI AND Ultrasonography AND Hip
Date	18/05/2006
Database	Medline CRD databases (DARE, NHS EED and HTA):
Date covered	No limits
Search Strategy	(("magnetic resonance imaging"[TIAB] NOT Medline[SB]) OR "magnetic resonance imaging"[MeSH Terms] OR MRI[Text Word]) AND ("ultrasonography"[Subheading] OR "ultrasonography"[MeSH Terms] OR Ultrasonography[Text Word]) AND ("hip"[MeSH Terms] OR Hip[Text Word]) AND specificity[Title/Abstract]
Note	8 hits, 4 relevant[448, 446, 447, 445]

Keywords	MRI AND Hip
Date	18/05/2006
Database	CRD databases (DARE, NHS EED and HTA):
Date covered	No limits
Search Strategy	((("magnetic resonance imaging"[TIAB] NOT Medline[SB]) OR "magnetic resonance imaging"[MeSH Terms] OR MRI[Text Word]) AND ("hip"[MeSH Terms] OR Hip[Text Word])) AND systematic[sb]
Note	8 hits, 3 relevant[442, 441, 440]

Keywords	MRI AND Hip
Date	18/05/2006
Database	Medline CRD databases (DARE, NHS EED and HTA)
Date covered	No limits
Search Strategy	((("magnetic resonance imaging"[TIAB] NOT Medline[SB]) OR "magnetic resonance imaging"[MeSH Terms] OR MRI[Text Word]) AND ("hip"[MeSH Terms] OR Hip[Text Word])) AND specificity[Title/Abstract]
Note	49 hits, 11 relevant[448, 454, 446, 455, 447, 453, 451, 452, 445, 450, 449]

Upper limb

Shoulder

Database	Medline (Pubmed)
Date covered	1992 until 31.3.2006
Search Strategy	MeSH terms: X-ray, computed tomography" AND "magnetic resonance imaging" AND "shoulder pain" or "shoulder impingement syndrome" or "shoulder dislocation". MEDLINE: 4215 (2347 items when limited to "human", "English") **Clinical queries:** Magnetic resonance imaging AND shoulder impingement syndrome: 119 (review 32) syst.rev 1, diagn narrow 5, broad 59 Magnetic resonance imaging AND rotator cuff tears: 344 (review 59) - syst.rev 3, diagn narrow 60, broad 281 Magnetic resonance imaging AND shoulder labral tears: 94 (review 17) - syst.rev 0, diagn narrow 27, broad 86 Magnetic resonance imaging AND shoulder instability: 299 (review 94) - syst.rev 1, diagn narrow 34, broad 248

Elbow

Database	Medline (Pubmed)
Date covered	No restrictions
Search Strategy	MeSH terms: "Magnetic Resonance Imaging"[MeSH] AND "Tomography, X-Ray Computed"[MeSH] AND elbow joint Medline: 32 **Clinical queries:** Magnetic Resonance imaging and elbow osteochondritis dissecans: 32 (review 10) syst.rev 0, diagn narrow 1, broad 27 Magnetic resonance imaging and chronic epicondylitis: 13 (review 3) - syst.rev 1, diagn narrow 1, broad 11 Magnetic Resonance imaging and elbow collateral ligament injury: 45 (review 9) - syst.rev 0, diagn narrow 3, broad 36 Magnetic Resonance imaging and elbow nerve entrapment: 24 (review 8) - syst.rev 0, diagn narrow 2, broad 22 Magnetic Resonance imaging and elbow biceps tendon tear: 5 syst.rev 0, diagn narrow 0, broad 5

Bone marrow

Keywords	Magnetic Resonance Imaging, Bone Marrow, Bone Marrow Diseases, Bone Marrow Neoplasms, Multiple Myeloma, Lymphoma, Hodgkin Disease, Non-Hodgkin Lymphoma, Myelodysplastic Syndromes
Date	8 Feb 2006
Database	Medline (Pubmed)
Date covered	1990-2006
Search Strategy	"Bone Marrow"[MAJR] OR "Bone Marrow Diseases"[MAJR] OR "Bone Marrow Neoplasms"[MAJR] OR "Multiple Myeloma"[MAJR] OR "Lymphoma"[MAJR] OR "Hodgkin Disease"[MAJR] OR "Lymphoma, Non-Hodgkin"[MAJR] OR "Myelodysplastic Syndromes"[MAJR] AND "magnetic resonance imaging"[MAJR] NOT ("case reports"[Publication Type] OR "case reports"[Text Word]) NOT ("letter"[Publication Type] OR "correspondence"[MeSH Terms] OR "letters"[Text Word]) NOT ("comment"[Publication Type] OR "comment"[Text Word]) NOT ("editorial"[Publication Type] OR "editorial"[Text Word]) AND Humans[Mesh] AND ("1990"[PDat]:"2006"[PDat]): 495
Note	46 articles were useful for this study.

Keywords	Magnetic Resonance Imaging, Bone Marrow Diseases
Date	17/02/2006
Database	Embase (OVID)
Date covered	2000-2006
Search Strategy	'mri'/exp/mj AND 'bone marrow disease'/exp/mj AND ([article]/lim OR [review]/lim) AND [english]/lim AND [humans]/lim AND [embase]/lim AND [2000-2006]/py/: 56
Note	

Keywords	Magnetic Resonance Imaging, Bone Marrow, Bone Marrow Diseases, Bone Marrow Neoplasms, Multiple Myeloma, Lymphoma, Hodgkin Disease, Non-Hodgkin Lymphoma, Myelodysplastic Syndromes
Date	2/8/2006
Database	Pubmed – Clinical queries
Date covered	1990-2006
Search Strategy	("Magnetic Resonance Imaging"[MeSH] AND ("Bone Marrow"[MeSH] OR "Bone Marrow Diseases"[MeSH])) AND specificity[Title/Abstract]: 46 Opties:narrow, diagnosis
Note	9 articles were useful for this study

Bone tumour

Keywords	nuclear magnetic resonance imaging, bone tumor
Date	17 Feb 2006
Database	EMBASE (incl. pubmed)
Date covered	2000-2006
Search Strategy	'mri'/mj AND 'bone tumor'/exp/mj AND ([article]/lim OR [review]/lim) AND [english]/lim AND [humans]/lim AND [embase]/lim AND [2000-2006]/py: 118
Note	

Soft Tissue Injury

Keywords	MRI AND Injuries AND Tomography, X-Ray Computed
Date	19/05/2006
Database	medline CRD databases (DARE, NHS EED and HTA)
Date covered	no limits
Search Strategy	((("magnetic resonance imaging"[TIAB] NOT Medline[SB]) OR "magnetic resonance imaging"[MeSH Terms] OR MRI[Text Word]) AND ("injuries"[Subheading] OR ("wounds and injuries"[TIAB] NOT Medline[SB]) OR "wounds and injuries"[MeSH Terms] OR Injuries[Text Word]) AND ("x-ray computed tomography"[Text Word] OR "tomography, x-ray computed"[MeSH Terms] OR Tomography, X-Ray Computed[Text Word])) AND specificity[Title/Abstract]
Note	64 hits, one relevant but old study[621]

Clinical Study

Keywords	MRI AND Injuries AND Tomography, Spiral Computed
Date	18/05/2006
Database	medline, CRD databases (DARE, NHS EED and HTA)
Date covered	No limits
Search Strategy	((("magnetic resonance imaging"[TIAB] NOT Medline[SB]) OR "magnetic resonance imaging"[MeSH Terms] OR MRI[Text Word]) AND ("injuries"[Subheading] OR ("wounds and injuries"[TIAB] NOT Medline[SB]) OR "wounds and injuries"[MeSH Terms] OR Injuries[Text Word]) AND ("spiral computed tomography"[Text Word] OR "tomography, spiral computed"[MeSH Terms])) AND specificity[Title/Abstract]
Note	2 not relevant hits

Keywords	MRI AND Ultrasonography AND Injuries
Date	18/05/2006
Database	medline CRD databases (DARE, NHS EED and HTA)
Date covered	No limits
Search Strategy	((("magnetic resonance imaging"[TIAB] NOT Medline[SB]) OR "magnetic resonance imaging"[MeSH Terms] OR MRI[Text Word]) AND ("ultrasonography"[Subheading] OR "ultrasonography"[MeSH Terms] OR Ultrasonography[Text Word]) AND ("injuries"[Subheading] OR ("wounds and injuries"[TIAB] NOT Medline[SB]) OR "wounds and injuries"[MeSH Terms] OR Injuries[Text Word])) AND specificity[Title/Abstract]
Note	45 hits, 12 relevant: clinical studies [622 -631] systematic review [473]

Soft Tissue Infection/inflammation

Systematic Reviews

Keywords	MRI AND Infections AND Tomography, X-Ray Computed
Date	18/05/2006
Database	CRD databases (DARE, NHS EED and HTA)
Date covered	No limits
Search Strategy	((("magnetic resonance imaging"[TIAB] NOT Medline[SB]) OR "magnetic resonance imaging"[MeSH Terms] OR MRI[Text Word]) AND (("infection"[TIAB] NOT Medline[SB]) OR "infection"[MeSH Terms] OR Infections[Text Word]) AND ("x-ray computed tomography"[Text Word] OR "tomography, x-ray computed"[MeSH Terms] OR Tomography, X-Ray Computed[Text Word])) AND systematic[sb]
Note	8 hits, not relevant

Keywords	MRI AND Infections AND Tomography, Spiral Computed
Date	18/05/2006
Database	CRD databases (DARE, NHS EED and HTA)
Date covered	No limits
Search Strategy	((("magnetic resonance imaging"[TIAB] NOT Medline[SB]) OR "magnetic resonance imaging"[MeSH Terms] OR MRI[Text Word]) AND (("infection"[TIAB] NOT Medline[SB]) OR "infection"[MeSH Terms] OR Infections[Text Word]) AND ("spiral computed tomography"[Text Word] OR "tomography, spiral computed"[MeSH Terms])) AND systematic[sb]
Note	No hits

Keywords	MRI AND Ultrasonography AND Infections
Date	18/05/2006
Database	CRD databases (DARE, NHS EED and HTA)
Date covered	No limits
Search Strategy	((("magnetic resonance imaging"[TIAB] NOT Medline[SB]) OR "magnetic resonance imaging"[MeSH Terms] OR MRI[Text Word]) AND ("ultrasonography"[Subheading] OR "ultrasonography"[MeSH Terms] OR Ultrasonography[Text Word]) AND (("infection"[TIAB] NOT Medline[SB]) OR "infection"[MeSH Terms] OR Infections[Text Word])) AND systematic[sb]
Note	1 hit, not relevant

Clinical Studies

Keywords	MRI AND Infections AND Tomography, X-Ray Computed
Date	18/05/2006
Database	CRD databases (DARE, NHS EED and HTA)
Date covered	No limits
Search Strategy	((("magnetic resonance imaging"[TIAB] NOT Medline[SB]) OR "magnetic resonance imaging"[MeSH Terms] OR MRI[Text Word]) AND (("infection"[TIAB] NOT Medline[SB]) OR "infection"[MeSH Terms] OR Infections[Text Word]) AND ("x-ray computed tomography"[Text Word] OR "tomography, x-ray computed"[MeSH Terms] OR Tomography, X-Ray Computed[Text Word])) AND specificity[Title/Abstract]
Note	45 hits, one relevant[632]

Keywords	MRI AND Infections AND Tomography, Spiral Computed
Date	18/05/2006
Database	CRD databases (DARE, NHS EED and HTA)
Date covered	No limits
Search Strategy	((("magnetic resonance imaging"[TIAB] NOT Medline[SB]) OR "magnetic resonance imaging"[MeSH Terms] OR MRI[Text Word]) AND (("infection"[TIAB] NOT Medline[SB]) OR "infection"[MeSH Terms] OR Infections[Text Word]) AND ("spiral computed tomography"[Text Word] OR "tomography, spiral computed"[MeSH Terms])) AND specificity[Title/Abstract]
Note	one hit, not relevant

Keywords	MRI AND Ultrasonography AND Infections
Date	18/05/2006
Database	CRD databases (DARE, NHS EED and HTA)
Date covered	No limits
Search Strategy	((("magnetic resonance imaging"[TIAB] NOT Medline[SB]) OR "magnetic resonance imaging"[MeSH Terms] OR MRI[Text Word]) AND ("ultrasonography"[Subheading] OR "ultrasonography"[MeSH Terms] OR Ultrasonography[Text Word]) AND (("infection"[TIAB] NOT Medline[SB]) OR "infection"[MeSH Terms] OR Infections[Text Word])) AND specificity[Title/Abstract]
Note	21 hits, 3 relevant[634, 633, 632]

APPENDIX 3: EVIDENCE TABLES

NEURORADIOLOGY

Epilepsy

Systematic reviews

Pathology/diagnosis + prevalence	Study ID	Imaging techniques compared	Quality/ Level of evidence	Remarks	Conclusions
Epilepsy (0,5-1%) Seizures (up to 10% in a lifetime)	Bernal (2003)[24]	CT and MRI	Very Good 1	Literature search for evidence	Febrile seizures: MRI and CT not recommended Acute symptomatic Seizures: -CT scan is the best tool for the work-up of patients with acute symptomatology Initial unprovoked seizure: -MRI is the modality of choice in the work-up of initial unprovoked seizure -Neuromimaging is positive in 3 to 38% of events with higher probability in cases of partial seizures and focal neurologic deficit -Neuroimaging is advised in children children less than 1 year of age and in those with significant unexplained cognitive and motor impairment or prolonged postictal deficit -significant findings influencing medical care are found in as many as 50% of adults and 12% of children Temporal lobe epilepsy: -MRI best assesses temporal lobe epilepsy -sensitivity reaches 97% for hippocampal sclerosis
Epilepsy (0,5-1%)	Kuzniecky (2005)[27]	MRI	Fair 4	Descriptive	-MRI is the diagnostic tool of choice Therapeutic Impact -When a lesion is detected with MRI in a patient with new onset seizures a recurrence of the seizures can be expected within 2 years in 80% of patients, meaning drug therapy should be started -Detection of hippocampal sclerosis is a strong prognostic indicator for intractability with anti-epileptic drugs -In case of tumors, the decision making process is expedited by the imaging features -MRI findings in patients with malformations of cortical development are critical for surgical decision making

Clinical studies

Pathology/ diagnosis	Study ID	Design	Quality/ Level of evidence	Population + prevalence	Conclusions
Refractory epilepsy	Bronen 1996[13]	Prospective study Comparison MRI and CT Golden standard=pathology	Very Good 2	117 patients with refractory epilepsy undergoing pre-surgical evaluation	Sensitivities for detecting abnormalities were 95% (104 of 109) for MR imaging and 32% (35 of 109) for CT; specificities were 87% (13 of 15) for MR imaging and 93% (14 of 15) for CT (P < .001 for MR versus histopathologic findings)
Mesial Temporal Sclerosis (MTS)	Jack 1996[16]	Blinded reader study MRI only	Good 2	36 patients with intractable complex partial seizures mesial temporal sclerosis confirmed by pathology	The accuracy of FLAIR images was 97% versus 91% for SE images (P<.02).
First Seizure	King 1998[18]	Prospective MRI only	Good 2	-300 consecutive adults and children presented with unexplained seizures -263 patients imaged	-38 epileptogenic lesions (14%), including 17 tumours -MRI aids diagnosis and should be done for all patients except for those with idiopathic generalised epilepsies and for children with benign rolandic epilepsy.
Intractable temporal lobe epilepsy	Lee 1998[807]	Retrospective MRI only	Good 2	MR studies from 186 of 274 consecutive patients who underwent temporal lobectomy neuroradiologist, who was blinded to the side of seizure activity and to pathologic findings.	-MR imaging exhibited 93% sensitivity and 83% specificity in detecting hippocampal/amygdalar abnormalities (n = 121), and 97% sensitivity and 97% specificity in detecting abnormalities in the rest of the temporal lobe (n = 60). -Sensitivity and specificity of MR imaging in detecting temporal lobe tumors (n = 42) were 83% and 97%, respectively, based on abnormal signal and mass effect. -After surgery, 63% of patients were seizure free and 28% had a significant reduction of seizure frequency at an average of 24 months (range, 12 to 78 months) after surgery. Patients with a single lesion in the anterior temporal lobe or hippocampus/amygdala had a better outcome than patients with multiple lesions (n = 22)
Mesial Temporal Sclerosis (MTS)	Oppenheim 1998[808]	Retrospective MRI only Case/control	Fair 2	-63 hippocampi with MTS -60 hippocampi without MTS	With a sensitivity of 92% and a specificity of 100%, the finding of complete loss of digitations in the hippocampal head may be used as a major diagnostic criterion to establish the MR diagnosis of MTS

Pathology/ diagnosis	Study ID	Design	Quality/ Level of evidence	Population + prevalence	Conclusions
Newly diagnosed epilepsy	Berg 2000[14]	Prospective MRI mainly Some CT	Good 2	-388 children imaged -also patients with generalized epilepsy	-Of 613 children, 488 (79.6%) had imaging: 388 (63. 3%) magnetic resonance imaging, 197 (32.1%) computed tomography scans, and 97 (15.8%) both. -Half of children with idiopathic generalized epilepsy had imaging studies compared with 70% to 100% of children with other forms of epilepsy, depending on the specific type. -Etiologically relevant abnormalities were found in 62 (12.7% of those imaged) -In 18 of 62 patients with etiologically relevant abnormalities, both CT and MRI were performed. In 3 patients (16%), the CT was normal and the MRI abnormal.
Intractable epilepsy	Sinclair 2001[15]	Restrospectiv e MRI versus CT	Very Good 2	-Forty-two pediatric patients undergoing temporal lobectomy for intractable epilepsy -Pathology=golden standard	-MRI was abnormal in 27/42 cases (64%), while CT scan was found to be abnormal in only 12/39 (31%). Surgical outcome was excellent, with 34/42 patients (80%) having an Engel class I outcome. -MRI is superior to CT in the detection of pathology, which may be subtle in children
Intractable epilepsy	Cakirer 2002[20]	MRI only	Fair 2	-73 patients with intractable epilepsy	-Detection of lesion in 70% of patients -MRI plays a primary role in planning of the treatment, primarily surgical therapy, by detecting structural epileptogenic lesions
Intractable epilepsy	Von Oertzen 2002[25]	MRI standard versus MRI optimized	Very Good 2	-Postoperative pathology was standard -comparison of expert and non-expert radiologists diagnostic sensitivity in standard and optimized scan protocols	Sensitivity of "non-expert" reports of standard MRI reports for focal lesions was 39%, of "expert" reports of standard MRI 50%, and of epilepsy dedicated MRI 91%. Dedicated MRI showed focal lesions in 85% of patients with "non-lesional" standard MRI. Neuropathological diagnoses (n=90) were predicted correctly in 22% of "non-expert" standard MRI reports but by 89% of dedicated MRI reports. Conclusions: Standard MRI failed to detect 57% of focal epileptogenic lesions. Patients without MRI lesion are less likely to be considered candidates for epilepsy surgery. Patients with refractory epilepsy should be referred to an MRI unit with epileptological experience at an early point.
Intractable epilepsy	Goyal 2004[809]	Prosepective High resolution versus standard	Fair 2	-only 13 patients -high resolution MRI versus standard MRI	high-resolution MRI identified lesions not detected by standard MRI in more than half the children (56%). Technical advances such as four-coil phased surface array MRI can help identify and better delineate lesions, improving the diagnosis of patients who are candidates for surgical treatment of refractory epilepsy.
Intractable	Urbach	Prosepective	Good	-385 patients	-Lesions in 318 patients (83%).

Pathology/ diagnosis	Study ID	Design	Quality/ Level of evidence	Population + prevalence	Conclusions
epilepsy	2004[21]	MRI only	2		- Following presurgical evaluation, 209 (66%) underwent surgery, and 109 (34%) did not. -Freedom from seizures was achieved in 130 (70%) of 186 patients. -Hippocampal sclerosis most common lesion (52%) and correctly characterized in 101 (97%) of 104 patients.
Localisation related seizures	Griffiths 2005[19]	Prosepective MRI only	Good 2	-120 patients	- The overall frequency of abnormalities shown by MR was 31/120 (26%) and the commonest abnormality shown was mesial temporal sclerosis found in 10/ 120 (8%).
Intractable focal epilepsy	Knake 2005[26]	Prosepective 3T phased array MRI versus standard 1,5 MRI epilepsy studies	Good 4	-40 patients	- additional diagnostic information in 48% (19/40) compared to routine clinical reads at 1.5T. -In 37.5% (15/40), this additional information motivated a change in clinical management. -In the subgroup of patients with prior 1.5T MRIs interpreted as normal, 3T PA-MRI resulted in the detection of a new lesion in 65% (15/23)
Intractable epilepsy	Lefkopoulos 2005[22]	Prosepective MRI only	Good 2	-120 patients	-Pathological scans were acquired in 78 patients (65%). -Hippocampal sclerosis was detected in 30 patients (25%), cerebral, tumoral, mass lesions in 12 patients (10%), vascular malformations in nine patients (7.5%), cortical infarcts in eight patients (6.7%), cerebral infections in four patients (4.2%) and developmental disorders in 15 patients (12.5%). -The most common location of the lesions was the temporal lobe (60%)

Impact studies

Pathology/ diagnosis	Study ID	Design	Quality/ level of evidence	Population	Conclusions
Refractory temporal lobe epilepsy	Kuzniecky 1993[28]	Prospective study	Good 3	34 patients	Significant associations were found between either the presence of a restricted foreign-tissue lesion or hippocampal atrophy and an excellent surgical outcome. An abnormal MRI had an 82% predictive value and a normal MRI had a 56% predictive value for surgical success.
Refractory temporal lobe	Berkovic 1995[29]	Actuarial analysis	Good 5	135 patients	-Sixty months after surgery, 69% of patients with foreign tissue lesions, 50% with hippocampal sclerosis, and 21% with normal

Pathology/ diagnosis	Study ID	Design	Quality/ level of evidence	Population	Conclusions
epilepsy					MRIs had no postoperative seizures. An eventual seizure-free state of 2 years or more, whether the patient was seizure-free since surgery or not, was achieved by 80% of patients with foreign tissue lesions, 62% of those with hippocampal sclerosis, and 36% of those with normal MRIs. Outcome was worse in those with normal MRIs than in the other two groups. -This information can now be used in preoperative counseling.
Refractory temporal lobe epilepsy	Gilliam 2000[810]	Intent-to-treat analysis	Good 3	90 consecutive patients asssesed for temporal lobe surgery	-intent-to-treat analysis of 90 consecutive patients assessed for possible ATL, including 13 who did not undergo ATL because of inconclusive intracranial ictal EEG. -Four (31%) of these 13 patients had unilateral mesial temporal abnormalities on their MRIs. -The positive predictive value of MRI-MTS for seizure cessation decreased from 0.69 to 0.63 after adjustment for these additional false positive results. - previous studies had revealed a positive predictive value (PPV) of 0.75 (0.72 after similar adjustment). -The authors conclude that the predictive value of MRI-MTS for outcome from ATL may be overestimated by small retrospective studies of highly selected postoperative patients.
Refractory temporal lobe epilepsy	Velasco 2000[30]	Prospective study	good	22 patients	The study corroborates that no single predictive study (including non-invasive MRI and invasive ictal EEG activity) is predictive of the success or failure of ATL. Rather, a concordant combination of non-invasive and invasive studies is more likely to be predictive of a high probability of success. The high efficiency of ATL (86% of patients seizure-free) was accomplished by using all available predictor studies.
Refractory temporal lobe epilepsy	Antel 2002[811]	Retrospective study	Good 3	81 patients who underwent surgical treatment	-Two approaches were taken. First, outcome was defined as experiencing worthwhile improvement with >90% reduction of seizure frequency (Classes I, II, and III) or not (Class IV). A second approach was to define outcome as experiencing freedom from seizures following surgery (Class I) or not (Classes II, III, and IV). For each approach, a Bayesian classifier was constructed to predict outcome by calculating the probability of a patient's pattern of results from spectroscopic analysis of the temporal lobes and volumetric analysis of the amygdala and hippocampus being associated with the various outcome groups.

Pathology/ diagnosis	Study ID	Design	Quality/ level of evidence	Population	Conclusions
					-The worthwhile improvement classifier correctly predicted the surgical outcomes of 60 of 65 (92%) of patients who experienced worthwhile improvement and 10 of 16 (63%) of patients who did not. The seizure-free classifier correctly predicted the surgical outcomes of 39 of 52 (75%) of patients who became seizure free and 21 of 29 (72%) of patients who did not. **Conclusion:** MR features are important markers of surgical outcome in patients with TLE and can provide assistance in identifying surgical candidates.
Refractory epilepsy	Bronen 1997[17]	Retrospective study Cost savings in presurgical evaluation by replacing CT with MRI	Fair 6	117 patients	-Cost savings were based on the paradigm that intracranial electroencephalogram monitoring (costing about $50,000) would have been necessary for preoperative localization of the epileptogenic zone in those patients without positive imaging findings. Savings attributed to replacing CT with MR were based on patients with positive MR and normal CT. A similar paradigm was used to calculate savings for replacing MR with CT. National savings were based solely on patients with neoplasms or vascular lesions because paradigms for other lesions vary considerable depending on institutional philosophy. -Replacing CT with MR imaging would have eliminated preoperative intracranial electrode procedures in 29 of 117 patients, with potential savings of $1,450,000 at our institution. In the 37 patients with neoplastic or vascular substrates, MR would have eliminated 10 invasive electrode procedures with estimated savings of $0.5 million institutionally and $3 to $4 million per year nationally. There were no cases to support replacing MR with CT. -CONCLUSION: Replacing CT with MR decreases health costs associated with preoperative evaluation of intractable epilepsy requiring surgical amelioration.

Multiple sclerosis

Pathology/ diagnosis	Study ID	Imaging techniques compared	Quality/ Level of evidence	Remarks	Conclusions
Multiple sclerosis study performed in patients with specific pathology Gray literature	Young, 1981[45]	MRI, CT	Good 1	10 subjects with MS	This very early study on the comparisson between MR and CT in MS demonstrated that all lesions visible on CT were also seen on MRI, and MRI demonstrated 112 further lesions. The authors conclude that '*NMR ...demonstrates abnormalities in MS on a scale not previously seen except at necropsy.*' This study only used an inversion recovery sequence.
Multiple sclerosis	Moseley, 1983[47]	MRI, CT	Good 2	review article	In this review article, Moseley refers to Young [Young 1981 #1] and Mastaglia [Mastatglia 1981 #1], but also to two more studies [] which compare NMR to CT, but in a variety of pathological conditions, one of which was MS. This author concludes that "*...Early work with nuclear magnetic resonance imaging indicates that this new technique is more sensitive even than computed tomography for the detection of demyelisation, and may well prove to be the technique of choice for the investigation of this problem.*"
Multiple sclerosis study performed in patients with specific pathology Gray literature	Lukes, 1983[50]	MRI, CT	Good 2	10 patients with definite MS	The authors researched that CT did not demonstrate demyelinating lesions with sufficient sensitivity to be useful in the assessment of MS. The additional use of a spin-echo sequnece yielded more lesions. The authors conclude that 'Spin-echo and inversion recovery imaging each demonstrate more extensive abnormalities than did computed tomography'.
Multiple sclerosis study performed in patients with specific pathology	Sheldon, 1985[52]	MRI, CT, clinical evidence (including labo tests)	Good 2	none	MRI and clinical evidence had equal sensitivity for the detection of MS lesions, MRI was more specificific for the location.The authors conclude that MR imaging is more sensitive than computed tomography (CT), which was positive in 25% of 59 patients with definite MS; it is always positive when CT is positive; and it probably can replace CT in the diagnosis and follow-up of patients with MS.
Multiple sclerosis study performed in patients with specific pathology	Jacobs [53]	MR, CT	Fair 2	27 patients with MS	The authors report a sensitivity of 78% for MR and 63% for CT for lesion detection
Multiple sclerosis study performed in patients with	Osborn, 1990[54]	MRI, CT	Fair 2	none	CT and MRI in 12 adolescent patients with MS: MR was more sensitive than CT in detecting demyelinating plaques.

