Magnetresonanztomographie des Kniegelenks

Vergleich von MRT-Untersuchungen mit verschiedenen Feldstärken.
Systematischer Review

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Magnetic resonance tomography of the knee joint

Comparing MRT examinations using different field strengths (< 1.0 T versus ≥ 1.5 T). Systematic review

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Übersetzung und Erklärung der wichtigsten Begriffe und Abkürzungen

ACL	anterior cruciate ligament; vorderes Kreuzband
arthroscopy	Arthroskopie; Gelenkspiegelung; kann diagnostisch oder therapeutisch eingesetzt werden
CI	confidence interval; in der Regel 95% Konfidenzintervall = der Bereich, innerhalb dessen der wahre Wert mit 95%iger Wahrscheinlichkeit liegt
cruciate ligament	Kreuzband
cartilage	Knorpel
chondral	aus Knorpel bestehend
field strength	Stärke des Magnetfelds: gemessen in Tesla; wirkt sich auf die Signalqualität der gemessenen Daten aus
FN	false-negativ; falsch-negativer Befund
FP	false-positiv; falsch-positiver Befund
gold standard	so wird dasjenige Untersuchungsverfahren bezeichnet, das aktuell die höchste Sicherheit bei der Diagnose oder dem Ausschluss einer bestimmten Erkankung aufweist
meniscus	Meniskus
MR	Magnetresonanz
MRI	magnetic resonance imaging; Bildgebung mittels Magnetresonanztomographie
MRT	Magnetresonanztomographie
patella	Kniescheibe
PCL	posterior cruciate ligament; hinteres Kreuzband
sensitivity	Sensitivität; gibt an, wie viele Kranke mit einem bestimmten Verfahren als krank diagnostiziert werden; Bp. Sensitivität = 0,93 heißt: 93 von 100 Kranken werden als krank erkannt
specificity	Spezifität; gibt an, wie viele Gesunde mit einem bestimmten Verfahren als gesund erkannt werden; Bp. Spezifität = 0,88 heißt: 88 von 100 Gesunden werden als gesund erkannt
T	Tesla; Maßeinheit für die Feldstärke bei der MRT
TP	true-positive; richtig-positiver Befund
TN	true-negative; richtig-negativer Befund

Zusammenfassung

Die Magnetresonanztomographie (MRT) spielt als nicht-invasives Verfahren bei der Untersuchung von muskuloskelettalen Verletzungen und Erkrankungen eine sehr wichtige Rolle. Die meisten MRT-Untersuchungen werden auf Ganzkörper-Hochfeld-Systemen (> 1.0 Tesla) durchgeführt. Für spezifische klinische Fragestellungen sind auch sogenannte Niedrig- oder Mittelfeld Extremitätenscanner verfügbar. Weit seltener werden in der Zwischenzeit offene Ganzkörper-Niedrigfeld-Systeme verwendet.

wichtige Rolle der MRT in der muskuloskelettalen Radiologie; die meisten Untersuchungen werden auf Ganzkörper-Hochfeld – Systemen duchgeführt

Ziel dieses systematischen Reviews war es, die diagnostische Genauigkeit, die mit MRT-Geräten verschiedener Feldstärken (< 1.0 Tesla versus ≥ 1.5 Tesla) bei Knieverletzungen und –pathologien erzielt werden kann, zu eruieren bzw. zu vergleichen. Die Vorgehensweise bei der Erstellung dieser Arbeit entsprach den üblichen Standards für systematische Reviews von diagnostischen Genauigkeitsstudien.

Ziel: Vergleich der diagnostischen Genauigkeit von Niedrig- versus Hochfeld-MRT in der Bildgebung des Kniegelenks

Mit der systematischen Literatursuche in Datenbanken und einer zusätzlichen Handsuche wurden mehr als 10.000 Treffer erzielt. Es wurden schließlich 1.547 Abstracts gelesen und 76 Volltextartikel bestellt. Der weitere Auswahlprozess führte zum Einschluss von 4 systematischen Reviews (die 94 diagnostische Primärstudien zusammenfassten) sowie 6 zusätzlichen Primärstudien, deren Ergebnisse der vorliegenden Arbeit zu Grunde liegen.

1547 Abstracts gelesen; 4 systematische Reviews und 6 zusätzliche Primärstudien eingeschlossen

Die 4 systematischen Reviews waren in den Jahren 2003, 2011 und 2012 publiziert worden. Zwei befassten sich mit Meniskus- und Kreuzbandverletzungen und schlossen sowohl Niedrig- als auch Hochfeld-MRT-Studien mit ein. Die anderen beiden Arbeiten fassten Studien zur Hochfeld-MRT bei Knorpeldefekten im Knie zusammen. Weiters inkludierten wir 6 Primärstudien, die zwischen 1995 und 2003 publiziert worden waren, und die die diagnostische Genauigkeit der Niedrigfeld-MRT bei Knorpeldefekten im Knie untersuchten.

die systematischen Reviews waren 2003, 2011 und 2012 erschienen; die Primärstudien zwischen 1995 und 2003

Eine kritische Bewertung der vorliegenden Evidenz ergab, dass es bei Meniskus- und Kreuzbandverletzungen zwischen der Niedrig- und Hochfeld-MRT keine Unterschiede hinsichtlich diagnostischer Genauigkeit gibt. Sensitivität und Spezifität der MRT sind für den medialen Meniskus und die Kreuzbänder sehr hoch und unabhängig von der verwendeten Feldstärke. Die Sensitivität der MRT ist für den lateralen Meniskus deutlich niedriger, was aber nicht mit der verwendeten Feldstärke zusammenhängt.

keine Unterschiede zwischen Niedrig- und Hochfeld-MRT bei der Detektion oder beim Ausschluss von Meniskus- oder Kreuzbandverletzungen

keine Evidenz für die Niedrigfeld-MRT bei Knorpeldefekten und Kniegelenksarthrosen; die meisten diesbezüglichen Studien wurden auf Hochfeldsystemen durchgeführt

In Bezug auf die Detektion oder das Staging von Knorpeldefekten im Knie oder der Kniegelenksarthrose zeigt sich die MRT einigermaßen spezifisch, jedoch nicht besonders sensitiv. Diese Aussage gilt jedoch nur für die Hochfeld-MRT und wird untermauert durch zahlreiche Studienergebnisse. Für die Niedrigfeld-MRT liegt hier praktisch keine Evidenz vor, da nur wenige Studien, großteils mit sehr kleinen Stichproben und divergierenden Ergebnissen, durchgeführt wurden.

Empfehlungen für die Niedrigfeld-MRT beim Verdacht auf Verletzungen von Meniskus oder Kreuzband

Daraus abgeleitet können wir die Niedrigfeld-MRT beim Verdacht auf Verletzungen von Meniskus oder Kreuzband mit folgenden Einschränkungen bzw. unter Bedachtnahme folgender Begleitumstände empfehlen:

- Die MRT-Untersuchungen mit Niedrigfeld-Extremitäten-Scannern sollten von entsprechend ausgebildeten und erfahrenen Radiolog/inn/en befundet werden; eine enge Zusammenarbeit mit dem Kliniker ist jeweils anzustreben.
- Die MRT-Untersuchung sollte die klinische Diagnose nicht ersetzen, sondern sie ergänzen; dies gilt speziell für komplexere Verletzungen.
- Einem negativen Befund nach einer Niedrigfeld-MRT-Untersuchung wird evtl. weniger vertraut; deshalb sind Wiederholungsuntersuchungen an Hochfeldsystemen zu erwarten.
- Selbstzuweisungen, z.B. durch Nicht-Radiologen, die eine Niedrigfeld-MRT in ihrer Ordination installieren, sind zu kontrollieren.

MRT-Untersuchungen von Knorpeldefekten bzw. der Kniegelenksarthrose besser in spezialisierten Zentren duchführen

Auf Basis der vorliegenden Evidenz können wir die Untersuchung von Knorpeldefekten und/oder Kniegelenksarthrosen auf Niedrigfeldsystemen nicht empfehlen. Da die diesbezügliche Sensitivität, die in Studien mit Hochfeldsystemen erzielt werden konnte, suboptimal ist, sollten solche Untersuchungen primär in spezialisierten Zentren durchgeführt werden.

Summary

Important role of MR imaging in musculoskeletal radiology; most MR imaging performed on whole-body high-field scanners

The role of magnetic resonance (MR) imaging as a noninvasive technique in the detection and evaluation of musculoskeletal diseases is unquestionable. Most MR imaging is performed on whole-body high-field scanners (> 1.0 Tesla). For specific clinical questions, so-called low- (or medium-)field strength MR scanners, dedicated to the study of upper and lower extremities, can be used. Less common are meanwhile open low-field whole-body scanners.

aim: to compare diagnostic performance of low- versus high-field strength MR imaging of the knee

The aim of this systematic review was to compare the diagnostic performance of MR imaging using a field strength of < 1.0 Tesla versus using a field strength of ≥ 1.5 Tesla for diagnosing or ruling out knee injuries or knee pathologies. This work has been carried out using methods defined for sytematic reviews of diagnostic accuracy studies

1547 abstracts reviewed, 4 systematic reviews and 6 primary studies included

The systematic literature research revealed more than 10000 references, and 1547 abstracts were reviewed and 76 full-text articles were retrieved. The further selection process resulted in the inclusion of 4 systematic reviews (of totally 94 diagnostic primary studies) and 6 primary studies.

systematic reviews published in 2003, 2011 and 2012; primary studies published between 1995 and 2003

Of the 4 systematic reviews, one was published in the year 2003, one in 2011, and two in 2012. Two of them, dealing with meniscal and cruciate ligament lesions, included both low- and high-field MRT studies, and the other two, addressing cartilage defects in the knee, had used a minimum field strength of 1.5 T as an inclusion criteria. Therefore, we also included 6 primary studies of cartilage defects of the knee, published between 1995 and 2003, using low-field MR imaging and meeting our inclusion and exclusion criteria.

no differences in the diagnostic performance of low- versus high-field MR imaging for the detection or exclusion of meniscal or cruciate ligament tears

A critical review of study results revealed that there are practically no differences in the diagnostic performance of low- versus high-field MR imaging for the detection or exclusion of meniscal or cruciate ligament tears. Specifically, the likelihood to detect or exclude medial meniscal or cruciate ligament tears with MR imaging is very high, regardless of the field strength used. However, MR imaging has a lower sensitivity in detecting lateral meniscal tears while its specificity is very high, but also irrespective of the field strength used.

no evidence for low-field MR imaging of cartilage defects and osteoarthritis; most studies performed on high-field MRT scanners

Regarding the detection and/or grading of cartilage defects and/or osteoarthritis of the knee, MR imaging seems to be tolerably specific but scarcely sensitive. While the evidence for this result is strong for high-field MR imaging, there is literally no evidence for low-field MR imaging because only a few studies with small sample sizes and equivocal findings have been performed.

recommendations for MR imaging of suspected meniscal or cruciate ligament injuries

Therefore, we recommend the use of low-field strength systems in suspected meniscal or cruciate ligament injuries with the following constraints or considerations, respectively:

- MR imaging on extremity scanners is best performed by musculoskeletal-trained radiologists with experience in reading images obtained on low-field systems, working closely with the referring clinician.
- MR imaging should not replace clinical diagnosis, but used in connection with clinical findings and history to provide a more complete picture, especially in complex injuries.
- Since the level of confidence in decision-making has been reported significantly superior with high-field imaging, equivocal findings with low-field units may lead to an increased number of second examinations on high-field units.
- The rates of self-referral, e.g. by non-radiologists who install these systems in their offices, should be controlled.

MR imaging of knee cartilage defects and/or osteoarthritis should be performed in specialized centers, if possible

Based on the existing evidence, we cannot recommend the use of low-field strength systems for the diagnosis and grading of knee cartilage defects and/or osteoarthritis. Since the sensitivity of high-field MR imaging for chondral lesions is, according to study results, also suboptimal, we recommend to refer those patients to specialized centers if possible.

1 Introduction

1.1 Diagnosing knee pathologies

Patienten mit Knieverletzungen /-problemen: zunächst Anamnese und klinische Untersuchung

In patients who present with abnormalities of the knee, the first step to diagnosis is usually taking the clinical history and a physical examination, which involves various manipulative tests. In patients in whom the diagnosis is uncertain and the symptoms persist, physicians must turn to other diagnostic modalities, and, in the past, this was usually the diagnostic arthroscopy.

invasive diagnostische Arthroskopie oder nicht-invasive Magnetresonanztomographie?

Although diagnostic arthroscopy is an invasive and relatively high-cost procedure, proponents point to its accuracy and to the surgeon's ability to diagnose and treat abnormalities with a single intervention [4]. Nevertheless, due to the invasive nature of arthroscopy, orthopedic surgeons increasingly turn to magnetic resonance (MR) imaging.

1.2 Different field strengths in MR imaging

die Magnetresonanztomographie hat viele diagnostische Vorzüge

The role of MR imaging as a noninvasive technique in the detection and evaluation of musculoskeletal conditions and diseases is unquestionable, because MR imaging has the advantages of the combined evaluation of bones, ligaments, and soft tissue [28]. MR imaging has proved reliable and safe and offers advantages over diagnostic arthroscopy, which is currently regarded as the reference standard (*gold standard*) for the diagnosis of internal derangements of the knee [18]. Arthroscopy is an invasive procedure with certain risks and discomfort for the patient and is preferably performed only for treatment purposes, provided that alternative noninvasive diagnostic modalities such as MR imaging are available [18].

für die meisten klinischen Fragestellungen werden in der Zwischenzeit Hochfeld-MRT Geräte verwendet

Most MR imaging is performed on whole-body high-field scanners (> 1.0 T; T = Tesla). For specific clinical questions in pathologies of the upper and lower extremities, so-called low- (or medium-) field strength MR scanners, dedicated to the study of extremities, can be used. Less common are meanwhile open low-field whole-body scanners. Low-field systems have, according to the literature, the following advantages and disadvantages [15,17,18,25,28].

Vorteile der Niedrigfeld-MRT: kostengünstiger, komfortabler für Patient/inn/en mit Klaustrophobie oder Übergewicht, geringerer technischer Aufwand beim Einbau, weniger Artefakte, etc.

Advantages of low-field MR imaging as compared to high-field MRI

- less expensive: lower purchase price, cheaper maintenance, less floor space required, lower electricity consumption, lower number of technicians required;
- no additional external radiofrequency shielding necessary;
- no need for cryogens;
- higher comfort for claustrophobic or overweight patients and for children;
- potential of dynamic imaging for athletes;
- possibility of central positioning of the area to explore because of the lateral displacement of the table;
- higher tissue contrast, specially on T1-weighted sequences;
- less metallic artifacts in patients who have undergone an operation;
- absence of phase artifacts from pulsatile blood flow, especially at the knee.

Nachteile der Niedrigfeld-MRT: schlechtere Bildqualität, längere Untersuchungszeiten, Zusatzkenntnisse notwendig, Fettunterdrückung kaum möglich, uneindeutige Ergebnisse führen zu Folgeuntersuchungen an Hochfeld-Systemen, etc.

