



Diagnostic Accuracy of MRI in Detecting ACL and PCL Tears: A Systematic Review

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ABSTRACT

Background: Magnetic resonance imaging (MRI) is widely used for diagnosing anterior cruciate ligament (ACL) and associated knee injuries, but reported sensitivity and specificity vary across imaging protocols and study settings.

Objective: To evaluate MRI's diagnostic accuracy, particularly compared with arthroscopy, in detecting ACL and related intra-articular knee pathologies.

Methods: A comprehensive literature search identified nine eligible studies published between 2020 and 2024 in Egypt, Sweden, China, Pakistan, and India. Designs included prospective, retrospective, cohort, and cross-sectional studies, with sample sizes ranging from 42 to 398 patients aged 14–69 years. Most participants had suspected or confirmed ACL tears, meniscal

injuries, or combined pathologies. Some studies assessed novel MRI sequences, special positioning, or alternative imaging modalities.

Results: MRI showed consistently high sensitivity for ACL injuries (often >90%), although specificity and predictive values varied with injury type and imaging protocol. Lateral decubitus MRI improved detection of partial ACL tears, while modified DPP-TSO-Sag-FS-PDWI sequences enhanced diagnostic accuracy and repeatability, especially for intermediate and Grade II injuries. MRI was less effective than arthroscopy in identifying ramp lesions but remained reliable for most intra-articular pathologies.

Conclusion: MRI demonstrates high accuracy in diagnosing ACL and associated knee injuries, often surpassing clinical tests and approaching arthroscopy, though limitations in detecting partial tears and subtle lesions highlight the need for standardized protocols, advanced imaging, and AI-assisted interpretation to optimize diagnostic pathways.

Keywords: MRI, anterior cruciate ligament, knee injury, diagnostic accuracy, arthroscopy

INTRODUCTION

Anterior cruciate ligament (ACL) injuries are among the most common knee pathologies, often associated with meniscal tears and other intra-articular lesions. Accurate diagnosis is crucial to guide timely and appropriate management, preventing chronic instability and degenerative joint changes. Magnetic resonance imaging (MRI) is widely used as a non-invasive diagnostic tool due to its high soft tissue contrast and multiplanar capability, while arthroscopy remains the gold standard for confirming intra-articular lesions.

Although numerous studies have evaluated the diagnostic accuracy of MRI for ACL and meniscal injuries, the reported sensitivity and specificity vary considerably. Factors influencing these variations include differences in MRI sequences, magnet strength, radiologist expertise, and lesion complexity. Standard MRI demonstrates high accuracy in detecting complete ACL ruptures but remains less reliable for partial tears, ramp lesions, and subtle meniscal injuries. MRI is less sensitive for detecting partial ACL tears compared to complete ruptures due to three main reasons. First, partial tears often leave some fibers intact, creating variable injury patterns that can mimic a normal ligament appearance.⁽¹⁾ Second, conventional and even 3T MRI have limited resolution, and subtle features such as thinning, waviness, or

inhomogeneous signals are not always present or discernible.(2) Third, the ACL's complex anatomy—consisting of distinct bundles that may be variably affected—combined with knee positioning challenges during imaging, further complicates accurate diagnosis.(3) Consequently, while MRI is useful, arthroscopy remains the gold standard for diagnosing partial ACL tears.(1)

Previous reviews have often been limited to single populations, conventional imaging protocols, or specific lesion types, leaving uncertainty about MRI performance across diverse clinical settings and with advanced imaging techniques. Moreover, recent studies incorporating newer protocols and positioning methods have not been comprehensively synthesized. Hyperpolarized MRI enables real-time metabolic imaging with tracers like [2-13C]pyruvate, though adoption is limited by technical challenges.(4) Advanced neuroimaging techniques, including perivascular diffusion tensor imaging, myelin imaging, and deep learning-enhanced arterial spin labeling, improve diagnostic accuracy but lack large-scale validation.(5) Additionally, 3D acquisitions, artefact reduction methods, ultra-structural imaging, and deep learning-based fast MRI offer enhanced sensitivity and efficiency, yet their clinical potential remains insufficiently explored.(6, 7)