Pathology/ diagnosis	Study ID	Imaging techniques compared	Quality/ Level of evidence	Remarks	Conclusions
specific pathology					
Multiple sclerosis study performed in patients with specific pathology	Nesbit [55]	MRI, CT	Weak 2	22 patients with MS	without quoting any numbers, only reported the detection of more lesions with MR than with CT in a series of 22 patients were both techniques were retrospectively reviewed
Multiple sclerosis study performed in patients with specific pathology Gray literature	Lee [56]	MRI, CT, SEP, VEP, CSF	Excellent 2	200 patients prospectively with suspected MS	From this study, sensitivity, specificity, positive predictive value and negative predictive value parameters calculated as 95%, 49%, 44% and 95% for MRI, and 38%, 80%, 45% and 75% for CT. Moreover, most of the reported abnormalities on CT were atrophy, a finding not very specific for MS. The authors conclude that CT was not diagnostically helpful and based on their data felt that when MRI is available, CT is not necessary for proving dissemination of lesions in space.

Stroke

Systematic reviews

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
Stroke Systematic review, 47 studies on DWI, 18 studies on PI and 19 studies on DWI-PI.	Keir, 2000[85]	CT vs. MRI (DW/PW)	2	Randomized trials of stroke treatment are necessary to find out which tissue is still viable.	There is insufficient information to enable firm conclusions about sens/spec of DW/PW in identifying lesions not visible on CT Not sufficient information to draw firm conclusions about sensitivity/specificity of DWI and PI for identifying ischaemic lesion.
Stroke 130 studies in the literature and 2 prospective observational studies from the author Decision analysis model was developed to represent the pathway of care in acute stroke using "scan all within 48 h" as the comparator against which to cost 12 alternative scan strategies	Wardlaw, 2004[86]	Accuracy of CT&/or MRI in diagnosing hemorrhage or infarct.	2	Heavy cost-effectiveness orientation. CT is not effective after 8 days to detect hemorrhage.	Most cost-effective strategy was "scan all patients immediately" Cost of providing CT was less than cost of inpatient care
Stroke Evidence based literature review Systematic review 1966-2002	Vo, 2003[93]	Scientific evidence of using diagnostic imaging in acute stroke	2		Non-contrast CT to exclude hemorrhage. The routine use of MRI before t-PA is not supported. Clinical outcome data are lacking. CT is recommended because detection of hemorrhage and rapid evaluation are the primary goals in work-up of a stroke patient.

Clinical studies

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
Stroke 50 patients with ischaemic stroke	Fiebach, 2002[88]	CT vs. MRI CT and DWI in randomized order < 6h in hyperacute stroke patients. 5 stroke experts and 4 residents blinded to clinical details.	2		Sens and accuracy of CT/MR infarct detection was 61/91%. DWI should be used instead of CT. Interrater variability of lesion detection was significantly better for DWI (CT/DWI, kappa= 0.38/0.76).
Stroke 22 patients with acute stroke	Schramm, 2004[92]	CT(PCT, CTA) vs. MRI (DW,PW)	2	Assessment of diagnostic value in <6h acute stroke	PCT time to peak & cerebral blood volume and PI time to peak and cerebral blood volume yield comparable results. CTA source images volumes and DWI volumes were comparable. CT protocol can be achieved in 15 minutes. CTA can be helpful when MRA is not available or not possible.
Stroke 691 consecutive patients with acute suspected stroke	Mullins, 2002[89]	CT vs. MRI-DW	2		By using DW MRI < 6 hours after presentation sens/spec of MRI-DW 97% (95% CI: 92% , 100%) /100 % (95% CI: 69%, 100%), MRI 58% (29%-84%) /100% (16%- 100%) and CT 40% (35% - 45%) /92% (84%- 97%). NPV was resp. 73%/42%/24%. DWI is superior
Stroke Detection of hemorrhage Prospective multi-center study 200 patients	Kidwell, 2004[91]	CT vs. MRI	2	Accuracy of MRI & CT in detecting hemorrhage in acute <6h stroke patients	CT=MR for acute hemorrhage (96% concordance). MR>CT for chronic hemorrhage (microbleeds) For the diagnosis of any hemorrhage, MRI was positive in 71 patients wit CT positive in 29 (p<0.001).
Acute neuromedical and neurosurgical admissions Prospective study 114 patients	Griffiths, 2000[94]	CT vs. MRI	2	In many cases, MRI provided extra information of direct relevance not shown on CT	3% of strokes is incorrectly reported on CT. In 24% of the patients there is additional diagnostic information on MRI. Subarachnoid hemorrhage was missed in 2 patients on MRI

Aneurysm

Systematic reviews

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
Aneurysm Meta-analysis 21 studies, 1251 patients, prospective comparison (all studies between 1995-2002)	Chappell, 2003[96]	CTA vs. DSA	2		Sens/spec 93% (range, 75.4-100%) /87% (range, 0-100%) After weighting for number of patients sens/spec decrease to 92.7%/77.2% DSA remains standard method in the literature but there are clear advantages in using CTA.
Aneurysm Systematic review (103 studies) 38 scored > 50%	White, 2000[95]	CTA vs. MRA	2	Bias because of population with high aneurysm prevalence n=14 DSA vs. CTA n=18 DSA vs. MRA n=2 DSA vs. MRA/CTA n=4 transcranial US vs. DSA Limited information is available in subjects with low prevalence of aneurysm and no comparison with DSA.	Per subject and per aneurysm Sens >3 mm CTA/MRA: 96%/94% Sens </or 3 mm CTA/MRA: 61%/38% (95% CI overlapped) NPV/aneurysm was 67% for CTA and 77% for MRA.

Clinical studies

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Conclusions
Aneurysm Retrospective study 35 patients	Kouskouras, 2004[98]	CTA and MRA vs. DSA	2	Sens/spec CTA 97%/50% , MRA 100%/50% (but small number studied by MRA Ppv/npv CTA 92%/75% Both original and reconstructed images should be evaluated together for higher accuracy.
Aneurysm Prospective study in 2 centers 142 patients	White, 2001[100]	CTA vs. MRA and DSA	2	Accuracy for the best observer was 87% at CTA and 85% at MRA CTA and MRA have limited sensitivity but good interobserver agreement. For aneurysms of 5 mm or smaller both non-invasive modalities are not reliable even when US is added. A sensitivity of 57% for CTA and 35% for MRA.
Aneurysm Retrospective observational study 200 patients	Young, 2001[99]	CTA vs. DSA	2	Sens/spec CTA 97%/86% Incl. aneurysms of 3 mm and less. Spiral CTA is very useful in demonstrating intracranial aneurysms.
Aneurysm Retrospective study 51 patients	Nome, 2002[101]	MRA vs. DSA Follow-up after treatment with GDC	2	Sens/spec 97%/91% in revealing residual flow. MRA useful as long term follow-up. Initial follow-up: MRA and DSA
 Retrospective study 33 intracranial aneurysms	Westerlaan, 2005[102]	MRI	2	Sensitivity and PPV of MRA in revealing residual aneurysms: 89% and 80%. Specificity of MRA in ruling out remnant necks and residual flow: 91% and 97% MRA is a reliable diagnostic tool in the follow-up of GDC treatment.
Aneurysm Prospective study 33 patients	Okahara, 2004[103]	MRA vs. DSA	2	MRA is useful and could partly replace DSA Sens/spec 72.7%/90.9% for diagnosis of residual or recurrent aneurysm.
Aneurysm 626 first degree relatives of a consecutive series of 193 patients with subarachnoid hemorrhage	Raaymakers, 1999[97]	MRA vs. DSA 3 observers 33 aneurysms in 25 relatives. MRA as screening modality in patient at risk	2	Sens/spec: 83% (CI 65-94%)/97% (CI 94-98%). Interobserver agreement was poor MRA is feasible provided that 2 neuroradiologists independently assess MRA

Tumour

Systematic reviews

Pathology/diagnosis	Study ID	Level of evidence	Remarks	Conclusions
Systematic review 1966-2002 using Medline and several cancer databases	Hutter, 2003[104]	2	Many of the so-called cost-effective analyses fail to evaluate efficiency rigorously.	A decision tree for work-up of patients with suspected brain neoplasm is proposed but his may need to be tailored to the individual patient. Sens/spec CT is 84%/92% and MRI 92%/99% Proceed directly to MRI if metastese (and known primary cancer) would alter management.

Clinical studies

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
Pituitary macroadenoma 50 patients Prospective study before and at different timepoints after surgery	Kremer, 2002[108]	Assessment of postoperative MRI	2		Immediate postoperative MR is not useful. A postoperative MR 3 months after surgery is recommended
Pediatric tumour Retrospective study 59 patients	Kovanlikaya, 2003[106]	MRA vs. DSA	2-4	Surveillance imaging 93.8% of recurrences occur within 29 months	Depending on degree of tumour resection: Subtotal resection: every 3 months for the first 2 years after surgery, then every 6 months for the next 2 years and yearly for the next 5 years. Surveillance imaging does not appear to offer any benefit for patients undergoing total resection.
Metastasis 125 patients with focal neurological findings and a small cell lung cancer in order to detect asymptomatic metastases	Hochstenbag, 2000[105]	MRI	2-4	15% have metastases	MRI should be included in the staging of small cell lung cancer patients as well as for prognosis and therapy.

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
MR venography 55 patients	Lee, 2005[109]	MRA vs. DSA	2	In 45/55 patients there was no comparison with the gold standard DSA	3D CE MRV can be regarded as a valuable diagnostic method in assessing venous sinuses and cortical draining veins.

Degenerative disease

Systematic reviews

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
Systematic review (Medline search and systematically checking through the bibliographies of relevant articles) 626 patients with mild cognitive impairment (insufficient to meet the dementia criteria)	Wolf, 2003[112]	MRI in mild cognitive impairment	2	Larger studies are still needed, with long prospective follow-up.	Significant hippocampal and entorhinal cortex volume reductions in mild cognitive impairment, a well established risk factor for development of Alzheimer dementia.
Alzheimer dementia Evidence-based review	Kantarci, 2003[113]	MRI	2	MR volumetry to predict future development of Alzheimer dementia in patients with mild cognitive impairment or at risk of developing Alzheimer dementia. Routine imaging is done to rule out potentially treatable causes.	Structural imaging measures are potential surrogate markers for disease progression in patients with established AD and in patients with prodromal AD, who may benefit from disease modifying therapies underway. The accuracy of MR volumetry is comparable to the accuracy of a pathologically confirmed clinical diagnosis.

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
Dementia Systematic review of 7 studies (Medline supplemented by other strategies)	Gifford, 2000[111]	MRI	2	6/7 studies included less than 15 cases of potentially reversible dementia. There is an urgent need for well-deigned studies evaluating the utility of neuroimaging in patients with dementia.	There is considerable uncertainty on the evidence underlying clinical prediction rules to identify which patients with dementia should undergo neuroimaging.
Probable Alzheimer disease Quantitative review of the literature Meta-analysis (121 studies, 3511 patients + 1632 healthy controls)	Zakzanis, 2003[114]	MRI	2		Supports the use of MR volumetry. There is compelling evidence for early involvement of the hippocampal formation in the natural history of Alzheimer disease.

Clinical studies

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
Creutzfeldt-Jakob disease 40 probable/definite CJD and 53 controls	Young, 2005[115]	MRI	2		MRI is highly sensitive (91%) and specific (95%) for CJD and the accuracy was 94%. Interrater variability was high (kappa = 0.93). MRI should be used whenever there is a clinical suspicion of CJD.
Parkinson's disease Prospective randomized comparison of CT and MRI 24 patients	Honey, 2000[116]	MRI vs. CT	2		MRI co-ordinates are significantly closer to target than those from CT for pre-operative localization in pallidotomy (but no difference in surgical outcome)
Retrospective study using a decision-analytic Markov model and cost-effectiveness analysis. 315 children with	Medina, 2001[122]	CT-MRI	2	Low risk (non migraine headache > 6 months and estimated tumour prevalence of 0.01%. Intermediate risk (migraine headache and estimated tumour	Low risk: no imaging is least costly and most effective. Intermediate risk: CT and MRI when CT is positive is the most effective but at a high cost

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
headache and a suspected brain neoplasm				prevalence of 0.4%) High risk (headache < 6 months and red flag signs with estimated tumour prevalence of 4%)	1.000.00/QALY. High risk: MRI at a cost of 113.800/QALY gained

Headache

Clinical studies

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
Migraine Retrospective observational study in 80 patients	Paemeleire, 2005[121]	MRA	2	MRA was requested to exclude a vascular malformation in patients with migraine and a normal neurological examination.	MRA is not indicated
302 patients with chronic daily headache and uncomplicated migraine Retrospective analysis	Lewis, 2000[117]	MRI and CT	2		None of the imaging findings were apparent clinically and their discovery did not influence the diagnosis, management or outcome. No imaging indicated in these patients when the neurological examination is normal

Cranial nerves

Clinical and economic studies

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
Prospective single blinded comparative study in 92 patients	Patel, 2003[123]	MRI	2	76/92 MRI and surgery compression 8/92 MRI and surgery normal 8/92 false negative MRI 0/92 false positive MRI	Sens/spec 90.5/100% for demonstrating compression in trigeminal nerve neuralgia. Posterior fossa surgery can be recommended.

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
Optic neuritis vs. nonarteritic anterior optic nerve neuropathy 64 patients	Rizzo, 2002[125]	MRI	2		MRI is useful in differentiating these entities.
Cost-effectiveness of the diagnostic evaluation of sixth nerve palsies (Medline literature search) Retrospective cohort study of 407 patients.	Miller, 1999[124]	CT vs MRI	2	Prospective study with a matched control group is needed.	Sensitivity/specificity of MRI is higher. There is a role for CT in acute trauma, those with calcification/bone disease and those unable to undergo MRI.

Paediatric neurology

Clinical studies

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
48 patients Retrospective study	Robertson, 2003[126]	MRI and CT	2	Cross modality agreement and interobserver agreement of CT and MR in term neonate	Similar findings but greater interobserver agreement. Good to moderate with CT, excellent with MRI

Expert opinions

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Conclusions
Report of the quality standards subcommittee of the American Academy of Neurology and the practice committee of the child neurology society	Shevell, 2003[127]	CT vs MRI	2	Neuroimaging is recommended as part of the diagnostic evaluation of the child with global developmental delay. As the presence of physical findings increases the yield of making a specific neuroimaging diagnosis, particularly this subgroup may benefit from a scan. If available, MRI should be obtained in preference to CT scan when a clinical decision has been made that neuroimaging is indicated.
Expert opinion based on wide experience in the medical management of child abuse and extensive involvement in the medicolegal aspects of non accidental head injury	Jaspan, 2003[128]	CT/MRI	2	Whenever there is a high suspicion of non-accidental head injury the following guidelines are recommended: CT at d1, skeletal survey at d1 or d2, MR (+CT) at d3 or d4, CT at d10 and MR after 2-3 months.

Fetal neuroimaging

Clinical studies

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
Prospective study in 100 patients	Whitby, 2004[129]	US vs. MRI	2-3	In a subgroup of patients with an insufficient ultrsonographic diagnosis, MRI provided additional information in 48% of the cases. MRI is a tertiary referral center technique	N=52: MR =US N=12: MR>US but without change in management N=35: MR changed diagnosis (n=29) or provided extra information that could have altered management (n=6). In 11/35 cases the MRI changed the diagnosis by showing a normal brain.
214 patients	Levine, 2003[130]	MRI vs. US	2-3		When US appears normal, MRI is not indicated. US=MR in 69/214 (69.3%) MR changed diagnosis in 31.7% of patients with abnormal US. 18% change in diagnosis or case management can be altered. Changes in management are gestational age dependent

SPINE AND SPINAL CORD

Degenerative disease

Clinical studies

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Conclusions
29 patients with primary ganglionopathy	Lauria, 2000[133]	MRI	2	MRI is useful to support this clinical diagnosis.
Prospective study in 18 patients with of the degenerative disease cervical spine	Dorenbeck, 2004[131]	Myelo-CT vs. MRI	2	Myelo-CT is better for bony structures and anterior/posterior nerve roots. MR=CT in assessing narrowing of neural foramina and spinal stenosis.

Systematic reviews

Pathology/diagnosis	Study ID	Imaging techniques compared	Quality/ level of evidence	Remarks	Conclusions
Lumbar spine Degenerative disc disease Comparison of techniques Imaging guidelines	Jarvik, 2002[134]	MR, plain radiography, CT, bone scan	Good 2	MEDLINE search (January 1966 to September 2001) for articles and reviews relevant to the accuracy of the clinical and radiographic examination of patients with low back pain.	The sensitivity and specificity of magnetic resonance imaging for herniated discs (Se = 0.6 to 1.0 and Sp = 0.43 - 0.97) were slightly higher than those for computed tomography (Se = 0.62 to 0.9 and Sp = 0.7 - 0.87) The data suggest a diagnostic strategy similar to the 1994 Agency for Health Care Policy and Research guidelines. For adults younger than 50 years of age with no signs or symptoms of systemic disease, symptomatic therapy without imaging is appropriate. For patients 50 years of age and older or those whose findings suggest systemic disease, plain radiography and simple laboratory tests can almost completely rule out underlying systemic diseases. Advanced imaging should be reserved for patients who are considering surgery or those in whom systemic disease is strongly suspected.

Lumbar spine Degenerative disc disease Comparison of techniques	Anderson, 2004[136]	MR, discography	Good 2		Although multiple imaging modalities, most notably MRI, can show morphologic abnormalities of the spine, discography remains the only test that provides physiologic information regarding what role a given intervertebral disk plays in a patient's symptom complex.
Lumbar spine Degenerative disc disease Value of MR	Davies, 2002[138]	MR	Good 2	Comparison symptomatic and asymptomatic individuals	MRI is commonly used in the imaging of the lumbar spine and demonstrates a wide spectrum of abnormalities attributable to degenerative intervertebral disc disease in both symptomatic and asymptomatic individuals. Careful clinical correlation is essential to determine the significance of these abnormalities and to ensure appropriate treatment.
Lumbar spine Degenerative disc disease Imaging guidelines	Drape, 2000 [141]	MR	Good 2	Imaging strategy in acute and chronic low back pain	Imaging strategy varies according to the background of acute or persistent low back pain. In case of acute low back pain with associated symptoms of a cauda equina syndrome or any atypical clinical signs PA and lateral radiographs of the lumbar spine are required. An additional MRI examination is often necessary, even with negative radiographs. In the other cases, radiographs are only obtained when the low back pain persists longer than 7 weeks. Secondary, MRI may be performed in case of worsening and persistence of the clinical symptoms or if a specific low back pain is suspected. In case of chronic low back pain, with a severe socio-professional impact or a planed invasive treatment, plain films of the lumbar spine must be obtained, eventually with additional MRI examination

Clinical studies

Pathology/diagnosis	Study ID	Design	Quality/ Level of evidence	Population + prevalence	Conclusions
Lumbar spine Degenerative disc disease	Braithwaite, 1998[137]	Comparison MR - discography Prospective study Case control	Good 2	58 patients clinical diagnosis of discogenic back pain correlation of 58 MR with with discographic pain reproduction at 152 disc levels	MR "Modic changes" appear to be a relatively specific but insensitive sign of a painful lumbar disc in patients with discogenic low back pain. Se = 23 %, Sp = 97 %, PPV = 91 %, NPV = 47 %
Lumbar spine Degenerative disc disease	Mitra, 2004[139]	Comparison MR (basic and follow-up MR) with clinical symptoms Retrospective study Case control study	Good 2	56 patients with degenerative disease of the lumbar spine	There is no statistical correlation between degenerative disc disease with high intensity zones demonstrated at MR and the patient's symptoms. MR does not allow to predict clinical evolution.
Lumbar spine Degenerative disc disease	Yoshida, 2002[135]	Comparison MR - discography Prospective study Case control	Fair (selection bias) 2	23 patients; 56 lumbar discs clinical diagnosis of chronic low back pain correlation of MR with with discographic pain reproduction at 56 disc levels	The high sensitivity and the high negative predictive value of T2-weighted MR imaging in detecting the symptomatic disc indicate that MR imaging can be a useful screening tool in avoiding unnecessary discography in patients with chronic low back pain. Ability to detect symptomatic disc : On T2-weighted imaging : Se = 94%, Sp = 71%, PPV = 59%, NPV = 97%. On gadolinium-DTPA-enhanced images Se = 71%, Sp = 75%, PPV = 56%, NPV = 86%.
Lumbar spine Degenerative disc disease	Borenstein, 2001[140]	Comparison MR (basic and follow-up MR) with clinical symptoms Prospective study Case control study	Good 2	50 asymptomatic patients Follow-up after 10 years	The findings on magnetic resonance scans are not predictive of the development or duration of low-back pain in the future. Clinical correlation is essential to determine the importance of abnormalities on magnetic resonance.

Impact studies

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
Lumbar spine Degenerative disc disease Cost of MR	Ackerman, 1997[144]	Study of cost of MR estimate the annual adjusted odds of lumbosacral spine radiography, MR imaging, unenhanced computed tomography (CT), or CT myelography use Retrospective	Good 6	2374 patients with persistent low back pain period 1987 – 1990 (introduction period of MR !)	In this introduction period of MR (1987 – 1990) the volume and cost of diagnostic imaging for persistent low back pain have increased because MR imaging was used primarily as an add-on rather than a substitute for other imaging modalities in the evaluation of persistent low back pain. The adjusted odds of performing MR imaging in 1990 relative to 1987 was 3.44 (95% confidence interval, 2.63, 4.51), which reflects an estimated increase from 22 studies per 100 enrollees in 1987 to 75 studies per 100 enrollees in 1990. Use of MR imaging in combination with radiography, unenhanced CT, or CT myelography increased. The additional national cost of diagnostic imaging for persistent low back pain in 1990 relative to 1987 was estimated at $70-$176 million
Lumbar spine Degenerative disc disease Cost-benefit analysis of MR	Annertz, 1996[143]	Cost-benifit study of MR Retrospective	Good 6	Two 5-month periods were compared: period 1--before MR; and period 2--after introduction of a 2nd MR device. In period 1, patients were examined with myelography and/or CT after referral from specialists only, whereas in period 2 both specialists and general practitioners could refer patients for MR imaging. The direct cost (neuroradiologic methods and hospitalization) and indirect cost (sick-leave and estimated loss of production caused by the diagnostic procedure) were estimated. In period 1, investigations were started in 75 patients (62 myelographies and 13	Comparison of introduction period of MR with “full access” period shows that the cost of preoperative investigation per operated patient decreases by 35%. This is due to a decreased use of MR imaging as add-on imaging technique (and more as immediate second investigation after plain radiography).

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
				CT examinations); in period 2, in 227 patients (198 MR, 21 CT, and 8 myelographies)	
Lumbar spine Degenerative disc disease Cost-benefit analysis of MR	Gilbert, 2004 [142]	Study of cost of MR Prospective Randomized controlled trial	Very good 6	In a multicenter randomized study, two imaging policies for LBP were compared in 782 participants with symptomatic lumbar spine disorders who were referred to orthopedists or neurosurgeons. Participants were randomly allocated to early (393 participants) or delayed selective (389 participants) imaging groups. Delayed selective imaging referred to imaging restricted to patients in whom a clear clinical need subsequently developed. Clinical treatment was similar in both groups.	Early use of imaging does not appear to affect treatment overall. Decisions about the use of imaging depend on judgments concerning whether the small observed improvement in outcome justifies additional cost. Differences in total costs reflected cost of imaging. Imaging provided an adjusted mean additional QALY of 0.041 during 24 months at a mean incremental cost per QALY of $2,124
Lumbar spine Degenerative disc disease Cost-benefit analysis of MR	Jarvik, 2003[145]	Study of cost of rapid MR versus plain radiography Prospective Randomized controlled trial	Very good 6	Randomized controlled trial of 380 patients with low back pain. Patients were randomly assigned to receive lumbar spine evaluation by rapid MRI or by radiograph. The mean back-related disability modified Roland score for the 170 patients assigned to the radiograph evaluation group was 8.75 vs 9.34 for the 167 patients assigned the rapid MRI evaluation group (mean difference, -0.59; 95% CI, -1.69 to 0.87). The mean differences in the secondary outcomes were not statistically significant: pain bothersomeness (0.07; 95% CI -0.88 to 1.22), pain frequency (0.12; 95% CI, -0.69 to 1.37), and SF-36 subscales of bodily pain (1.25; 95% CI, -4.46 to 4.96),	Rapid MR imaging and radiographs resulted in nearly identical outcomes for primary care patients with low back-pain. Although physicians and patients preferred the rapid MRI, substituting rapid MRI for radiographic evaluations in the primary care setting may offer little additional benefit to patients. It may increase the costs of care because of the increased number of spine operations that patients are likely to undergo.

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
				and physical functioning (2.73, 95% CI -4.09 to 6.22). Ten patients in the rapid MRI group vs 4 in the radiograph group had lumbar spine operations (risk difference, 0.34; 95% CI, -0.06 to 0.73). The rapid MRI strategy had a mean cost of $2380 vs $2059 for the radiograph strategy (mean difference, $321; 95% CI, -1100 to 458).	

Spinal trauma

Systematic reviews

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
Evidence-based approach to use of MR imaging in acute spinal trauma	Cohen, 2003[147]	MR	I	No methodology given	MR is superior in imaging spinal cord trauma.
Meta-analysis of a total of 392 cases of patients with spinal cord injury without radiographic abnormality.	Launay 2005[151]	MRI	2		MRI is indicated in the acute stage but also in the follow-up because evidence of injury might not appear immediately.

Clinical studies

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Conclusions
Efficacy of MRI in pediatric cervical spine injury Retrospective before-and-after study using two cohorts Cost-effectiveness analysis	Frank, 2002[146]	MRI	2	MRI is effective and results in cost savings in the evaluation of cervical spine inury in obtunded and intubated pediatric trauma patients.
Spinal trauma in 97 patients with altered mental status Retrospective observational study	Adams, 2006[148]	MRI	2-4	83/92: CT=MR 12/92: degenerative instead of fracture 2/92:new MR injury MRI should be reserved for cases when initial CT is suggestive of traumatic injury

Spinal malignancy

Systematic reviews

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Conclusions
Systematic review (using Medline,Cancerlit and Cochrane) Diagnosis and therapy of extradural spinal cord compression	Loblaw, 2005[152]	MRI	2	Although sensitivity and specificity of MRI and CT-myelography are comparable, MRI is indicated because it is less invasive.