Disadvantages of low-field MR imaging as compared to high-field MRI

- lower signal-to-noise ratio leading to lower image quality;
- longer acquisition times;
- limitations in homogeneous static magnetic field;
- inability to achieve fat-saturated imaging;
- no reliable distinction between fat and contrast media;
- equivocal findings, leading to a second examination on a high-field unit;
- specialized training and expertise is required to optimize imaging parameters;
- not possible in patients with larger knee or thigh circumferences or in patients with very short thighs;
- not possible in those cases in which a more panoramic view is needed, such as soft tissue or bone neoplastic or diffuse diseases.

2 Methods

2.1 Research question

This review has been carried out using methods defined for sytematic reviews of diagnostic accuracy studies [22,29]. The aim was to compare the diagnostic performance of MR imaging using a field strength of < 1.0 Tesla versus using a field strength of ≥ 1.5 Tesla for diagnosing or ruling out knee injuries or pathologies.

Fragestellung: Vergleich der diagnostischen Genauigkeit, die mit MRT-Geräten verschiedener Feldstärken (< 1.0 Tesla versus ≥ 1.5 Tesla) bei Knieverletzungen und –pathologien erzielt wird

Data for this review were acquired through previously published work, no patient or hospital data were accessed. Therefore, written consent and institutional ethical review was not required for this research.

2.2 Diagnostic parameters and inclusion criteria

The main steps in critical appraisal of the evidence are assessing its validity (closeness to truth /lackness of bias), impact (size of effect), and applicability (usefulness) for the clinical practice. With regard to the usefulness of a diagnostic test, such as MR imaging, for a specific condition or disease, sensitivity and specificity are the most important parameters [22]. In order to calculate sensitivity and specificity values, results of the diagnostic test have to be compared to the results of a reference tool that is supposed to be the currently best available tool for diagnosing the condition, therefore it is usually called *gold standard*. In order to calculate sensitivity and specificity, the results of the test and the gold standard in the same patients must be known and can be inserted into a 2 x 2 contingency table (Table 1).

Sensitivität und Spezifität sind die wichtigsten Parameter zur Beurteilung der diagnostischen Genauigkeit und Nützlichkeit eines Testverfahrens bzw. einer Untersuchungsmethode

Sensitivity is a statistical measure of how well a diagnostic test correctly identifies a condition or disease and measures the proportion of actual positives that are correctly identified as such. It is calculated as TP / [TP+FN] – see Table 1. Sensitivity can be displayed as a figure between 0 and 1 or as a percentage between 0% and 100%. A sensitivity of 1.0 or 100%, for example, means that the diagnostic test recognizes all people with the disease as such [7]. Results should be presented with appropriate indicators of measurement error or uncertainty, such as confidence intervals (CI). A 95% confidence interval is the range of values within which the true result will lay 95% of the time.

Die Sensitivität gibt an, wie sicher man mit dem Verfahren Kranke als krank erkennt. Die Werte liegen zwischen 0 und 1 oder zwischen 0% und 100%.

Erstellung einer 4-Felder-Tafel, in die man die Ergebnisse des interessierenden Testverfahrens und die Ergebnisse des Referenzverfahrens (*gold standard*) einträgt

Table 1: 2x2 contingency table for calculating sensitivity and specificity of a diagnostic test

Test outcome	**Condition / disease present? (results of reference test / gold standard)**	
	yes	no
positive	TP = true-positive: number of sick people correctly diagnosed as sick with a positive test result	FP = false-positive: number of healthy people wrongly identified as sick with a positive test result
negative	FN = false-negative: number of sick people wrongly identified as healthy with a negative test result	TN = true-negative: healthy people correctly identified as healthy with a negative test result

Die Spezifität gibt an, wie sicher man mit dem Verfahren Gesunde als gesund erkennt.

Specificity is a statistical measure of how well a test correctly identifies the negative cases or those who do not have the condition or disease. It is calculated as TN / [TN+FP] - see Table 1. As with sensitivity, specificity values should be presented with confidence intervals.

Diagnostische Genauigkeit kombiniert Sensitivität und Spezifität.

Diagnostic accuracy is also used as a statistical measure and combines sensitivity and specificity results. It is calculated as TP+TN / [TP+FP+FN+TN] – see Table 1. An accuracy of 1.0 or 100%, for example, means that the test correctly identifies all people with and without the condition of disease [7].

PPV und NPV sind ebenfalls häufig dargestellte Outcome-Parameter; speziell interessant für klinische Fragestellungen

In the radiological literature, results with regard to the positive predictive value (PPV) and negative predictive values (NPV) are also often presented. They are specifically important for the clinical practice. However, a PPV or NPV reported in a study performed in one institution is not necessarily indicative of a PPV or NPV of the same test in another institution because the prevalence of the condition or disease may differ in the study samples. Therefore, PPV and NPV will not be the the focus of this work.

Bewertung der Qualität von diagnostischen Studien, z.B. mit der QUADAS Checkliste

Reliable results on diagnostic accuracy studies can, however, only be achieved in high-quality studies. To appraise the quality of such studies, Whiting et al. have developed a checklist called QUADAS (Quality Assessment of Diagnostic Accuracy Studies) [30]. It is meanwhile available in a revised version [31] and contains items assessing risk of bias, sources of variation, and reporting quality.

Based on these considerations, we formulated our criteria for inclusion and exclusion of articles. They are displayed at Table 2.

Einschluss- und Ausschlusskriterien, die dieser Arbeit zu Grunde liegen: sprachliche Einschränkungen; nur Knieverletzungen bzw. –pathologien; die MRT Feldstärke muss angeführt sein; als Referenzverfahren müssen Ergebnisse von Arthroskopie, Operation oder Histologie eingesetzt worden sein; Sensitivität und Spezifität und/oder Ergebnisse hinsichtlich TP, TN, FP oder FN müssen angeführt sein; keine postoperativen MRT-Ergebnisse, keine indirekten MRT-Ergebnisse oder hochspezifische Zeichen

Table 2: Criteria for inclusion and exclusion of systematic reviews and primary studies

Inclusion criteria	Articles published in English, German, Spanish, Turkish, French or Italian language
	Depicting lesions of the collateral ligaments, the retinacular, or the cartilage of the human knee
	Magnetic field strength reported
	Findings at arthroscopy or surgery or histological workup used as a reference standard
	Sensitivity and specificity of MR imaging and/or rates of true-positive, true negative, false-positive or false-negative results reported
Exclusion criteria	MR imaging used for postoperative evaluation
	Only the diagnostic value of specific features or indirect signs of knee pathologies at MR imaging, such as the empty notch sign, anterior tibial subluxation, or bone bruise, assessed

2.3 Literature search

A preliminary review of the results of the literature search revealed that a considerable number of systematic reviews on the topic, published between 2003 and 2012, were already available. Additionally, it was observed that diagnostic accuracy studies using low-field MR imaging systems had been published mainly in the 1990's. We decided to rely primarily on the available systematic reviews to answer our research question provided that they met our inclusion criteria. In case those systematic reviews would not fully meet our needs, also primary studies were to be considered.

es waren bereits einige systematische Reviews zu ähnlichen Themen publiziert worden; wegen engem Zeitfenster sollte primär auf vorhandene systematische Reviews zurückgegriffen werden

For the literature search in the data bases Medline, Cochrane Database of Systematic Reviews, and Scopus, combinations of the following search terms were used: "magnetic resonance imaging", "MR imaging", ""MRI", "MRT", "knee", "meniscus", "cruciate ligament", "cartilage", "chondral" and "arthroscopy". The search was limited to papers published between 1990 and 2012. Additionally, we screened the reference lists of the original articles for work that was not found with the described literature search.

Suchbegriffe für die systematische Literatursuche; Suche in mehreren Datenbanken; ergänzt durch Handsuche nach Durchsicht der Abstracts wurden relevante Volltext-artikel bestellt und überprüft

All articles that could not be excluded on the basis of title and/or the abstract of the article were retrieved in full text. One author decided if the selected studies met the inclusion and exclusion criteria for this review (Table 2 on previous page). The two other authors checked if the selection process was correct.

2.4 Selection of studies

Auswahl der Literatur, beschrieben im PRISMA flowchart; ausgewählt wurden 4 systematische Reviews (die 94 Primärstudien abdecken) und 6 zusätzliche Primärstudien

The literature search revealed 10613 references of which 2320 were duplicates and 6746 could be excluded based on the title. Of the remaining 1547 articles, the abstracts were reviewed. Out of these, 76 full-text articles were retrieved. As explained in chapter 2.3 we focused on existing systematic reviews to answer our research question. Therefore, primary studies that were retrieved in full text but were included in one of the presented systematic review, were later excluded. This resulted in the final inclusion of 4 systematic reviews (of totally 94 diagnostic primary studies) and 6 primary studies. The flowchart of study selection, retrieval, and inclusion is displayed at Fig. 1.

zusätzlich 21 Arbeiten als „Hintergrund-literatur“ verwendet

Additionally, 21 articles on various topics were used for explanations, interpretations, etc. Therefore, the reference list contains 31 references.

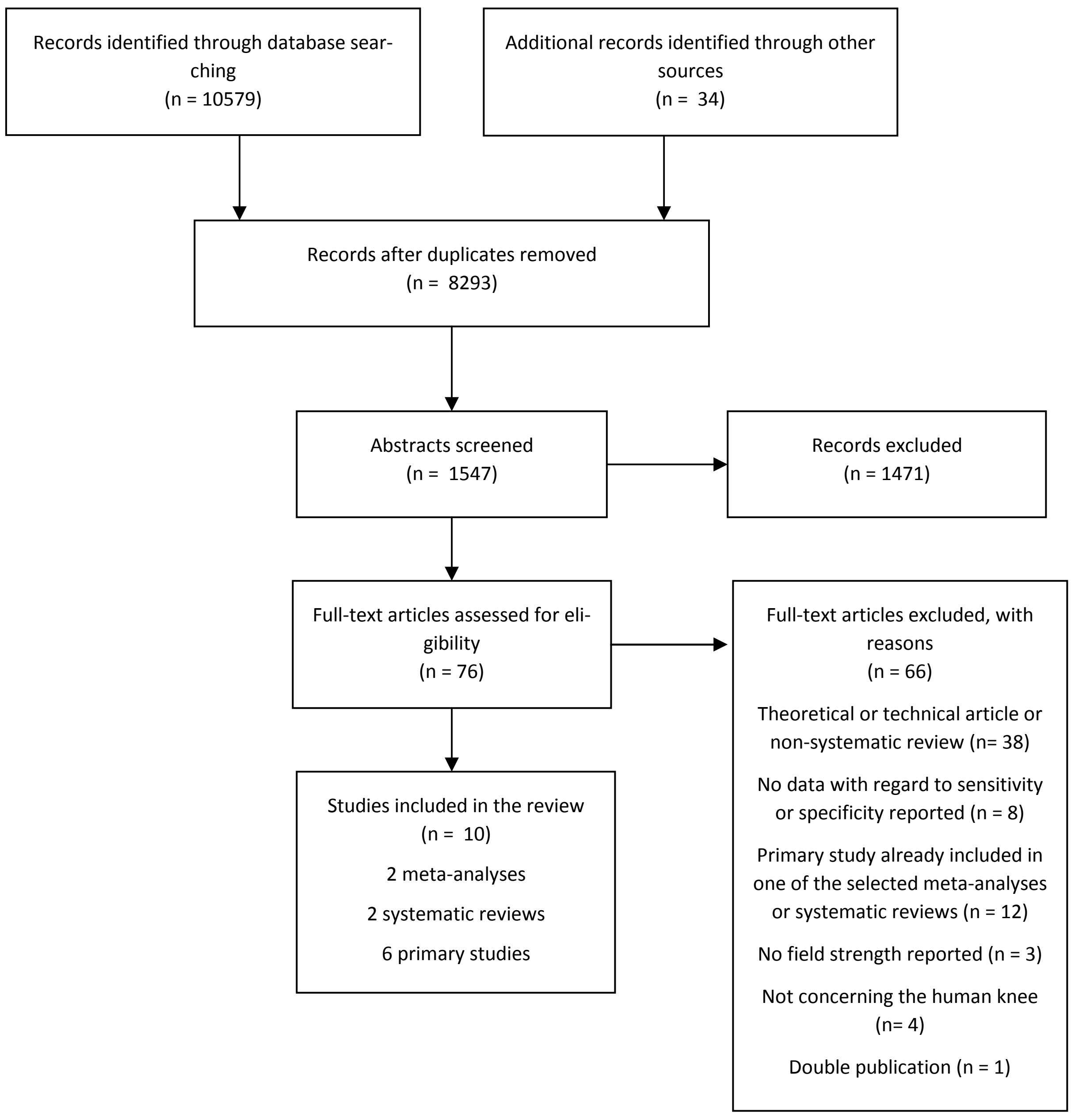

Figure 1: PRISMA flowchart of study selection, retrieval, and inclusion.

3 Study characteristics

We found 4 systematic reviews referring to the diagnostic performance of MR imaging in knee pathologies, that met our inclusion and exclusion criteria. One was published in the year 2003, one in 2011, and two in 2012. Two of them included both low- and high-field MRT studies [18,26], and the other two [11,23] had used a minimum field strength of 1.5 T as an inclusion criteria.

Ergebnisse aus 4 systematischen Reviews, publiziert in den Jahren 2003, 2011 und 2012

Oei et al. [18] displayed a meta-analysis of 29 articles in their systematic review study to determine the diagnostic performance of all-strength MR imaging of the menisci and cruciate ligaments and to assess the effect of study design characteristics and magnetic field strength on diagnostic performance. Smith et al. [26] evaluated the diagnostic accuracy of anterior cruciate ligament (ACL) rupture using all-strength MR imaging by performing a pooled meta-analysis. They included 53 articles of which 16 articles had already been referred to by Oei et al. in their review published 9 years earlier. Details regarding the methodological quality of these two meta-analyses are displayed at Table 3.

2 Meta-Analysen zur diagnostischen Genauigkeit von MRT-Untersuchungen des Meniskus und Kreuzbands mit verschiedenen Feldstärken (Tab. 3)

Quatman et al. [23] wanted to reveal the clinical utility and diagnostic performance of MR imaging for the identification of knee osteoarthritis. They found 27 studies that met their inclusion criteria. One of these criteria was a minimum fied strength of 1.5 T used for MR imaging. The diagnostic performance of MR imaging demonstrated a wide range, and there were large inconsistencies between imaging techniques, specifically heterogeneity of MRI sequences. One year later, Harris et al. [11] presented a systematic review on the sensitivity of MR imaging for detection of patellofemoral articular cartilage defects. Inclusion criteria were that patients underwent both MR imaging and arthroscopy, and that the minimum field strength was 1.5 T. Thirteen studies were considered in this review, but significant heterogeneity across studies precluded meta-analysis. Details regarding the methodological quality of these two systematic reviews are displayed at Table 4.