This systematic review aims to evaluate the diagnostic accuracy of MRI for ACL and associated intra-articular knee injuries, using arthroscopy as the reference standard. In settings where arthroscopy is not readily available, clinicians must rely more on clinical assessments, non-invasive imaging, and patient preferences to guide treatment.(8) For conditions like osteoarthritis, MRI or clinical diagnosis may suffice, while in pediatric septic arthritis, laboratory markers and synovial biopsy play a critical role.(9) In trauma cases, traditional surgical approaches and fluoroscopy remain viable alternatives to arthroscopy.(10, 11) Ultimately, shared decision-making and evidence from systematic reviews ensure that patients receive safe and effective care even without direct access to arthroscopy.(12-14) By synthesizing recent literature, it seeks to provide an updated and comprehensive understanding of MRI's capabilities and limitations, and to inform clinical decision-making in knee injury assessment.

RESULTS

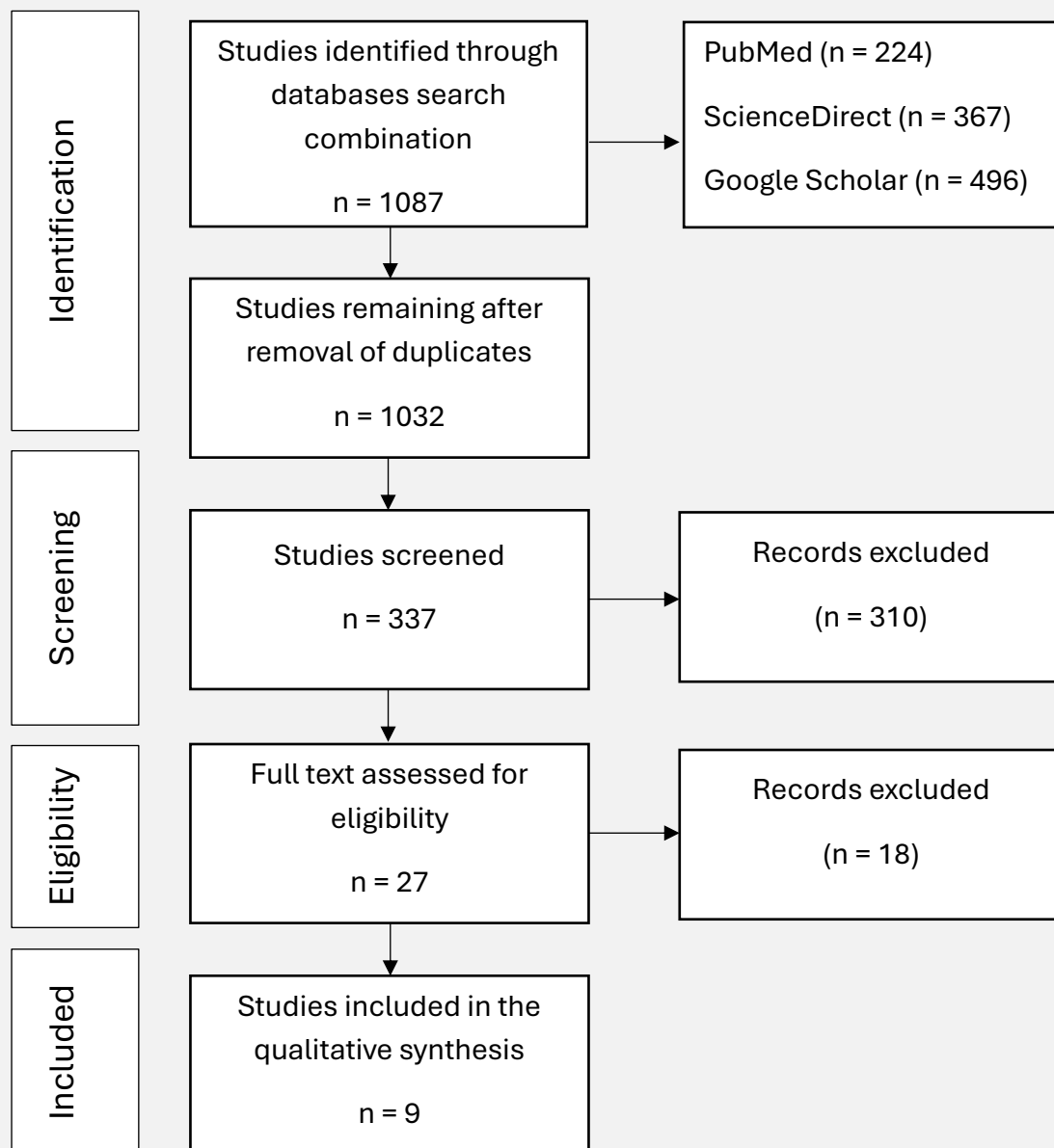


Figure 1. PRISMA Guideline for article selection process

Tabel 1. Extraction form

Author, Year, Country.	Study Design and Population	Sample size	Intervention (Approach)	Age	Injury to operation period	Key Outcomes	Result	Conclusion
Mohamed Samir, Ehab Alieldin, Ahmed T Ashour, Ahmed Abouelnaga, Ahmed Attia, Ahmed Ashour, Ahmed Ismail, Ahmed Waly, Tarek Elkhadrawy. 2024. Egypt.	Prospective observational design. Patients who presented with complete ACL tears.	100	including plain X-ray and Magnetic Resonance Imaging (MRI) (anteroposterior and lateral views). Arthroscopic ACL involved both standard anteromedial and anterolateral diagnostic	18-40 years old	Within three months (40%), between three and six months (52%), and after six months (8%).	