Clinical studies

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Conclusions
Known malignancy and suspected spinal canal disease 159 patients	Loughrey, 2005[153] Manchester, U.K.	MRI	2	MRI with Gd is recommended when no correlation with clinical findings and when intraspinal pathology is suggested.
Prospective study in 280 patients with suspected malignant spinal cord compression	Husband, 2001[154]	MRI vs. plain X-ray/neurological examination	3-4	MRI has led to a change in radiotherapy in 53% of the patients (21% major change). Focal X-ray changes and consistent neurological findings the presence and level of disease (spec 98%)

Expert opinion

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Conclusions
Expert opinion based on available evidence in the literature Guidelines in the diagnosis and management of multiple myeloma 2005	Smith, 2005[155]	MRI	2	MRI is the technique of choice for investigation of patients with a neurological presentation suggestive of cord compression. MRI should be performed in patients with an apparently solitary plasmocytoma of bone irrespective of site of the index lesion

Systematic reviews

Pathology/diagnosis + prevalence	Study ID	Imaging techniques compared	Quality/ Evidence level	Remarks	Conclusions
Spinal metastasis Detection	Gualdi, 1999 [157]	MR imaging compared with CT and plain radiography	Poor 2		The sensitivity and multiplanar capabilities inherent in magnetic resonance imaging make it the imaging procedure of choice in detecting and characterizing a spinal bone lesion. Spiral computed tomography with multiplanar reconstruction may be a useful supplementary procedure, especially when detailed bony anatomy,is required for surgical intervention. Plain films play little if any role in modern imaging.
Spinal metastasis Detection	Jarvik, 2002[134]	MR, CT scan	Good 2	MEDLINE search (January 1966 to September 2001) for articles and reviews relevant to the accuracy of the clinical and radiographic examination of patients with low back pain.	Sensitivity for cancer was highest for magnetic resonance imaging (0.83 to 0.93) and radionuclide scanning (0.74 to 0.98). Specificity was highest for magnetic resonance imaging (0.9 to 0.97) and radiography (0.95 to 0.99)

Clinical studies

Pathology/diagnosis	Study ID	Design	Quality	Population	Conclusions
Spinal metastasis Detection	Taoka, 2001[159]	Comparison MR – bone scintigraphy Retrospective study No gold standard Case control	Poor 2	74 patients with known widely disseminated metastatic disease	Location (the presence of cortical bone involvement on MR imaging) and size of the vertebral body metastases appear to be important contributing factors to the difference in detection rates between MR imaging and bone scintigraphy. Cortical involvement is likely the cause of positive findings on bone scans. Early vertebral metastases tend to be small and located in the medullary cavity without cortical involvement, and therefore, findings may be positive on MR images but negative on bone scans

Pathology/diagnosis	Study ID	Design	Quality	Population	Conclusions
Spinal metastasis Detection	Krappel, 2001[158]	Comparison MR – plain radiography and bone scintigraphy Prospective study No gold standard Case control	Poor 2	15 patients with suspected metastatic disease	Plain radiography and 99mTc bone scanning gave a diagnostic suspicion but no definite diagnosis or therapeutic consequence. MR imaging of the spine including whole spine images allows clear cut decision making in diagnosis and treatment of cases suspicious for metastatic disease of the spine. Careful history taking and clinical examination provide enough information to opt for whole spine MRI as the first choice investigation. This will provide maximum benefit to the patient and avoid examination cascades
Spinal metastasis Detection	Feun, 1990[156]	Comparison MR – plain radiography and bone scintigraphy Case report	Poor 2	2 patients with suspected metastatic disease	MR imaging demonstrates metastatic disease to the bone and spinal cord compression in patients who presented with back pain and had unremarkable or equivocal roentgenograms and radionuclide scans.
Spinal metastasis Detection	Levack, 2002[160]	Comparison MR – plain radiography and bone scintigraphy Prospective study No gold standard Case control	Poor 2	319 patients with suspected metastatic disease	Plain films and bone scans requested for patients predicted accurately the level of compression in only 21% and 19% of cases, respectively. The only accurate investigation to establish the presence and site of a compressive lesion is magnetic resonance imaging. MR imaging should be performed very early, when weakness and/or sensory problems are noticed, and should not be delayed until pain or paresis appear.
Spinal metastasis Differential diagnosis with vertebral fracture	Chen, 2002[162]	Prospective study No gold standard Case control	Poor 2	42 patients with suspected metastatic disease or vertebral fracture	Time-intensity curves (TIC) are valuable in the differentiation of benign and malignant vertebral lesions. TIC with rapid contrast wash-in followed by early wash-out : PPV for metastasis = 100 % TIC with rapid contrast wash-in with a second slower-rising slope : PPV for benign compression fracture = 85,7 %

Pathology/diagnosis	Study ID	Design	Quality	Population	Conclusions
Spinal metastasis Differential diagnosis with osteoporotic vertebral fracture	Fu, 2004[164]	Prospective study Histopathological correlation Case control	Good 2	98 patients 48 patientswith metastatic vertebra 50 patients with osteoporotic vertebral fracture	Certain MRI characteristics allow early differentiation of benign and malignant vertebral fractures. Absence of enhancement indicates benign fracture (NPV = 100 %) Signs favouring malignancy : Paraspinal soft tissue mass : Se = 96 %; Sp = 92 %; Acc 94 %; PPV = 92 %; NPV = 96 % Pedicle involvement : Se = 94 %; Sp = 88 %; Acc 91 %; PPV = 88 %; NPV = 94 % Posterior element involvement : Se = 83 %; Sp = 96 %; Acc 90 %; PPV = 95 %; NPV = 86 %
Spinal metastasis Differential diagnosis with osteoporotic vertebral fracture	Baur, 2002[161]	Prospective study Histopathological correlation Case control	Good 2	87 patients 35 patientswith metastatic vertebra 52 patients with osteoporotic vertebral fracture	Fluid sign represents osteonecrosis and edema is significantly correlated with osteoporotic fracture (P <0.001) and occurs rarely in metastatic fracture. Se = 21 %; Sp = 94 %; Acc 62 %; PPV = 91 %; NPV = 52 %
Spinal fracture Osteoporotic vertebral fracture	Kanchiku, 2003[163]	Comparison MR – plain radiography Retrospective study No gold standard Case control	Poor 2	34 patients 316 osteoporotic fractures	The diagnostic rate for vertebral fractures is 98% for MR imaging and 87% for plain radiography.
Spinal fracture Osteoporotic and traumatic vertebral fracture	Fu, 2005 [165]	Retrospective study No gold standard Case control	Poor 2	107 patients 42 osteoporotic fractures 65 traumatic fractures	This descriptive study reveals that MR imaging can differentiate spinal traumatic fracture from osteoporotic fracture.
Spinal metastasis Detection and MR imaging technique Technical efficacy	Castillo, 2000 [166]	Comparison MR – conventional MR imaging with diffusion MR Prospective study No gold standard Case control	Poor 1	15 patients with metastatic disease	Diffusion-weighted MR imaging of the spine shows no advantage in the detection and characterization of vertebral metastases as compared with noncontrast T1-weighted imaging, but is considered superior to T2-weighted imaging.
Spinal metastasis Detection and MR imaging technique Technical efficacy	Herneth, 2000[167]	Comparison MR – conventional MR imaging with diffusion MR Prospective study No gold standard	Poor 1	5 patients with metastatic disease	Diffusion-weighted MR imaging of the spine is feasible and allows differentiation of normal vertebra from metastatic vertebra.

Pathology/diagnosis	Study ID	Design	Quality	Population	Conclusions
		Case control			
Spinal metastasis Detection and MR imaging technique Technical efficacy	Ohno, 2003[168]	Comparison MR – conventional MR imaging with opposed phase MR Prospective study No gold standard Case control	Poor 1	27 patients with metastatic vertebra 21 patients with non-neoplastic vertebral lesion	Minimal difference between conventional MR (Se = 85 %, Sp = 93,3 %) and opposed-phase MR (Se = 98,5 %, Sp = 82,4 %) for detection of vertebral metastases.

Impact studies

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population	Conclusions
Spinal metastasis Detection	Hollingworth, 2003[170]	Decision model with Markov state transitions to calculate the cost per case detected and cost per quality-adjusted life year (QALY) of rapid MR imaging. Model parameters were estimated from the medical literature. The costs of x-ray and rapid MR were calculated in an activity-based costing study.	Good 6	Hypothetical cohort of primary care patients, not suspected for spinal metastasis, referred for imaging to exclude cancer as the cause of their pain	The rapid MR strategy was more expensive due to higher initial imaging costs and larger numbers of patients requiring conventional MR and biopsy. The overall sensitivity of the rapid MR strategy was higher than that of the x-ray strategy (62% vs 55%). However, because of low preimaging prevalence of cancer-related low back pain, this generates <1 extra case per 1,000 patients imaged. Therefore, the incremental cost per case detected using rapid MR was high ($213,927). The rapid MR strategy resulted in a small increase in quality-adjusted survival (0.00043 QALYs). The estimated incremental cost per QALY for the rapid MR strategy was $296,176. There is currently not enough evidence to support the routine use of rapid MR to detect cancer as a cause of low back pain in primary care patients

Spinal metastasis Treatment planning	Prott, 2002 [169]	Cost benefit analysis Retrospective study	Good 6	137 patients with known disseminated metastatic disease	In 73% of patients (101 patients), magnetic resonance imaging resulted in marked corrections of the irradiation fields which would have resulted in the necessity of treatment for recurrence in the case of treatment planning without MRI. Consequently, the higher cost of MRI of 176,40 EUR lead to a saving of 254,11 EUR compared to a recurrence treatment of 10 fractions and of 730,12 EUR compared to 20 fractions. The transport expenses for the second treatment could be saved as well. Even under economic considerations MRI is effective.

Spinal infection

Systematic reviews

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Conclusions
Spinal infection Review	Tins, 2004[172]	MRI	2	High sensitivity and specificity of MRI is emphasized. MRI plays an essential role in the decision-making process concerning conservative vs. surgical treatment and is the best technique to monitor the effect of treatment.

Clinical studies

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Conclusions
59 patients with thoracic or lumbar spondylodiscitis	Wirtz, 2000[171]	MRI	2	MRI is indicated particularly to differentiate between those without and those with abscesses. CT is recommended in the follow-up to show regressive inflammation and increasing osseous consolidation after 5-6 weeks (MRI after 12 weeks only visible)

Spine congenital

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Conclusions
Systematic review 20 primary studies included. Cost utility analysis	Medina 2001[173]	MRI	2	High risk: MR preferred modality and cost saving. Low risk (intergluteal dimple or infant of diabetic mother): US Intermediate risk:US or MR. A large prospective cohort study is required.

CARDIAL RADIOLOGY

Myocardial ischemia

Systematic reviews

Pathology / Diagnosis / Prevalence	Study ID	Imaging Techniques compared	Quality Level of evidence	Remarks	Conclusions
Coronary Artery Disease (CAD) 50% stenosis of CA lumen in patients with complaints of myocardial ischemia. Patients referred for cardiac catheterization because of CAD complaints High pre-test probability	Budoff 2003[174]	Diagnostic performance of magnetic resonance coronary angiography (MRCA), electron beam tomography (EBT) and multislice computed (MSCT) tomography versus cardiac catheterization	Very good Level 2-3	MEDLINE	-EBT(10 studies), 583 patients Se 87%, Sp 91%, 16% unevaluable -MSCT 4-8-16 slices (8 studies) 513 patients Se 59%, Sp 89%, 31% unevaluable -MRCA (9 studies) 387 patients Se 77%, Sp71%, number of unevaluable segments not given.

Pathology / Diagnosis / Prevalence	Study ID	Imaging Techniques compared	Quality Level of evidence	Remarks	Conclusions
Coronary Artery Disease (CAD) 50-75% stenosis of CA lumen with complaints suggestive of myocardial ischemia. Patients referred for cardiac catheterization (CA) because of CAD complaints High pre-test probability	Danias 2004[175]	Diagnostic performance of magnetic resonance coronary angiography (MRCA) vs coronary angiography (CA)	Very good Level 2-3	MEDLINE – EMBASE search	39 studies (1991-2004) 993 subjects (4620 segments - Detection CAD Se 75% Sp 85% - Subject level Se 88% Sp 56% Summary ROC Conclusion : Moderate high Se for detecting significant proximal stenoses and has value to exclude significant multivessel CAD in subjects considered for diagnostic CA
Coronary artery disease (CAD) > 50% stenosis of CA lumen with complaints suggestive of myocardial ischemia. Patients referred for cardiac catheterization because of CAD complaints High pre-test probability	Schuijf 2006[176]	Diagnostic performance of MRCA and multislice computed tomography (MSCT, up to 16 slice) versus CA	Very good Level 2-3	MEDLINE + manual search (cardiology – radiology journals (1999-2005 + reference list of cited manuscripts + only literature	51 studies (31 MRCA studies) Se / Sp / odds ratio significantly higher for MSCT that MRCA Se 85% vs 72% Sp 95% vs 87% Odss ratio 16.9 fold vs 6.4 fold for the presence of significant stenosis.

Cardiac Masses and Tumours

Pathology / Diagnosis / Prevalence	Study ID	Imaging Techniques compared	Quality/ Level of Evidence	Remarks	Conclusions
Thrombus formation is a frequent complication in patients with diseased left ventricle (ischemic heart disease) Intermediate pre-test probability	Mollet, 2002[201]	Comparison of MRI (contrast-enhanced MRI, dynamic cine MRI) versus routinely used technique (transthoracic echocardiography)	Fair (no reference standard) Level 2	57 patients with acute, chronic myocardial infarction / ischemic cardiomyopathy	CE-MRI detected 12 mural thrombi, versus cine MRI (6 thrombi) and echocardiography (5 thrombi). Presence of thrombus formation on CE-MRI was related to larger end-diastolic volumes, lower ejection fractions, the region of delayed myocardial enhancement and lowest wall motion score.
Though cardiac tumors are rare, differentiation between benign and malignant lesions is important is choosing the most appropriate treatment High pre-test probability	Hoffmann 2003[219]	The usefulness of MRI was compared with histology to distinguish benign from malignant lesions in 55 patients	Good Level 2	55 patients, 22 malignant, 33 benign lesions	Tumor location, tissue composition, and pericardial or pleural effusion all were identified as key predictors of lesion type. ROC analyses for the accuracy of prediction of the lesion type showed an area under the curve (0.88 reader 1) and (0.92 reader 2) with an acceptable interobserver variability (kappa: 0.64).

Myocarditis and cardiomyopathies

Pathology / Diagnosis / Prevalence	Study ID	Imaging Techniques compared	Quality/ Level of Evidence	Remarks	Conclusions
Patients with presumptive diagnosis of myocarditis High pretest probability	Laissy 2002[221]	Comparison of different MRI techniques, no comparison with reference technique	Fair Level 2	20 patients with myocarditis, 7 control subjects	Myocardial enhancement (focal / diffuse) was seen in all patients (sensitivity and specifity: 100%)
Patients with clinical diagnosis of myocarditis High pretest probability	Mahrholdt 2004[198]	Comparison of MRI with endomyocardial biopsy (taken into the region of contrast enhancement)	Very Good Level 1	32 patients with myocarditis (biopsy proven)	Contrast-enhancement was found in 88% of patients (single / multiple foci) Biopsies in the region of enhancement revealed active myocardiits in 19/21 patients, whereas only in 1/11 patients with biopsies in non-enhanced areas.
Patients with acute myocarditis High pretest probability	Abdel-Aty 2005[222]	Comparison of MRI techniques (single performance versus combined performance of MRI techniques, ie T2-weighted spin-echo MRI, post-contrast T1-weighted spin-echo MRI, inversion-recovery contrast-enhanced gradient-echo MRI	Good Level 2	25 patients with suspected acute myocarditis, 23 healthy controls	Best diagnostic performance was obtained when 2/3 MRI sequences were positive, yielding a Se of 76%, Sp of 95.5%, and diagnostic accuracy of 85%
Patients suspected of having hypertrophic cardiomyopathy (HCM) or with confirmed diagnosis High pre-test probability	Rickers 2005[224]	Comparison of MRI with echocardiography	Good Level 3	48 patients with HCM	MRI is capable of identifying regions of LV hypertrophy (especially anterlateral wall) not recognized by echocardiography. MRI was able to diagnose HCM in a minority of patients (6%).

Pathology / Diagnosis / Prevalence	Study ID	Imaging Techniques compared	Quality/ Level of Evidence	Remarks	Conclusions
Patients with HCM have increased risk of heart failure and sudden death Intermediate pre-test probability	Moon 2003[225]	Myocardial enhancement versus other risk factors, and follow-up (5 years)	Good, Blinded prospective Level 4	53 HCM patients, with the presence (n=23) or absence (n=30) of increased clinical risk of sudden cardiac death and/or progressive left ventricular remodelling	In patients with progressive disease and two or more risk factors for sudden death, a greater extent of myocardial enhancement was found (28.5% versus 8.7%, p<0.0001, and 15.7% versus 8.6% p=0.02, respectively).
Patients with dilated cardiomyopathy versus patients with left ventricular dysfunction caused by coronary artery disease High pre-test probability	McCrohon 2003[231]	Assessment of the pattern and location of myocardial enhancement	Good Level 3	90 patients with heart failure (63 dilated cardiomyopathy / 27 significant CAD) – 15 control patients	Myocardial enhancement is a powerful tool to distinguish dilated cardiomyopathy from dysfunction related to CAD. Normal coronary angiography does not exclude presence of LV dysfunction caused by CAD

Pericardial disease

Pathology / Diagnosis	Study ID	Imaging Techniques compared	Quality/ Level of Evidence	Remarks	Conclusions
Patients with clinical suspicion of constrictive pericarditis Intermediate to high pre-test probability	Giorgi 2003[238]	Assessment of ventricular septal motion on breath-hold MRI and its value to differentiate between constrictive pericarditis and restrictive cardiomyopathy	Good Level 2	41 patients with clinical suspicion of constrictive pericarditis, 12 control subjects	Abnormal ventricular septal motion yielded a Se of 81%, Sp of 100 %, and diagnostic accuracy of 90% to differentiate between restrictive cardiomyopathy and constrictive pericarditis

Pathology / Diagnosis	Study ID	Imaging Techniques compared	Quality/ Level of Evidence	Remarks	Conclusions
Patients with clinical suspicion of constrictive pericarditis High pre-test probability	Francone 2006[241]	Evaluation of respiratory-related ventricular septal motion Histological confirmation	Good Level 2	18 patients with constrictive pericarditis, 6 patients with inflammatory pericarditis, 15 restrictive cardiomyopathy patients, 17 normal subjects	Ventricular coupling is increased in patients with surgically-proven constrictive pericarditis, enabling to differentiate with restrictive cardiomyopathy patients.
Patients with clinical suspicion of inflammatory pericarditis High pre-test probality	Taylor 2005[242]	MRI versus histology and or microbiology	Fair Level 2	16 patients with clinical suspicion of pericardial disease 12 control subjects	MRI shows a sensitivity and specificity of 100% to detect inflammatory pericarditis, whereas patients with chronic fibrosing pericarditis show no enhancement

Valvular Heart Disease

Pathology / Diagnosis / Prevalence	Study ID	Imaging Techniques compared	Quality Level of Evidence	Remarks	Conclusions
Patients with severe aortic stenosis High pre-test probability	Kupfahl 2004[243]	Quantification of aortic valve area (planimetry) using cardiac catheterization as reference	Good Level 2	44 symptomatic patients, Aortic valve area (< 0.8 cm2)	MRI vs CA Se 78%, Sp 89% Transesophageal US vs CA Se 70%, Sp 70% Transthoracic US vs CA Se 74%, Sp 67%
Patients with mitral stenosis High pre-test probability	Djavidani 2005[247]	Quantification of mitral valve area (planimetry)	Good Level 2	22 patients Mitral valve area < 1.5 cm2	MRI showed good correlation with cardiac catheterization (r=0.89, p<0.0001) and echocardiography (r=0.81, p<0.0001) Se: 89%, Sp: 75%

Pathology / Diagnosis / Prevalence	Study ID	Imaging Techniques compared	Quality Level of Evidence	Remarks	Conclusions
Patients with symptomatic aortic stenosis High pre-test probability	Friedrich 2002[244]	Quantification of aortic valve (planimetry)	Good Level 2	31 patients	MRI versus catheterization 0.78 MRI versus echocardiography: 0.52
Patients with aortic stenosis (0.5 to 1.8cm2) High pre-test probability	Caruthers 2005[246]	Quantification of aortic valve area using the continuity equation Correlation with Doppler ultrasound	Fair Level 2	24 patients	Correlation coefficients between modalities for pressure gradients were r= 0.83 for peak and r=0.87 for mean

VASCULAR RADIOLOGY

Carotid and vertebral artery disease

Systematic Reviews

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
Carotid artery disease Systematic review of 10 studies	Berry, 2002[261]	MRA (mainly unenhanced) vs. DSA	2	* Primarily to determine cost-effectiveness * to synthesize evidence about diagnostic performance of MRA compared with DSA, at surgical decision thresholds * most studies used unenhanced MRA results, that are not considered up to date anymore	Unenhanced 2D and 3D TOF MRA are accurate for identifying occlusions and 70-99% stenosis, but not for 50-99% stenoses. Results for enhanced MRA appear better but could not be quantified (too few studies).

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
Carotid and vertebral artery disease 43 studies (range 10-216 patients each, mean < 30) Systematic review	Hollingworth, 2003[271]	CTA vs. DSA	2	41/43 used single slice CTA. CT technology has advanced compared to this review.	CTA is sensitive (95%) and specific (98%) in identifying atherosclerotic stenosis and there seems to be no overestimation of the degree of stenosis For blunt or penetrating trauma there is not sufficient evidence
Carotid artery disease Systematic review of 6 studies on MRA and one systematic review : Blakeley et al. Noninvasive carotid artery testing. A meta-analytic review Ann Int Med 1995;122(5):360-367.	Meenan, 2002[262]	MRA (mainly unenhanced) vs. DSA	2	Report published in July 2002; it remains unclear when the literature search ended. Studies on MRA were of fair to poor quality.	Few studies have compared MRA to DSA and the accuracy of MRA may vary from center to center depending on the available technique. Sensitivity (92%) and specificity (97%) for severe stenosis. Estimates of accuracy must be anticipated cautiously.
Carotid artery disease Systematic review of 62 studies	Nederkoorn, 2003[812]	MRA and US vs. DSA	2	No cost calculation	MRA > US in assessing 70-99% stenosis: sensitivity 95% (95% CI:92%;97%) specificity 90% (95% CI:86%;93%) for MRA compared to sensitivity 86% (95% CI:84 to 89%) and specificity 87% (95% CI:84%;90%) for US. MRA and US are very accurate in detecting occlusion, resp. 98%/100% and 96%/100%

Clinical studies

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
Carotid artery disease Prospective study, 70 articles included	Long, 2002[267]	No direct comparison, reproducibility/sensitivity/specificity of US , CTA and ce-MRA were assessed	2	Direct comparisons between results was not possible since the findings originated from different populations. Reproducibility could not be assessed (CTA,MRA) because there are only few studies available.	Regardless of the technique, a sensitivity >80% and a specificity >90 % were found in more than 2/3 of the studies. Following US, MRA is more frequently used and when both techniques agree a better diagnosis is reached.
Carotid artery disease Prospective study 43 patients Observational study	Lenhart, 2002[264]	ce-MRA vs. DSA	2	Diagnostic accuracy and interobserver reliability for suspected stenosis	Ce-MRA is reliable for assessing 70-99% stenosis Sensitivity 98% and specificity 86 %. Excellent interobserver agreement. No significant difference between ce-MRA (0.794 kappa value) and DSA (0.788 kappa value).
Carotid artery disease Prospective study of 40 patients Observational study	Alvarez-Linera J, 2003[813]	ce-MRA and single slice CTA vs. DSA	2	Higher correlation coefficient between ce-MRA (r=0.98) and DSA (r=0.86). There was more under- and overestimation with CTA than with MRA in comparison with DSA.	Sens/Spec of MRA 97.1%/95.2% and of CTA 74.3%/97.6% for stenosis of 70% or more MRA is more accurate than CTA and can replace DSA
Carotid artery disease 39 symptomatic patients	Borisch, 2003[269]	ce-MRA and US vs. DSA 4 readers	2	Sens/spec ce-MRA 94.9%/79.1%, US 92.9%/81.9% and both ce-MRA&US 100%/81.4%, for concordant results of ce-MRA and US. Ce-MRA and US together are preferable than DSA.	
Vertebrobasilar and carotid artery disease 40 patients Suspected atherosclerotic disease	Yang, 2005[266]	ce-MRA vs. DSA 2 readers	2	Sens/spec for carotid 94/97% and for vertebral 88/98% with excellent interobserver reliability (kappa value 0.92). Sens/spec for entire system is 90/97%	

Pathology/diagnosis	Study ID	Imaging techniques compared	Level of evidence	Remarks	Conclusions
Retrospective study of 140 carotid arteries	Honish, 2005[263]	US vs. DSA and MRA	2	Stenosis > 70%: US: sens 87%, spec 80%, PPV 70%, NPV 93% MRA: sens 75%, spec 100%, PPV 100%, NPV 85% MRA technique needs to be standardized. Combining US and MRA, increases the sens to over 90% withhout compromising spec.	
50 consecutive patients evaluated for carotid endarterectomy	Johnston, 2002[265]	ce-MRA vs. DSA	2	Stenosis > 70%: ce-MRA: sens 92%, spec 62%, PPV 78%, NPV 89% Kappa scores for MRA and DSA are comparable (0.72 and 0.75 resp.) 24% of the patients were misclassified when using MRA only and 17% when using MRA and US.	

HEAD AND NECK

Systematic reviews

Pathology/diagnosis + prevalence	Study ID	Imaging techniques compared	Quality	Remarks	Conclusions
Temporomandibular disk displacement. Prevalence between 32-78%.	Liedberg 1996[390]	arthrography, CT and MRI	very good	Comprehensive literature search 1978-1994; >400 publications were reviewed; publications were weighted according to their quality (taking into account prevalence of disease and gold standard used)	Arthrography has the best diagnostic performance for anterior disk displacement compared to MRI (LR+ 4,5 vs. 2,3), but is less good for sideways and rotational displacement compared to MRI (LR+ 3,8 vs. 6,2). The interobserver reproducibility is moderate to substantial for arthrography, but almost perfect for MRI. CT is a less good discriminator compared to arthrography and MRI. As arthrography is an invasive procedure, MRI is the preferred imaging method.