2 systematische Reviews zur diagnostischen Genauigkeiten von MRT-Untersuchungen bei Knorpeldefekten und Arthrose des Kniegelenks mit Feldstärken ≥ 1.5 Tesla (Tab. 4)

The available meta-analyses and systematic reviews did not include low-field MR imaging studies for the detection of cartilage defects and/or osteoarthritis of the knee. Therefore, we searched for relevant primary studies. Actually, only a handful of studies, that used a reference standard to determine sensitivity and specificity of low-field MR imaging, had been performed and/or could be identified. These studies are displayed at Table 5. They were published between 1995 and 2003, at at time when quality standards for the perfor-

es gab keine Niedrigfeld-MRT Studien für Knorpeldefekte und Kniegelenksarthrosen in den vorliegenden systematischen Reviews; deshalb Suche nach Primärstudien mance of diagnostic accuracy studies were not yet widely spread. Nevertheless, we tried to describe the methodological strengths and weaknesses of the individual studies considering the questions contained in the QUADAS checklist [30,31] and summarized those in "strengths and weaknesses of the study".

die beiden Meta-Analysen zur MRT-Untersuchung von Meniskus und Kreuzband können als hochqualitativ bezeichnet werden

Table 3: Description of the meta-analyses of Oei et al. 2003 [18] and Smith et al. 2012 [26] with regard to their methodological quality

	Oei et al. 2003	**Smith et al. 2012**
Country of origin	Netherlands	Great Britain
Specialization of authors	radiology, epidemiology, biostatistics	not indicated
MR imaging of	menisci and cruciate ligaments	anterior cruciate ligament (ACL) rupture
Eligibility criteria for articles clearly specified	yes	yes
Data extraction	2 authors independently, discrepancies resolved by a third author	2 authors independently, discrepancies resolved by discussion
Publication bias addressed	yes, with the use of funnel plots; publication bias very unlikely due to almost perfectly shaped funnel plots	yes, but not specified
Reasons for excluding full text articles were given	yes	yes
Quality check of included studies performed	check for possibility of verification bias performed (QUADAS checklist not yet available)	each study's methodological quality was assessed using the QUADAS checklist

Table 4: Description of the systematic reviews of Quatman et al. 2011 [23] and Harris et al. 2012 [11] with regard to their methodological quality

	Quatman et al. 2011	**Harris et al. 2012**
Country of origin	USA	USA
Specialization of authors	sports medicine, orthopedics, physical therapy	sports medicine, orthopedic surgery, radiology
MR imaging of	articular cartilage abnormalities in the knee, early and advanced knee osteoarthritis	patellofemoral articular cartilage defects
Eligibility criteria for articles clearly specified	yes	yes
Data extraction	2 independent reviewers evaluated methodological quality of articles; no information about data extraction	not indicated
Publication bias addressed	no	no
Reasons for excluding full text articles were given	not in detail	yes
Quality check of included studies performed	yes; only articles of level I and II were included in the review*	yes; only articles of level I, II and III were included in the review*

*level I = consecutive patients, prospective study, gold-standard comparison; level II = consecutive patients, retrospective study, gold-standard comparison; level III = non-consecutive patients or did not use established diagnostic criteria.

klare Fragestellungen der systematischen Reviews zur Hochfeld-MRT von Knorpeldefekten und Arthrose des Kniegelenks und solider Qualitätscheck der inkludierten Studien; allerdings ist die Vorgehensweise (Studienauswahl, -synthese, Datenextraktion, etc.) tlw. schwer nachvollziehbar

einige wenige Primärstudien (erschienen 1995-2003), die Niedrigfeld-MRT bei Knorpeldefekten im Vergleich zu einem Referenzverfahren (hauptsächlich Arthroskopie) untersuchten

alle Studien weisen methodische Stärken und Schwächen auf

meist nur wenige Patient/inn/en untersucht, was die Unsicherheit in Bezug auf die Ergebnisse erhöht

der Schweregrad der Knorpelläsionen wurde in den meisten Studien berücksichtigt

Konfidenzintervalle für die diagnostischen Outcome-Parameter fehlen weitgehend

Table 5: Methodological strengths and weaknesses of identified studies evaluating low-field MR imaging of knee cartilage defects [1,3,10,12,14,24]

First author (year of publication)	**Specialization of authors**	**Strengths of study**	**Weaknesses of study**
Ahn (1998)	radiology, orthopedic surgery, pathology	macroscopic findings used as reference; grading of cartilage lesions considered; relevance of MR imaging sequences considered	only 10 patellae from human cadavers, and not living subjects, evaluated; all cadavers from patients > 78 years, thus not reflecting a clinically relevant population; double reading of MRT images, but single reading of macroscopic examinations; sensitivity and specificity results have a wide range
Bredella (2001)	radiology	consecutive patients; grading of cartilage lesions considered; exact numbers of TP, TN, FP and FN results can be derived	only 20 patients; arthroscopers not blinded to MR imaging results; MR imaging interpretation performed by consensus of two readers, not independently
Harman (2003)	radiology, orthopedic surgery	50 knees of 42 patients; grading of cartilage lesions considered; arthroscoper blinded to MR imaging results	no confidence intervals for diagnostic parameters calculated; MR imaging interpretation performed by consensus of two readers, not independently

Table 5 to be continued on next page

Table 5 continued: Methodological strengths and weaknesses of identified studies evaluating low-field MR imaging of knee cartilage defects [1,3,10,12,14,24]

First author (year of publication)	Specialization of authors	Strengths of study	Weaknesses of study
Kladny (1995)	orthopedic rheumatology	directly comparing 0.2 versus 1.5 T MR imaging and using arthroscopic results as a reference for both (in 1 case there is arthrotomy the reference standard); all patients gave informed consent; wide age range of patients (14-70 y); short interval between MR imaging and arthroscopy; grading of cartilage lesions considered	totally 22 patients examined, cartilage defects detected only in 6/22 patients, results are therefore very insecure; no sensitivity and specificity values for knee cartilage lesions displayed; arthroscopers not blinded to MR imaging results
Kreitner (1999]	radiology, orthopedic surgery, statistics	75 patients prospectively examined with MR imaging and arthroscopy, with 31 patients showing cartilage lesions; confidence intervals for sensitivity and specificity intervals calculated; reading independently performed by an experienced and a less experienced radiologist	low number of patients with cartilage defects, and large confidence intervals for sensitivity values; arthroscopers not blinded to MR imaging results
Riel (1999)	sports orthopedics, radiology	244 consecutive patients prospectively evaluated, of which 62 showed full-thickness cartilage lesions	no confidence intervals for diagnostic parameters calculated; only full-thickness cartilage lesions detected /considered

4 Data extraction

Data were abstracted by the first author (SP) and checked for accuracy and completeness independently by the two co-authors (YCKK, LE). Any disagreements were resolved through discussion.

Datenextraktion durch Erstautor und Datencheck durch 2 Co-Autor/inn/en

4.1 Meniscal and cruciate ligament tears

We extracted data from two high-quality meta-analyses dealing with the diagnostic accuracy of MR imaging in knee injuries related to the menisci and the cruciate ligaments [18,26]. Number and content of included articles, publication period of included articles, inclusion criteria and results with regard to differences in diagnostic performance between low- and high-field MR imaging are displayed at Table 6.

Ergebnisse aus 2 hochqualitativen Meta-Analysen (siehe Tab. 6)

The conclusions of the meta-analyses of both Oei et al. [18] and Smith et al. [26] regarding our research question were that there are no differences between low- and high-field MR imaging in the detection of meniscal and/or cruciate ligament tears. However, since the authors did not provide detailed data and also included studies using a field strength of 1.0 T in their analyses, we decided to recalculate their results. For these recalculations, which are displayed in chapters 4.1.1 to 4.1.4, we included all studies for which an MRT field strength of < 1.0 Tesla or ≥ 1.5 Tesla was reported. The corresponding forest plots can be found in the attachment.

trotzdem war eine Rekalkulation der Unterschiede zwischen Niedrig- und Hochfeld-MRT nötig – siehe Kap. 4.1.1-4.1.4 sowie Forest plots im Anhang

Table 6: Meta-analyses that contained detailed data on the field strengths used in the individual studies [18,26]

	Oei et al.	**Smith et al.**
Year of publication	2003	2012
Journal	Radiology	Eur J Orthop Surg Traumatol

Table 6 to be continued on next page

Die Meta-Analysen wurden 2003 und 2012 publiziert. Die MRT Feldstärken wurden extra ausgewiesen und deren Effekt auf die diagnostische Genauigkeit wurde bewertet.

Die Einschlusskriterien waren in beiden Arbeiten sehr ähnlich.

Die Meta-Analyse von Oei et al. [2003] inkludierte 29 Studien, die zwischen 1991 und 2000 publiziert wurden.

Die Meta-Analyse von Smith et al. [2012] inkludierte 53 Studien, die zwischen 1986 und 2009 publiziert wurden.

Beide Meta-Analysen kamen zu dem Schluss, dass es hinsichtlich diagnostischer Genauigkeit keine Unterschiede zwischen Niedrig- und Hochfeld-MRT bei Meniskus- und Kreuzbandverletzungen gibt

Table 6 continued: Meta-analyses that contained detailed data on the field strengths used in the individual studies[18,26]

	Oei et al.	**Smith et al.**
No. and content of included articles	29 MR imaging articles, comprising 27 studies on both menisci, 23 studies on ACL tears, and 12 studies on PCL tears	53 MR imaging articles, all comprising studies on complete anterior cruciate ligament [ACL] tears
Articles published in the years	1991-2000	1986-2009
No. of articles that were included in both reviews	16	
Inclusion criteria for the articles	≥ 30 patients studied	No cadaveric and animal studies
	Arthroscopy used as a reference standard	Arthroscopy or open surgery findings used as a reference standard
	Magnetic field strength reported	No restrictions
	Positivity criteria for MR imaging defined	No arthrogram studies
	Absolute numbers of true-positive, false-positive, true-negative, and false-negative results available or derivable	Absolute numbers of true-positive, false-positive, true-negative, and false-negative results available or derivable
	Only English-language articles	No restrictions
Results with regard to differences in diagnostic performance between low- and high-field MR imaging	The results of the separate pooled weighted analyses for various categories of magnetic field strengths (not tabulated) suggested a modest trend toward better diagnostic performance for higher-field-strength categories. None of the differences were found to approach statistical significance, however, and the confidence intervals were all wide.	No differences between low- and high-field MR imaging in the detection of ACL tears.

4.1.1 Medial meniscal tears

Table 7: A recalculation of pooled sensitivity and specificity values for medial meniscus MRI studies included in the review of Oei et al. [18] and using a field strength of < 1.0 Tesla

author	year	Tesla	TP	FP	TN	FN	total
Barnett	1993	0.5	71	4	38	5	
Boerree	1991	0.5	58	6	63	2	
Cotten	2000	0.2	50	0	33	7	
Elvenes	2000	0.5	15	6	20	0	
Fischer	1991	0.35	70	11	83	13	
Fischer	1991	0.6	32	9	27	5	
Fischer	1991	0.35	8	11	15	2	
Franklin	1997	0.2	19	0	13	3	
Grevitt	1992	0.2	23	3	27	2	
Kelly	1991	0.5	33	6	20	1	
Kinnunen	1994	0.1	7	5	20	1	
Rappeport	1997	0.1	12	9	24	2	
Riel	1999	0.2	106	3	127	8	
			504	73	510	51	1138
pooled sensitivity = 0.91 [0.88;0.93] pooled specificity = 0.87 [0.85;0.90]							

Tabelle 7: bei Läsionen des medialen Meniskus zeigt die Niedrigfeld-MRT eine Sensitivität von 0,91 und eine Spezifität von 0,87 [18]. Die Konfidenzintervalle sind eng, daher hohe Sicherheit.

Table 8: A recalculation of pooled sensitivity and specificity values for medial meniscus MRI studies included in the review of Oei et al. [18] and using a field strength of ≥ 1.5 Tesla

author	year	Tesla	TP	FP	TN	FN	total
Araki	1992	1.5	19	2	18	1	
Bui-Mansfield	1997	1.5	18	1	29	2	
Chen	1995	1.5	13	5	30	2	
Cheung	1997	1.5	127	23	123	16	
Cotten	2000	1.5	51	0	33	6	
De Smet	1993	1.5	100	13	79	8	
Fischer	1991	1.5	270	33	170	10	
Fischer	1991	1.5	37	2	45	2	
Gluckert	1992	1.5	34	3	42	1	
Heron	1992	1.5	44	3	52	1	
Justice	1995	1.5	360	16	170	15	
Lundberg	1996	1.5	14	17	33	5	
Weinstabl	1997	1.5	48	4	22	1	
			1135	122	846	70	2173
pooled sensitivity = 0.94 [0.93;0.95] pooled specificity = 0.87 [0.85;0.89]							

Tabelle 8: bei Läsionen des medialen Meniskus zeigt die Hochfeld-MRT eine Sensitivität von 0,94 und eine Spezifität von 0,87 [18]. Die Konfidenzintervalle sind eng, daher hohe Sicherheit.

4.1.2 Lateral meniscal tears

Tabelle 9: bei Läsionen des lateralen Meniskus zeigt die Niedrigfeld-MRT eine Sensitivität von 0,76 und eine Spezifität von 0,95 [18]. Die Sensitivität liegt gerade noch im klinisch akzeptablen Bereich.

Table 9: A recalculation of pooled sensitivity and specificity values for lateral meniscus MRI studies included in the review of Oei et al. [18] and using a field strength of < 1.0 Tesla

author	year	Tesla	TP	FP	TN	FN	total
Barnett	1993	0.5	21	3	89	5	
Boerree	1991	0.5	25	2	99	1	
Cotten	2000	0.2	24	6	55	5	
Elvenes	2000	0.5	2	4	32	3	
Fischer	1991	0.35	20	5	148	19	
Fischer	1991	0.6	9	8	55	5	
Fischer	1991	0.35	6	2	27	1	
Franklin	1997	0.2	8	0	26	1	
Grevitt	1992	0.2	8	1	45	1	
Kelly	1991	0.5	19	5	34	2	
Kinnunen	1994	0.1	1	1	28	3	
Rappeport	1997	0.1	2	1	41	3	
Riel	1999	0.2	38	7	191	8	
			183	45	870	57	1155
pooled sensitivity = 0.76 [0.70; 0.81] pooled specificity = 0.95 [0.93; 0.96]							

Tabelle 10: bei Läsionen des lateralen Meniskus zeigt die Hochfeld-MRT eine Sensitivität von 0,78 und eine Spezifität von 0,95 [18]. Die Sensitivität liegt gerade noch im klinisch akzeptablen Bereich.