The diagnosis rate of ramp lesions by both MRI and arthroscopy, statistical significance of MRI signs, and the mean medial meniscal slope.	Ramp lesions were found in 9 out of 100 ACL-injured patients (9%). While MRI signs were present in all cases, only peri-meniscal fluid showed a statistically significant association with ramp lesions ($\chi^2=5.019$, $FEp=0.039$), unlike other MRI signs	Arthroscopy is superior to MRI for diagnosing ramp lesions due to its cost-effectiveness, direct visualization, and immediate treatment capability.

							($\chi^2=1.884$, FEp=0.348).	
Ann-Sofi Bjorkman, Hakan Gauffin, Anders Persson, Seppo K. Koskinen. 2022. Sweden.	Prospective study. Patients with suspected ACL injury	48	Dual Energy CT (DECT) and Magnetic Resonance Imaging (MRI). Arthroscopy was used as the definitive reference method for diagnosing ACL tears.	15-37 years old. Mean: 23 years.	Range of 47-349 days. Mean: 195 days. Median: 168 days.	Sensitivity and Positive Predictive Value (PPV) for DECT and MRI. Diagnostic performance difference between DECT and MRI, and interobserver agreement for both methods.	Of 21 patients, 19 had ACL tears confirmed by arthroscopy. DECT showed 76.3% sensitivity and 93.5% PPV, while MRI had 86.8% sensitivity and 91.7% PPV.	DECT demonstrated lower sensitivity than MRI for detecting ACL ruptures, but this difference was not statistically significant. Both methods showed a high positive predictive value.
Xin Zhang, Jie Zhou, Xiande Jin, Yuhui Ji, Kaile	Retrospective analysis. Patients with suspected	110	MRI for preoperative diagnosis and arthroscopy.	38 to 69 years. Mean:	-	Sensitivity, specificity, positive and negative	MRI showed a smaller ACL angle and higher L/H value than	MRI is an excellent imaging technique for the diagnosis of