Clinical studies

Pathology/diagnosis	Study ID	Design	Level	Quality.	Population and prevalence	Conclusions	Comments
sensorineural hearing loss	Rupa 2003[342]	screening for acustic schwannoma in patients with asymmetric hearing loss with auditory brainstem responce (ABR) and Gd-enhanced MRI prospective patient series gold standard = MRI	2	fair	90 patients with asymmetric audiovestibular symptoms; 4 had VS, and 2 CPA-meningioma on MRI	ABR as preliminary screen is cost-effective in patients with mild or moderate hearing loss (se=100%; sp=61,9%; PPV=13,3%; NPV=100%)	consecutive patients? 'hearing loss' not further defined; hearing loss and tinnitus, or and/or tinnitus?; it is unclear if patients with only vertigo were included. 18/90 patients without response on ABR (due to profound SNHL) were excluded
	Cueva 2004[343]	screening for acustic schwannoma in patients with asymmetric sensorineural hearing loss with auditory brainstem responce (ABR) and Gd-enhanced MRI prospective patient series gold standard = MRI	2	good	multicenter study; 312 patients with asymmetric SNHL; 31 patients (9,9%) had lesion explaining their hearing loss on MRI (24 VS)	ABR is not reliable as screening method (se=71%; sp=74%; PPV=23%; NPV=96%); a focused (GD-enhanced) MRI protocol is recommended as screening test; duration of symptoms and patient's age should be taken into account	patients with severe SNHL were not included
	Obholzer 2004[344]	optimalization of ABR criteria for diagnosing vestibular schwannoma retrospective patient series gold standard = MRI	2	good	36 patients with positive MRI + 100 patients with negative MRI, during year 2000 in two centres	Best ABR protocol has se=97% and sp=49%; application would have reduced number of MRI scans by 57%, missing one tumor	patients from centres without established selection guidelines; no information on size of tumors

Pathology/diagnosis	Study ID	Design	Level	Quality .	Population and prevalence	Conclusions	Comments
	Shin 2000[345]	effectiveness of conservative management of acoustic neuromas retrospective patient series gold standard = MRI or CT	3	good	97 patients with VS initially treated conservatively for various reasons; 87 had at least 2 MRI or CT studies	60 (62%) were still treated conservatively at end of study period (mean interval 15 months); 12% was treated; 26% quitted follow-up program. The tumor did not grow in 36%, shrinked in size in 11%, grew <2mm in 24%, 2-5mm in 16% and >5mm in 13%. Tumor growth over time should be monitored by imaging and is factor in treatment decision.	Study is showing the possible value of follow-up MRI in selected patients with VS
	Mafong 2002[347]	Use of laboratory testing and CT and/or MRI in children with unexplained SNHL retrospective patient series gold standard = audiometry	2	fair	114 consecutive children with SNHL, 97 underwent imaging	Routine laboratory evaluation has a low diagnostic yield. Imaging revealed abnormalities of the temporal bone in 39%. All children with SNHL should undergo radiologic evaluation.	Study confirms role of CT, but has insufficient evidence for additonal value of MRI. Imaging results have impact on management, but this was not specifically studied.
	Kösling 2003[348]	Use of MRI in suspected inner ear malformations prospective patient series gold standard = audiometry	2	good	50 patients with suspected inner ear malformation after clinical and audiometric testing (n=86); 42 patients also had CT	MRI revealed abnormalities in 32%. All inner ear abnormalities were also seen on CT, but MRI displayed finer details; in 1 patient, MRI also showed isolated absence of the cochlear nerve in 1 patient (this patient was not deaf)	MRI is recommended as modality of choice in suspected inner ear malformations, but CT is necessary when also middle/external ear abnormalities are present, and in the pre-operative evaluation of cochlear implant patients.

Pathology/diagnosis	Study ID	Design	Level	Quality.	Population and prevalence	Conclusions	Comments
	Sennaroglu 2002[350]	Incidence of cochlear nerve anomaly in patients with congenital hearing loss prospective patient series gold standard = audiometry+C19	2	good	27 patients with congenital hearing loss, evaluated for cochlear implant procedure	14 patients had normal CT and MRI findings. In 13 patients with various abnormalities of the cochleovestibular system on CT, 4 had absence of the vestibulocochlear nerve; all 4 had narrow or absent IAC on CT. Isolated absence of cochlear nerve was seen in 1 patient with enlarged IAC and Mondini malformation on CT	Authors use CT as primary imaging tool in congenital hearing loss before cochlear implant; MRI is added if CT is abnormal, for demonstration of cochlear nerve. In acquired hearing loss, MRI should be used.
	Ellul 2000[349]	Comparison between CT and MRI for showing cochlear patency in cochlear implant candidates retrospective patient series gold standard = surgical findings	2	good	31 patients with various causes of hearing loss, evaluated for cochlear implant procedure	Thin-section T2-weighted MRI is accurate in predicting cochlear anomalies, and adds additional information (presence of cochlear nerve); in 4/31 cases, CT revealed abnormalities not seen on MRI, but these findings were of no consequence to eventual treatment	MRI can show cochlear fibrosis, not shown on CT, but there were no such cases in this study group. Only MRI can detect all cases of cochlear nerve aplasia, and show acquired degeneration of this nerve following viral illness or meningitis. CT is needed in complex congenital anomalies to show the course of the facial nerve.

Pathology/diagnosis	Study ID	Design	Level	Quality .	Population and prevalence	Conclusions	Comments
	Glastonbury 2002[346]	MRI findings in cochlear nerve deficiency retrospective patient series no gold standard	2	good	22 patients with congenital or acquired cochlear nerve deficiency	In 11/12 patients with congenital deficiency, the IAC was abnormal; in 10/10 patients with acquired congenital deficiency, the IAC was normal	Absence of the cochlear nerve in congenital case is a contra-indication to cochlear implant. In acquired cases, size determination of th nerve may be of importance in predicting success and choosing the best side for implantation
pharyngeal neoplasms	Dammann 2005[352]	Comparison of CT, MRI and FDG-PET in pre-operative staging of oral cavity and oropharyngeal squamous cell carcinoma Prospective Patient series Gold standard = histology	2	fair	79 patients, with SCC; 15 were excluded (11 inoperable, 4 MRI could not be performed); eventual population: 67 SCC in 64 patients	Primary tumor: confidence level for diagnosis was significantly lower with CT, compared to MRI and PET. Lymph node metastasis: no significant difference between CT, MRI and PET (ROC analysis)	All primary tumors were detected by clinical examination. Imaging of the primary tumor is performed to evaluate its anatomical extent: this was not evaluated
	Hsu 2005[353]	Accuracy of MRI to show abscence of fixation of laryngeal or pharyngeal cancer to prevertebral space Retrospective Patient series Golden standard = surgical findings and histology	2	good	75 patients, collected over 5 years, with T3 or T4 laryngeal or pharyngeal cancer	preservation of retropharyngeal fat plane, between tumor and prevertebral component, has negative predictive value of 97,5%	High NPV (82%) was previously reported for CT (Righi 1996). It is unlikely that CT and MRI would yield significantly different results.
	Bolzoni 2004[351]	Accuracy of MRI to show mandibular involvement in oral-oropharyngeal SCC Prospective Patient series	2	very good	43 patients, collected over 10 years; 15 had mandibular invasion	Se=93%; Sp=93%; acc=93%; NPV=96%; PPV=87,5%	Similar results in (retrospective) CT study (Mukherji 2001): Se=96%; Sp=87%; NPV=95%; PPV=89%

Pathology/diagnosis	Study ID	Design	Level	Quality .	Population and prevalence	Conclusions	Comments
		Gold standard = histology after mandibular resection					
	King 2000[354]	Detection of parapharyngeal tumor extension (PTE) in nasopharyngeal cancer by CT and MRI Retrospective Patient series No gold standard (patients were treated by radiotherapy)	2	?	78 patients with nasopharyngeal cancer, examined both by CT and MRI	CT and MRI are in accordance in 76-78% of patients (depending on criterion); when discordant, MRI shows nearly always absence of PTE in case of positive CT (95%), rarely early PTE in case of negative CT (4%)	Despite absence of golden standard, relevant study, as PTE is influencing staging of tumor
	Poon 2000[355]	Comparison of CT and MRI in showing tumor extent and T-stage of nasopharyngeal carcinoma Retrospective? Patient series No golden standard (patients were treated by radiotherapy)	3	?	48 patients with nasopharyngeal cancer, examined both by CT and MRI	MRI shows more extensive disease in 33% of patients, with increase of T-stage in 17%; planning of radiotherapy was adapted to findings on MRI	Effect of adaptation of RT to tumor extent visible on MRI was not examined
	Chang 2005[359]	Impact of imaging modality on tumor control and survival in nasopharyngeal cancer with cranial nerve palsy Retrospective Patient series No golden standard (patients were treated by radiotherapy)	5		330 patients with NPC with CN palsy, collected over 22 years, examined by conventional tomography (n=47), CT (n=195), or MRI (n=88)	In a multivariate analysis, the imaging modality is significantly associated with local control, disease-specific survival and overall survival, with best results for MRI. The hazard ratios for CT vs MRI (95% CI) are: LC: 1,98 (1,16-3,26) DSS: 1,48 (1,02-2,15) OS: 1,85 (1,26-2,73)	The better results obtained with MRI are explained by better delineation of the tumor extent

Pathology/diagnosis	Study ID	Design	Level	Quality .	Population and prevalence	Conclusions	Comments
	Lu 2004[358]	Influence of skull base abnormality on MRI on survival in nasopharyngeal cancer treated by radiotherapy Retrospective Patient series No golden standard (patients were treated by radiotherapy)	3		122 patients with NPC, collected over 6 years	In a multivariate analysis, skull base abnormality as seen on MRI is not associated with worse outcome (p=0,69), unless >2 skull base sites are involved (p=0,04)	More extensive disease is associated with worse outcome, as expected. Tumor stage was not included in this analysis.
	Chung 2004[814]	Comparison between CT and MRI for detection of intracranial spread in nasopharyngeal cancer Retrospective Patient series No golden standard (patients were treated by radiotherapy)	2		258 patients with NPC, collected over 3 years	In 40,3% of cases, MRI shows intracranial extension not visible on CT	MRI provides more detailed information, influencing target delineation in RT (not analysed in this study)
	Nihioka 2000	Implications on local outcome of skull base abnormality only seen on MRI in nasopharyngeal cancer Retrospective Patient series No golden standard (patients were treated by radiotherapy)	4		48 patients, collected over 9 years	Skull base invasion only seen on MRI (38% of patients) does not relate to local recurrence provided careful treatment planning is performed, using both CT and MRI	RT set-up was done on CT, corrected with information from MRI
laryngeal neoplasms	Atula 2001[363]	Value of MRI in diagnosing laryngeal cartilage invasion prospective? patient series golden standard=histology	2	fair	18 patients with laryngeal carcinoma, examined by MRI and treated by total laryngectomy	se=67%; sp=67%	Small number of patients, but MRI clearly sometimes under- or overestimates cartilage invasion; in doubtful cases, MRI findings should not determine the choice of

Pathology/diagnosis	Study ID	Design	Level	Quality .	Population and prevalence	Conclusions	Comments
							treatment
	Murakami 2000[364]	Predictive value of MRI in T1 and T2 glottic cancer treated by radiotherapy patient series retrospective gold standard=local outcome	3	fair	80 patients with laryngeal cancer, staged T1 or T2, examined by MRI (collected 1992-1997)	In a multivariate analysis, the relationship of the tumor to the thyroid cartilage, as seen on MRI, was the only statistically significant predictive independent factor for local control	Deep tumor spread is known to be an adverse predictive factor (can also be seen on CT). Tumor adjacent or involving the thyroid cartilage is nowadays staged T3 (sixth edition UICC classification 2002)
	Murakami 2005[365]	Predictive value of MRI in T1 and T2 glottic cancer treated by radiotherapy patient series retrospective gold standard=local outcome	3	good	130 patients with laryngeal cancer, staged T1 or T2, examined by MRI (collected 1989-1998) extension of Murakami 2000)	In a multivariate analysis, the relationship of the tumor to the thyroid cartilage, as seen on MRI, was the only statistically significant predictive independent factor for local control, laryngeal preservation, cause-specific and overall survival	idem
neck adenopathies	Curtin 1998[366]	value of CT and MRI in diagnosing lymph node metastasis in head and neck squamous cell cancer prospective patient series gold standard = histology	2	very good	213 patients in 3 institutions, enrolled 1991-1994	CT: NPV=84%; PPV=50%; MRI: NPV=79%; PPV=52% (with use of a 1 cm size criterion or an internal abnormality to indicate a positive node)	CT performed slightly better than MRI for all interpretative criteria

Pathology/diagnosis	Study ID	Design	Level	Quality .	Population and prevalence	Conclusions	Comments
	Sigal 2002[370]	value of USPIO (Sinerem)-enhanced MRI of lymph node metastasis in head and neck squamous cell cancer prospective patient series (multicenter phase III trial) gold standard = histology	2	good	81 patients in 5 institutions; time of enrollement not specified. On-site and centralized reading	Sinerem-MRI: NPV 90%; PPV 51%; Plain-MRI: NPV 90%; PPV 28%; ROC-analysis: p 0.59	The potential contribution of Sinerem is limited by technical problems (motion, susceptibility artifacts, spatial resolution)
	Mack 2002[372]	value of USPIO (Sinerem)-enhanced MRI of lymph node metastasis in head and neck squamous cell cancer patient series prospective gold standard = histology	4	good	30 consecutive patients; 69/1029 lymph node were malignant	Sinerem-MRI: se=86%: sp=100%; NPV=99%; PPV=100%. Extent of surgery was changed in 7 patients based on the MRI findings	No comparison was made with plain MRI; the additional impact of Sinerem on treatment can not be judged
	Sumi 2003[373]	potential of diffusion-weighted MRI to discriminate metastatic cervical lymph nodes prospective patient series gold standard = histology	2	fair	31 consecutive patients (17 with SCC, 3 with lymphoma, 11 with benign lymphadenopathy). Patients with small nodes, or in whom the MR studies showed artefacts, were excluded.	ADC-value in SCC is higher than in benign lymphadenopathies (p<0,01); the ADC is lower in lymphoma than in benign disease (p<0,05). ROC-analysis comparing ADC and signal abnormalities on T1W and T2W-SE images in metastatic nodes: p=0,99	Study shows potential of DW-MRI, but results are potentially biased by exclusion of a number of patients
	Steinkamp 2002 [367]	value of MRI in detecting extranodal spread in metastatic neck nodes prospective patient series gold standard = histology	2	good	110 patients with SCC	se=74,4%; sp=72,2%	The value of MRI is only partially satisfying; extranodal spread is mainly not detected in metastatic adenopathies <1cm

Pathology/diagnosis	Study ID	Design	Level	Quality .	Population and prevalence	Conclusions	Comments
	King 2004[369]	comparison of CT and MRI in detecting extranodal spread in metastatic neck nodes prospective patient series gold standard = histology	2	good	17 patients with SCC; 51 malignant nodes examined	CT: se=65%; sp=93%; acc=73%; MRI: se=78%; sp=86%; acc=80%. No significant difference between both imaging modalities (p>0,13)	Both techniques are poor in detecting extranodal spread in nodes <1cm: this criterion is not reliable for detecting small metastatic adenopathies
	King 2004	comparison of CT, MRI and ultrasound in showing necrosis in metastatic neck nodes prospective patient series gold standard = histology	2	good	27 consecutive patients (enrolled 1999-2002); 43/89 malignant nodes were necrotic on pathology	CT: se=91%; sp=93%; acc=92%; MRI: se=93%: sp=89%; acc=91%; US: se=77%; sp=93%; acc=85%	CT and MRI are comparable for the detection of nodal necrosis, both showing a higher sensitivity than US.
	Baghi 2005[371]	value of USPIO (Sinerem)-enhanced MRI of lymph node metastasis in head and neck squamous cell cancer prospective patient series gold standard=histology	2	fair	28 patients with SCC; 34/363 nodes were malignant	Sinerem-MRI: se=82%; sp=100%. Plain-MRI: se=52%; sp=85%	Same group as Mack 2002. Unusual low sensitivity and high specificity for plain-MRI. There was (some) impact of Sinerem-MRI on treatment, but this is not further analysed and reported.
sinonasal neoplasms	Eisen 2000[377]	Value of CT and MRI to diagnose intra-orbital invasion in sinonasal tumors retrospective patient series gold standard=operative and/or pathologic report	2	fair	25 patients, who had either CT, MRI or both preoperatively; most patients suffered a malignant neoplasm	By combining several criteria: se=67%; sp=80%; acc=72%. CT was slightly more accurate than MRI regarding most criteria	Patients evaluated by CT and MRI came from two different, although overlapping, populations
	Oikama 2003	Value of MRI to define the extend of inverted papilloma retrospective patient series	2	fair	21 patients	MRI predicted accurately the tumor extent (PPV>68%; NPV>93%, depending on paranasal sinus)	

Pathology/diagnosis	Study ID	Design	Level	Quality.	Population and prevalence	Conclusions	Comments
		gold standard=operative and/or pathologic report					
	Maroldi 2004[376]	Value of MRI to diagnose inverted papilloma retrospective patient series gold standard=histology	2	good	46 patients (23 with inverted papilloma, 23 with malignant sinonasal tumors)	A columnar pattern on MRI is specific for inverted papilloma (PPV=95,8%)	
Salivary neoplasms	Koyuncu 2003[378]	Value of CT and MRI in parotid tumors, for defining tumor localisation, tumor margins, and infiltration of surrounding tissues prospective patient series gold standard=histology	2	very good	40 patients with clinical suspicion of a parotid tumor, all examined by CT and MRI	Both CT and MRI have a sensitivity of 100%; MRI is slightly more specific than CT (MRI: 84-100%; CT: 73-94%, depending on evaluated parameter)	MRI is slightly better than CT. There is no advantage in using both imaging modalities in the same patient.
	Divi 2004[380]	Value of CT and MRI in predicting sacrifice of facial nerve during surgery for parotid tumor retrospective patient series gold standard=surgery		fair	35 patients with a parotid tumor (27 had CT, 9 had MRI). Sacrifice of facial nerve was predicted in malignant tumors involving both parotid lobes (retromandibular vein was used as reference)	se=83%; sp=80%; PPV=63%; NPV=92% (results for malignant tumors)	CT/MRI not separately analysed
	Raine 2003[381]	Value of imaging in primary parotid malignancy retrospective patient series gold standard=histology		poor	42 patients, examined by CT (32), MRI (9), and US (3); studies were performed in various institutions (not all studies were contrast-enhanced)	MRI is better than CT in showing a poorly defined tumor boundary and local infiltration (p=0.01). Imaging alone is unreliable in predicting tumor histology	Based on the figures published in this article, the imaging quality may have been suboptimal in this patient population

Pathology/diagnosis	Study ID	Design	Level	Quality .	Population and prevalence	Conclusions	Comments
	Chikui 2004[379]	Value of imaging in determining the localisation of a submandibular mass (intra- or extraglandular) retrospective patient series gold standard=histology	2	fair	48 patients with a submandibular mass, collected over 15 years, excluding sialadenitis and metastatic adenopathies from head and neck cancer	accuracy: CT=87%; MRI=91%	
	Folia 2002[382]	Value of FNAC and MRI in diagnosing malignant parotid tumors prospective patient series gold standard=histology	2	poor	40 patients (2001-2002) with a parotid swelling; criteria for malignancy on MRI were poor delineation, infiltration of surrounding tissues and low T2-signal intensity	FNAC (excluding 20% non-representative punctions): se=67%; sp=79%; PPV=86%; NPV=100% MRI: se=55%; sp=86%; PPV=89%; NPV=75%	FNAC: NPV-value:should be 65%? PPV=79%?NPV=66%?
	Paris 2005[383]	Value of FNAC and MRI in diagnosing malignant parotid tumors retrospective patient series gold standard=histology	2	good	148 patients underwent FNAC, 87 MRI, 54 had both (patient material collected over 11 years)	FNAC (10% were non-diagnostic): se=81%; sp=96%; acc=92%. MRI (one case was non-diagnostic): se=87%; sp=94%; acc=93%. Combination of both: se=100%; sp=88%; acc=91%	MRI is considered more efficient (less non-diagnostic cases), and provides also anatomical information
parathyroid hyperplasia/adenoma	De Feo 2000[384]	Value of CT, MRI, US and Tc-MIBI scintigraphy to demonstrate parathyroid disease retro- and prospective patient series gold standard=histology	2	fair	retrospective study in 49 patients (1993-1995), prospective in 16 patients (1995). No CT performed in prospective study because of poor performance in retrospective study.	Prospective study (better results than in retrospective study): MRI, US: se=50, 67%; sp=78, 94%; Tc-MIBI: se=71%; sp=89%; combination of US and Tc-MIBI: se=96%; sp=83%; PPV=88%; NPV=94%. Other combinations did not yield better results.	only patients with parathyroid disease in the neck (no ectopic glands); none of the patients had previous surgery. Tc-MIBI and US should be performed in all patients; CT/MR is only indicated for spatial localisation of abnormal MIBI-signal in the mediastinum

Pathology/diagnosis	Study ID	Design	Level	Quality.	Population and prevalence	Conclusions	Comments
	Lopez 2000[385]	Value of contrast-enhanced MRI to localise parathyroid lesions prospective patient series gold standard=histology	2	fair	28 patients (1996-1999)	se=75%-82%; sp=100%-99% (resp. hyperplasia/adenomas)	consecutive patients?
	Wakamatsu 2001[386]	Value of different scintigraphic techniques, MRI and US for detection of abnormal parathyroid glands prospective patient series gold standard=surgery	2	good	28 patients (1997-1999)	Sensitivities: scintigraphic techniques: 46-53%; MRI: 57%; US: 58%	gold standard is not precisely defined. No information on specificity, as difference between true and false-negative results can not be determined (all patients had hyperparathyroidism)
	Wakamatsu 2003[387]	Comparison of MIBI/I substraction scintigraphy, delayed Tc-MIBI scintigraphy, MRI and US for detection of abnormal parathyroid glands prospective patients series gold standard=histology	2	good	39 consecutive patients (1999-2000)	Sensitivities: MIBI/I US>MRI delayed Tc-MIBI; difference between sensitivies is statistically not significant; sensitivity dependend on weight of parathyroid gland, not on number or histology	gold standard is not precisely defined.
	Gotway 2001[389]	Comparison between MRI and Tc-MIBI scintigraphy in recurrent or persistent hyperparathyroidism retrospective patient series gold standard=surgery and histology	2	fair	98 consecutive patients	MRI: se=82%; PPV=89%; Tc-MIBI: se=85%; PPV=89% (p=0.7); MRI and Tc-MIBI together: se=94%; PPV=98%	MR images were reviewed, and compared to the *reports* of Tc-MIBI scans

Pathology/diagnosis	Study ID	Design	Level	Quality.	Population and prevalence	Conclusions	Comments
	Ruf 2004[388]	Use of MRI and Tc-MIBI in the preoperative localisation of parathyroid glands prospective patient series gold standard=histology	2	fair	17 patients (consecutive?)	MRI: se=64%; Tc-MIBI: se=76%	Both techniques are better in showing parathyroid adenomas than parathyroid hyperplasia
temporomandibular joint disorders	Larheim 2001	Correlation of joint effusion on MRI with clinical symptoms patient series retrospective gold standard: none	2	good	70 patients showing joint effusion on MRI (9% bilateral effusion), out of a series of 523 consecutive patients examined for TMJ problems	Condyle marrow abnormalities were found in 31% of the 70 patients; 83% had complete anterior disk displacement. Effusion and condyle marrow abnormalities are significantly associated with joint pain; this may explain why some patients with disk displacement have no pain.	Occurence of condyle marrow abnormalities without joint effusion was not assessed.
	Emshoff 2002	Correlation of clinical diagnostic criteria for anterior disk dislocation without reduction, with MRI findings patient series prospective gold standard=MRI	2	good	69 consecutive patients with a clinical diagnosis of unilateral anterior disk dislocation without reduction	Compared to MRI, clinical evalution has se=75%; sp=83%. Clinical evaluation alone is an insufficient predictor for MRI-related diagnosis.	

Pathology/diagnosis	Study ID	Design	Level	Quality.	Population and prevalence	Conclusions	Comments
	Emshoff 2003	MRI predictors of TMJ pain patient series prospective gold standard=clinical examination	2	good	118 consecutive patients with TMJ pain	Risk of TMJ pain increases significantly with anterior disk dislocation without reduction (OR=10,2), and bone marrow edema (OR=15,6). No correlation with anterior disk dislocation with reduction and joint effusion. The pain variation in the population was not entirely explained by MRI findings.	Therapy based on pure morphological factors may be unwarranted.

MUSCULOSKELETAL RADIOLOGY

Knee

Systematic reviews

Pathology/ diagnosis	Study ID	Imaging techniques compared	Quality/ Evidence level	Conclusions
Knee meniscus	Davis, 2002[408]	MR	Good 2	Conventional MR is less accurate after meniscal repair, in which the repair site usually maintains altered signal for years. MR arthrography has higher sensitivity for detecting retears in menisci and is the procedure of choice in many situations.
Knee meniscus	De Smet, 2005[427]	MR	Good 2	Conventional MR is less accurate after meniscal repair, in which the repair site usually maintains altered signal for years. MR arthrography has higher sensitivity for detecting retears in menisci and is the procedure of choice in many situations.

Pathology/ diagnosis	Study ID	Imaging techniques compared	Quality/ Evidence level	Conclusions
Knee meniscus	Guten, 2002 [410]	MR	Good 2	A retrospective review of the literature from 1989 through 1999 on MR imaging of the knee in asymptomatic volunteers revealed that starting in the third decade, there is "age-dependent degeneration" of the meniscus with increasing MR signals in the meniscus. By the fourth and fifth decades, significant MR changes are present, especially in the medial meniscus, yet these patients are asymptomatic. The authors urge that "clinicians match clinical signs and symptoms with magnetic resonance imaging before instituting surgical treatment." The diagnosis of meniscal degeneration with signal changes grade 1, 2, or 3 are often misdiagnosed as "tears."

Clinical studies

Pathology/ diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
Knee Meniscus	Bhattacharyya, 2003[434]	MR Prospective study With age-matched controls	Good 2	154 patients 49 age-matched asymptomatic controls	Meniscal tears are highly prevalent in both asymptomatic and clinically osteoarthritic knees of older individuals. However, osteoarthritic knees with a meniscal tear are not more painful than those without a tear, and the meniscal tears do not affect functional status. These data do not support the routine use of magnetic resonance imaging for the evaluation and management of meniscal tears in patients with osteoarthritis of the knee.
Knee Meniscus	Blackmon, 2005[426]	MR Case control	Fair 2	216 patients comparison 2 MR techniques	MR can detect meniscal tears with high sensitivity (80 – 90 %), depending on imaging technique used.
Knee Meniscus	Cothran, 2001[405]	MR Case report	Poor 2	6 patients	MR can detect meniscal contusion, often in association with cruciate ligament tears.
Knee Meniscus	Chang, 2004 [419]	MR Retrospective study Case control Gold standard = arthroscopy	Good 2	148 patients 78 meniscal tears	MR can detect meniscal tears Se = 92 %, Sp = 87 %
Knee	Runkel,	MR	good	172 knees	MR can detect meniscal tears medial : Se = 98 %, Sp = 96 %,

Pathology/ diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
Meniscus	2000[404]	Prospective study Case control Selection bias Gold standard = arthroscopy	4	102 medial meniscal tears 29 lateral meniscal tears	Acc = 92 %, PPV = 97 %, NPV = 97 % Lateral : Se = 85 %, Sp = 98 %, Acc = 92 %, PPV = 88 %, NPV = 85 % Under the prerequisite that the MRI is carried out correctly and assessed by an experienced radiologist, the accuracy of the MR imaging for meniscus diagnosis is almost equivalent to the one by arthroscopy. Under these conditions, MR imaging can be recommended when no safe and sufficient clinical diagnosis can be made. The rate of unnecessary arthroscopies with a pure diagnostic purpose can be lowered significantly by means of MR imaging.
Knee Meniscus	Magee, 2002[411]	MR Prospective study Case control Selection bias : only patients with successive arthroscopy Gold standard = arthroscopy	good 2	200 knees 28 radial meniscal tears	MR can detect radial meniscal tears medial : Se = 68 - 89 %, PPV = 100 %
Knee Meniscus	Munk, 2004[423]	MR Prospective study Case control	fair 2	45 patients with meniscal degeneration 5-year follow-up study	About 25% of MR examinations of the knee show meniscal degeneration After 5 years : 76 % show no change, 8 % regress and 16 % progress, usually after 40 y Clinical symptoms occur in only 18 % of patients
Knee Meniscus	Shiozaki, 2002 [412]	MR Retrospective study Case control Gold standard = arthroscopy	Good 2	60 patients with 61 symptomatic semilunar peripheral lateral meniscal tears degeneration detection of repairable or irrepariable meniscal tear	Detection rate of lateral meniscal tears is low (69 %). The sensitivity for detection of repairable meniscus is very low (33 %), but has a high accuracy (91 %). The sensitivity for predicting irrepairability (larger tear) is very high (90 %), with high accuracy (90 %)
Knee Meniscus	Sparacia, 2002[414]	MR Retrospective study Case control Gold standard = arthroscopy	Fair 2	495 patients with 48 bucket-handle meniscal tears	MR imaging is highly accurate in diagnosing bucket-handle tears of the menisci due to its ability to identify a displaced fragment of the meniscus in the intercondylar notch or flipped over the anterior horn of the meniscus of origin. The accuracy of MR to detect bucket=handle meniscal tears is 98 %.