Table 10: A recalculation of pooled sensitivity and specificity values for lateral meniscus MRI studies included in the review of Oei et al. [18] and using a field strength of ≥ 1.5 Tesla

author	year	Tesla	TP	FP	TN	FN	total
Araki	1992	1.5	13	0	27	0	
Bui-Mansfield	1997	1.5	9	0	35	6	
Chen	1995	1.5	17	3	27	3	
Cheung	1997	1.5	69	13	180	27	
Cotten	2000	1.5	25	3	58	4	
De Smet	1993	1.5	48	12	130	10	
Fischer	1991	1.5	81	20	378	34	
Fischer	1991	1.5	18	3	66	2	
Gluckert	1992	1.5	12	0	68	0	
Heron	1992	1.5	17	5	77	1	
Justice	1995	1.5	134	8	390	29	
Lundberg	1996	1.5	13	7	36	13	
Weinstabl	1997	1.5	17	1	56	1	
			473	75	1528	130	2206

pooled sensitivity = 0.78 [0.75;0.82] pooled specificity = 0.95 [0.94; 0.96]

Table 10 continued

4.1.3 ACL complete tears

Table 11: A recalculation of pooled sensitivity and specificity values for MRI studies of ACL tears included in the review of Oei et al. [18] and using a field strength of < 1.0 Tesla

author	year	Tesla	TP	FP	TN	FN	total
Barnett	1993	0.5	26	3	89	0	
Barry	1996	0.3	25	4	31	3	
Boerree	1991	0.5	32	11	89	1	
Cotten	2000	0.2	14	2	73	1	
Fischer	1991	0.35	28	8	157	0	
Fischer	1991	0.6	13	5	56	5	
Fischer	1991	0.35	5	7	27	2	
Grevitt	1992	0.2	8	4	43	0	
Kelly	1991	0.5	7	3	49	1	
Kinnunen	1994	0.1	5	4	23	1	
Rappeport	1997	0.1	6	3	37	1	
			169	54	674	15	912
pooled sensitivity = 0.92 [0.87;0.95] pooled specificity = 0.93 [0.90; 0.94]							

Tabelle 11: bei Läsionen des vorderen Kreuzbands zeigt die Niedrigfeld-MRT eine Sensitivität von 0,92 und eine Spezifität von 0,93 [18]. Die Konfidenzintervalle sind eng, daher hohe Sicherheit.

Table 12: A recalculation of pooled sensitivity and specificity values for MRI studies of ACL tears included in the review of Oei et al. [18] and using a field strength of ≥ 1.5 Tesla

author	year	Tesla	TP	FP	TN	FN	total
Bui-Mansfield	1997	1.5	20	3	27	0	
Chan	1994	1.5	19	6	93	2	
Chen	1995	1.5	22	3	24	1	
Cotten	2000	1.5	14	0	75	1	
Fischer	1991	1.5	100	30	396	4	
Fischer	1991	1.5	17	3	70	0	
Gentili	1994	1.5	48	1	39	1	
Gluckert	1992	1.5	18	1	60	1	
Ha	1998	1.5	54	4	157	2	
Heron	1992	1.5	20	4	73	2	
Lerman	1995	1.5	23	0	22	2	
Niitsu	1991	1.5	20	3	21	8	
			375	58	1057	24	1514

Tabelle 12: bei Läsionen des posterioren Kreuzbands zeigt die Hochfeld-MRT eine Sensitivität von 0,94 und eine Spezifität von 0,95 [18]. Die Konfidenzintervalle sind eng, daher hohe Sicherheit.

pooled sensitivity = 0.94 [0.91;0.96] **pooled specificity = 0.95 [0.93; 0.96]**

Table 12 continued

Tabelle 13: bei kompletten Rissen des vorderen Kreuzbands zeigt die Niedrigfeld-MRT eine Sensitivität von 0,92 und eine Spezifität von 0,93 [26]. Die Konfidenz-intervalle sind eng, daher hohe Sicherheit.

Table 13: A recalculation of pooled sensitivity and specificity values for MRI studies of ACL tears included in the review of Smith et al. [26] and using a field strength of < 1.0 Tesla

author	year	Tesla	TP	FP	TN	FN	
Adalberth	1997	0.3	35	2	2	1	
Barnett	1993	0.5	26	3	89	0	
Boerree	1991	0.5	32	11	89	1	
Cotten	2000	0.2	14	2	73	1	
Ekelund	1991	0.04	13	1	1	0	
Fischer	1991	0.35	28	8	157	0	
Fischer	1991	0.6	13	5	56	5	
Fischer	1991	0.35	5	7	27	2	
Glashow	1989	0.35	14	5	19	9	
Kelly	1991	0.5	7	3	49	1	
Kinnunen	1994	0.1	5	4	23	1	
Mandelbaum	1986	0.3	13	0	70	0	
Rappeport	1997	0.1	6	3	37	1	
Sanchis-Alfonso	1993	0.5	23	0	21	1	
Saragaglia	1989	0.5	45	0	40	0	
			279	54	753	23	1109
pooled sensitivity = 0.92 [0.89;0.95] **pooled specificity = 0.93 [0.91;0.95]**							

Tabelle 14: bei kompletten Rissen des vorderen Kreuzbands zeigt die Hochfeld-MRT eine Sensitivität von 0,92 und eine Spezifität von 0,95 [26]. Die Konfidenzintervalle sind eng, daher hohe Sicherheit.

Table 14: A recalculation of pooled sensitivity and specificity values for MRI studies of ACL tears included in the review of Smith et al. [26] and using a field strength of ≥ 1.5 Tesla

author	year	Tesla	TP	FP	TN	FN	
Bari	2003	1.5	22	1	26	1	
Bui-Mansfield	1997	1.5	20	3	27	0	
Challen	2007	1.5	10	5	26	3	
Chung	2000	1.5	10	1	17	7	
Cook	1995	1.5	6	4	0	0	
Cotten	2000	1.5	14	0	75	1	
Craig	2005	3.0	13	1	42	0	
Duc	2008	1.5	16	2	38	4	
Fischer	1991	1.5	173	54	757	13	
Gentili	1994	1.5	48	1	39	1	
Gluckert	1992	1.5	18	1	60	1	

Gul-eKhanda	2008	1.5	13	3	32	2	
Ha	1998	1.5	54	4	157	2	
Halbrecht	1992	1.5	1	2	17	0	
Heron	1992	1.5	22	3	71	3	
Jackson	1988	1.5	7	3	77	0	
Jung	2009	3.0	36	1	49	1	
Kijowski	2009	1.5	53	2	132	3	
Kijowski	2009	3.0	72	2	126	0	
Lee	1999	1.5	18	3	21	1	
Lerman	1995	1.5	23	0	22	2	
Lundberg	1996	1.5	37	2	24	2	
McDermott	1998	1.5	14	0	33	4	
Munk	1997	1.5	15	2	37	0	
Munk	1998	1.5	6	2	44	9	
Niitsu	1991	1.5	20	3	21	8	
Polly	1988	1.5	6	1	31	0	
Sampson	2008	3.0	28	0	33	0	
Schaefer	2006	1.5	16	0	12	3	
Tung	1993	1.5	48	3	50	2	
Winters	2005	1.5	12	3	51	1	
			779	112	2147	74	3112
pooled sensitivity = 0.92 [0.90;0.94] pooled specificity = 0.95 [0.94; 0.96]							

Table 14 continued

4.1.4 PCL complete tears

Table 15: A recalculation of pooled sensitivity and specificity values for MRI studies of PCL tears included in the review of Oei et al. [18] and using a field strength of < 1.0 Tesla

author	year	Tesla	TP	FP	TN	FN	total
Fischer	1991	0.35	3	0	195	0	
Fischer	1991	0.6	1	9	79	0	
Fischer	1991	0.35	0	1	40	0	
Gross	1992	0.3	13	0	190	0	
Kinnunen	1994	0.1	0	1	32	0	
			17	2	536	0	555
pooled sensitivity = 1.00 [0.80;1.00] pooled specificity = 0.98 [0.96; 0.99]							

Tabelle 15: bei Läsionen des posterioren Kreuzbands zeigt die Niedrigfeld-MRT eine Sensitivität von 1,00 (allerdings mit weitem Konfidenzintervall) und eine Spezifität von 0,98 [18]

Tabelle 16: bei Läsionen des posterioren Kreuzbands zeigt die Hochfeld-MRT eine Sensitivität von 0,88 (allerdings mit weitem Konfidenzintervall) und eine Spezifität von 0,98 [18]

Table 16: A recalculation of pooled sensitivity and specificity values for MRI studies of PCL tears included in the review of Oei et al. [18] and using a field strength of ≥ 1.5 Tesla

author	**year**	**Tesla**	**TP**	**FP**	**TN**	**FN**	total
Bui-Mansfield	1997	1.5	1	8	41	0	
Chen	1995	1.5	4	0	46	0	
Fischer	1991	1.5	2	3	530	2	
Fischer	1991	1.5	2	1	90	0	
Gluckert	1992	1.5	0	0	80	0	
Heron	1992	1.5	1	0	98	0	
Niitsu	1991	1.5	4	1	47	0	
			14	13	932	2	961
pooled sensitivity = 0.88 [0.62;0.98] **pooled specificity = 0.98 [0.97; 0.99]**							

Bewertung dieser Ergebnisse – siehe Kap. 5 und 6; Forest-Plots siehe Anhang

A critical appraisal of these results and their interpretation in the light of other study results and expert opinions can be found in the chapters „5. Summary of the evidence“ and „6. Discussion“. The forest plots of the results displayed at Tables 7 to 16 can be found in the attachment.

4.2 Cartilage defects and osteoarthritis

4.2.1 High-field strength MR imaging

A systematic review in which low- and high-field strength MR imaging of cartilage defects and/or osteoarthritis of the knee were compared could not be found in the literature. However, we identified two relevant systematic reviews summarizing high-field strength MR imaging results [11,23]. Number and content of included articles, publication period of included articles, inclusion criteria and results with regard to sensitivity and specificity of MR imaging are displayed at Table 17.

kein systematischer Review, der Niedrig- und Hochfeld-MRT bei Knorpeldefekten vergleicht, gefunden

Table 17: Description of the methodology and results of the two systematic reviews on the diagnostic performance of high-field MR imaging of cartilage defects and knee osteoarthritis

	Quatman et al.	**Harris et al.**
Year of publication	2011	2012
Journal	American Journal of Sports Medicine	Arthroscopy
No. and content of included articles	27 MR imaging articles, comprising 27 studies on articular cartilage abnormalities, and 20 studies on knee osteoarthritis	13 MR imaging articles on articular cartilage defects
Articles published in the years	1988-2010	1994-2009
No. of articles that were included in both reviews	13	
Inclusion criteria for the articles	human knee	human knee
	arthroscopy used as a reference standard	arthroscopy used as a reference standard
	magnetic field strength of ≥1.5 T	magnetic field strength of ≥1.5 T
	MRT sequences reported	No MRT outcomes after cartilage surgery

Die systematischen Reviews wurden 2011 und 2012 publiziert. Die MRT Feldstärken betrugen mindestens 1.5 Tesla.

Die Einschlusskriterien waren in beiden Arbeiten sehr ähnlich.

Die Arbeit von Quatman et al. [23] inkludierte 27 Studien, die zwischen 1988 und 2010 publiziert wurden.

Die Arbeit von Harris et al. [11] inkludierte 13 Studien, die zwischen 1994 und 2009 publiziert wurden.

Die Ergebnisse konnten nicht meta-analytisch zusammengefasst werden, da die verwendten MRT-Techniken zu verschieden waren.

Beide systematische Reviews kamen zu dem Schluss, dass generelle Aussagen zur diagnostischen Genauigkeit von Hochfeld-MRT bei Knorpeldefekten und Arthrosen des Kniegelenks mit hoher Unsicherheit behaftet sind.

Die Spezifität ist generell höher als die Sensitivität.

Table 17 continued: Description of the methodology and results of the two systematic reviews on the diagnostic performance of high-field MR imaging of cartilage defects and knee osteoarthritis

Results		
A meta-analyis could not be performed due to the wide variety of imaging techniques (sequences, slice size, plane of data collection, positioning of patients, and types of scanners used)		
	Quatman et al.	**Harris et al.**
Sensitivity of MR imaging in articular cartilage defects in the various locations	medial tibial plateau: 0.17-0.96	
	lateral tibial plateau: 0.00-0.58	
	medial femoral condyle: 0.28-1.00	
	lateral femoral condyle: 0.33-1.00 in	
	trochlea: 0.55-1.00	trochlea: 0.62-1.00
	patella: 0.21-1.00	patella: 0.00-0.95
	patellofemoral compartment: 0.44-0.95	
	tibiofemoral compartment: 0.42-0.81	
Specificity of MR imaging in articular cartilage defects	> 0.85 in almost all studies and locations, with the exception of two studies (patella: 0.75; and lateral femoral condyle: 0.78)	patella: 0.62-1.00 trochlea: 0.81-0.97
Sensitivity of MR imaging in early osteoarthritis	0.00-0.86	
Specificity of MR imaging in early osteoarthritis	0.48-0.95	
Sensitivity of MR imaging in advanced osteoarthritis	0.47-0.98	
Specificity of MR imaging in advanced osteoarthritis	0.60-1.00	

The data displayed at Table 17 suggest that no clear conclusion can be drawn yet. The identified studies used a large variety of imaging techniques including sequences, slice size, plane of data collection, positioning of patients, and types of scanners. This and the varying qualification and experience of involved radiologists and arthroscopers may have contributed to the wide range of diagnostic performance results. Altogether, the results show that high-field MRT seems to be more specific than sensitive for the detection and/or grading of cartilage defects of the knee, and that sensitivity is associated with the (severity) grade of the lesions (explanation of severity grading - see Table 18).

neben den verschiedenen MRT Geräten und Techniken streuten die Ergebnisse möglicherweise auch wegen der unterschiedlichen Qualifikationen der beteiligten Befunder so stark

4.2.2 Low-field strength MR imaging

Since the available meta-analyses and systematic reviews did not include low-field MR imaging studies for the detection of cartilage defects and/or osteoarthritis of the knee, we had to rely on primary studies to answer the research question. Therefore, we searched for relevant primary studies. We identified six studies [1,3,10,12,14,24], that used a reference standard to determine sensitivity and specificity values and that met also our other inclusion and exclusion criteria (see Table 2 in chapter 2.2). Since the (severity) grade of a cartilage lesion is important for diagnostic work-up, we present the diagnostic accuracy parameters for each study considering the grading of the lesions. The most widely used MRT grading system is from Outerbridge [20], which is displayed at Table 18, and which was also used for data extraction. Data and results extracted from the six primary studies can be seen at Table 19.