Wang. 2024. China.	meniscal tears and anterior cruciate ligament injuries of the knee.			45.02 ± 5.24 years		predictive values, agreement rate, kappa value, and Youden index of MRI.	arthroscopy (P < .05), with both detecting 68 meniscal injuries and MRI demonstrating high diagnostic accuracy.	meniscal tears and anterior cruciate ligament injuries of the knee, demonstrating high sensitivity and accuracy.
Mengou Zhao, Ying Zhou, Junru Chang, Jie Hu, Huixia Liu, Shuhang Wang, Donglei Si, Yaqin Yuan, Haiyan Li. 2020. China.	Prospective design. Patients admitted to the hospital with highly suspected ACL injury.	78	MRI and arthroscopy	Range of 21- 59 years old. Mean: 42.64 ± 6.57 years old.	-	Sensitivity, specificity, and accuracy of MRI in diagnosing ACL injury, both overall and for complete/partial tears	MRI detected 95.45% of 66 arthroscopically confirmed ACL injuries with 94.87% accuracy, 95.45% sensitivity, and 91.67% specificity; accuracy was 92.86% for complete and 94.74% for partial tears.	MRI offers high accuracy in diagnosing ACL injury and shows good consistency with arthroscopic diagnosis.

Junaid Zeb, Muhammad I. Chaudary, Marwa Zeb, Mahmoud Mersal, Bilal Ahmad, Mohamed Alsonbaty. 2024. Pakistan.	Descriptive cross-sectional study. Patients with knee injury.	86	Anterior Drawer test, Lachman test, Magnetic Resonance Imaging (MRI).	Range of 18 to 55 years. Mean: 35.73 years $\pm$ 12.7	-	Sensitivity, specificity, and diagnostic accuracy of MRI, the Lachman test, and the Anterior Drawer test in detecting ACL tears, all compared to arthroscopy.	MRI showed 98.57% sensitivity, 87.5% specificity, and 96.51% accuracy in detecting ACL tears, outperforming the Lachman test (90%, 87.5%, 89.53%) and Anterior Drawer test (88.57%, 87.5%, 88.37%).	All three non- invasive tests (MRI, Lachman test, and Anterior Drawer test) can be effectively used for the diagnosis of anterior cruciate ligament injury with optimal results.
Kumar Shantanu, Shailendra Singh, Shubham Srivastava, Atul K. Saroj. 2021. India.	Prospective cohort study. Patients presenting with knee, specifically those with suspected	60	MRI, and diagnostic arthroscopy.	18-45 years	Approx. two months	Accuracy, sensitivity, specificity, positive predictive value (PPV), and negative predictive value	MRI showed higher accuracy for ACL (98.3%) and meniscal tears (medial: 86.7%, lateral: 93.3%) compared to clinical exams (ACL:	MRI is an accurate and non-invasive modality for assessing ligamentous and meniscal injuries of the knee.

	anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), and meniscus injuries.					(NPV) of clinical examination and MRI against arthroscopy for ACL, PCL, and meniscal injuries.	88.3%, medial: 81.7%, lateral: 91.7%), with perfect sensitivity, specificity, and agreement ($\kappa=1.000$) for PCL tears in both; MRI was more sensitive, while clinical exams were more specific for meniscal injuries.	
Zijun Xu, Yichao Chen, Jianghua Zhu, Lin Zhang, and Peng Wu. 2021. China.	Comparative study. Patients with suspected partial ACL tears.	398	Routine MRI (MRI R) and maximum knee flexion in the lateral decubitus position MRI	Range of 17 to 65 years. Mean: $42.1 \pm$	Subacute (6 weeks–3 months), intermediate (53 months–1 year), and	Sensitivity and specificity of MRI R and MRI S against arthroscopy results	In 204 patients, MRI S detected partial ACL tears with 80.3% sensitivity vs. MRI R's 48.8%, especially in the	MRI of partial ACL tears using maximum knee flexion in the lateral decubitus position significantly