Pathology/ diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
Knee Meniscus	Sproule, 2005[430]	MR Retrospective study Case control Gold standard = arthroscopy	Fair 2	64 patients with high signal in posterior horn of medial meniscus	A meniscal tear is unlikely when MR shows a focus of high signal intensity in the posterior horn of the medial meniscus that does not unequivocally extend to involve the inferior or superior joint surface. An appropriate trial of conservative treatment is recommended in such questionable cases. MR is a useful diagnostic tool-however, it should be used selectively, and in conjunction with history and clinical examination in evaluating internal derangements of the knee
Knee Meniscus Cartilage	Kaplan, 2005[429]	MR Prospective study Case control Gold standard = arthroscopy	Good 4	40 knees of 20 asymptomatic professional basketball players	There is a higher prevalence of meniscal lesions (20 %) and patello-femoral articular cartilage lesions (47,5 %) in asymptomatic male professional basketball players than previously reported in the literature. No treatment is required.
Knee Meniscus	Vives, 2003 [418]	MR, conventional, indirect and direct arthrography Prospective cohort study Gold standard = arthroscopy	Good 2	41 patients with previous meniscal repair or partial resection Purpose : To compare the accuracy of nonenhanced magnetic resonance imaging with that of intraarticular contrast-enhanced direct magnetic resonance arthrography and intravenous contrast-enhanced indirect magnetic resonance arthrography for detection of recurrent meniscal tears	Direct or indirect MR arthrography has an increased accuracy compared to conventional non-contrast MR in detecting recurrent meniscal tears. Conventional MR imaging: Se = 58%, Sp = 80%, Acc = 63 %. Intravenous contrast MR: Se = 91 %, Sp = 100%, Acc = 94 %. Intraarticular contrast MR: Se = 92 %, Sp = 100%, Acc = 93 %.
Knee Meniscus	White, 2002 [415]	MR, conventional, indirect and direct arthrography Prospective cohort study Gold standard = arthroscopy	Good 2	364 patients with previous meniscal repair or partial resection 94 patients with second look arthroscopy Purpose : To compare the accuracy of nonenhanced	Direct or indirect MR arthrography has a slightly increased accuracy compared to conventional non-contrast MR in detecting recurrent meniscal tears. Conventional MR imaging: Se = 86%, Sp = 67%, Acc = 80%, PPV = 83 %, NPV = 71 % Intravenous contrast MR: Se = 83 %, Sp = 78 %, Acc = 81 %, PPV = 90 %, NPV = 64 % %.

Pathology/ diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
				magnetic resonance imaging with that of intraarticular contrast-enhanced direct magnetic resonance arthrography and intravenous contrast-enhanced indirect magnetic resonance arthrography for detection of recurrent meniscal tears	Intraarticular contrast MR:. Se = 90 %, Sp = 78%, Acc = 85 %, PPV = 90 %, NPV = 78 %.
Knee Meniscus	Zanetti, 2003[432]	MR Prospective study Comparative left/right knee	Good 2	100 patients with symptomatic knee comparison with asymptomatic contralateral knee	Horizontal or oblique meniscal tears are frequently encountered in both asymptomatic and symptomatic knees and may not always be related to symptoms. However, radial, vertical, complex, or displaced meniscal tears and abnormalities of the collateral ligaments, pericapsular soft tissues, and bone marrow are found almost exclusively on the symptomatic side and appear to be clinically more meaningful
Knee Internal derangement	Dongola, 2004 [420]	MR Retrospective study Case control Gold standard = arthroscopy	Fair 2	33 patients detection of medial and lateral meniscal tears and cruciate ligament tear	MR can detect tears of Medial meniscus : Se = 87,5 %, Sp = 76 %, PPV = 46,1 %, NPV = 95 % Lateral meniscus : Se =75 %, Sp = 96 %, PPV = 85,7 %, NPV = 96 % Anterior cruciate ligament : Se = 83,3 %, Sp = 77,7 %, PPV = 45,1 %, NPV = 95,4 %
Knee Internal derangement	Jee, 2004[422]	MR Retrospective study Case control Gold standard = arthroscopy	Good 2	41 patients detection of medial and lateral meniscal tears in patients with anterior cruciate ligament tear	MR can detect tears of Medial meniscus : Se = 100 %, Sp = 88 %, Acc = 90 % Lateral meniscus : Se =57 %, Sp = 100 %, Acc = 85 % In the presence of acute anterior cruciate ligament tears, MRI imaging has relatively low sensitivity for detecting meniscal tears due to missed tears in the posterior horn of the lateral meniscus.
Knee Internal derangem	Kocabey, 2004 [435]	MR Comparative study with clinical examination	Fair 2	50 patients detection of medial and lateral meniscal tears in	There was no statistical difference between MR imaging or clinical examination in diagnosing medial or lateral meniscal tears or anterior cruciate ligament tears (P >.05).

Pathology/ diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
ent		Case control Selection bias, only young patients with recent sports trauma Gold standard = arthroscopy		patients with anterior cruciate ligament tear	The accuracy of the clinical examination and MRI evaluation was equal for diagnosing meniscal tears and anterior cruciate ligament ruptures. A well-trained qualified surgeon can safely rely on clinical examination for diagnosing meniscal and anterior cruciate ligament injuries. Clinical examination is at least as accurate as MRI in the skilled orthopaedic surgeon's hand. MRimaging should be reserved for more complicated and confusing cases. The routine ordering of an MRIscan of the knee before examination by a well-trained orthopaedic surgeon is not recommended.
Knee Internal derangement	Esmaili Jah, 2005[436]	MR Comparative study with clinical examination Case control single blind study Gold standard = arthroscopy	Good 2	detection of medial and lateral meniscal tears in patients with anterior cruciate ligament tear	There was no statistical difference between MRI or clinical examination in diagnosing medial or lateral meniscal tears or anterior cruciate ligament tears. The accuracy of the clinical examination and MRI evaluation was equal for diagnosing meniscal tears and anterior cruciate ligament ruptures. A well-trained qualified surgeon can safely rely on clinical examination for diagnosing meniscal and anterior cruciate ligament injuries. Clinical examination is at least as accurate as MRI in the skilled orthopaedic surgeon's hand. MRI should be reserved for more complicated and confusing cases. The routine ordering of an MRI scan of the knee before examination by a well-trained orthopaedic surgeon is not recommended.
Knee Anterior cruciate ligament (ACL) tear	Duc, 2005[428]	MR Case control study Gold standard = arthroscopy	Good 2	91 patients 32 normal 4 partial tear 55 complete tear Comparative study of 3 MR imaging techniques (different imaging planes; coronal and paracoronal) Aim = detect ACL tear	MR can accurately detect ACL tears: Se = 95 %, Sp = 80 %. Partial tears are missed most frequently (> 75 % missed)
Knee Anterior cruciate	Tsai, 2004 [425]	MR Retrospective study Case control study	Fair 2	48 patients 32 complete tears accurately detected	MR can not accurately detect ACL tears: Acc = 67 % Partial tears are missed most frequently (33 % missed) Since conservative treatment is sufficient for incomplete

Pathology/ diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
ligament (ACL) tear		Gold standard = arthroscopy		16 partial tears false positively classified as complete tears	ACL tears, the decision to undertake ACL reconstruction should not be based on MR findings alone
Knee Anterior cruciate ligament (ACL) tear reconstruction and retear	Nakayama, 2001 [407]	MR Prospective study Case control study Gold standard = arthroscopy	Good 2	52 patients evaluation of ACL reconstruction 2 torn Aim = detect ACL reconstruction tear	MR can not accurately detect ACL reconstruction tears: Se = 22 %, Sp = 100 %, Acc = 87 %, PPV = 100 %, NPV = 86 %.
Knee Posterior cruciate ligament	Servant, 2004 [424]	MR Retrospective study Case control study Gold standard = arthroscopy	Fair 2	10 patients chronic posterior cruciate ligament tear	Although MRI may be reliable in diagnosing acute posterior cruciate ligament injury, MRI is not so reliable in evaluating chronic injuries: the accuracy in diagnosing a chronic posterior cruciate ligament injury was 57% (40-80%). It is postulated that, in the case of a chronic posterior cruciate ligament injury, healing in continuity may occur, producing an intact but lax ligament.
Knee Posterior cruciate ligament	Griffin, 2002 [409]	MR Retrospective study Case control study Gold standard = clinical follow-up Follow-up of healing of posterior cruciate ligament injury	Fair 2	10 patients chronic posterior cruciate ligament tear	Although MRI may be reliable in diagnosing acute posterior cruciate ligament injury, MRI is not so reliable in evaluating chronic injuries: the accuracy in diagnosing a chronic posterior cruciate ligament injury was 57% (40-80%). It is postulated that, in the case of a chronic posterior cruciate ligament injury, healing in continuity may occur, producing an intact but lax ligament.
Knee Posterior cruciate ligament reconstruction	Sherman, 2001[431]	MR Follow-up of healing of posterior cruciate ligament injury with MR Prospective study Case control study Gold standard = clinical follow-up	Good 2	10 patients with posterior cruciate ligament (partial) tear Assessment of value of follow-up MR and correlation with clinical stability 85 % of ligaments with "healed" appearance on MR are clinically unstable	Despite the healed appearance of posterior curciate ligament on imaging studies, laxity is detected on clinical examination in 85 % of patients. Although MRI may be reliable in evaluation of continuity of posterior cruciate ligament reconstruction, there does not appear to be a relationship between clinical stability and findings at MR imaging.

Pathology/ diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
				with increased laxity.	
Knee Cartilage	Daenen, 1998 [403]	MR versus CT arthrography Prospective study Case control CT arthrography as gold standard	Good 2	50 patients CT arthrography and fat-suppressed fast low-angle shot (FLASH) 3D MR imaging	Fat-suppressed FLASH 3D is an adequate pulse sequence for the detection of patellar cartilage ulcers. It can be applied on a routine clinical basis, but it does not show as many fissures as CT arthrography and is less precise for grading of lesions.
Knee Cartilage	Friemert, 2004[421]	MR versus CT arthrography Prospective study Case control Gold standard = arthroscopy	Good 2	195 patients evaluation of cartilage and detection of cartilage lesions with 3 different MR study protocols	MR can detect cartilage lesions: Se = 33 – 53 %; Sp = 98 %; PPV = 48 – 75 %; NPV = 97 %. MR examination techniques recommended in the literature at present are not able to replace arthroscopy for the diagnosis of cartilage damages of the knee joint. In view of the high specificity (97%-99%) and the high negative prediction value (97%-98%), MR is suitable for the exclusion of cartilage lesions. For a negative MRI associated with a cartilage injury, a cautious attitude towards an operative cartilage treatment is therefore justified. Because the MR can not replace the arthroscopy for diagnostic of cartilage damage, arthroscopy still has to be seen as the method of choice for the evaluation of cartilage damage.
Knee Cartilage	Mohr, 2003 [417]	MR Comparison of 2 imagings sequences Prospective study Case control Gold standard = arthroscopy	Good 2	26 patients evaluation of cartilage and detection of cartilage lesions with 2 different MR study protocols	MR can detect cartilage lesions: Se = 46 – 91 %; Sp = 92 – 98 %; PPV = 81 – 96 %; NPV = 74 – 95 %.
Knee Cartilage	Sonin, 2002 [413]	MR Prospective study Case control Gold standard = arthroscopy	Good 2	54 patients evaluation of cartilage and detection of partial and full-thickness defects	MR can detect cartilage lesions: Se = 59 - 74 %; Sp = 87 - 90 %; PPV = 60 - 73 %; NPV = 86 - 91 %, Acc = 79 - 86 %.
Knee Cartilage	Murphy, 2001[406]	MR Prospective study Case control Gold standard = arthroscopy	Good 2	26 patients evaluation of cartilage and detection of grade 3 and 4 cartilage lesions	MR can detect cartilage lesions: Se = 83 %; Sp = 97 %; PPV = 87 %; NPV = 95 %, Acc = 93 %.

Pathology/ diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
Knee Cartilage	Macarini, 2003 [416]	MR versus CT arthrography Prospective study Case control Gold standard = arthroscopy	Good 2	90 patients evaluation of cartilage and detection of superficial or deep cartilage lesions	MR can detect cartilage lesions: Acc = 94 % for deep cartilage lesions and 70 – 78 % for superficial cartilage lesions, resp. femoro-tibial and femoropatellar compartment.

Impact studies

Pathology	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
Knee injury	Bryan, 2001[433]	HTA : The cost-effectiveness of magnetic resonance imaging for investigation of the knee joint The role of MRI in the diagnosis of knee injuries The diagnostic accuracy of clinical investigation and MRI in acute knee injuries An investigation of variation between radiologists in knee MRI interpretation The value of the diagnostic and therapeutic impact of knee MRI: a stated preference survey	Good 6	The research presented in this report considered the role of MRI in the diagnosis of knee abnormalities and injuries in a district general hospital setting. The principal objective was to identify whether the use of MRI in patients presenting with knee problems had a major impact on the clinical management of patients, whether it brought about an overall reduction in costs and whether it improved patient outcome. In addition, the research: • explored how diagnostic accuracy of the initial clinical investigation varied across clinicians (i.e. orthopaedic trainees, a consultant knee specialist and a consultant radiologist) • considered the variability	Trial results In terms of patient health outcomes, the central finding was that there were no statistically significant differences between groups in all measures of health outcome, although a trend in favour of the no-MRI group was observed. The use of MRI was found to be associated with a positive diagnostic/therapeutic impact: a significantly smaller proportion of patients in the MRI group underwent surgery ($p = 0.001$). Overall, similar mean NHS costs for both the MRI and no-MRI groups were found, indicating that the increased cost associated with the use of MRI in all patients was offset in full by the reduced requirement for surgery. Substudies Investigation of diagnostic accuracy The investigation of diagnostic accuracy of the initial clinical investigation of the knee provided data, which suggested that, when compared to orthopaedic trainees (44% correct diagnoses) or to radiologists reporting on an MRI scan (68% correct diagnoses), the accuracy rate was higher for knee specialists (72% correct diagnoses). Therefore, reliance on the results of an MRI scan without the necessary skilled clinical assessment may lead to the mismanagement of patients.

Pathology	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
				and diagnostic accuracy of interpretations of knee MRI investigations between radiologists from typical district general hospital settings • measured the strength of preference for the potential diagnostic/therapeuticimpact of knee MRI (i.e. the avoidance of surgery).	Investigation of the generalisability of results This substudy demonstrated that, in general terms, radiologists in district general hospitals provided broadly comparable and consistently accurate interpretations of knee MRI images, and reports that were similar to a radiologist at a specialist centre. The areas of the knee for which these results did not hold were the lateral collateral ligament and bony surfaces, where agreement tended to be poor.

Hip

HTA reports (database York)

Table of evidence for hip AND magnetic resonance imaging AND CT

Pathology/Diagnosis	Study ID	Search period	Evidence	Imaging Techniques Compared	Conclusions
Osteoporosis Bone Density measurement	[437]	1985-1994	? Not published yet	SPA, DPA, SXA, DEXA, US, quantitative CT quantitative MR	Not available

Table for evidence for hip AND magnetic resonance imaging

Pathology/Diagnosis	Study ID	Search period	Evidence	Imaging Techniques Compared	Conclusions
Hip arthroscopy	Augustovski, 2005[438]	Two case series (40 and 102 patients)	Poor Level 1	Arthroscopy, MRI and MRI with gadolinium contrast	Patients with chronic pain would benefit from arthroscopy since in half of the cases treatable pathologies were found
Hip occult fractures	Rubin, 1998 [439]	Single study, 40 patients Retrospective cohort	Fair Level 3	MRI and bone scintigraphy (RBS)	RBS Sens: 90.9%, Spec: 100%, Acc: 95% MRI Sens, spec, acc: 100%

Systematic Reviews

Pathology/Diagnosis	Study ID	Imaging Techniques compared	Quality	Remarks	Conclusions
Sports medicine	Brukner, 2006[440]	XR, Arthrography MRI, MR-arthrography	Poor	No accuracy sensitivity and specificity	X-ray, arthrography and MRI are inadequate in diagnosis
Osteoarthritis treatment	Abadie, 2004[441]	XR, MRI	Poor	No accuracy	may be used as an outcome in phase II DMOAD's studies
Sportsman's hernia	Fon, 2000 [442]	CT, MRI, US, scintigraphy	Poor	No accuracy	The costs of CT and MRI are such that their routine use for assessment of patients with groin pain cannot be justified

Clinical Studies

Pathology/diagnosis	Study ID	Design	Quality	Population Prevalence	Conclusions
Cartilage Disease in Hip Dysplasia	Nishii, 2005[443]	MDCT Arthrography MRI Artroscopy = gold Standard Prospective Case control study	Good Level 2	N = 20 Known Hip dysplasia without OA	MDCT > MRI MRI Sens 49%/67% Spec 89%/76% MDCT Sens 67%/67% Spec 89%/82%
Subchondral Fracture Detection	Stevens, 2003[444]	XR, CT, MRI CT = gold standard Prospective Case control study	Fair Level 2	N = 45 Known AVN	CT > MRI > XR MRI sens 38% Spec 100% XR sens 71% specificity 97%
Synovial Inflammation	Cantini, 2005[445]	MRI, US Clinical evaluation= Gold standard Prospective Cohort Case control study	Poor Level I	N = 20 Clinical Polymya. Rheuma.	MRI > US for hip joint and Iliopsoas bursa US = MRI for trochanteric bursitis
Hip pathology	Mitchell, 2003[446]	MR Arthrography US, Arthroscopy Prospective Cohort Case control study	Poor Level I	N = 25 All kinds of hip pathology	Arthroscopy > MRA > US

Pathology/diagnosis	Study ID	Design	Quality	Population Prevalence	Conclusions
Hip synovitis	Soini, 2003[447]	MRI, US Gold Standard = MRI Case control study	Poor Level I	N = 40 RA patients	MRI > US US sens 87% spec 42%
Acute hip pain	White, 2001[448]	MRI, XR Prospective Cohort Case control study	Good Level 2-3	N = 50 Children Non traumatic hip pain	MRI acc 81% XR acc 72%
Hip prosthesis Peri-prostethic Acetabular Osteolysis	Weiland, 2005[449]	Case control study MRI, XR	Poor Level 2	N = 3 cadavers	MRI spec 98%, sens 95% acc 96% XR spec 96%, sens 52% (dependent on lesion location)
Femoro-Acetabular Impingement	Leunig, 2005[450]	Retrospective, Case control study MRI, XR MRI = gold standard	Poor Level I	N = 61	XR spec 93%, sens 64%
Articular Hip pathology	Keeney, 2004[451]	Prospective Cohort MRI, arthroscopy = Gold standard	Good Level 2	N = 102	Labrum pathology Sens 71% Spec 44% Acc 69% Cartilage pathology Sens 47% spec 89% Acc 67%
Cartilage	Knuesel, 2004[452]	Prospective Cohort MRI, arthrotomy = Gold standard	Good Level 2	N = 21	Sens 58-62/81-62% Spec 88-94/88-100%
Gluteus tendon Tears	Cvitanic, 2004[453]	Retrospective MRI, surgery = gold standard	Good Level 2	N = 74	Sens 73% Spec 95% Acc 91%
Hip pain Stress injury	Kiuru, 2003[454]	Cohort XR, MRI = gold standard	Good Level 2	N = 340	XR sens 37%, spec 79% Acc 60%
Cartilage	Schmid, 2003[455]	Retrospective Case study MR arthrography Arthrotomy = gold standard	Good Level 2	N = 42	Sens 50-79, spec 77-84%

SHOULDER

Systematic reviews

Pathology/diagnosis + prevalence	Study ID	Imaging techniques compared	Quality/ level of evidence	Remarks	Conclusions
Rotator interval abnormalities Biceps brachii tendon instability	Morag 2005[470]	MRA and arthroscopy	Good		Clinical and arthroscopic diagnoses are difficult. Understanding of function through the anatomy (using MRA) is a key in making diagnosis of subtle findings that may otherwise be missed or untreated.
Partial-thickness rotator cuff tears	Matava 2005[468]	MRI and US	Good		Sensitivity 94%, specificity 93% for US (Wiener and Seitz 1993) but operator dependant (evidenced by only a 41% detection rate of partial-thickness tears) Sensitivity 84%, specificity 96%, accuracy 91% for MR (Meister 2004)
Internal impingement	Kaplan 2004[471]	MRI and arthroscopy Retrospective review	Good Diagnostic; level 3		From 769 shoulder arthroscopies, 9 throwing athletes had internal impingement (including posterosuperior labral and rotator cuff lesions)
Full-thickness and partial rotator cuff tears	Dinnes 2003[473]	US, MRI and MRA Systematic review	Very good Level 6	-38 US studies -29 MRI studies -6 MRA studies	Concerning the effectiveness of diagnostic tests for the assessment of shoulder pain due to soft tissue disorders, the relative benefits of these technologies for the diagnosis of shoulder pain in terms of accuracy and cost-effectiveness are currently unknown. Either MRI or ultrasound could equally be used for detection of full-thickness rotator cuff tears. All the imaging modalities were less accurate for partial-thickness tears but indirect comparison between them suggests that MRA and ultrasound might be more accurate at detecting such tears than MRI

Clinical studies

Pathology/diagnosis	Study ID	Design	Quality	Population + prevalentie	Conclusions
Full-thickness rotator cuff tears	Teefey 2004[462]	-MRI and US, -Prospective -reference: arthroscopy	good Diagnostic study; level I	72 patients with shoulder pain undergoing surgery	Sensitivity 98%[94-100], specificity 80%[64-96], accuracy 94 %[89-100] for US; Sens 100%[100-100], spec 68%[50%-86%], acc 89%[81%-100%] for MRI [95% confidence interval]

Pathology/diagnosis	Study ID	Design	Quality	Population + prevalentie	Conclusions
Full-thickness rotator cuff tears	Martin-Hervas 2001[461]	-MRI and US -prospective -reference: arthroscopy and open surgery	fair	72 patients with shoulder pain undergoing arthroscopy	Sensitivity 81%[62-91], specificity 97%[85-99] for MRI [95% confidence interval]
Full-thickness rotator cuff tears	Blanchard 1999[459]	-MRI and arthrography -prospective -reference: arthroscopy and open surgery	Diagnostic & therapeutic impact level 4	38 patients	Sensitivity 82%, specificity 78% Sensitivity of MRI higher; specificity lower than arthrography
Full-thickness rotator cuff tears	Sahin-Akyar 1998[458]	-MRI -retrospective -reference: arthroscopy and open surgery		39 patients referred for arthroscopy or arthrotomy	Sensitivity 83-100%, specificity 78-96% for MRI [95% confidence interval]
Full-thickness and partial rotator cuff tears	Balich 1997[457]	-MRI -Retrospective -reference: arthroscopy	good level 2	222 symptomatic patients who underwent arthroscopy	Sensitivity 84-96%, specificity 94-98%, accuracy 92-97% for full-thickness tears Detection of full-thickness tears with MRI is highly sensitive, specific and accurate. Diagnosis of a full-thickness tear can be learned to a high degree of accuracy Sensitivity 35-44%, specificity 85-97%, accuracy 77-87% for partial tears The sensitivity for diagnosis of partial tears is poor
Any tears	Tuite 2001[460]	-MRI -Retrospective -reference: arthroscopy		75 patients who underwent arthroscopy and bursoscopy	Sensitivity 73-88%, specificity 54-92% for MRI
Any tears	Hodler 1992[456]	-MRI and MRA -reference: arthroscopy		36 patients	Sensitivity 71%, specificity 84%, accuracy 78% for MRA Sensitivity 41%, specificity 79%, accuracy 61% for MRI
Full-thickness tears after rotator cuff repair	Duc 2006[472]	-MRA -retrospective -ref: revision surgery		48 patients	Sensitivity 86-90%, specificity 59-89%, accuracy 71-90% for supraspinatus tears Sensitivity 79-100%, specificity 94-100%, accuracy 90-100% for infraspinatus tears Sensitivity 82-91%, specificity 92-100%, accuracy 92-96% for suprascapularis tears
Subscapularis tendon tears	Pfirrmann 1999[463]	-MRA -retrospective -reference: arthroscopy and open surgery		50 patients undergoing arthroscopy or open surgery	Sensitivity 90-100%, specificity 55-90% for MRA

Pathology/diagnosis	Study ID	Design	Quality	Population + prevalentie	Conclusions
Anterior instability: anteroinferior labroligamentous injuries	Waldt 2005[474]	-MRA -Retrospective -reference: arthroscopy	good level 4	-104 patients with proved labroligamentous injuries -101 patients with intact labroligamentous complex (control group)	sens 88%(82-94), spec 91%(85-97), acc 89%(85-93) [95% confidence interval]
Frozen shoulder	Mengiardi 2004[475]	-Preop MRA -retrospective -reference: arthroscopy	good	22 patients with frozen shoulder underwent arthroscopic capsulotomy and were compared with 22 control subjects without frozen shoulder	Sensitivity 59%[36-79], specificity 95%[77-100] for thickening of coracohumeral ligament Sensitivity 64%[41-83], specificity 86%[65-97] for thickening of capsule in rotator cuff interval Sensitivity 32%[7-22], specificity 100%[85-100] for complete obliteration of subcoracoid fat triangle [95% confidence interval] The 3 signs are characteristic MRA findings in frozen shoulder
Internal shoulder derangements	Oh 1999[476]	-double contrast arthrography, MRI and MRA -decision tree and cost-effectiveness analysis	Good Level 6		Average effectiveness: dble C arthrography 0.66, MRI 0.67, MRA 0.72
Glenohumeral ligaments (GHL), capsule and labrum	Chandnani 1995[477]	-MRA -retrospective -reference: surgery	good	46 patients with shoulder instability, impingement syndrome	Sensitivity 100%, 89%, 88% for diagnosis of superior, middle and inferior GHL respectively Specificity 94%, 88% and 100%
Glenoid labral tears	Chandnani 1993[478]	-MRI,MRA,CTA -prospective -reference: arthroscopy and open surgery	good	30 patients with shoulder instability or shoulder pain	MRA and MRI showed labral tears with greater sensitivity than CTA. MRA was the most sensitive. Sensitivity 93%, 96%, 73% for MRI, MRA and CTA respectively.
Elbow articular cartilage lesions	Waldt 2005[481]	MRA and multislice CTA		26 cadaveric specimens	Overall sensitivity 80% and specificity 93% for CTA Overall sensitivity 78% and specificity 95% for MRA; Sensitivity 87% and specificity 94% for the diagnosis of grade 3 and 4 lesions with CTA; Sensitivity 85% and specificity 95% with MRA

Pathology/diagnosis	Study ID	Design	Quality	Population + prevalentie	Conclusions
Lateral epicondylitis	Savnik 2004[487]	MRI		30 patients with clinical symptoms of lateral epicondylitis; 22 healthy controls	Persistence of degenerative changes at 6-week follow-up MRI, although the patients improved clinically
Epicondylitis	Miller 2002[493]	MRI and US	Poor	10 patients and 6 volunteers	Sensitivity 64-82% for US and 90-100% for MRI; specificity 67-100% for US and 83-100% for MRI MRI as specific as US; MRI more sensitive than US
Heterotopic calcification and tears of ulnar collateral ligament (UCL)	Mulligan 2000[499]	MRI and radiography -retrospective -reference: surgery		42 patients with heterotopic calcification; 34 (of 42) underwent surgery	Sensitivity 96% for all tears of UCL, 83% for partial tears, 82% for complete tears The MRI detection of calcification is less sensitive than that of radiography and comparison of MRI with radiography is required
Lateral UCL abnormalities in patients with lateral epicondylitis	Bredella 1999[485]	MRI	Fair	35 patients with lateral epicondylitis 11 (of 35) underwent surgery	MRI is useful in detecting and characterizing the degree of tendon and associated lateral UCL degeneration and tearing in patients with lateral epicondylitis
Epicondylitis	Martin 1998[484]	MRI	fair	24 patients with epicondylitis (22 lateral) and 19 elbows of 16 volunteers	Increased intratendinous T1 and T2 signal intensity with tendon thickening is associated with epicondylitis but a small minority of asymptomatic volunteers also demonstrate these findings.