Bewertung von 6 Primärstudien zur Niedrigfeld-MRT bei Knorpeldefekten und/oder Kniegelenksarthrose

Table 18: The most frequently used MRT grading system for cartilage defects, source: Outerbridge [20]

grade 0	Cartilage with a normal intrinsic signal and a normal surface contour on MR images
grade 1	Signal heterogeneities within the cartilage in the presence of a smooth surface
grade 2	Fibrillation or erosion composing less than 50% of the cartilage thickness
grade 3	defects of more than 50%, with or without small bone ulcerations
grade 4	Extended full-thickness lesions with denudation of the bone

Tabelle 18: das Grading-Schema von Outerbridge zur Bestimmung des Schweregrads einer Knorpelläsion: 0 = normal, 4 = hochgradige Knorpelläsion mit freiliegendem Knochen; dieses Schema wurde für die Datenextraktion verwendet

Sechs Primärstudien zur Niedrigfeld-MRT bei Knorpelläsionen gefunden, publiziert zwischen 1995 und 2003

Niedrigfeld-MRT bei Knorpelläsionen im direkten Vergleich weniger sensitiv als Hochfeld-MRT

Die Wahl der richtigen MRT-Untersuchungs-parameter (z.B. Sequenzen) spielt, wie so oft, auch hier eine große Rolle für die diagnostische Genauigkeit

weniger stark ausgeprägte Knorpeldefekte im Knie werden in der Niedrigfeld-MRT häufig übersehen

hochgradige Knorpeldefekte im Knie können auch mit der Niedrigfeld-MRT entdeckt werden

die Erfahrung des Untersuchers (Radiologen) scheint große Rolle bei der Detektion von Knorpeldefekten zu spielen

Table 19: Study details and results of low-field MR imaging studies, evaluating cartilage defects in the human knee and using a reference standard

First author (year)	Study details and results
Ahn (1998)	Country of origin: USA; magnet field strength: 0.2 T; extremity only magnet, Artoscan Italy; knee coil; evaluation of 4 regions of patellae from cadavers; reference standard used: macroscopic findings; sequences: SE T1, TSE PD, TSE T2, STIR, 2D GRE, 3D GRE, 2D GRE MTC, 3D GRE MTC. ***Sensitivity***: grade 0 lesions: --, grade 1 lesions: --, grade 2 lesions: 0.25-0.62, grade 3 lesions: 0.50-0.75, and grade 4 lesions: 0.60-0.90 (depending on the sequences used). ***Specificity***: grade 0 lesions: 0.36-0.79, grade 1 lesions: --, grade 2 lesions: 0.25-0.62, grade 3 lesions: 0.50-0.75, and grade 4 lesions: 0.60-0.90 (depending on the sequences used).
Bredella (2001)	Country of origin: USA; magnet field strength: 0.35 T, open superconductive magnet, Opart, Toshiba, USA; knee coil; evaluation of cartilage lesions in 20 consecutive patients; reference standard used: arthroscopy; sequences: STIR, Dixon. ***Sensitivity***: grade 0 lesions: 0.73 (0.62;0.82), grade 1 lesions: 0.50 (0.24;0.76), grade 2 lesions: 0.27 (0.09;0.55), grade 3 lesions: 0.74 (0.51-0.89, and grade 4 lesions: 0.57 (0.20;0.88). ***Specificity***: grade 0 lesions: 0.80 (0.67;0.89), grade 1 lesions: 0.87 (0.80;0.92), grade 2 lesions: 0.92 (0.85;0.96), grade 3 lesions: 0.94 (0.88;0.97), and grade 4 lesions: 0.97 (0.92;0.99).
Harman (2003)	Country of origin: Turkey; magnet field strength: 0.3 T; open magnet HITACHI AIRIS I; knee coil; evaluation of chondromalacia patella in 50 knees of 42 patients; reference standard used: arthroscopy; sequences: T1-weighted, proton density-weighted and T2-weighted; additionally MR arthrography performed. ***Sensitivity***: grade 0 lesions: --, grade 1 lesions: 0.23-0.30, grade 2 lesions: 0.33-0.50, grade 3 lesions: 0.43-0.71, and grade 4 lesions: 0.87 (depending on the sequences used). ***Specificity***: grade 0 lesions: ---, grade 1 lesions: 0.95-0.97, grade 2 lesions: 0.92-0.94, grade 3 lesions: 0.88-0.94, and grade 4 lesions: 1.00 (depending on the sequences used). MR arthrography was superior to conventional MR imaging in the detection of all grades of chondromalacia patella.

Table 19 to be continued on next page

Table 19 continued: Study details and results of low-field MR imaging studies, evaluating cartilage defects in the human knee and using a reference standard

First author (year)	Study details and results
Kladny (1995)	Country of origin: Germany; magnet field strength: 0.2 and 1.5 T comparing low- versus high-field MR imaging; Siemens P8 and Siemens SP Germany; knee coil; evaluation of meniscal and ACL tears as well as cartilage lesions in 22 patients; reference standard used: arthroscopy; sequence: 3D gradient-echo in both systems (FISP). ***Sensitivity***: both systems (0.2 and 1.5 T) could not show different stages of cartilage degeneration (grades 1-3). Grade 4 lesions: all six lesions were detected in the high-field imaging system, while the low field imaging system found only one of six lesions. ***Specificity***: there were no false-positive evaluations of grade 4 lesions in either (0.2 or 1.5 T) investigation.
Kreitner (1999)	Country of origin: Germany; magnet field strength: 0.2 T; Magnetom Open Siemens Germany; knee coil; evaluation of meniscal, cruciate ligament and cartilage lesions in 150 consecutive patients; reference standard used: arthroscopy; sequences: proton-density weighted SE, T2-weighted *Flash-2D, STIR and DESS; 2 independent readers with different levels of experience. ***Sensitivity***: for cartilage lesions overall 0.74 (0.57-0.86) by the very experienced -, and 0.48 (0.29-0.62) by the less experienced radiologist. For grade 1 lesions, sensitivity dropped to 0.55 and 0.27, respectively. ***Specificity***: for cartilage lesions overall 0.93 (0.82-0.98) by the very experienced -, and 0.91 (0.79-0.96) by the less experienced radiologist.
Riel (1999)	Country of origin: Germany; magnet field strength: 0.2 T; extremity only magnet, Artoscan Italy; type of coil not given; evaluation of meniscal, cruciate ligament, full-thickness cartilage lesions, and other abnormalities (plicae, loose bodies…) in 224 consecutive patients; reference standard used: arthroscopy; sequences: SE T1, SE T2, GRE T2. ***Sensitivity***: for full-thickness cartilage lesions (comparable to grade 4 lesions of the Outerbridge classification): 0.72. Lesions of lower grades were not detected by the low-field unit. ***Specificity***: for full-thickness cartilage lesions (comparable to grade 4 lesions of the Outerbridge classification): 1.00.

Die Schlußfolgerungen der Autor/inn/en der einzelnen Primärstudien decken sich mit unseren Beobachtungen nach Datenextraktion (siehe Tab. 19): uneindeutige Befunde, kaum Evidenz für diagnostische Genauigkeit der Niedrigfeld-MRT bei Knorpelläsionen

Here are the conclusions that the authors of the studies displayed at Table 19 drew (in the order of their publication year): A direct comparison between 0.2 and 1.5 T systems showed no differences in the diagnostic accuracy for the detection of meniscal and cruciate ligament tears, but found the 0.2 T system to be less sensitive than the 1.5 T in cartilage lesions [12], which might have been an effect of the different fields of view used. High-grade cartilage lesions can be evaluated reliably with low-field-strength MR imaging by using a combination of imaging sequences [1]. Low-field MR imaging systems show good specificity, but low sensitivity for articular cartilage lesions; i.e. high-grade lesions are reliably detected while low-grade lesions are often overlooked [24]. In the detection of cartilage defects and their correct stageing, the experience level of the radiologist seems to be of considerable clinical relevance [14]. Our observation suggests that high-grade cartilage abnormalities can be evaluated reliably with low-field-strength MR imaging using the three-point Dixon sequence [3]. All imaging techniques were insensitive to grade 1 lesions and highly sensitive to grade 4 lesions [10].

5 Summary of the evidence

5.1 Meniscal and cruciate ligament tears

Table 20 contains a summary of the calculated sensitivity and specificity values of MR imaging for the detection of various knee injuries, which were presented in detail in chapter 4 of this review. The table shows these parameters separated by MRT field strength.

Tabelle 20: Zusammenfassung der in Kap. 4 im Detail dargestellten Ergebnisse zur Sensitivität und Spezifität von Niedrig- versus Hochfeld-MRT bei Meniskus- und Kreuzbandverletzungen

Table 20: Pooled sensitivity and specificity values of MR imaging for the detection of various knee injuries, including 95% confidence intervals and separated by field strength

	field strength of < 1.0 T		**field strength of ≥ 1.5 T**	
Type of injury	**Sensitivity**	**Specificity**	**Sensitivity**	**Specificity**
Medial meniscal tear [18]	0.91 [0.88;0.93]	0.87 [0.85;0.90]	0.94 [0.93;0.95]	0.87 [0.85;0.89]
Lateral meniscal tear [18]	0.76 [0.70;0.81]	0.95 [0.93;0.96]	0.78 [0.75;0.82]	0.95 [0.94;0.96]
PCL complete tear [18]	1.00 [0.80;1.00]	0.98 [0.96;0.99]	0.88 [0.62;0.98]	0.98 [0.97;0.99]
ACL complete tear [18]	0.92 [0.87;0.95]	0.93 [0.90;0.94]	0.94 [0.91;0.96]	0.95 [0.93;0.96]
ACL complete tear [26]	0.92 [0.89;0.95]	0.93 [0.91;0.95]	0.92 [0.90;0.94]	0.95 [0.94;0.96]

It was expected that high-field MR imaging raises the likelihood of detecting those lesions, which is not the case. Actually, there are practically no differences in the diagnostic performance of low- versus high-field MR imaging for the detection of meniscal or cruciate ligament tears. In order to compare the above results to other work on the topic, irrespective of the MRT field strengths, we refer to a meta-analysis published by Crawford et al. in 2007 [6]. The authors included 43 articles reporting on MRI scans and arthroscopies for the detection of meniscal and ACL injuries. The pooled sensitivity and specificity values of MR imaging calculated by Crawford et al. are displayed at Table 21, together with the values presented by Oei et al. and Smith et al. for all field strengths MR imaging. Reviewing the values displayed at both table 19 and table 20, hardly any differences can be identified. The conclusion that can be drawn, is: The likelihood to detect or exclude medial meniscal or cruciate ligament tears with MR imaging is very high, regardless of the MRT field strength. However, MR imaging has a lower sensitivity in detecting

Die Wahrscheinlichkeit, mittels MRT Meniskus- oder Kreuzband-verletzungen zu entdecken oder auszuschließen, ist sehr hoch; die MRT-Feldstärke scheint dabei keine Rolle zu spielen.

Ausgenommen sind Verletzungen des lateralen Meniskus, wo die Sensititvität der MRT generell weniger hoch, aber nicht abhängig von der Feldstärke ist.

lateral meniscal tears while its specificity is very high, but also here, the field size used has no effect.

Die Ergebnisse aus 3 Meta-Analysen aus den Jahren 2003, 2007 und 2012 zur MRT-Diagnostik von Meniskus- und Kreuzbandverletzungen ohne Berücksichtigung der MRT-Feldstärken sind sehr konsistent

Table 21: Pooled sensitivity and specificity values of MR imaging of all field strengths for the detection of various knee injuries from 3 meta-analyses [6,18,26], including the number of examined patients (cases) and the 95% confidence intervals

	all field strengths			
Type of injury	**meta-analysis**	**cases**	**Sensitivity**	**Specificity**
Medial meniscal tear	Oei et al. 2003	3311	0.93 [0.92;0.95]	0.88 [0.85;0.91]
	Crawford et al. 2007	2607	0.91 [0.90;0.93]	0.81 [0.79;0.83]
Lateral meniscal tear	Oei et al. 2003	3361	0.79 [0.74;0.84]	0.96 [0.95;0.97]
	Crawford et al. 2007	2620	0.76 [0.73;0.79]	0.93 [0.92;0.94]
PCL complete tear	Oei et al. 2003	1516	0.91 [0.83;0.99]	0.99 [0.99;1.00]
ACL complete tear	Oei et al. 2003	2435	0.94 [0.92;0.96]	0.94 [0.93;0.96]
	Crawford et al. 2007	2040	0.86 [0.83;0.90]	0.95 [0.94;0.96]
	Smith et al. 2012	4221	0.94 [0.92;0.96]	0.95 [0.93;0.97]

5.2 Cartilage defects and osteoarthritis

Knorpeldefekte: Ergebnisse aus 2 Meta-Analysen, die die MRT-Feldstärke nicht berücksichtigten [6,16]: durchschnittliche Sensitivität ≈ 0.60-0.70, durchschnittliche Spezifität ≈ 0.80-0.95, bei stark heterogenen Ergebnissen.

Crawford et al., whose work was discussed already in chapter 5.1, also calculated pooled sensitivity and specificity values for „other knee pathology“, such as bone oedema and osteonecrosis, on the basis of 23 studies [6]. While the specificity was very high (0.98), the sensitivity was only 0.69. Recently, another systematic review about the diagnostic performance of MR imaging in osteoarthritis, without consideration of the MRT field strength, was published [16]. The meta-analysis that is described in this article was performed by including those studies that presented complete sensitivity and specificity data needed to derive the true positive, false positive, true negative, and false negative values. The authors identified 20 studies that met the inclusion criteria, of which 16 could be used for the meta-analysis. Reference standards included histology, arthroscopy, open visualisation, X-ray, computed tomography, and clinical examination. Pooled sensitivity was 0.61 and pooled specificity was 0.82. There was significant heterogeneity in these parameters.

These two meta-analytic results [6,16] confirm our results displayed in detail in chapter 4 suggesting that, according to published diagnostic accuracy studies, MR imaging seems to be tolerably specific but scarcely sensitive for the detection and/or grading of cartilage defects and/or osteoarthritis of the knee. MR imaging is therefore currently more useful in ruling out those conditions than ruling them in. While the evidence for these result is rather strong for high-field MR imaging, there is literally no evidence for low-field MR imaging because only a few studies with small sample sizes and equivocal findings have been published.

Die Sensitivität der MRT ist relativ niedrig und stark assoziiert mit der Ausprägung der Knorpelläsion; die Spezifität ist akzeptabel. Diese Evidenz liegt nur für Hochfeld-MRT vor; keine Evidenz für Niedrigfeld-MRT

6 Discussion

Several authors who published review articles on low-field versus high-field MR imaging of the extremities agree that low-field strength MRI systems provide the ability to diagnose substantial pathologies within the ligaments and menisci of the knee [8,26,28]. This is in accordance with our findings. All pooled sensitivity values were high, except for those values that were observed for the lateral meniscus. But this was not associated with the used MRI field strength. A reason for the latter result may be that radiologists are undersensitized for recognizing lateral meniscal lesions because they are less common than medial meniscal or ACL tears [8].

Diskussion in der radiologischen Fachwelt entspricht unseren Ergebnissen: starke Evidenz für diagnostische Genauigkeit der Niedrigfeld-MRT bei Meniskus- und Kreuzbandverletzungen

Many studies concerning MR imaging at low field have been reported from countries with government-controlled health economies [21,28]. One such country is the Netherlands, in which an interesting study on low-field MR imaging was performed and published in 2005 [17]. The purpose of this study was to assess if a short imaging examination with low-field MR imaging in addition to radiography is effective and cost-saving compared with radiography alone in patients with recent acute traumatic injury of the wrist, knee, or ankle. The study design was a pragmatic randomized clinical trial, and the MR imaging was performed with a 0.2 T extremity scanner using a short protocol with a total examination time of about 15 minutes. The MR imaging examination did not have any effect in patients with wrist or ankle injuries. However, in patients with acute knee injury, MR imaging shortened the diagnostic work-up, reduced the number of diagnostic procedures during follow-up, improved quality of life in the first 6 weeks, and, though not statistically significant, may reduce costs associated with lost productivity. The sample size of patients with knee injury was n=93 in the intervention and n=93 in the control group; thus, the study had sufficient power.