			(MRI S) examinations.	9.6 years.	chronic groups (>1 year post- injury)		intermediate stage (94.4% vs. 51.4%), while both showed similar specificity (~89–96%) and no difference in diagnosing complete tears.	improved the diagnostic rate compared to routine MRI examination.
Kun Li, Felix Young Jhonatan, Zhaohui Yu, Jiachen Liu, Lixin Huang, Huilin Yang, Jun Du. 2024. China.	Retrospective design. Patients who received both MRI and arthroscopy examinations of the knee joint.	42	1.5-T MRI scans using both standard sequences and the new modified DPP- TSO-Sag-FS- PDWI sequence & Arthroscopy.	Men mean: 29 ± 7 years (range: 19-54 years). Women mean: 31 ± 12 years (range:	<1 month	Diagnostic consistency and diagnostic accuracy metrics (sensitivity, specificity, accuracy, positive predictive value (PPV), and negative	The new DPP-TSO- Sag-FS-PDWI sequence showed higher consistency ($K > 0.83$), better repeatability ($K =$ 0.794), and greater accuracy (PPV > 84%)—notably improving Grade II injury diagnosis	The DPP-TSO- Sag-FS-PDWI sequence improves ACL injury diagnosis by enhancing anatomical detail and classification accuracy, especially for Grade II injuries.

				14-52 years).		predictive value (NPV).	(PPV: 92.3% vs. 53.9%).	
Qazi Shahrukh, Osama Sherjeel Khan, Qaisar Azim, Ahmad Jawad Mufti, Zahid Askar. 2023. Pakistan.	Prospective, cross-sectional design. Patients with a history of knee trauma and suspected meniscal and ligament injuries.	100	MRI with coronal T2 FSE, coronal PD FATSAR, and axial STIR sequences.	Range of 14 to 55 years of age.	-	Plain MRI in diagnosing cruciate ligament and meniscal injuries compared to arthroscopy	MRI showed high sensitivity for ACLI (93.4%) and PCLI (100%), but low PPV for PCLI (20%) and LMI (27.27%); MMI had moderate sensitivity (81.6%) and low specificity (45.3%).	MRI has high sensitivity and NPV for ACLI and PCLI. However, it has low sensitivity for LMI, low specificity for MMI, and low PPV for PCLI, MMI, and LMI.

The nine included studies, conducted between 2020 and 2024 in Egypt, Sweden, China, Pakistan, and India, examined MRI's diagnostic accuracy—often compared with arthroscopy—for anterior cruciate ligament (ACL) and associated knee injuries. Designs ranged from prospective observational and cohort studies to retrospective and cross-sectional analyses, with sample sizes from 42 to 398 patients aged 14–69 years. Most involved suspected or confirmed ACL tears, meniscal injuries, or combined pathologies, with several incorporating novel MRI sequences, special positioning, or other imaging modalities such as Dual Energy CT (DECT).

MRI consistently showed high sensitivity for ACL injuries (often >90%), with variable specificity and predictive values depending on injury type and imaging protocol. Mohamed Samir et al. (2024, Egypt) found ramp lesions in only 9% of ACL-injured patients, with arthroscopy outperforming MRI in their detection. Xin Zhang et al. (2024, China) and Mengou Zhao et al. (2020, China) reported sensitivities above 95% for ACL and meniscal injuries, while Kumar Shantanu et al. (2021, India) confirmed MRI's superiority over clinical exams (ACL accuracy 98.3%; medial meniscus 86.7%, lateral 93.3%). Xu et al. (2021, China) showed lateral decubitus MRI (MRI S) improved sensitivity for partial ACL tears (80.3% vs. 48.8%), especially in intermediate-stage injuries. Kun Li et al. (2024, China) validated the modified DPP-TSO-Sag-FS-PDWI sequence, which improved accuracy, repeatability ($K > 0.83$), and PPV (>84%), particularly for Grade II injuries.

Other comparisons found MRI outperforming clinical tests: Junaid Zeb et al. (2024, Pakistan) reported 96.5% accuracy for ACL tears, exceeding Lachman and Anterior Drawer tests. Björkman et al. (2022, Sweden) found MRI more sensitive than DECT (86.8% vs. 76.3%) with similar PPVs. Qazi Shahrukh et al. (2023, Pakistan) noted high sensitivity for ACLI (93.4%) and PCLI (100%), but low PPV for PCLI (20%) and LMI (27.27%), highlighting MRI's limitations in specific ligament evaluations. Overall, MRI is a reliable, non-invasive tool for diagnosing ACL and related injuries, with advanced protocols enhancing accuracy, although arthroscopy remains the gold standard for subtle lesions like ramp tears or challenging partial injuries.