Bone Marrow

Systematic reviews

Pathology/diagnosis	Study ID	Imaging techniques compared	Quality/ Level of evidence	Remarks	Conclusions
Bone marrow Infiltration Multiple diseases	Negendank, 1993[519]	MR	Good 2		Magnetic resonance imaging provides a non-invasive means to evaluate a large fraction of marrow in less than one hour. Marrow disorders produce non-specific changes in marrow signal intensities which primarily reflect changes in proportions of fat and cellular elements. The pattern of these signal changes narrows the differential diagnosis, and the combination of these features with the clinical context allows interpretations which are clinically useful in many ways. These include: 1) the diagnosis of avascular necrosis (and its distinction from other causes of joint pain), 2) detection of osteomyelitis, 3) differential diagnosis of hypoplastic disorders, 4) staging of lymphomas and myeloma, 5) selection of patients for autologous bone marrow transplant, 6) objective measures of marrow response to therapy, 7) detection of leukemic transformation, and 8) improved detection of marrow disease (primary or secondary) in patients with otherwise unexplained bone pain
Bone marrow Infiltration Multiple myeloma	Baur-Melnyk, 2004 [549]	MR Plain radiography CT	Good 2		MRI is superior to radiography for the detection of focal as well as diffuse infiltration. Due to the direct visualization of the bone marrow with MRI, MRI is superior in detecting early infiltrations with myeloma cells without osteolysis. In advanced multiple myeloma, CT on the other hand, enables for more precise assessment of bony destructions and fracture risk
Bone marrow Infiltration Multiple myeloma	Pertuiset, 1996[523]	MR Plain radiography	Good 2	Meta-analysis 500 patients	MRI is superior to radiography for the detection of focal as well as diffuse infiltration and for differentiating solitary plasmocytoma from multiple myeloma. MR is superior in detecting early infiltrations with myeloma cells without osteolyses. MR has prognostic significance.

Pathology/diagnosis	Study ID	Imaging techniques compared	Quality/ Level of evidence	Remarks	Conclusions
Bone marrow Infiltration Leucemia	Takagi, 1998 [532]	MR	Good 2		Evaluation of the bone marrow by MRI is essential to assess disease status in patients with lymphoma. Visual and quantitative assessment of the bone marrow by magnetic resonance imaging is useful for the detection of occult lymphomatous marrow involvement and for the evaluation of disease extent in the bone marrow. Abnormal images on marrow MRI may be associated with a significantly poorer survival in patients with lymphoma, regardless of histologic findings in the marrow.
Bone marrow osteomyelitis	Imhof, 1994 [561]	MR	Good 2		MR diagnosis of bony inflammations has sensitivity of up to 96%, but specificity of only 70-87%. The most common reasons for false-positive results are fractures, infarctions, neoplasms, septic arthritis and aggressive metastasis. Complications of osteomyelitis (e.g. soft tissue abscesses) can be diagnosed by MR imaging with high sensitivity. MR can replace bone scintigraphy, which has poor morphological resolution.

Clinical studies

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
Bone marrow Detection of bone marrow iron storage	Isokawa, 1997[529]	MR Concentrations of serum iron, serum ferritin, and transferrin saturation were measured to evaluate body iron status Prospective Case control	Poor 2	22 patients detection of bone marrow iron concentration with MR	MR can quantitatively assess bone marrow iron concentration in patients with bone marrow iron concentrations below 400 micrograms/ml, but not in patients with extremely high iron levels.
Bone marrow Detection of bone marrow infiltration by Gaucher storage disease	Maas, 2002 [537]	MR Assessment of fat fraction in vertebrae Prospective Control group of healthy volunteers	Good 3	30 patients Assessment of fat fraction in vertebrae and correlation with peripheral bone involvement	MR can quantitatively assess bone marrow fat fraction of the lumbar spine. Low fat fractions are associated with the occurrence of bone complications. It may, therefore, be a clinically useful parameter

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
Bone marrow Detection of bone marrow infiltration by Gaucher storage disease	Maas, 2002[537]	MR Assessment of bone marrow burden by Gaucher disease Prospective Case control	Good 2	30 patients Assessment of bone marrow burden by Gaucher disease	MR can semi-quantitatively assess bone marrow infiltration.
Bone marrow Detection of bone marrow infiltration by Gaucher storage disease	Magnaldi, 1997[531]	MR Assessment of bone marrow burden by Gaucher disease Prospective Control group of healthy volunteers	Good 2	26 patients; 18 with follow-up MR 22 age-matched controls Assessment of bone marrow burden by Gaucher disease	MR can quantitatively assess bone marrow infiltration and monitor effect of therapy.
Bone marrow Detection of bone marrow infiltration by Gaucher storage disease	Terk, 2000[536]	MR Assessment of response to therapy in Gaucher disease Prospective Case control	Good 2	42 patients; 32 treated; 15 with follow-up MR Assessment of bone marrow burden by Gaucher disease	MR can quantitatively assess bone marrow infiltration and monitor effect of therapy.
Bone marrow Infiltration by malignant process	Disler, 1997 [528]	MR No histologic confirmation with biopsy Prospective Selection bias : only patients with suspected bone marrow lesions Case control	Poor 2	31 patients detection of marrow infiltration with MR : Se = 100 %, Sp = 94 %	MR can detect bone marrow infiltration
Bone marrow Infiltration by malignant process	Goo, 2005[547]	MR, scintigraphy and CT No histologic confirmation Prospective Selection bias : only patients with suspected bone marrow lesions Case control	Poor 2	36 patients detection of marrow infiltration with MR : Se = 99 %, PPV = 94 % compared to bone scan : Se = 26 % and PPV = 76 %	Whole body MR can substitute for bone scintigraphy in detecting skeletal metastases of paediatric malignant tumours, and it is useful in evaluating initial tumour staging and early treatment responses. However, it still has only a complementary role in detecting extraskeletal metastases.
Bone marrow Infiltration by metastasis from	Steinborn, 1999[534]	MR, scintigraphy No histologic confirmation Prospective	Poor 2	18 patients detection of metastases with MR (91,4 %) and with	Whole body MR can substitute for bone scintigraphy in detecting skeletal metastases of carcinoma.

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
carcinoma		Selection bias : only patients with suspected bone marrow lesions Case control		bone scintigraphy (84,8 %)	
Bone marrow Infiltration by metastasis from breast carcinoma	Layer, 1994 [545]	MR, scintigraphy No histologic confirmation Prospective Selection bias : only patients with suspected bone marrow lesions Case control	Poor 2	46 patients detection of marrow infiltration with MR : Se = 92 %, Sp = 97 % compared to bone scan : Se = 58 % and Sp = 85 %	Whole body MR can substitute for bone scintigraphy in detecting skeletal metastases of breast carcinoma.
Bone marrow Infiltration by metastasis from breast carcinoma	Sanal, 1994 [521]	MR, scintigraphy Histologic confirmation with bone marrow biopsy Prospective Selection bias : only patients with suspected bone marrow lesions Case control	Good 2	23 patients detection of marrow infiltration with MR : Se = 100 %, Sp = 69 %, Acc = 83 %, PPV = 71%, NPV = 100 %	MR can substitute for bone scintigraphy in detecting skeletal metastases of breast carcinoma.
Bone marrow Infiltration by metastasis from breast carcinoma	Tausig, 2000 [548]	MR, scintigraphy No gold standard Prospective Selection bias : only patients with suspected bone marrow lesions Case control	Fair 2	20 patients known breast cancer Comparison of detection of metastases with MR and bone scintigraphy	MR can not substitute for bone scintigraphy in detecting skeletal metastases of breast carcinoma. Lesions most frequently missed are in skull an thorax (ribs, sternum and scapulae)
Bone marrow Infiltration by systemic mastocytosis	Roca, 1999[533]	MR Histologic confirmation with bone marrow biopsy Prospective Selection bias : only patients with suspected bone marrow lesions Case control	Good 2	10 patients detection of marrow infiltration with MR : Se = 100 %, Sp = 100 %	MR imaging is a sensitive technique for detecting marrow abnormalities in patients with systemic mastocytosis. There is no correlation between percentage of mast cells in bone marrow biopsy and extent or pattern of bone marrow involvement
Bone marrow Infiltration Lymphoma	Altehoefer, 1997[525]	MR Immunoscintigraphy Histologic confirmation	Good 2	32 patients lymphoma (Hodgkin and non Hodgkin)	Diagnostic imaging is essential for optimal staging in malignant lymphoma, as blind biopsies appear to have low sensitivity for bone marrow

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
		with biopsy Prospective		detection of marrow infiltration with MR : Se = 92 %, Sp = 95 %, Acc = 94 %, PPV = 95 %, NPV = 92 %	infiltration because of frequent involvement in noncrest marrow. Both imaging modalities show a high rate of detection of bone marrow infiltration
Bone marrow Infiltration Lymphoma	Stroszczynski, 1999[535]	MR Ga scintigraphy Histologic confirmation with biopsy Prospective	Good 2	21 patients lymphoma detection of marrow infiltration with MR : Se = 90 %, Sp = 80 %, compared to Ga scintigraphy : Se = 70 % , Sp = 93 %.	These data show that monitoring malignant lymphoma of the bone still presents diagnostic problems. Given the high sensitivity of MRI and the high specificity of 67Ga scintigraphy but the limited specificity of MRI and sensitivity of 67Ga scintigraphy, both methods are valuable but should be used as complementary diagnostic tools
Bone marrow Infiltration Lymphoma	Knauf, 1991[543]	MR Histologic confirmation with biopsy Prospective Case control	Fair 2	27 patients lymphoma (non Hodgkin) detection of marrow infiltration with MR : Se = 92 %, Sp = 87 %, Acc = 89 %, PPV = 85 %, NPV = 93 %	Both biopsy and MR imaging show a high rate of detection of bone marrow infiltration
Bone marrow Infiltration Lymphoma	Yasumoto, 2002 [538]	MR Histologic confirmation with biopsy Prospective Case control	Fair 2	53 patients lymphoma detection of marrow infiltration with MR : Se = 85 %, Sp = 97 %	Both biopsy and MR imaging show a high rate of detection of bone marrow infiltration
Bone marrow Infiltration Lymphoma	Tardivon, 1995[550]	MR Histologic confirmation with biopsy Prospective Case control	Fair 2	40 patients lymphoma detection of marrow infiltration with MR : Se = 92 %, Sp = 87 %, Acc = 89 %, PPV = 85 %, NPV = 93 %	Both biopsy and MR imaging show a high rate of detection of bone marrow infiltration. MR is strongly recommended in patients with abnormal clinical and laboratory findings with normal blind bone biopsy

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
Bone marrow Infiltration Leucemia	Bollow, 1997 [527]	MR Contrast-enhanced MR Correlation with the clinical stage according to Binet (stages A, B, C) and response to therapy Histologic confirmation with biopsy Prospective Control group	Good 2	30 patients with B-cell-type chronic lymphocytic leukemia 45 controls detection of marrow infiltration with MR	MR is able to show the extension of bone marrow infiltration in leucemia and to predict response.
Bone marrow Infiltration Leucemia	Lecouvet, 1997 [530]	MR Correlation with the clinical stage according to Binet (stages A, B, C) and response to therapy Histologic confirmation with biopsy Prospective Case control	Good 2	29 patients with chronic lymphocytic leukemia detection of marrow infiltration with MR	MR is able to detect quantitative changes of bone marrow in leucemia. Quantitative MR fails to detect leukemic marrow infiltration in 41% of patients.
Bone marrow Infiltration Leucemia	Vande Berg, 1996[553]	MR Correlation with response to therapy Histologic confirmation Prospective Case control	Good 2	16 patients with acute lymphoid leukemia 51 patients with acute myeloid leukemia evaluation of response to chemotherapy by quantitative measurement of marrow infiltration with MR	Sequential quantitative MR imaging during treatment appears valuable for prediction of response in patients with acute lymphoid leukemia but not in those with acute myeloid leukemia.
Bone marrow Infiltration Myelodysplastic syndrome Aplastic anemia	Kusumoto, 1997 [554]	MR Histologic confirmation with biopsy Prospective Case control	Fair 2	35 patients with myelodysplastic syndrome 13 patients with aplastic anemia 45 controls detection of marrow infiltration with MR	MR is able to show the extension of bone marrow infiltration or depletion in myelodysplastic syndrome and aplastic anemia, and follow-up therapy response.
Bone marrow Infiltration	Foster, 2004 [540]	MR Histologic confirmation	Fair 2	4 patients with neuroblastoma	MR can detect bone marrow infiltration and indicate the best site for biopsy.

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
Neuroblastoma		with biopsy Prospective Case control		detection of marrow infiltration with MR	Biopsy is the most sensitive method for the detection of occult neuroblastoma cells in bone marrow and peripheral blood. However, because invasion of the bone marrow by neuroblastoma may have a focal distribution, sampling errors can occur. Therefore, not only biopsy, but also MR, need to be used to rule out marrow involvement, especially at diagnosis and relapse.
Bone marrow Infiltration Multiple myeloma	Baur-Melnyk, 2004 [549]	MR Dynamic contrast-enhanced MR Histologic confirmation with biopsy Prospective Case control	Good 2	24 patients multiple myeloma detection of marrow infiltration with MR	Increased contrast uptake in the bone marrow of multiple myeloma patients indicates tumor involvement. The contrast enhancement correlates with vessel-density and serum markers of disease activity.
Bone marrow Infiltration Multiple myeloma	Rahmouni, 2003 [539]	MR Dynamic contrast-enhanced MR Histologic confirmation with biopsy Prospective Case control	Good 2	42 patients 31multiple myeloma, 8 non-Hodgkin lymphoma, 3 Hodgkin lymphoma detection of marrow infiltration with MR	Increased dynamic contrast uptake in the bone marrow of patients indicates tumor involvement (Acc = 99 %)t. The dynamic contrast enhancement correlates with bone marrow involvement grade. Decrease in dynamic contrast enhancement indicates response to treatment.
Bone marrow Infiltration Multiple myeloma	Wasser, 2004[555]	MR Dynamic contrast-enhanced MR Confirmation of response to therapy on clinical base Prospective Case control	Good 2	63 patients refractory or relapsed multiple myeloma evaluation of response to thalidomide monotherapy or combination therapy (thalidomide and chemotherapy)	MR can be used to monitor response to therapy Dynamic contrast-enahanced MR can quantify significant changes of bone marrow microcirculation solely during treatment with thalidomide combined with chemotherapy, not with thalidomide alone Decrease in dynamic contrast enhancement indicates response to treatment.
Bone marrow Infiltration Multiple myeloma	Baur-Melnyk, 2004 [549]	MR, contrast-enhanced MR, plain radiography Histologic confirmation with biopsy Prospective With control group	Good 2	61 patients with multiple myeloma 50 controls detection of marrow infiltration with MR	MR is more sensitive than radiography. MR is able to show the type and the extension of bone marrow infiltration in multiple myeloma. Diffuse involvement can be demonstrated with contrast enhancement. False negative results in low interstitial marrow infiltration possible (11 %)

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
Bone marrow Infiltration Multiple myeloma	Wasser, 2005 [542]	MR, contrast-enhanced MR Histologic correlation and confirmation with biopsy Prospective Case control	Good 2	22 patients with multiple myeloma detection of marrow infiltration with MR : Se = 67 %, Sp = 86 %, Acc = 73 %, PPV = 91 %; NPV = 55 %	MR is able to show the type and the extension of bone marrow infiltration in multiple myeloma. False negative results are high in patients with low interstitial marrow infiltration. Advanced bone marrow infiltration can reliably be detected.
Bone marrow Infiltration Multiple myeloma	Stabler, 1996 [524]	MR, contrast-enhanced MR Histologic confirmation with biopsy Correlation with clinical stage Prospective With control group	Good 2	53 patients with multiple myeloma 53 controls detection of marrow infiltration with MR	MR imaging patterns of spinal bone marrow involvement are correlated with several clinical parameters of disease severity and have prognostic value in multiple myeloma: patients with more involvement on MR needed earlier treatment. MR adds to the evaluation of patients with multiple myeloma and their management
Bone marrow Infiltration Multiple myeloma and breast carcinoma	Baur-Melnyk, 2004 [549]	MR, contrast-enhanced MR Histologic confirmation with biopsy Prospective With control group	Good 2	20 patients with multiple myeloma, 10 with breast carcinoma 94 controls detection of marrow infiltration with MR	Contrast material enhancement in healthy persons can vary greatly and is dependent on age, while intermediate-grade and high-grade diffuse malignant bone marrow infiltration can be objectively assessed with contrast enhanced MR. There is overlap between enhancement in younger adults and patients with low-grade (biopsy < 20 vol%) diffuse malignant bone marrow infiltration.
Bone marrow Infiltration Multiple myeloma	Baur-Melnyk, 2004 [549]	MR, contrast-enhanced MR, compared with haematological staging system of Duri and Salmon Histologic confirmation with biopsy Prospective With control group	Good 3	77 patients with multiple myeloma detection of marrow infiltration with MR	MR is able to show the type and the extension of bone marrow infiltration in multiple myeloma. The combination of the staging system of Durie and Salmon and MR was highly significant with respect to survival (P < 0.0001, log rank analysis) and provides a significant prognostic tool for patients with multiple myeloma.
Bone marrow Infiltration Multiple myeloma	Lecouvet, 1998 [546]	MR, compared with haematological staging system Confirmation with biopsy	Good 3	80 patients with multiple myeloma stage III detection of marrow infiltration with MR	MR imaging patterns of spinal bone marrow involvement are correlated with several clinical parameters of disease severity and have prognostic value in stage III multiple myeloma.

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
		Prospective Case control		comparison of marrow infiltration pattern with therapy response and survival	However, in low grade disease MR may be false negative.
Bone marrow Infiltration Multiple myeloma	Moulopoulos [552]	MR, compared with haematological staging system Confirmation with biopsy Prospective Case control	Good 3	38 patients with asymptomatic multiple myeloma detection of marrow infiltration with MR comparison of marrow infiltration pattern with therapy response and survival	MR imaging patterns of spinal bone marrow involvement are correlated with several clinical parameters of disease severity and have prognostic value in multiple myeloma: patients with more involvement on MR needed earlier treatment.
Bone marrow Infiltration Multiple myeloma	Moulopoulos [556]	MR, compared with haematological staging system Confirmation with biopsy Prospective Case control	Good 3	142 patients with symptomatic multiple myeloma detection of marrow infiltration with MR comparison of marrow infiltration pattern with therapy response and survival	MR imaging patterns of spinal bone marrow involvement are correlated with several clinical parameters of disease severity and have prognostic value in multiple myeloma: patients with more involvement on MR needed earlier treatment. MR adds to the evaluation of patients with multiple myeloma and their management
Bone marrow Infiltration Multiple myeloma	Moulopoulos [520]	MR, compared with therapy response and survival Confirmation with haematological staging system of Duri and Salmon Prospective Case control	Good 2	80 patients with multiple myeloma stage III detection of marrow infiltration with MR comparison of marrow infiltration pattern with laboratory indexes of disease	MR imaging patterns of spinal bone marrow involvement are correlated with several parameters of disease severity. However, in low grade disease MR may be false negative.
Bone marrow Infiltration Multiple myeloma versus solitary bone plasmocytoma	Moulopoulos [544]	MR, compared with plain radiography Confirmation with biopsy Prospective Case control	Good 2	12 patients with solitary bone plasmocytoma detection of additional marrow infiltration with MR 4 patients understaged; 1 of them progressed to	MR imaging can detect spinal involvement and change initial diagnosis of solitary plasmocytoma into multiple myeloma.

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
				multiple myeloma	
Bone marrow Infiltration nonmyelomatous monoclonal gammopathy of undetermined or borderline significance	Vande Berg, 1997[551]	MR Clinical follow-up Retrospective Case control	Fair 2	37 patients with monoclonal gammopathy of undetermined or borderline significance detection of marrow infiltration with MR 7 patients with bone marrow infiltration; 4 of them progressed to malignamcy	MR imaging can detect or exclude bone marrow involvement in patients with monoclonal gammopathy of undetermined or borderline significance. These findings have prognostic significance.
Bone marrow Bone bruise and bone marrow edema	Lazzarini, 1997[558]	MR With control group	Poor 2	20 runners 12 nonrunners detection of bone marrow edema	MR is able to detect bone marrow edema in runners, due to exercise.
Bone marrow Osteomyelitis	Davies, 2005 [568]	MR, comparison with plain radiography Retrospective study Histologic confirmation	Fair 2	100 patients with proven osteomyelitis detection of specific signs of osteomyelitis	MR is able to diagnose acute, subacute and chronic osteomyelitis
Bone marrow Osteomyelitis	Erdman, 1991[559]	MR Combined prospective and retrospective study Histologic confirmation	Fair 2	110 patients with proven osteomyelitis detection of specific signs of osteomyelitis Se = 98 %, Sp = 75 – 82 %	MR imaging is sensitive and specific for diagnosis of osteomyelitis if characteristic appearances and pitfall diagnoses are incorporated into the diagnostic criteria
Bone marrow Osteomyelitis	Hovi, 1996 [563]	MR and leucocyte bone scan (99mTc-HMPAO-labeled leukocytes) Prospective study Histologic confirmation Case control	Good 2	32 patients 12 osteomyelitis, 27 soft tissue infection Comparison for osteomyelitis detection MR : Se = 100%, Sp 81 % Scintigraphy : Se = 42 %, Sp = 75 %	MR imaging is sensitive and specific for detection of osteomyelitis.
Bone marrow Osteomyelitis	Huang, 1998[571]	MR Prospective study Histologic, surgical and	Good 4	44 patients 59 consecutive MR examinations	MR is accurate in the diagnosis of osteomyelitis and associated soft tissue abnormalities in spinal cord-injured patients.

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
		microbiological confirmation Case control		diagnosis of osteomyelitis with MR : Se = 98%, Sp 89 %, Acc = 97 %	MR can delineate the extent of infection in guiding limited surgical resection and preserving viable tissue
Bone marrow Osteomyelitis	Kaim, 2000 [564]	MR, comparison with combined bone scintigraphy and immunoscintigraphy using 99mTc-labelled murine antigranulocyte antibodies Retrospective study; selection bias Surgical, and histological confirmation Case control	Fair 2	18 patients Diagnosis of chronic osteomyelitis with MR Differentiation from aseptic reactive fibrous tissue MR: Se = 100%, Sp = 60%, Acc = 79%, PPV = 69%, NPV = 100% Nuclear medicine : Se = 77%, Sp = 50%, Acc = 61%, PPV = 58%, NPV = 71%	MR is more accurate in the diagnosis of chronic osteomyelitis than combined bone scintigraphy and immunoscintigraphy . Acute activity in a chronic osteomyelitis can be excluded with high probability if the MR findings are negative. In the first postoperative year fibrovascular scar cannot be distinguished accurately from reactivated infection on MR and scintigraphy may improve the accuracy of diagnosis. MR is more sensitive in low-grade infection during the later course than combined bone scintigraphy and immunoscintigraphy. Scintigraphic errors due to ectopic, peripheral, haematopoietic bone marrow can be corrected by MR.
Bone marrow Osteomyelitis	Lederma nn, 2000[565]	MR Retrospective study Microbiological confirmation or clinical follow-up Case control	Fair 2	15 patients with relapse of chronic osteomyelitis Diagnosis of osteomyelitis with MR : Se = 100 %, Sp 63 %	MR is accurate in the diagnosis of relapse of chronic osteomyelitis, with a very high negative predictive value, but rather low sensitivity due to overlap with scarring and edema.
Bone marrow Osteomyelitis	Mahnken, 2000 [566]	MR Retrospective study Surgical, and microbiological confirmation or clinical follow-up Case control	Fair 2	79 patients 112 MR examinations Diagnosis of osteomyelitis with MR : Se = 100 %, Sp 83 %	MR is accurate in the diagnosis of osteomyelitis. Use of gadolinium contrast agents in not necessary.
Bone marrow Osteomyelitis	Mazur, 1995 [562]	MR Prospective study Surgical, and microbiological confirmation	Good 2	43 patients Diagnosis of osteomyelitis with MR : Se = 97 %, Sp 92 %	MR is accurate in the diagnosis of osteomyelitis

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
		Case control			
Bone marrow Osteomyelitis	Morrison, 1993[560]	MR, comparison with scintigraphy Prospective study Surgical, and microbiological confirmation Case control	Good 2	51 patients Diagnosis of osteomyelitis with MR : Se = 88 %, Sp 93 % Scintigraphy (30 patients) : Se = 61 %, Sp = 33 %	MR is accurate in the diagnosis of osteomyelitis, with higher sensitivity and specificity than bone scintigraphy.
Bone marrow Osteomyelitis	Rademacher, 2003[570]	MR, static and dynamic contrast-enhanced MR Prospective study Surgical, and histological confirmation Case control	Good 2	51 patients Diagnosis of acute and chronic osteomyelitis with MR	MR is accurate in the diagnosis of osteomyelitis. Dynamic contrast-enhanced MR is a valuable tool to discriminate between acute and chronic osteomyelitis.
Bone marrow Osteomyelitis	Umans, 2000[567]	MR, with contrast medium administration Retrospective study; selection bias Surgical, histological or clinical confirmation Case control	Fair 2	11 patients Diagnosis of acute osteomyelitis with MR Differentiation with acute medullary bone infarct MR: Se = 100%, Sp = 60%, Acc = 79%, PPV = 69%, NPV = 100% Nuclear medicine : Se = 77%, Sp = 50%, Acc = 61%, PPV = 58%, NPV = 71%	MR is more accurate in the diagnosis of chronic osteomyelitis than combined bone scintigraphy and immunoscintigraphy . Acute activity in a chronic osteomyelitis can be excluded with high probability if the MR findings are negative. In the first postoperative year fibrovascular scar cannot be distinguished accurately from reactivated infection on MR and scintigraphy may improve the accuracy of diagnosis. MR is more sensitive in low-grade infection during the later course than combined bone scintigraphy and immunoscintigraphy. Scintigraphic errors due to ectopic, peripheral, haematopoietic bone marrow can be corrected by MR.
Bone marrow Osteomyelitis	Wunsch, 2001[569]	MR Retrospective study Microbiological confirmation or clinical follow-up Case control	Fair 2	9 patients with acute osteomyelitis Diagnosis of osteomyelitis with MR : NPV = 100 %	MR is accurate in the diagnosis of acute osteomyelitis, with a very high negative predictive value.