Interessante hochqualitative Studie aus den Niederlanden [17]: Eine 15 Minuten dauernde Niedrigfeld-MRT Untersuchung bei Patienten mit akuter Knieverletzung verkürzte insgesamt die diagnostische Aufarbeitung, reduzierte die Anzahl der Folgeunter-uchungen und verbesserte die Lebensqualität der Patienten in den ersten 6 Wochen nach dem Unfall

Another article that was published by this Dutch group described the results of this randomized controlled trial in 189 patients with knee injury [18]. They used the low-field MR examination to identify those who require additional treatment versus those who do not and can be discharged without further follow-up. The authors stated that a prediction of the need for treatment in patients who present after acute knee trauma could be made on the basis of the age, trauma mechanism, and the radiographic results. A short scan time MR imaging, in addition to or instead of radiography, improved the prediction of the need for additional treatment but did not significantly aid in the identification of patients who can be discharged without further follow-up.

Weiterführende Analysen dieser Studie aus den Niederlanden zeigten, dass die Durchführung der Niedrigfeld-MRT nach Knieverletzung vor allem für die weitere Therapieplanung wichtig war ganz besonders wichtig bei Niedrigfeld-MRT: spezielle Qualifikation der Radiolog/inn/en

It should be stressed that specialized training is required for quality control and image interpretation in low-field MR imaging. According to Ghazinoor et al., a reason for insufficient diagnostic accuracy of low-field MR imaging systems are the use of large FOVs and poor-in-plane resolution [8]. They also recommend the performance of a STIR sequence to further improve their diagnostic capabilities. The importance of the radiologist's qualification was shown in an Austrian study [13]: In MRT examinations of knee pathologies, the number of false reports was dependent on the observer (= radiologist) rather than on the MRT field strength, and the rate of false interpretations was significantly higher in the less experienced group of radiologists.

mögliche Probleme, wenn Niedrigfeld-MRT breiter eingesetzt wird: höhere Rate an Folgeuntersuchungen an Hochfeld-Systemen; höhere Rate an Selbstzuweisungen

Relying on low-field imaging for the detection of meniscal and cruciate ligament injuries may, however, lead to a specific problem in case of equivocal findings: Since most radiologists' level of confidence is superior with high-field MR imaging, such findings after low-field MR imaging may increasingly lead to second examinations on high-field units. Another problem of the use of low-field MR systems are increasing self-referral rates, e.g. by non-radiologists who install these systems in their offices. It was shown that self-referring physicians used imaging procedures more frequently than those referring to a radiologist with a resultant increase in imaging charges for self-referring physicians [25].

Niedrigfeld-MRT wird jedoch nicht bei Knorpeldefekten empfohlen; dies entspricht auch unseren Ergebnissen

In contradistinction, the authors of the recent review articles on low-versus high-field MR imaging state that accurate diagnosis and characterization of articular cartilage lesions is difficult, if not impossible, in the setting of low-field strength imaging [8,25,28]. All in all, the increased noise inherent in low-field MR imaging seems to affect the detection of cartilage abnormalities when compared to high-field imaging. Full-thickness cartilage defects are easier to appreciate than lower-grade chondral abnormalities.

die in diagnostischen Studien erzielten Sensitivitätswerte der Hochfeld-MRT bei Knorpeldefekten sind jedoch auch nicht sehr hoch

However, also in high-field strength MR imaging the results, specifically with regard to sensitivity, are unsatisfactory and often below the usual clinical standard. Recently, Strickland & Kijowski presented a review article in which they discuss the current state of MR cartilage image and the existing problems [27]. There is a large variety of MR imaging techniques available for evaluating articular cartilage (see, for example, the results of different MRT sequences at Figure 2). Limited spatial resolution, supoptimal tissue contrast, and artifacts remain major hurdles in the development of clinically useful sequences. The authors believe that the main factor that limits the abilitiy of currently available MR imaging techniques to identify early cartilage degeneration is suboptimal spatial resolution, and expect MRT systems with higher field strengths (e.g. 3.0 T) to improve cartilage imaging because they can produce images with higher spatial resolution and decreased slice thickness without reducing signal-to-noise ratio or prolonging acquisition time.

Table 1
Diagnostic performance of various two-dimensional and three-dimensional sequences for detecting surgically confirmed cartilage lesions within the knee joint

Sequence	Field Strength	Voxel Size (mm)	Number of Subjects	Sensitivity (%)	Specificity (%)
2D fast spin echo[52]	1.5T	0.3×0.6×3.5	88	87	94
2D fast spin echo[49]	1.5T	0.5×0.7×4.0	130	94	99
2D fast spin echo[48]	1.5T	0.3×0.6×4.0	54	59–74	87–91
2D fast spin echo[93]	1.5T	0.6×0.6×4.0	26	91	98
2D fast spin echo[95]	1.5T	0.4×0.7×3.0	30	63–67	88–94
2D fast spin echo[50]	1.5T	0.5×0.6×3.0	100	61–74	70–90
2D fast spin echo[51]	1.5T	0.5×0.6×3.0	26	59–74	92–97
Water excitation SPGR[95]	1.5T	0.4×0.4×1.7	30	62–74	78–89
Fat-saturated SPGR[7]	1.5T	0.5×0.9×1.5	114	75–85	94–97
Water excitation true-FISP[95]	1.5T	0.4×0.7×1.7	30	58–64	80–94
Water excitation true-FISP[89]	1.5T	0.6×0.6×0.6	30	45–63	82–83
VIPR-SSFP[88]	1.5T	0.5×0.5×0.5	95	77	92
Water excitation FLASH[93]	1.5T	0.6×0.6×2.0	26	46	92
DESS[96]	1.5T	0.6×0.8×1.4	80	83	97
Water excitation DESS[95]	1.5T	0.4×0.7×1.7	30	56–72	78–95
DEFT[75]	1.5T	0.3×0.8×3.0	24	69	93
2D fast spin echo[50]	3.0T	0.4×0.6×3.0	100	70–71	80–93
2D fast spin echo[51]	3.0T	0.4×0.6×3.0	26	67–80	92–97
IDEAL-GRASS[94]	3.0T	0.4×0.7×1.0	95	66–71	93–94
Fat-saturated FSE-Cube[56]	3.0T	0.7×0.7×0.7	100	73	89

Ranges are for multiple readers in some studies.

Figure 2: Some sequences for MR imaging of cartilage lesions of the knee [27].

Sequenzen der Hochfeld-MRT, die hinsichtlich diagnostischer Ergebnisse evaluiert wurden, und in einem rezent erschienenen Übersichtsartikel [27] dargestellt sind

Not only the diagnostic work-up, but also the selection of the right therapy is difficult in case of cartilage defects. A Swiss group performed a systematic review of studies concerning current treatment of chondral defects of the knee [2]. The selected 133 studies supplied data concerning microfracturing, the osteochondral autograft transplantation system, the autologous chondrocyte implantation and the matrix induced chondrocyte implantation. Unfortunately, most of these studies were of low methodological quality. Therefore, Benthien et al. could not recommend a certain operative procedure because the pertaining literature was contradictory, prospective randomised trials were scarce, and the applied outcome measurement tools were mostly unvalidated.

Knorpeldefekte im Kniegelenk sind jedoch nicht nur diagnostisch herausfordernd. Auch für die richtige Therapie gibt es noch kaum Evidenz [2].

The clinical value of MR imaging of knees with no radiographic evidence of osteoarthritis was assessed in the Framingham osteoarthritis study [9]. It turned out that in 89% of those people (n = 710, of which 206 had knee pain in the past month, all were aged > 50 y, and none had shown radiographic signs of osteoarthritis) some kind of abnormality was seen on MR images, of which osteophytes, cartilage damage, and bone marrow lesions were the most common. The older the subjects were, the higher was the prevalence of MRI detected osteoarthritis features. However, MRI features suggestive of os-

im MRT werden oft auch Zeichen einer Kniegelenksarthrose bei symptomlosen älteren Personen gesehen; d.h. die MRT allein ist hier für das diagnostische Work-up nicht aussagekräftig teoarthritis are also often seen in people without knee pain, implying that MR imaging alone is not diagnostically useful to discriminate between people with and without pain in the context of knee osteoarthritis. But MR imaging might still play an important diagnostic role, especially in younger people, in whom other reasons for knee pain should be considered, such as inflammatory arthritides, insufficiency fractures, or spontaneous osteonecrosis [9]. The Framingham osteoarthritis study also highlights the limitations of conventional radiography to detect a large number of abnormalities related to osteoarthritis in the knee. Recently, an international osteoarthritis working group, recommended, after performing systematic literature reviews, conventional radiography to assess joint space width, and MR imaging for the evaluation of cartilage morphology [5].

Evidenz dafür, dass MRT in vielen Fällen die diagnostische Arthroskopie ersetzen und unnötige Eingriffe ersparen kann

Some authors say that the MR imaging techniques recommended in the literature at present are not able to replace arthroscopy for diagnosis of cartilage damage in the knee [6]. However, according the results of a randomized controlled trial the use of MR imaging in patients with chronic knee problems, in whom surgery was being considered, did not increase costs overall, was not associated with worse outcomes, and avoided surgery in a significant proportion of patients [4].

7 Conclusion and recommendations

Our review showed that the diagnostic reliability and utility of low-field MR imaging in detecting meniscus and cruciate ligament tears is comparable to that obtained from conventional units operating at higher magnetic fields. The accurate diagnosis and characterization of cartilage lesions, however, is difficult, if not impossible, in the setting of low-field strength imaging.

Niedrigfeld-MRT empfehlenswert bei Verdacht auf Verletzung von Meniskus und Bändern, aber nicht bei Verdacht auf Knorpeldefekte oder Kniegelenksarthrosen.

Therefore, we can recommend the use of low-field strength systems in suspicious meniscus and cruciate ligament injuries with certain constraints or specific considerations, respectively:

- MR imaging on extremity scanners is best performed by musculoskeletal-trained radiologists with experience in reading images obtained on low-field systems, working closely with the referring clinician.
- MR imaging should not replace clinical diagnosis, but used in connection with clinical findings and history to provide a more complete picture, especially in complex injuries.
- Since the level of confidence in decision-making has been reported significantly superior with high-field imaging, equivocal findings with low-field units may lead to an increased number of second examinations on high-field units.
- The rates of self-referral, e.g. by non-radiologists who install these systems in their offices, should be controlled.

Bei Niedrigfeld-MRT zu beachten: ausreichende Qualifikation der Befunder; klinische Diagnose wichtig nehmen; höhere Anzahl von Wiederholungs-MRT auf Hochfeldsystemen ist möglicherweise zu erwarten; die Rate der Selbstzuweisungen ist zu überwachen

Based on the existing evidence, we cannot recommend the use of low-field strength systems for the diagnosis and grading of knee cartilage defects and/or osteoarthritis. Since the sensitivity of high-field MR imaging for chondral lesions is, according to study results, also suboptimal, we recommend to refer those patients to specialized centers if possible.

Niedrigfeld-MRT für Knorpeldefekte oder Kniegelenksarthrosen nicht zu empfehlen; Überweisung der Patient/inn/en an hochspezialisierte Zentren, wenn möglich

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9 Attachment: forest plots for MRT studies

The displayed forest plots refer to the results of MR imaging studies of meniscal and cruciate ligament lesions displayed also at Tables 7 to 16 in chapters 4.1.1 to 4.1.4.

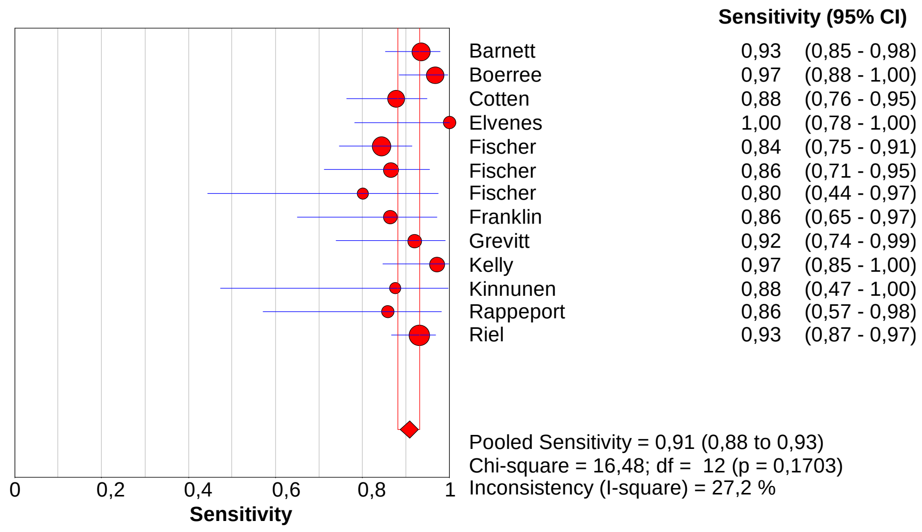

Figure 1 attached: refers to Table 7, sensitivity of low-field MRT in medial meniscus

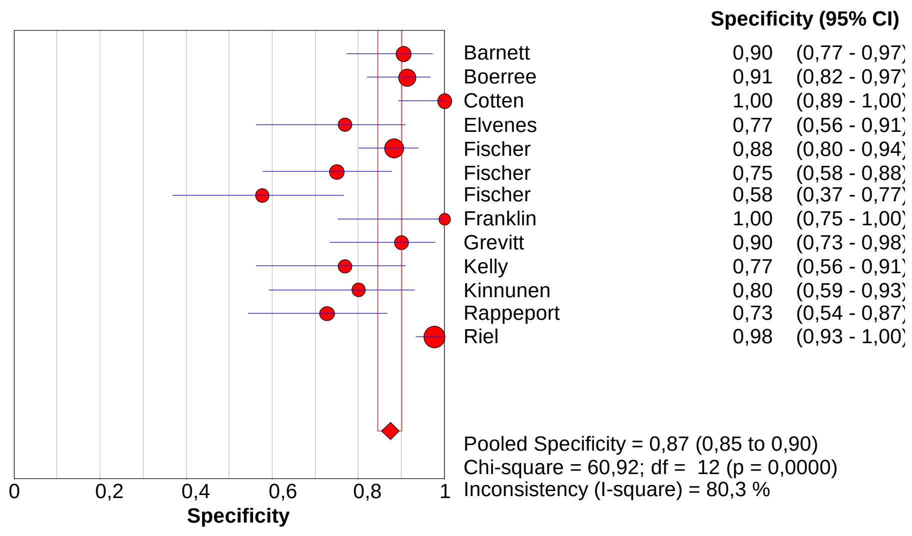

Figure 2 attached: refers to Table 7, specifity of low-field MRT in medial meniscus