Bone tumour

Systematic reviews

Pathology/diagnosis + prevalence	Study ID	Imaging techniques compared	Quality/ Evidence level	Conclusions
Benign bone tumours: cysts and tumours	Azouz, 2002[572]	Plain radiography, CT, bone scintigraphy MR	Good 2	Magnetic resonance imaging is considered the modality of choice for evaluation of benign musculoskeletal lesions (except non ossifying fibroma, osteochondroma and osteoid osteoma) because it is highly sensitive to changes in the signal intensity of bone marrow and adjacent soft tissues. Bone scanning is most useful for depicting multiple silent lesions as may be seen in multiple osteochondromatosis, nonossifying fibromas, and polyostotic fibrous dysplasia
Benign and malignant bone and soft tissue tumours	Berger, 2000 [580]	Only MR	Good 2	MR plays an important role in lesion detection and staging, lesion characterization, longitudinal assessment of tumours during radiation or chemotherapy, and detection of local recurrence
Malignant bone and soft tissue tumours	Dalinka, 1990 [573]	Plain radiography, MR	Good 2	MR imaging should follow plain films in the imaging analysis of soft-tissue tumours and bone tumours suspected of malignancy. MR imaging is primarily useful in tumour staging, although it may aid in diagnosis and the detection of recurrent or residual disease.
Malignant bone tumours in children	Davies, 2001[582]	Plain radiography, MR	Good 2	MR plays an important role in lesion detection and staging, lesion characterization, longitudinal assessment of tumours during radiation or chemotherapy, and detection of local recurrence

Clinical studies

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
Bone tumour staging	Rafique, 2004[585]	Comparison MR - histopathological diagnosis Prospective study Case control	Good 2	30 patients 23 malignant and 7 benign bone tumours	MR imaging proved to be accurate in local staging of bone tumours and determination of the extent of disease. Se = 100 %, Sp = 60 %, Acc = 93 %, PPV = 93 %, NPV = 100 %
Bone tumour staging	Golfieri, 1991[574]	Comparison MR - histopathological diagnosis Prospective study Case control	Good 2	35 patients all malignant bone tumours	MR imaging displays tumour extent with very high accuracy and fully satisfies surgeon's preoperative requirements in the assessment of therapy-responding neoplasms as well as in local tumour staging. Acc = 95 %
Bone tumour staging	Hoffer,	Comparison MR -	Good	40 children with	MR imaging accurately detected epiphyseal extension of

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
	2000[581]	histopathological diagnosis Prospective study Case control	2	osteosarcoma	osteosarcoma when readers distinguished suspected tumour from edematous or normal tissue Acc = 94 %
Bone tumour staging	Wu, 2001[583]	Comparison MR - histopathological diagnosis Prospective study Case control	Good 2	34 patients with osteosarcoma	MR imaging is helpful in preoperative evaluation and staging of osteosarcoma. It showed good sensitivity in detecting involvement of joint and physeal plate invasion, and good specificity in identifying the invasion of neurovascular bundle and skip lesions. involvement of joint, physeal plate invasion, neurovascular invasion, and skip metastasis. The sensitivity and specificity for involvement of joint were 100% and 60% respectively, for physeal plate invasion 95% and 62%, for neurovascular invasion 50% and 100%, and for skip metastasis 100% and 91%. The clinical positive predictive rate / clinical negative predictive rates for the four parameters mentioned above were 25% / 100%, 80% / 89%, 100% / 94 %, and 25% / 100%, respectively.
Bone tumour staging	Van Trommel, 1997[577]	Comparison MR - histopathological diagnosis Prospective study Case control	Good 4	32 patients with osteosarcoma	Study analyses to what extent MR imaging based decisions were correct in determining the surgical procedure in patients with osteosarcoma of the distal femur. If no tumour involvement of a structure was found on MR imaging and this was used as a determining factor, this proved to be correct. When nerve involvement was equivocal on MR imaging we found it valuable to reassess nerve involvement during surgery and reconsider limb salvage surgery. Extensive tumour involvement of any structure, as shown by MR imaging, could be used correctly as a decisive argument in planning a surgical procedure. Nerve involvement TP 24; FP 9; FN 0; TN 68; PPV 73; NPV 100; Se 100; Sp 88; Acc 91; Vascular involvement: TP 18; FP 21; FN 0; TN 62; Se 100; Sp 75; PPV 46; NPV 100; Acc 79
Bone tumour staging	Davies, 1997[576]	Comparison MR - plain radiography, bone scintigraphy and histopathological diagnosis Case report	Good 4	3 patients with Ewing sarcoma	Three cases of Ewing's sarcoma of bone in which MR imaging identified skip metastases not visualized on either contemporary radiographs or bone scintigraphy. There are important implications for patient management. MR is superior to plain radiography and scintigraphy, 2 methods failing to reveal the skip metastases.

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
Bone and soft tissue tumour staging	Pereira, 2004[584]	Comparison MR - histopathological diagnosis Prospective study Case control	Good 2	9 patients with bone or soft tissue tumour	Preoperative coil-marking guided by magnetic resonance imaging for exact delineation of a musculoskeletal tumour is technically feasible and can readily demonstrate the full extent of the tumour to the surgeon by use of intraoperative fluoroscopy. Use of magnetic resonance fluoroscopy reduces the time needed for the intervention.
Bone tumour staging	Szendroi, 1993[575]	Comparison MR – CT -histopathological diagnosis Prospective study Case control Imaging of resected specimens	Good 2	10 resected specimens of malignant bone tumours	CT was better than MR for detecting purely bony changes, but MR was more satisfactory for showing the extraosseous and intramedullary outline of the tumour.
Bone tumour assessment of response to chemotherapy	Erlemann, 1990[587]	Comparison MR - three-phase bone scintigraphy and histopathological diagnosis Case control	Good 2	15 patients with osteosarcoma and 6 with Ewing sarcoma	MR predicts tumour response to chemotherapy. Dynamic contrast-enhanced MR imaging had the highest degree of accuracy (85.7%) and was superior to scintigraphy (accuracy 73.7%)
Bone tumour assessment of response to chemotherapy	Hanna, 1992 [589]	Comparison MR - histopathological diagnosis Prospective study Case control	Good 2	6 patients with osteosarcoma	MR predicts tumour response to chemotherapy. Tumour slopes obtained with dynamic MR imaging after chemotherapy were highly correlated with histologic findings (r(s) = .65, P = .007)
Bone tumour assessment of response to chemotherapy	Torricelli, 2001[592]	Comparison MR - histopathological diagnosis Prospective study Case control	Good 2	24 patients with osteosarcoma	Pathologic area subtraction is a useful technique for assessing the response of osteosarcoma to chemotherapy and for detecting residual viable tumour tissue. Se = 93 %, Sp = 100 %, Acc = 100 %, PPV = 76 %, NPV = 88 %
Bone tumour assessment of response to chemotherapy	Dyke, 2003[593]	Comparison MR - histopathological diagnosis Prospective study Case control	Good 2	19 patients with osteosarcoma 10 with Ewing sarcoma	MR predicts tumour response to chemotherapy. The ability to determine response to induction chemotherapy by means of noninvasive monitoring of necrotic fraction with perfusion MR imaging methods may provide useful prognostic information and help surgical planning. PPV = 80 %, NPV = 86 %
Bone and soft tissue tumour assessment of	Fletcher, 1992[588]	Comparison MR - histopathological	Good 2	19 children with malignant bone	MR predicts tumour response to chemotherapy. Tumour slopes obtained with dynamic MR imaging after chemotherapy

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
response to chemotherapy		diagnosis Prospective study Case control		and soft tissue tumour	are highly correlated with histologic findings
Bone tumour assessment of response to chemotherapy	Reddick, 2001[591]	Comparison MR - histopathological diagnosis Prospective study Case control	Good 2	31 patients with osteosarcoma	MR with dynamic contrast enhancement study predicts disease free survival: regional contrast access after preoperative chemotherapy was significantly predictive of disease free survival (P = 0.035). Dynamic MRI estimates of regional contrast access after preoperative chemotherapy, when combined with tumour size, holds promise for the early identification of patients at risk of recurrence. The availability of such response predictors could facilitate the development of risk-adapted treatment approaches.
Bone tumour assessment of response to chemotherapy	Dunst, 2001[590]	MR; no gold standard Prospective study Case control	Poor 2	79 patients with Ewing sarcoma	MR may predict prognosis and risk of metastasis. The presence of non-perfused (presumably necrotic) areas on pretreatment contrast-enhanced MR-images is associated with an increased risk of metastases, especially an unfavorable pattern of metastatic spread at diagnosis. This observation may be explained by a more aggressive biological behavior of hypoxic tumour cells. The small group of patients with non-necrotic tumours (13%) had an excellent prognosis suggesting that the absence of necrosis might be helpful in identifying a very favorable prognostic subgroup in Ewing tumours
Bone tumour, specific diagnosis: osteoid osteoma	Assoun, 1993 [594]	Comparison MR – CT – bone scintigraphy and histopathological diagnosis Prospective study Case control	Poor 2	9 patients with osteoid osteoma 2 patients no histological confirmation	MRI plays only an ancillary role in the diagnosis of osteoid osteoma, which rests on the concomitant use of bone scintigraphy and CT scan. However, MRI can provide additional evidence to support the diagnosis of clinically suspected osteoid osteoma when CT scan findings are not conclusive
Bone tumour, specific diagnosis: osteoid osteoma	Liu, 2003 [596]	Comparison MR – and histopathological diagnosis retrospective study Case control	Poor 2	11 patients with osteoid osteoma	Osteoid osteomas can be imaged with greater conspicuity by using dynamic gadolinium-enhanced instead of nonenhanced MR imaging and with conspicuity equal to or better than that obtained with thin-section CT
Bone tumour, specific diagnosis: osteoid osteoma	Davies, 2002[595]	Comparison MR – CT – bone scintigraphy and	Fair 2	43 patients with osteoid osteoma	Reliance on MR imaging alone may lead to misdiagnosis. As the osteoid osteoma may be difficult to identify (in this study only 65 % detected with MR) and the MR features easily

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
		histopathological diagnosis Retrospective study Case control			misinterpreted. Unexplained areas of bone marrow oedema in particular require further imaging (scintigraphy and CT) to exclude an osteoid osteoma
Bone tumour, specific diagnosis: osteoid osteoma	Hosalkar, 2005 [597]	Comparison MR – CT and histopathological diagnosis Prospective study Case control	Very good 3?	12 patients with osteoid osteoma 5 patients no CT	CT is much better tham MR for diagnosis and detection of osteoid osteoma. With computed tomography scans, lesions were accurately identified as benign-latent (15/21 readings, 71%) and as osteoid osteoma (14/21 readings) more frequently than with magnetic resonance imaging scans (7/36 readings, 19%).
Bone tumour, specific diagnosis: intraosseous lipoma	Pacheco, 1999[579]	Only MR, no histological confirmation Case report	Poor 2	2 patients with intraosseous lipoma	Intraosseous lipoma is easily identified by MR since its image is that of a well defined lesion with a signal intensity similar to that of fatty tissue in all sequences
Bone tumour, specific diagnosis: chondroblastic osteosarcoma	Geirnaerdt, 1998[578]	MR with histological confirmation Cases and control group	Good 2	9 patients with chondroblastic osteosarcoma and 20 with conventional central osteosarcoma	Gd-enhanced MR imaging can assist in obtaining diagnostic biopsy material of chondroblastic osteosarcoma by identifying both osteoid- and chondroid-forming areas
Bone tumour, specific diagnosis: intraosseous lipoma	Sung, 2005[586]	MR and histopathological diagnosis Retrospective study Case control	Good 2	30 patients with chordoma	MR imaging is useful in the diagnosis and preoperative assessment of sacrococcygeal chordoma. Follow-up MR imaging is helpful to assess for recurrent or metastatic lesions of chordomas.
Bone and soft tissue tumours: Quality control of MR exams performed at non-specialised referral centres	Saifuddin, 2000 [598]	MR Quality control study	Good 2	50 patients with bone and soft tissue tumours	Magnetic resonance imaging (MRI) is essential in the pre-operative staging of suspected primary bone and soft-tissue sarcomas. Such lesions are ideally managed in specialist centres but it is becoming increasingly common for patients to undergo MRI before referral. The commonest mistake was the failure to image the whole bone for 'skip' metastases. Specific information regarding precise intraosseous and extraosseous extent of tumour and relationship to the neurovascular bundle and adjacent joint was commonly not included. This audit indicates that a greater awareness is needed amongst general radiologists of the MR imaging and

Pathology/diagnosis	Study ID	Design	Quality/ Evidence level	Population + prevalence	Conclusions
					reporting requirements for musculoskeletal tumours. In particular, all important axial imaging is sometimes omitted.

SOFT TISSUE NEOPLASM

HTA reports

Pathology/Diagnosis Prevalence	Study ID	Search period	Evidence	Imaging Techniques Compared	Conclusions
Soft Tissue Neoplasm Diagnosis, grading and management	HTA 1990-11/2001-CAG-00099N [599]	08/1987-5/1998	18 studies	FDG-Pet MRI and CT	**Primary diagnosis**: There are no good quality data on the comparative diagnostic performance of FDG-PET against CT or MRI **Local recurrence**: equivalent diagnostic performance of FDG-PET and MRI Distant metastasis: equivalent performance of FDG-PET and CT scan

Reviews

Pathology/Diagnosis Prevalence	Study ID	Design	Quality/ Evidence level	Population Prevalence	Conclusions
Soft tissue Sarcoma Surgical Resection MRI staging	Flugstad, 1999[604]	Retrospective cohort review MRI, pathology	Good Level 2-3	N = 90	a 99% negative margin rate was achieved
Soft tissue Sarcoma Follow up strategies	Whooley, 1999 [605]	Retrospective cohort review CT and MRI	Fair Level 2	N = 150	CT or MRI each year is not able to detect local recurrence
Children Fibrous Tumors Diagnosis and staging	Eich, 1998[606]	Retrospective case series	Low Level 1	N = 25	Some tumors have a characteristic presentation
Children benign fatty tumors	Ha, 1994[607]	Retrospective case series	Low Level 2	N = 4	In childhood, fatty lesions are almost always benign, a morphologic characterization by MRI may be sufficient to make critical therapeutic judgements

Clinical studies

Pathology/Diagnosis Prevalence	Study ID	Design	Quality/ Evidence level	Population Prevalence	Conclusions
Soft tissue Sarcoma and metastasis Staging of vascular invasion	Feydy, 2006[608]	Prospective cohort review MRI, surgery	Good Level 2-3	N = 31	sensitivity 64% specificity 95% accuracy 84%
Diagnosis of Glomus tumor	Al-Qattan, 2005 [609]	Retrospective cohort review MRI, pathology	Good Level 2	N = 42	sensitivity 90% specificity 50%
Soft tissue tumor Characterization	Gielen, 2004[610]	Prospective cohort review MRI, pathology	Good Level 2-3	N = 548	Differentiation between malignant and benign lesions: sensitivity 93% specificity 82% accuracy 85% Characterization: sensitivity 67% specificity 98% accuracy 96%
Soft tissue tumor Characterization	Wang, 2004[611]	Prospective cohort review MR spectroscopy Pathology	Good Level 2	N = 36	sensitivity 95% specificity 82% accuracy 89%
Residual tumor detection	Davies, 2004 [612]	Retrospective Case study MRI, pathology	Fair Level 2	N = 111	sensitivity 64% specificity 93%
Soft tissue sarcoma staging of osseous invasion	Elias, 2003[613]	Retrospective Case study MRI, pathology	Fair Level 2-3	N = 56	sensitivity 100% specificity 93%
Soft tissue tumor Characterization	Einarsdottir, 2003[614]	Retrospective Case study Dynamic MRI, pathology	Fair Level 2	N = 32	sensitivity 87% specificity 70%
Soft tissue sarcoma Reccurence	Moustafa, 2003 [615]	Prospective Cohort CT and/or MRI Tc-MIBI scan Pathology = gold standard	Fair Level 2	N = 40	Tc-MIBI: sens 93%, spec 95% acc 92% MRI and/or CT: sens 86% spec 75% acc 84%
Soft tissue Tumor Characterization	Gielen, 2003[616]	Retrospective Cohort	Good Level 1	N = 53	SE T1-WI with FS has additional value

Pathology/Diagnosis Prevalence	Study ID	Design	Quality/ Evidence level	Population Prevalence	Conclusions
		MRI and Pathology			
Differentiation of lipoma and well differentaited liposarcoma	Galant, 2003[617]	Retrospective Case study MRI and pathology	Fair Level 2	N = 92	specificity 76.6% sensitivity 100% for malignant lesions
Soft tissue tumor Characterization	Tacikowska, 2002[619]	Retrospective Case study MRI and pathlogy	Fair Level 2	N = 45	Differentiation between malignant and benign lesions: sensitivity 93% specificity 73%

SOFT TISSUE INJURY

Systematic reviews

Pathology/Diagnosis Prevalencer	Study ID	Imaging Techniques compared	Quality	Remarks	Conclusions
Rot Cuff Tear	Dinnes, 2003[473]	Clinical- US-MRI-MRA (Arthrography)	Good Level 3	Only cohort studies Clinical 10 US 38 MRI 29	Full Thickness MRI = US Partial Thickness US > MIR

Clinical studies

Pathology/diagnosis	Study ID	Design	Quality	Population Prevalence	Conclusions
Tib Post Tendon rupture	Rosenberg, 1988[621]	Monoslice CT-MRI Prospective Case control	Good Level 3	Old study N = 32	MRI > CT 91% CT 96% MRI
Achilles Tendon Partial rupture	Kayser, 2005[622]	Ultrasound-MRI Prospective Cohort MRI performed in problem cases MRI = gold standard	Fair Level 2-3	N = 320	MRI > US US Sens 50% Spec 81% US-MRI agreement In 61,5%

Pathology/diagnosis	Study ID	Design	Quality	Population Prevalence	Conclusions
Atrophy SS and IS	Strobel, 2005[623]	Ultrasound-MRI Prospective Cohort	Fair Level 2-3	N = 65	MRI >> US US Acc: 72-85%
Achilles disease	Reiter, 2004[624]	Ultrasound-MRI (Panoramic US) Prospective Case control Combination of MRI and US MRI = gold standard	Fair Level 2-3	N = 23	MRI >~US MRI sens 87.5 % Spec 100 %
Supraspinatus repair	Kraft, 2004[625]	Ultrasound-MRI Prospective Case control	Fair Level 2	N = 40	MRI = US Both low sensitivity US spec 90.3% Sens 33.3% MRI spec 87.1% sens 44.4%
Tib Post Tendon rupture	Gerling, 2003[626]	Ultrasound-MRI Cadaver study Double blinded Iatrogenic rupture	Good Level I	N = 16 64 tears	MRI = US Acc: MRI 72% US 72%
Forearm Interosseous Membrane Rupture	Fester, 2002[627]	Ultrasound-MRI Cadaver study Double blinded Iatrogenic rupture	Good Level I	N = 19	MRI = US Acc: MRI 96% US 94%
Epicondylitis	Miller, 2002[493]	Ultrasound MRI Case control MRI = gold standard	Fair Level 2	N = 11	MRI > US US Sens 64%-82% MRI Sens 90%-100% US Spec 67%-100% MRI Spec 83%-100%
Pulley tears	Klauser, 2002[628]	Ultrasound-MRI Case control MRI/surgery = Gold standard	Fair Level 2-3	N = 64	US Sens 98% US Spec 100%
Posterior Tibial Tendinopathy	Premkumar, 2002[629]	Ultrasound-MRI Case control MRI = gold standard	Fair Level 2-3	N = 44	MRI = Gold Standard US Sens 80-90% US Spec 80-90%

Pathology/diagnosis	Study ID	Design	Quality	Population Prevalence	Conclusions
Rot Cuff Tear	Kenn, 2000[630]	Arthrography Ultrasound-MRI Case control Surgery = gold standard	Good Level 3	N = 40	Arthro<US<MRI Complete tears Sens 91%, 69%, 92% Spec 100%, 93%, 93% Partial tears Sens 50%, 69%, 69% Spec 100%, 79%, 86%
Partial Finger Extensor Tendon Tears in RA	Swen, 2000[631]	Ultrasound-MRI Prospective Case control	Fair Level 2	N = 21	US > MRI But both insufficient Acc MRI Acc 69% US Acc 75%

SOFT TISSUE INFECTION AND INFLAMMATION

Clinical studies

Pathology/diagnosis	Study ID	Design	Quality	Population Prevalence	Conclusions
Retroperitoneal Cyst, abcess	Dombrovskii, 2003[632]	MRI Prospective Case control	Fair Level 3-4	N = 50	MRI < CT,US Sens 100 Spec 87,1-88,5 Acc 93,5-94,2
Diabetic Foot Osteomyelitis	Enderle, 1999[633]	MRI, US, XR, Scintigraphy Prospective Cohorte Case control Pathology = gold standard	Good Level 3-4	N = 19	MRI > US=Scinti > XR Sens, spec : US 79%, 80% XR 69% , 80% Scinti 83%, 75% MRI 100%, 75%
Retrocalc Bursitis	Olivieri, 1998 [634]	MRI, US Case control MRI = gold standard	Poor Level I	N = 28	MRI > US US sens 50% US spec 100%

BREAST

Peoperative staging of breast carcinoma

Clinical studies

Pathology/diagnosis	Study ID	Design	Quality	Population + prevalence	Conclusions
Suspicious for breast carcinoma	Gatzemeier, 1999 [815]	CE,MX,US,MR prospective	good	112 patients	On MR only: 28 additional ca 25 MF/MC,3 CL Mastectomy 14,3% FP 18%. Especially for the diagnosis of MF/MC lesions, MRI seems to be the method of choice. Consequently, MRI plays an important role in planning the operative procedure.
Symptomatic breast disease	Drew, 1999 [816]	Triple assessment, MR	good	178 cancers	On MR only: 15/26 MF/MC MRI detected occult MF/MC cancers. MRI of the breast should be considered for the preoperative planning.
Early stage breast cancer	Tillman, 2002 [817]	CE,MX,US,MR retrospective	good	207 women	MR affects clinical management in 20%, favorable in 11%MR. MR offers clinically useful information. Effect of MR was greater if performed before excisional biopsy. Therapy change correct in 11%, unnecessary in 7%.bv
Highly suggestive for malignancy	Hlawatsch, 2002 [818]	MX,US,MR	good	104 women	On MR: 27 MF/MC, sens MR=81%, MX+US=63% MR benefits 7 patients, FP in 8 patients MR is more sensitive, but routine preoperative use appears unnecessary if MX+US is used. MR may be restricted to problem cases with dense breasts.
Breast cancer, conservative treatment candidates	Liberman, 2003 [819]	MX,MR retrospective	good	70 women	MR detects additional cancer in 27%: 14 SQ/ 5DQ, especially in patients with familial breast cancer and ILC. Therapy change correct in 27%, unnecessary in 23%.
Breast cancer	Bedrosian 2003 [733]	retrospective	good	267 women Due to MRI: Therapy change in 26%, in 71% AP verification of malignancy Mastectomy in 16.5%	MRI studies may be particularly useful in surgical planning for and management of patients with lobular carcinoma. Therapy change correct in 18%, unnecessary in 7%
Breast cancer in dense breasts, conservative	Van Goethem 2004	MX,US,MR retrospective	good	65 patients with dense breasts	MR detected 11 additional cancers and 2 in the other breast. MR can detect additional cancer in patients with dense breasts. Therapy change correct in 32%, unnecessary in 11%.

Pathology/diagnosis	Study ID	Design	Quality	Population + prevalence	Conclusions
treatment candidates	820				
Known or suspected invasive breast cancer	Berg, 2004 821	MX,US,MR prospective	good	111	MR depicted additional ca in 12 breasts and 3 in the other breast Overestimation in 6 breasts . In nonfatty breasts, US and MR are more sensitive than MX, but may overestimate. Combination of CE,MX and MR is most sensitive
Mastectomy for breast cancer	Sardanelli, 2004 822	MR,MX	good	99 breasts	Sensitivity higher on MR. Sens MX/MR=75/80% for fatty breasts, 60/81% for dense breasts. MRI more sensitive than MX in dense breasts
Breast cancer	Schelfout, 2004 823	CE,MX,US,MR prospective	good	170 patients	MF/MC: detection MR 96/95, MX 37/18, US 41/9. MR is a useful tool in treatment planning. Correct therapy change in 30,6%, unnecessary in 6%.
Early stage breast cancer	Wiener, 2005 824	CE, MX,US,MR	fair	44 cancers	14(32%) add. lesions, 4 (9%) CL Mastectomy in 8 (18%) MR often results in better treatment planning and will result in no significant increase in biopsies of benign lesions.
Breast cancer	Schnall, 2005 724	MX,MR Multicenter study, 15 centers: (US,Canada,Germany)	Very good	426 women, confirmed breast cancer additional enhancing incidental lesions (ILs) considered suspect if Bi-Rads 4 and 5 lesions	MRI significantly higher yield of confirmed cancer ILs than MX (0.18 (95%CI: 0.142-0.214) for MRI versus 0.072 (95%CI: 0.050-0.100) for MX). Consideration needs to be given regarding the integration of breast MRI into the pretreatment evaluation of women seeking breast conservation therapy.

CE=clinical examination; MX=mammography; US=ultrasonography; MRI=Magnetic resonance imaging; DCIS=ductal carcinoma in situ; EIC=extended intraductal component; MF: multifocal; MC=multicentric; SQ=same quadrant; DQ=different quadrant; CL= contralateral breast

MR mammography of DCIS with invasive carcinoma

Pathology/diagnosis	Study ID	Design	Quality	Population + prevalence	Conclusions
Pathologically proven breast cancer	Kerslake, 1995[725]	MX,US,FNAC,MR	fair	50 patients 13 with Invasive ca+ DCIS	54% sensitivity of DCIS
patients with DCIS	Soderstrom, 1996[726]	MX,MR	fair	22 patients with DCIS, of which 11 EIC + carcinomas	100% detection of carcinoma 95%/74% accurate determination of extent on MR/MX
Breast cancer	Mumtaz,	CE,MX,FNAC,MR	good	19 EIC + carcinomas	MR value in preoperative locoregional staging and in

Pathology/diagnosis	Study ID	Design	Quality	Population + prevalence	Conclusions
	1997[825]				planning a single definitive surgical resection. Detection rate of MF,DCIS: MR:81% MX :62%
Breast cancer	Satake, 2000[727]	MX,US,MR	good	46 patients, 29 with Invasive ca + DCIS, of 25 MR images	Sensitivity to depict DCIS for US,MX,MR is 89%,55%,93% US has a tendency to underestimate DCIS of comedo type compared with MX and MR.
Breast cancer	Kristofferse, 2002[728]	MX,MR	good	76 cancers, of which 23 mixed invasive/in situ cancer	MR and MX underestimate both the extent of the mixed lesions.
breast cancer, conserving treatment	Komatsu, 2004[731]	MX,MR retrospective	fair	26 patients MR higher sensitivity and accuracy, lower specificity	MR better in evaluation of intraductal spread, more frequently seen in larger tumours. Sens, spec and accuracy of MR were 82.4%, 60.0% and 77.3%,. On MX, these were 21.1%, 100.0% and 42.3%.
Breast cancer	Ikeda, 2004[730]		Very good	93 women 59 EIC + carcinomas, 42 had linear or segmental enhancement	Sens, spec, and accuracy of MR in detecting EIC were 71%, 85%, and 76%.
Breast cancer	Hata,2004[729]	MR,MX,US	Very good	183 patients Accuracy of intraductal spread was 65.6% on MR, 50% on MX and US	MR can detect intraductal spread more accurately Sens, spec, and accuracy of detection of intraductal spread were 66.7%, 64.2%, and 65.6% with MR; 22.2%, 85.7%, and 50% with MX; and 20.6%, 85.2%, and 50% with US

CE=clinical examination; MX=mammography; US=ultrasonography; MRI=Magnetic resonance imaging; DCIS=ductal carcinoma in situ; EIC=extended intraductal component; MF: multifocal; MC=multicentric; SQ=same quadrant; DQ=different quadrant; CL= contralateral breast

Screening of the contralateral breast in patients with recently diagnosed breast cancer

Pathology/diagnosis	Study ID	Design	Quality	Population + prevalence	Conclusions
Breast cancer in 1 breast	Slanetz, 2002 [826]	CE,MX,MR	fair	17 patients	10 CL lesions, 9 were carcinomas In 5 patients biopsy due to MR: 4 carcinomas, seen on MR only. Breast MR imaging of the contralateral breast may be of value as a routine screen in those patients with a known or suspected malignancy. PPV 80%.
Breast cancer in 1	Liberman,	CE,MX,MR	good	223	72 biopsies, 12 cancers, seen on MR only Cancer detected only

Pathology/diagnosis	Study ID	Design	Quality	Population + prevalence	Conclusions
breast	2003[819]	retrospective			by MR in 5% of women. PPV 20%.
Breast cancer in 1 breast	Lee, 2003[827]	MR	good	182 patients	On MR in other breast: 15 enhancing lesions 7 malignant, 8 benign Feasibility of using MR imaging of the breast in a screening role, specifically to evaluate the contralateral breast . 8.2% enhancing lesions, 3.8% malignant result.
Breast cancer in 1 breast	Lehman, 2005[828]	MX,MR prospective	good	103 patients 12 biopsies, 4 carcinomas, seen on MR only	Approximately 4% occult invasive breast cancer detected in the opposite breast by MRI alone. PPV 33%.
Proved unilateral cancer	Pediconi, 2005[829]		good	50 patients 14 enhancing lesions in other breast: 9 cancers and 2 lobular carcinoma in situ, 3 FP	MR could be introduced to screen patients with carcinoma in 1 breast. MR: FN 0, FP 3

CE=clinical examination; MX=mammography; US=ultrasonography; MRI=Magnetic resonance imaging; DCIS=ductal carcinoma in situ; EIC=extended intraductal component; MF: multifocal; MC=multicentric; SQ=same quadrant; DQ=different quadrant; CL= contralateral breast; FP:false positive

Diagnosis of scar or recurrence

Pathology/diagnosis	Study ID	Design	Quality	Population + prevalentie	Conclusions
FU after treatment for breast cancer with breast conserving surgery and radiotherapy	Mumtaz, 1997[720]	CE,MX,FNAC,MR	good	30 patients with clinical suspicioun of recurrence 14 recurrences	Sens MX,FNAC, MR= 50%, 79%, 93% Spec MR=88%. MR accurate estimation of the extent
FU after treatment for breast cancer with breast conserving surgery	Rieber, 1997[743]		good	140 patients with possible recurrence	Recurrent disease was excluded in 82.8% with MR, detected in 13.6% MR was FP in 3.6% MR is sensitive for detecting or excluding recurrence. Will early detection of recurrence contribute to improvement of prognosis ?
FU after treatment for breast cancer with breast	Drew, 1998[744]	CE,MX,US,MR 1 MR of the	good	105 16 biopsies were performed 9 recurrences detected	Sens CE, MX, CE+MX, and MRI alone for the detection of recurrent cancer were 89%, 67%, 100%, and 100%, respectively, and the

Pathology/diagnosis	Study ID	Design	Quality	Population + prevalentie	Conclusions
conserving surgery		breast routinely in the period 1 to 2 years following treatment, or earlier if recurrence was suspected		other: FU	specificity was 76%, 85%, 67%, and 93%. MRI should be used when there is clinical or mammographic suspicion of recurrence

Role of MR soon after surgery

Pathology/diagnosis	Study ID	Design	Quality	Population	Conclusions
Surgery for breast cancer	Orel, 1997[746]	MX,MR	good	47 patients within mean time of 18 days after surgery	Accuracy MX,MR=7%,64%
Surgery for breast cancer	Soderstrom, 1997[747]		good	18 patients Within 10 months after initial surgery	Accuracy MR=84% MR can demonstrate presence or absence and the location and extent of recurrent tumor
Surgery for breast cancer	Kurtz, 2000 [748]		fair	38 patients intraductal carcinomas	Accuracy of MR=88%
Surgery for breast cancer	Kawashima, 2001[749]		good	50 patients 6 to 20 days (mean: 12 days) after excisional biopsy. Patients are excluded if US detected residual tumor.	Sens=66%, spec=81%, accuracy=72%, PPV=83%, NPV=63%. FP due to granulation and proliferative fibrocystic change.
Breast conserving surgery for breast cancer	Lee, 2004[750]		good	80 patients, 82 breasts Close or positive margin. Residual disease in 59.8%	Sens. and spec. for residual disease = 61.2% and 69.7%, respectively. PPV for additional suspicious lesion = 33.3%. Therapy change in 30%.

Monitoring response on neoadjuvant chemotherapy

Pathology/diagnosis + prevalence	Study ID	Imaging techniques compared	Quality	Remarks	Conclusions
Before and after completion of neoadjuvant chemotherapy	TEC,2004[723]	6 studies compare with conventional alternatives	Very good	18 studies, 17 compare with pathology Abraham et al., 1996 (n=39) Esserman et al., 2001 (n=33)	Sensitivity of presence of residual tumor of MR=90-100%, specificity= 50-100%. Estimation of size, extent correctly in 57%,63%,66%,83%,97%.

Pathology/diagnosis + prevalence	Study ID	Imaging techniques compared	Quality	Remarks	Conclusions
				Gilles et al.,1994 (n=18) Drew et al.,2001 (n=17) Belli et al.,2002 (n=45) Tsuboi et al., 1999 (n=31) Trecate et al., 1999 (n=30) Wasser et al., 2003 (n=31) Weatherall et al., 2001 (n=20) Nakamura et al., 2001 (n=15) Rosen et al., 2003 (n=21)	Correlation coefficient for size of residual tumor ranging from 0.72 to 0.98.
Before,during and after completion of neoadjuvant chemotherapy (subgroup of row 1)	TEC,2004[723]		Very good	6 studies (of 18,see row 1) Rieber et al., 2002 (n=58) Martincich et al.,2004 (n=30) Cheung et al.,2003 (n=33) Rieber et al. 1997 (n=13) Wasser et al. 2003 (n=21) Balu-Maestro et al.2002 (n=51)	NPV 38% and 83% Rieber 2002: Before 6 weeks not reliable Rieber 1997: Responders showed decreased enhancement even after 1st cycle, nonresponders showed no decrease. Wasser: Reduction in enhancement after 1st cycle, in size not before 3rd cycle. Reduced enhancement also in nonresponders. Martincich: after 2 cycles: reduction in volume and enhancement ratio =93% accuracy for achieving complete response
Evaluation of extent in locally advanced breast cancer (no chemotherapy used)	TEC,2004[723]	3 studies compare with conventional alternatives 2 prospective studies 2 include more than 50 subjects	Very good	4 studies Morris et al.,2000 (n=19) Mumtaz et al., 1997 (n=90) Kerslake et al., 1995 (n=50) Rodenko et al., 1996 (n=20)	
Evaluation of extent in locally advanced breast cancer Comparison with other techniques	TEC,2004[723]	CE,MX,MR		9 studies: 6 with chemotherapy, 3 without (row 3 and 4)	MR more sensitive in identifying residual tumor And defining size and extent. Drew (n=17): Sens. of MR,MX,CE= 100%,90%,50%. Spec. of MR,MX,CE= 100%,57%,86%. Partridge (n=52): Correlation AP-MR=0.89, CE=0.60. FN : MR=0, CE=5. Chest wall involvement MR better than CE,MX

Pathology/diagnosis + prevalence	Study ID	Imaging techniques compared	Quality	Remarks	Conclusions
					Nipple involvement: MR better then CE,MX

Monitoring response to neoadjuvant chemotherapy

Clinical studies

Pathology/diagnosis	Study ID	Design	Quality	Population + prevalentie	Conclusions
Residual disease after neoadjuvant chemotherapy	Londero, 2004[764]	MX,US,MR	good	15 patients MR before and after 2 and 4 cycles of chemotherapy	MRI identified 2/15 (13.3.%) clinically complete response (CR), 9/15 (60%) partial response (PR), 3/15 (20%) stable disease (SD) and 1/15 (6.7%) progressive disease. MX identified 1/15 (6.7%) clinically CR, 8/15 (53.3%) PR and 4/15 (27%) SD, and was not able to evaluate the disease in 2/15 (13%) cases. US presented the same results as MRI. MRI and US compared to MX correctly identified residual disease in 100% vs. 86%.
Presurgical evaluation of residual disease	Thibault, 2004[830]	CE,MX,US,MR	good	30 patients Before, during and after chemotherapy Size and morphology on MR 16 breast conserving 14 mastectomy	MRI results would have led to major beneficial therapeutic changes in six (20%) of the 30 patients and added valuable information in 14 (46.7%) Although the ultimate incidence of breast conservation was potentially similar for the patients (16/30, 53%) in whom the standard evaluation was used and for the patients (14/30, 47%) in whom the MRI-added evaluation was used, MRI was useful in establishing the final treatment earlier in the process, avoiding unnecessary preoperative chemotherapy, or selecting high-risk breast-conserving procedures.
Predicting residual tumor	Yeh, 2005[831]	CE,MX,US,MR Study cohort	good	31 patients Complete, partial, and stable clinical response as defined by clinical examination was seen in 15, 14, and 2 of the 31 patients, respectively.	Agreement about rate of response as measured by CE,MX,US and MR compared with pathology was 19%, 26%, 35%, and 71%, respectively. MR best correlation. However, MRI may overestimate (6%) or underestimate (23%) residual disease in approximately 29% of the patients (95% confidence interval, 14-48%).

Breast cancer screening

Reviews

Pathology/diagnosis + prevalence	Study ID	Imaging techniques compared	Quality	Remarks	Conclusions
High risk women	Kuhl, 2005[773]	MX, US, MR, CE	good	Described different management options that exist for women at high risk	MX, US, CE are not sufficient +MR early diagnosis seems possible. Efficacy is unclear in terms of morbidity and mortality.
High risk women	Irwig, 2004[771]	US, MR, DMX, CAD	good	Systematic review of literature Studies included small number of patients	MR not for population screening MR may have a better sensitivity than MX in selected high risk women
High risk women	Liberman, 2004[772]	MX,US,MRI	good	review	MRI can detect otherwise occult cancer in high risk patients.

Clinical studies of MR in breast cancer screening in high risk women

Pathology/diagnosis	Study ID	Design	Quality assessment	Population + prevalentie	Conclusions
Over 25% risk	Tilanus-Linthorst, 2000[776]	CE, MX, MR Prospective Costs	good	109 women 50% dense breasts	MR can advance detection of breast cancer but the cost may be considerable
Hereditary risk	Stoutjesdijk, 2001[777]	MX,MR	good	179 women	MR more accurate than MX in annual breast cancer surveillance
Breast cancer susceptibility gene suspected or proved	Trecate, 2003[778]	MX, US, MR Prospective Protocol for routine screening	fair	27 high risk patients	Accuracy of MR is higher than conventional imaging
15% risk or more	Kriege, 2004[774]	FU 2,9 years Controle group	Very good	1909 women	MR more sensitive than MX MR detected cancers are smaller cancers and have less lymphnode involvement
BRCA mutation carriers	Warner, 2004[779]	MX, US, MR	good	236 women	MR more sensitive in BRCA patients
Increased familial risk	Kuhl, 2005[832]	MX,US,MR Cohort	Very good	529 asymptomatic women FU 5,3 years	MX,MX+US insufficient for early diagnosis. MR higher sensitivity, more favourable stage.
Familial hereditary risk	Kuhl, 2005[780]	Semiannual CE,US Annual MX,US,MR	Very good	613 women Multicentre trial	Early diagnosis is feasible with MR

Pathology/diagnosis	Study ID	Design	Quality assessment	Population + prevalentie	Conclusions
				4 years 748 screen rounds	
Strong family history or mutation	MARIBS study group Leach, 2005[775]	Annual MX,MR	good	649 women	MR is more sensitive, especially in BRCA patients.
Genetically high risk women	Lehman, 2005[833]	CE,MX,MR	good	390 women	MR can detect cancer, occult on MX and CE

APPENDIX 4: CARDIOVASCULAR RADIOLOGY

CONSENUS PANEL REPORT - EUR HEART J 2004 BY CARDIOLOGISTS, RADIOLOGISTS, NUCLEAR MEDICINE SPECIALISTS, AND HEALTH ECONOMISTS

Class I indications

(provides clinically relevant information and is usually appropriate; may be used as first line imaging technique; usually supported by substantial literature)

- assessment of ventricular volumes, function and mass (right/left)
- myocardial infarction – viability imaging
- myocarditis
- apical form of hypertrophic cardiomyopathy (other forms?)
- arrhythmogenic right ventricular dysplasia
- dilated cardiomyopathy
- iron deposition cardiomyopathy (hemochromatosis)
- constrictive pericarditis and differentiation with restrictive cardiomyopathy
- cardiac tumors and masses
- valvular regurgitation
- assessment impact of valve dysfunction on ventricular mass , size and function
- assessment of the pulmonary valve (pulmonary regurgitation)
- initial evaluation and follow-up of adult congenital heart disease

Class II indications

(provides clinically relevant information and is frequently useful; other techniques may provide similar information; supported by limited literature)

- myocardial perfusion (stress myocardial perfusion)
- stress function imaging (dobutamine)
- hypertrophic cardiomyopathy (non-apical forms)
- isolated non-compaction cardiomyopathy
- restrictive cardiomyopathy
- cardiac sarcoidosis
- assessment of valve stenosis (gradient – valve area)
- atrial septal defect
- anomalies of the atrioventricular valves
- ventricular aneurysms and diverticula
- suprvalvular pulmonary stenosis

- malpositions of the great arteries
- valve morphology (bicuspid aortic valve)

Class III indications

(provides clinically relevant information but is infrequently used because information from other imaging techniques is usually adequate)

- anatomical detection of coronary artery stenoses
- pericardial effusion
- isolated ventricular septal defect
- isolated valvular pulmonary stenosis and valvular dysplasia
- isolated valvular aortic stenosis / subaortic stenosis
- patent ductus arteriosus
- quantification of valve stenosis
- valve morphology (valves other than aortic)

Class Investigative indications

(potentially useful, but still investigational)

- detection of (acute) rejection in cardiac transplants
- peripheral pulmonary stenosis
- MR flow measurements in the coronary arteries
- Acute coronary syndromes
- Arterial wall imaging
- Valvular vegetations
- Detection of paravalvular abscess
- Assessment of prosthetic valves

APPENDIX 5: FINANCING OF MRI

GENEESHEER-SPECIALIST VOOR RONTGENDIAGNOSE - RADIOLOGIE

officieuze coördinatie Art. 17 pag. 1

De hiernavolgende artikelen 17 en 17bis werden gewijzigd bij de koninklijke besluiten van 30 januari 1986, 28 november 1986, 7 januari 1987, 22 juli 1988, 23 oktober 1989, 13 november 1989, 7 december 1989, 10 juli 1990, 22 januari 1991, 7 juni 1991, 19 december 1991, 5 maart 1992 en 22 oktober 1992; 17bis, werd ingevoegd bij de koninklijke besluiten van 7 juni 1991 en gewijzigd bij de koninklijke besluiten van 19 december 1991, 2 september 1992 en 22 oktober 1992.

AFDELING 6. - Medische beeldvorming

Art. 17. Radiologie

§ 1er. Worden beschouwd als verstrekkingen waarvoor de bekwaming van specialist voor röntgendiagnose (R) vereist is:

1° Gynecologie - Verloskunde :

				"K.B. 9.10.1998" (in werking 1.1.1999)			
"	5000	450015	450026	Radiografie van het abdomen en/of van de bekkenstreek voor rechtstreeks onderzoek zonder manipulatie noch contrastmiddelen, ongeacht het aantal clichés (mag niet worden gecumuleerd met de verstrekkingen nrs. 450516 - 450520, 451010 - 451021, 455276 - 455280 dezelfde dag verricht)	N	35	"
	5001	450030	450041	Radiopelvimetrie (mag niet worden gecumuleerd met de verstrekking nr. 455276 - 455280, dezelfde dag verricht)	N	65	
	5003	450074	450085	Hysterosalpingografie (hysterografie), inclusief het abdomen zonder contrastmiddel en de eventuele laattijdige controleclichés met radioscopisch onderzoek met beeldversterker en televisie in gesloten keten	N	90	
				"K.B. 25.7.1994" (in werking 1.11.1994)			
"	5004	450096	450100	Mammografie per borst, inclusief de eventuele okselclichés (ongeacht het aantal clichés)	N	45	"
				"K.B. 23.5.2001" (in werking 15.6.2001) + "K.B. 25.2.2003" (in werking 1.5.2003)			
				"1°bis. Screeningsmammografie.			
		450192	450203	Mammografie van beide borsten, in het kader van een door een overheid georganiseerd bevolkingsonderzoek	N	120	

Deze verstrekking is enkel aanrekenbaar bij vrouwen vanaf de eerste dag van het kalenderjaar waarin ze 50 jaar worden tot en met de laatste dag van het kalenderjaar waarin ze 69 jaar worden, eenmaal per twee kalenderjaren. Zij is niet onderworpen aan de bepalingen van artikel 1, § 4bis.

Deze verstrekking kan enkel vergoed worden na attesteren van het nummer 450214 - 450225 voor dezelfde verzekerde door een tweede lezer. Ingeval van afwezigheid van één borst is het onderzoek ook aanrekenbaar.

K.B. 15.6.2005 In werking 1.7.2005
B.S. 30.6.2005

Wijzigen
Invoegen
~~Verwijderen~~

ARTIKEL 17 §1 - 11°bis Nucleaire Magnetische Resonantie.

De betrekkelijke waarde van de volgende verstrekkingen wordt vervangen.

459395	459406	NMR-onderzoek van het hoofd (schedel, hersenen, rotsbeen, hypofyse, sinussen, orbita(e) of kaakgewrichten), minstens drie sequenties, met of zonder contrast, met registratie op optische of elektromagnetische drager	N	180
459410	459421	NMR-onderzoek van de hals of van de thorax of van het abdomen of van het bekken, minstens drie sequenties, met of zonder contrast, met registratie op optische of elektromagnetische drager	N	260
459491	459502	NMR-onderzoek van de cervicale of thoracale of lumbosacrale wervelzuil, minstens drie sequenties, met of zonder contrast, met registratie op optische of elektromagnetische drager	N	180
459513	459524	NMR-onderzoek van een lidmaat, minstens drie sequenties, met of zonder contrast, met registratie op optische of elektromagnetische drager	N	100

QUESTIONNAIRE SENT TO INAHTA MEMBERS

ORGANISATION AND FINANCING OF MEDICAL IMAGING: MRI AND CT-SCANS

INTERNATIONAL COMPARISON: QUESTIONNAIRE

Introduction

The Belgian Minister of Social Affairs and Public Health has recently decided to significantly increase the capacity of MRI-apparatus in Belgium. The decision of the Minister was based on three considerations; 1) Increasing need for MRI to allow application of the practice guidelines of the Belgian Consilium Radiologicum; 2) Increasing the ratio MRI/CT, as MRI is considered a valuable alternative for CT; and 3) Reduction of the waiting lists for MRI.

Questions can be raised about the financial consequences of this measure and about the degree to which this will result in more MRI-examinations rather than CT-scans or whether this might simply increase the amount of both kinds of examinations.

This is considered to be an interesting opportunity to reflect on the ways these examinations are financed/reimbursed in Belgium, and how Belgium compares to other countries for this medical activity. This comparative analysis might also be of interest to other participant countries of INAHTA. We would therefore very much appreciate if you could take some time of the answer the following questions. May we ask to send the completed questionnaire to *luk.cannoodt@uzleuven.be* Giving the sharp deadline for conducting this study, it is important that we receive your answer by **April 15th** at the latest.

As you will notice, some of the questions are in black and bold. These are the most important questions for us. If it would be difficult for you to answer some of these questions (the data may simply not be collected in certain countries on a national level), just skip the question. To allow for a more in depth comparison between countries, we have also added some questions in blue colour. It may take more time for answering these questions (or for finding the source of information). They should be considered as OPTIONAL and should not discourage you from answering the rest of the questionnaire. But, of course, it would be great if some of you are able to answer these questions too.

Which country or region are you representing?
National population size of your country (2004)

Supply – Statistics

How many MRI-apparatus are in operation in your country?
How many of those are located in a hospital?
How many are located in an ambulatory setting?
How many are mobile units?

How many CT-scanners are in operation in your country?
How many of those are located in a hospital?
How many are located in an ambulatory setting?
How many are mobile units?
How many radiologists are operating in your country?

ACTIVITY- STATISTICS

PLEASE PROVIDE ACTIVITY DATA FOR 2004 OR (IF NOT AVAILABLE FOR 2004) MOST RECENT YEAR, NAMELY:

Total number of MRI-examinations in your country?

If further breakdowns are available, how many per type of examination (percentage)?

Abdominal	%	Musculoskeletal	%
Neuroradiology	%	Cardiac	%
Head and neck	%	Other:	%
Mammo	%	Other:	%

Total number of CT-scans in your country?

If further breakdowns are available, how many per type of examination (percentage)?

Abdominal	%	Musculoskeletal	%
Neuroradiology	%	Cardiac	%
Head and neck	%	Other:	%
Mammo	%	Other:	%

Percentage In-patient MRI-examinations (versus outpatient MRI's): %

Percentage In-patient CT-scans (versus outpatient CT-scans): %

FINANCING

How are the MRI-activities reimbursed in your country?

1) No separate reimbursement (within the budget of the hospital) ☐ YES ☐ NO

2) Separate financing of the apparatus ☐ YES ☐ NO

How, subsidies by the govt? ☐ YES ☐ NO

Other, please specify:

3) Separate financing of the MRI – operating costs? ☐ YES ☐ NO

How, subsidies by the govt? ☐ YES ☐ NO

Other, please specify:

4) Separate remuneration of the radiologist? ☐ YES ☐ NO

How, fee for service? ☐ YES ☐ NO

Other, please specify:

Is the financing system different for hospital-based MRI-apparatus versus ambulatory or mobile units? How?

How are the CT-scanning activities reimbursed in your country?

5) No separate reimbursement (within the budget of the hospital) ☐ YES ☐ NO

6) Separate financing of the equipment ☐ YES ☐ NO

How, subsidies by the govt? ☐ YES ☐ NO

Other, please specify:

7) Separate financing of the MRI – operating costs? ☐ YES ☐ NO

How, subsidies by the govt? ☐ YES ☐ NO

Other, please specify:

8) Separate remuneration of the radiologist? ☐ YES ☐ NO

How, fee for service? ☐ YES ☐ NO

Other, please specify:

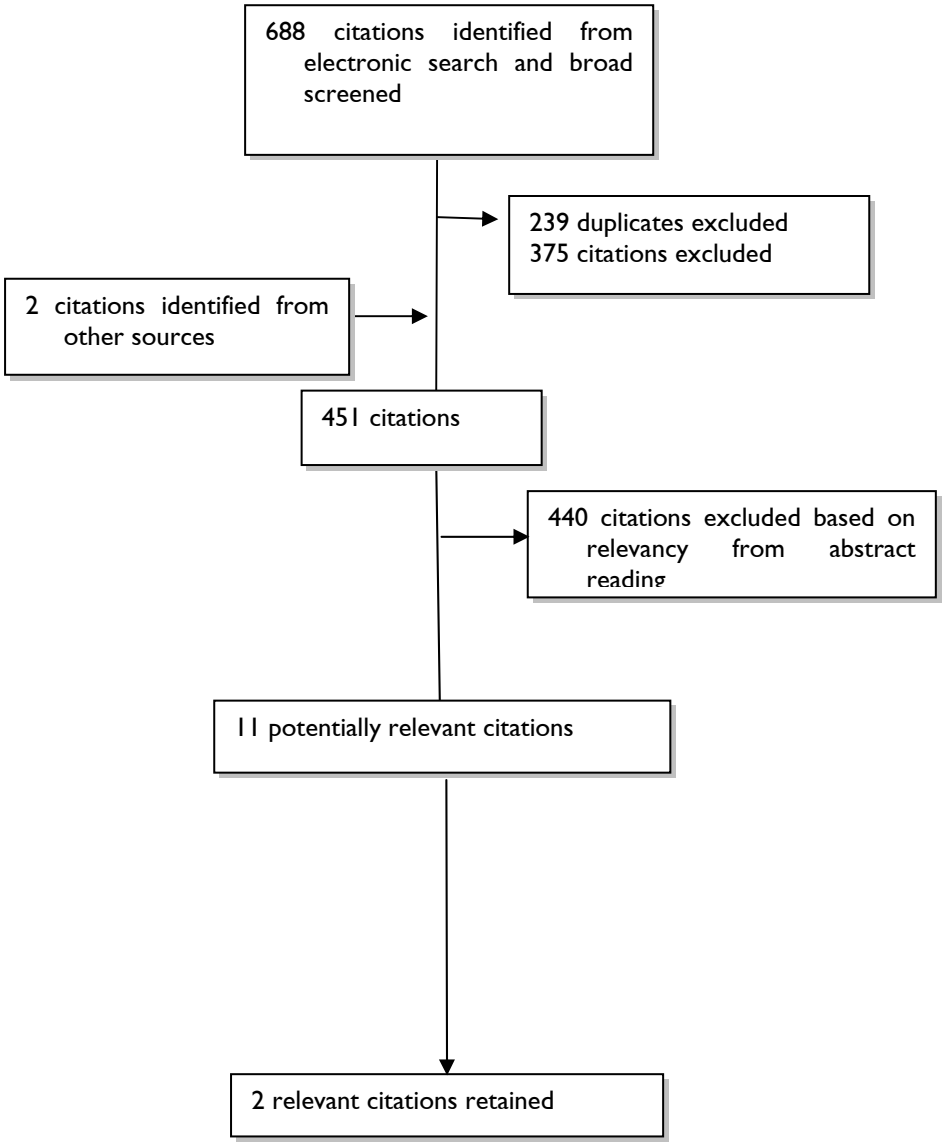
Is the financing system different for hospital-based CT-scanners versus ambulatory or mobile units? How?

……

THANK YOU VERY MUCH FOR YOUR COOPERATION!!!

Your e-mail address: *Your tel. number:*

APPENDIX 6: FLOW CHART LITERATURE SEARCH MOBILE MRI



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