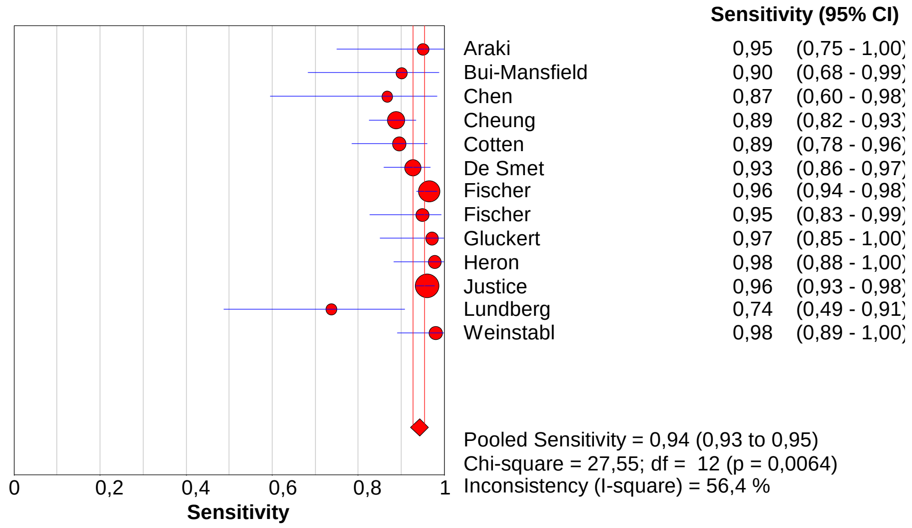

Figure 3 (attached): refers to Table 8, sensitivity of high-field MRT in medial meniscus

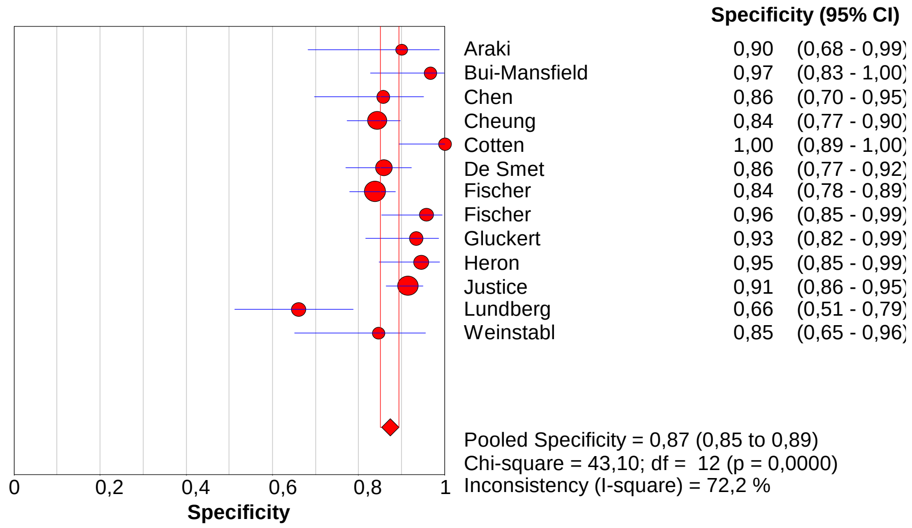

Figure 4 (attached): refers to Table 8, specifity of high-field MRT in medial meniscus

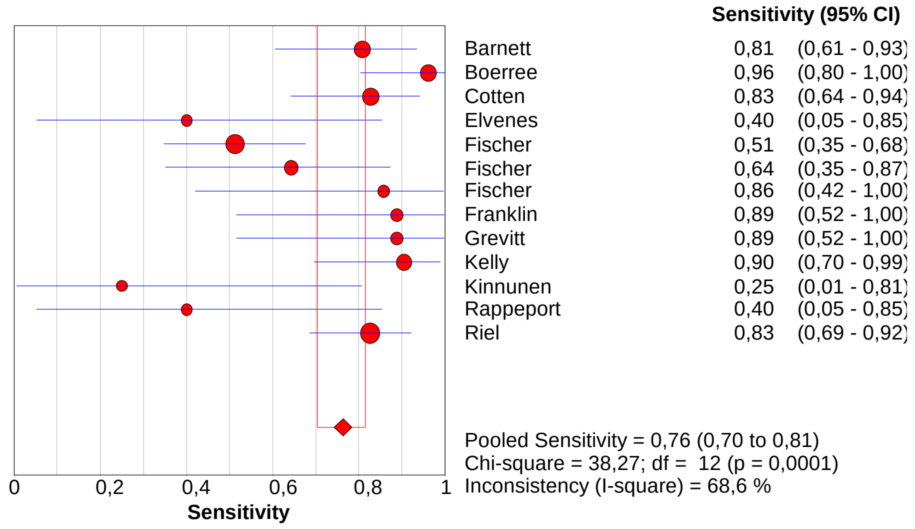

Figure 5 (attachment): refers to Table 9, sensitiviy of low-field MRT in lateral meniscus

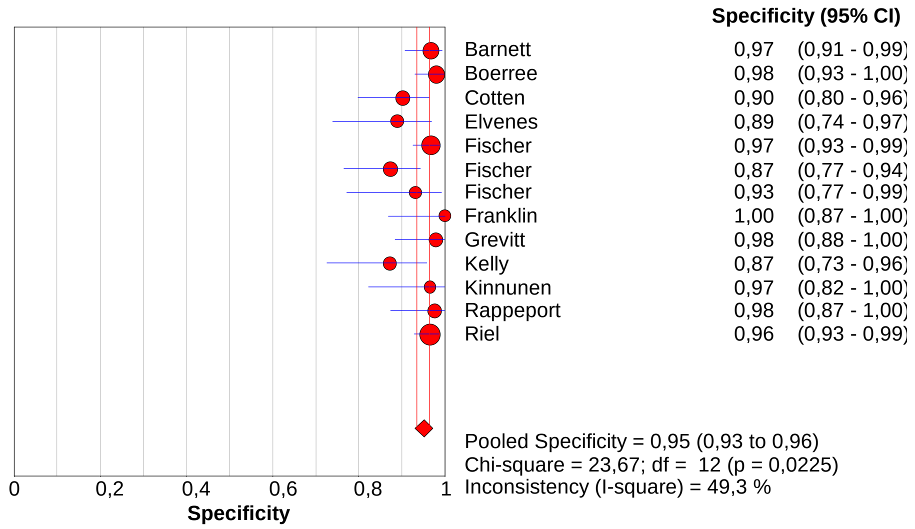

Figure 6 (attachment): refers to Table 9, specifity of low-field MRT in lateral meniscus

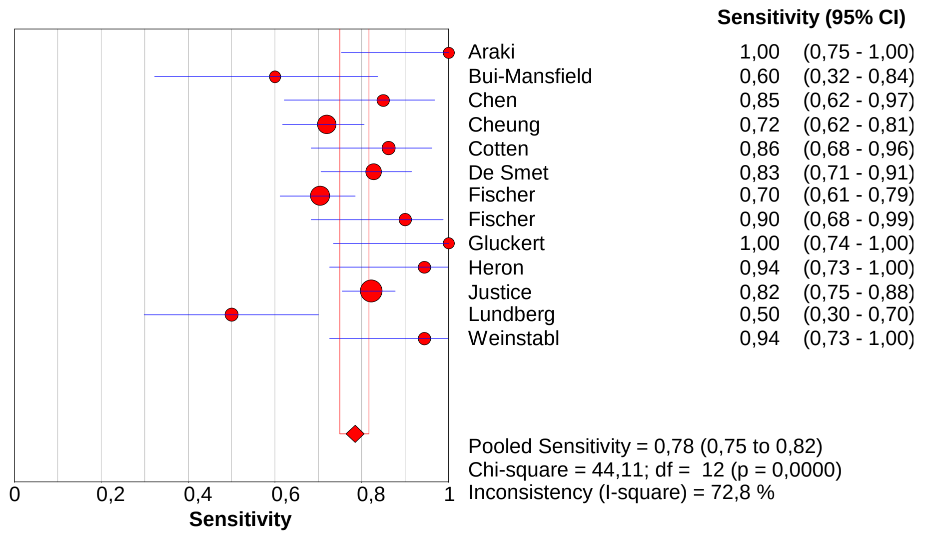

Figure 7 (attached) refers to Table 10, sensitivity of high-field MRT in lateral meniscus

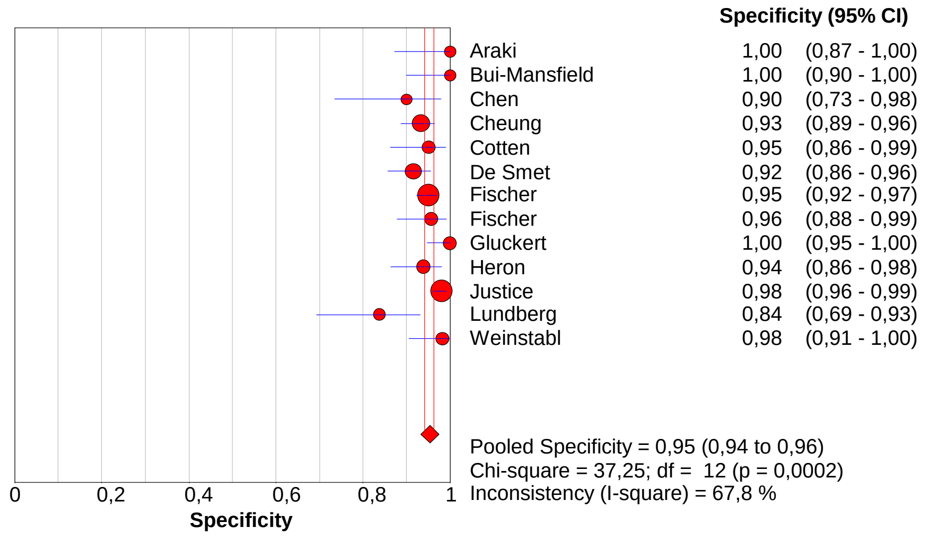

Figure 8 (attached): refers to Table 10, specifity of high-field MRT in lateral meniscus

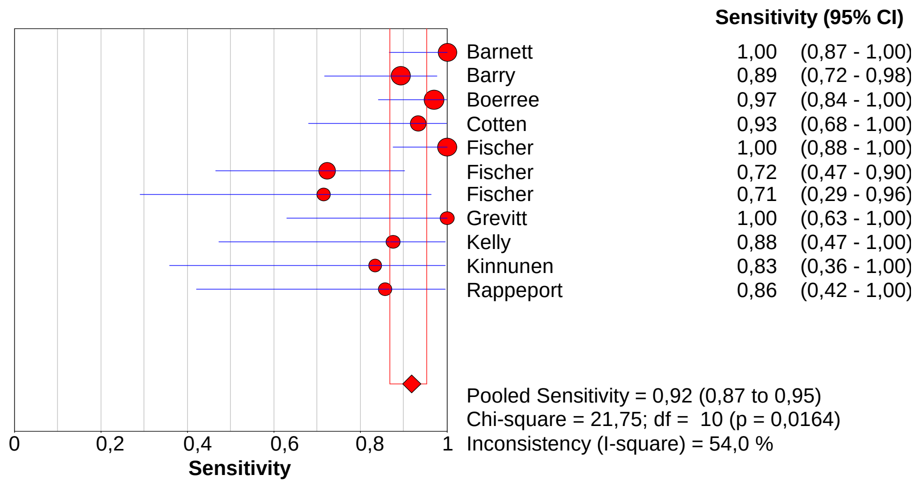

Figure 9 (attachment): refers to Table 11, sensitivity of low-field MRT in ACL tears

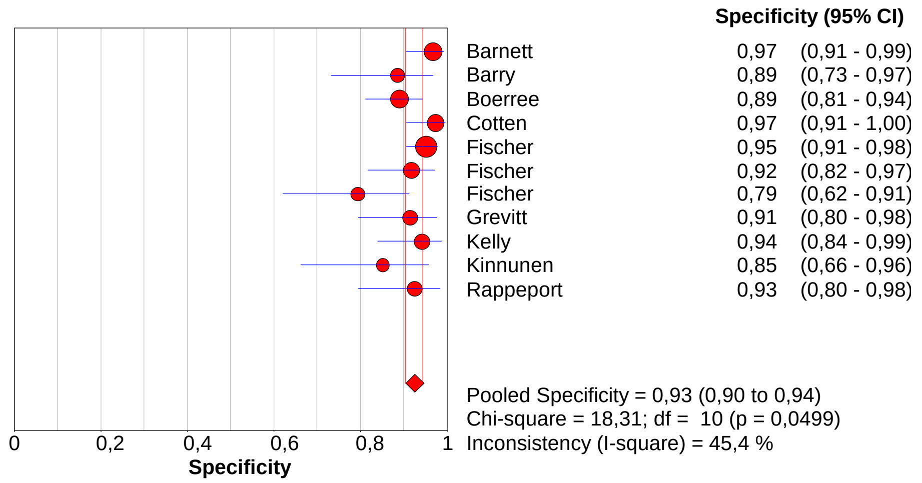

Figure 10 (attachment): refers to Table 11, specifity of low-field MRT in ACL tears

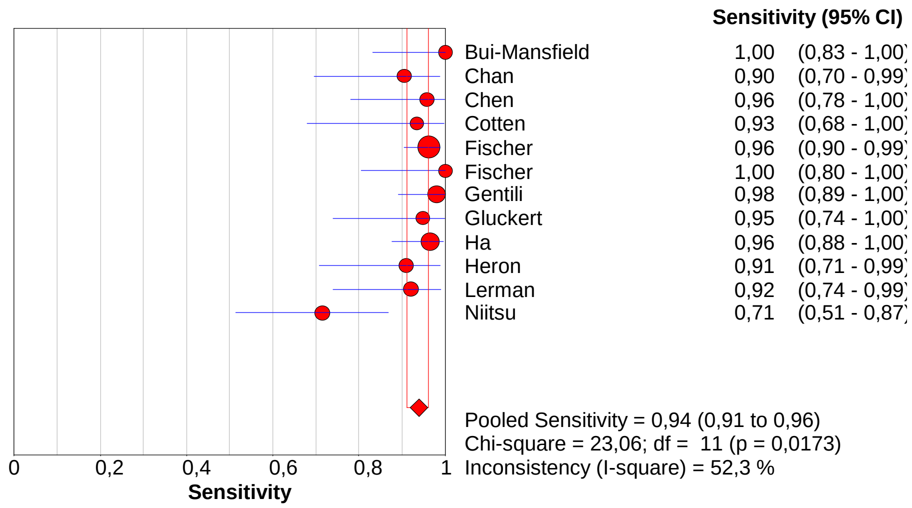

Figure 11 (attachment): refers to Table 12, sensitivity of high-field MRT in ACL tears

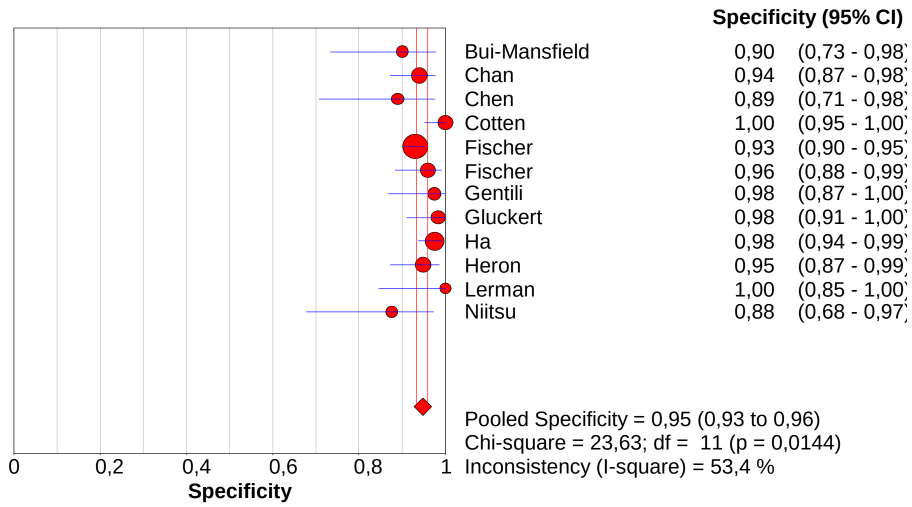

Figure 12 (attachment): refers to Table 12, specifity of high-field MRT in ACL tears

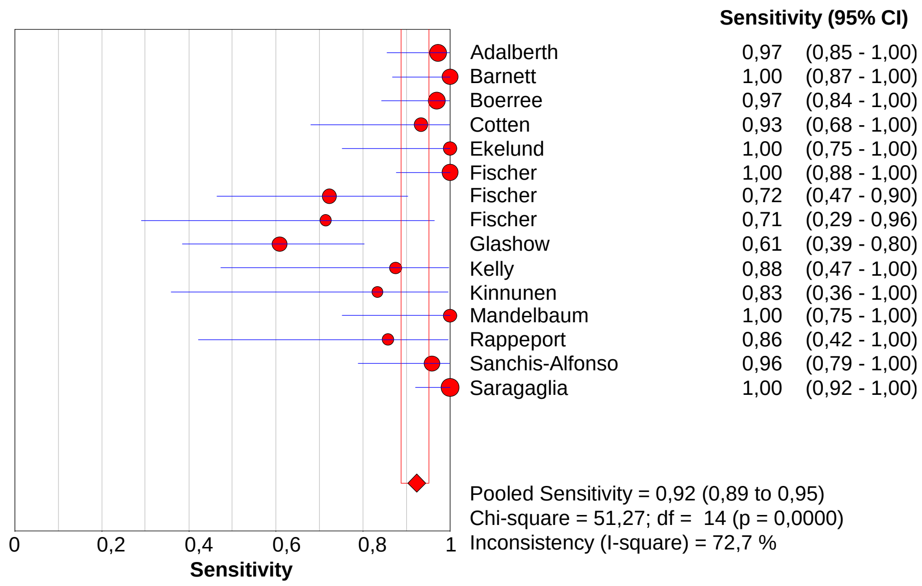

Figure 13 (attachment): refers to Table 13, sensitivity of low-field MRT in ACL tears

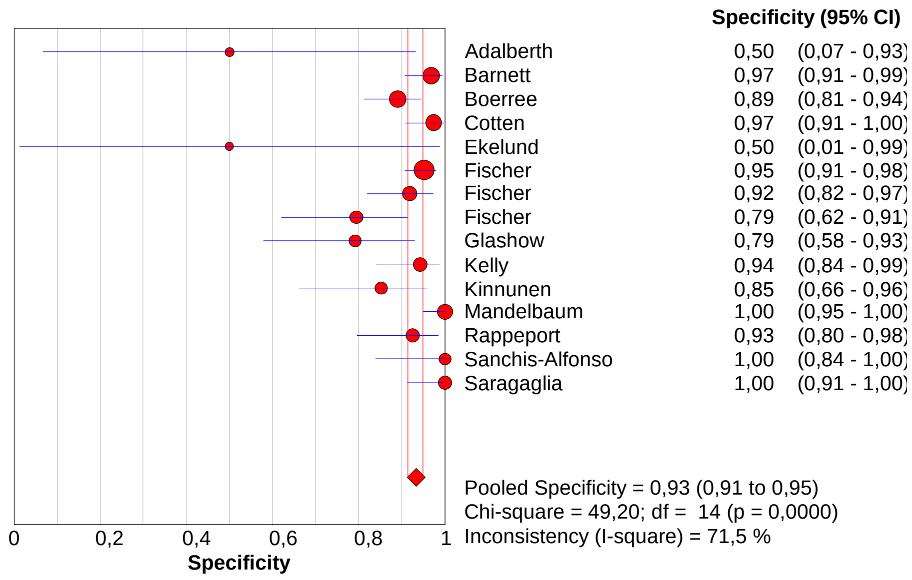

Figure 14 (attachment): refers to Table 13, specifity of low-field MRT in ACL tears

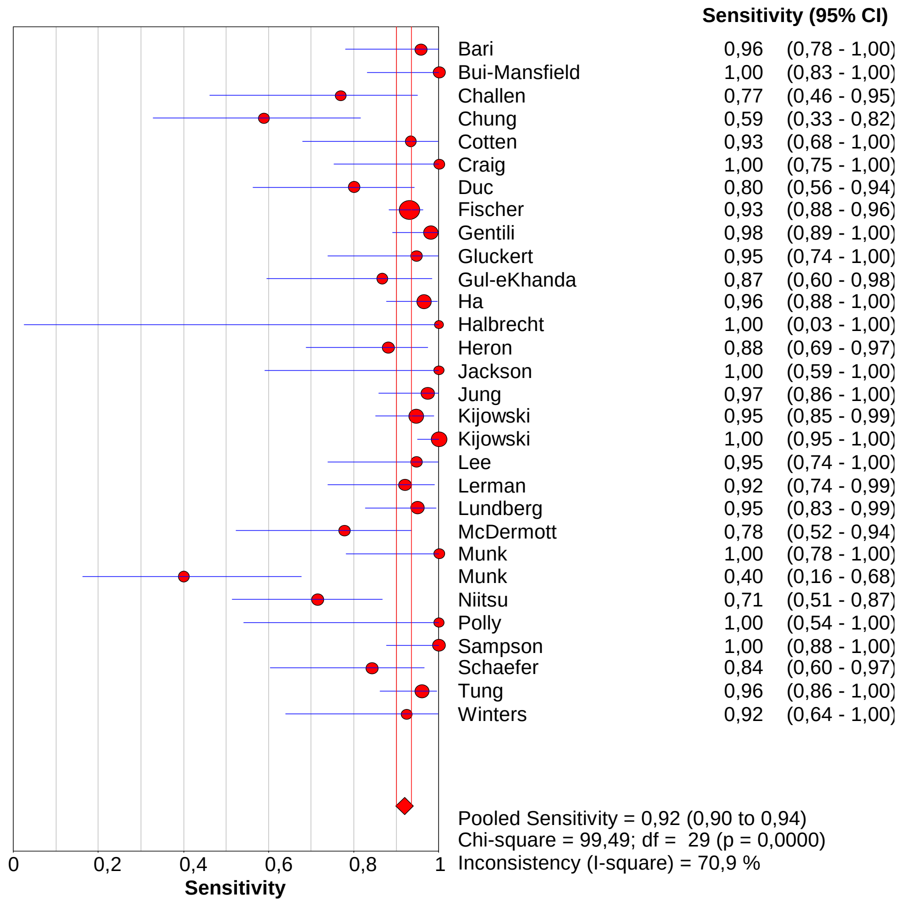

Figure 15 (attached): refers to Table 14, sensitivity of high-field MRT in ACL tears

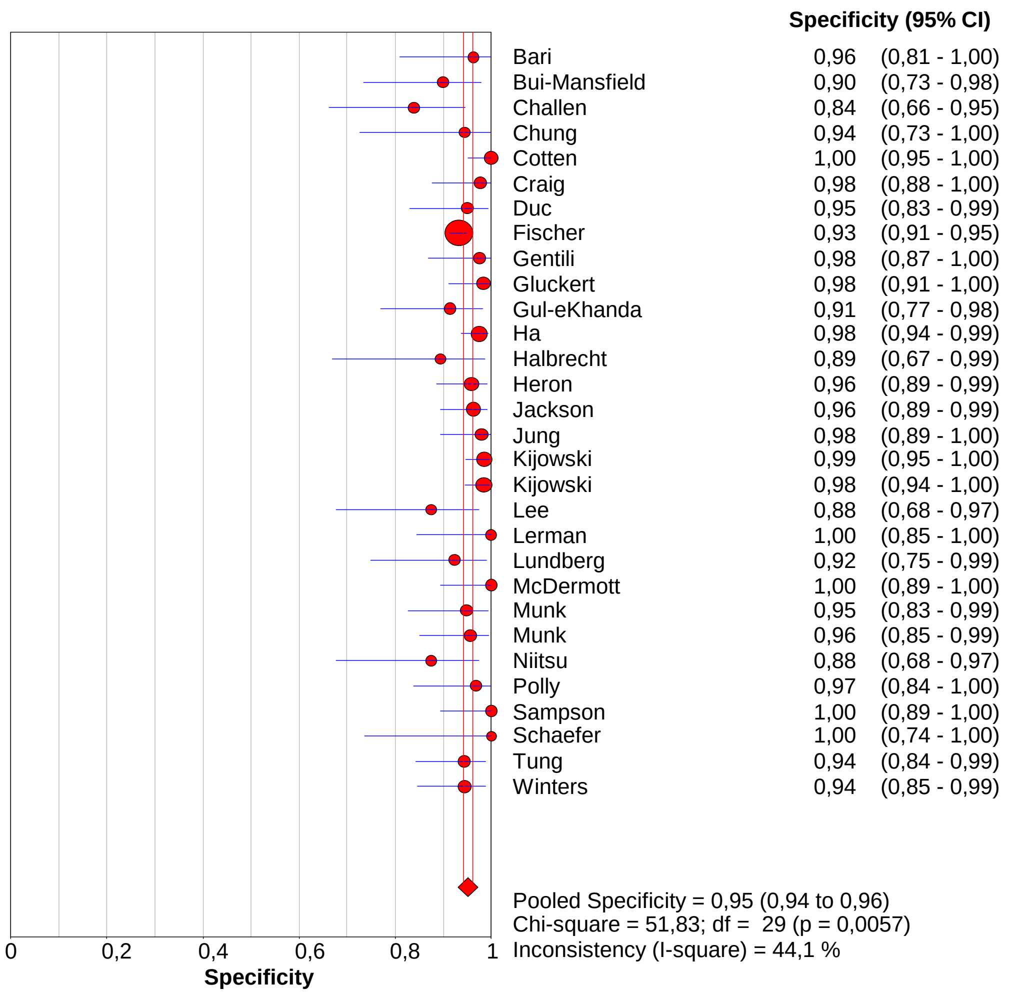

Figure 16 (attachment): refers to Table 14, specifity of high-field MRT in ACL tears

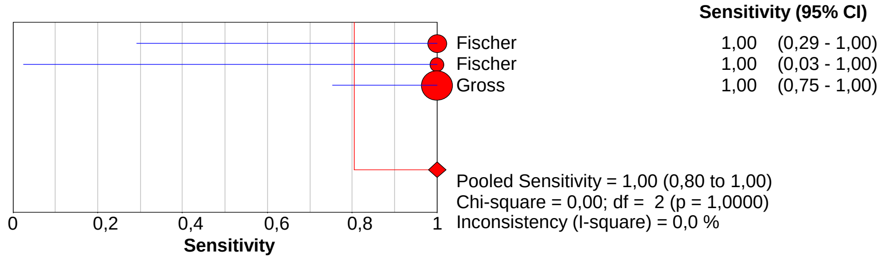

Figure 17 (attached): refers to Table 15, sensitivity of low-field MRT in PCL tears

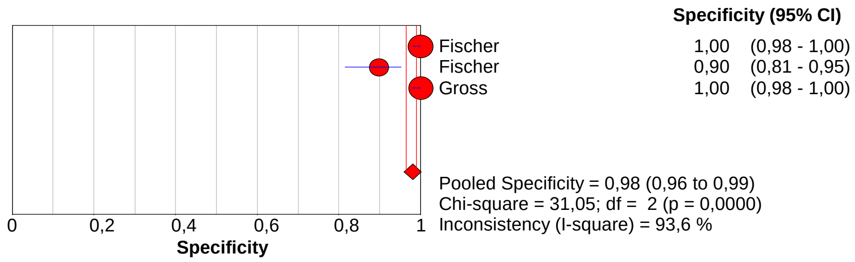

Figure 18 (attachment): refers to Table 15, specifity of low-field MRT in PCL tears

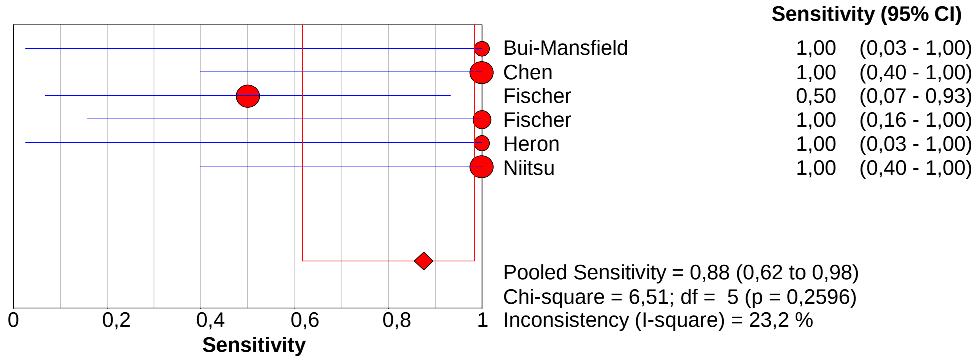

Figure 19 (attachment): refers to Table 16, sensitivity of high-field MRT in PCL tears

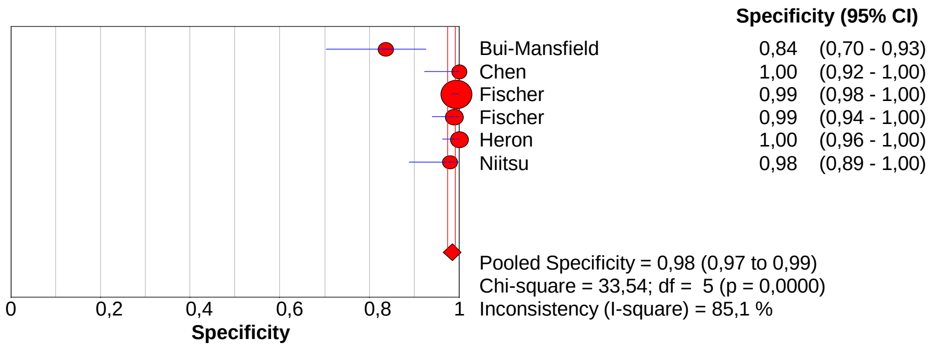

Figure 20 (attachment): refers to Table 16, specifity of high-field MRT in PCL tears