DISCUSSION

This systematic review synthesized findings from nine studies published between 2020 and 2024, conducted in Egypt, Sweden, China, Pakistan, and India, assessing the diagnostic accuracy of magnetic resonance imaging (MRI) for anterior cruciate ligament (ACL) and associated knee injuries, often compared to arthroscopy as the reference standard. Across diverse patient populations (42–398 patients, aged 14–69 years) and study designs, MRI consistently demonstrated high sensitivity for ACL tears—frequently exceeding 90%—although specificity and predictive values varied depending on injury type, imaging technique, and timing post-injury. Several studies incorporated novel MRI sequences, special patient positioning, or emerging imaging modalities such as Dual Energy CT (DECT), highlighting ongoing innovation in musculoskeletal imaging. A key finding across multiple studies was the strong performance of MRI for detecting complete ACL tears, with accuracy values approaching or surpassing those of established clinical tests such as the Lachman and Anterior Drawer tests. For example, Junaid Zeb et al. (2024, Pakistan) reported MRI accuracy of 96.5%, exceeding that of Lachman (89.5%) and Anterior Drawer (88.4%) tests.

MRI also performed well in detecting partial ACL tears in several studies, but sensitivity in this context was more variable and benefited significantly from technical modifications. Xu et al. (2021, China) demonstrated that lateral decubitus MRI (MRI S) substantially increased sensitivity for partial ACL tears (80.3% vs. 48.8% with conventional MRI), especially in intermediate-stage injuries. Similarly, Kun Li et al. (2024, China) reported that the modified DPP-TSO-Sag-FS-PDWI sequence improved accuracy, repeatability ($K > 0.83$), and PPV ($>84\%$), particularly for Grade II injuries—findings that emphasize the potential of technical optimization to address persistent diagnostic gaps.

Meniscal and other ligamentous injuries present a more challenging diagnostic landscape, with medial meniscus injuries (MMI) showing moderate to high sensitivity (81.6% in Qazi Shahrukh et al., 2023) but lower specificity and PPV, partly due to MRI's limitations in distinguishing acute from healed tears and detecting subtle lesions such as ramp lesions. For instance, Mohamed Samir et al. (2024, Egypt) reported that arthroscopy identified ramp lesions in 9% of ACL-injured patients, many of which were missed by MRI, underscoring the need for enhanced protocols or adjunct techniques. Emerging machine learning (ML) and deep learning (DL) approaches—such as 3D U-Net segmentation,⁽¹⁵⁾ transformer-based models,⁽¹⁶⁾ ACL-

DNet and ACL-SNet architectures, and random forest algorithms achieving AUC 0.944 for ramp lesion prediction(17)—offer promising solutions by boosting diagnostic accuracy and efficiency. Furthermore, lightweight, interpretable, and automated systems facilitate real-time clinical deployment, potentially reducing radiologist workload while improving detection of these elusive lesions.(18)

Comparative imaging studies refine the diagnostic approach to ACL injuries. MRI remains the gold standard, showing higher sensitivity than DECT (86.8% vs. 76.3%) with similarly high PPV (Björkman et al., 2022). DECT serves as a valuable alternative when MRI is unavailable or contraindicated, offering rapid assessment in acute trauma and in patients with metal implants, and can be cost-effective in select settings.(19-21) Ultrasound provides a portable, cost-effective option for emergency settings, patients with MRI contraindications, or those requiring dynamic functional assessment.(22-25) Time since injury influences MRI accuracy—its sensitivity advantage is most pronounced in intermediate injuries (3 months–1 year) but diminishes in subacute or chronic cases (Xu et al.). Early MRI can better detect associated injuries such as medial meniscal tears, which increase over time.(26, 27) Protocol optimization, including oblique sequences and reduced interslice intervals, enhances visualization, particularly in acute cases,(28) while chronic injuries remain challenging due to partial tears, cartilage damage, and complex pathologies.(29) These findings position MRI as an adaptable platform whose performance can be improved through tailored protocols and integration with adjunct imaging. Incorporating such evidence into structured clinical pathways can standardize care, reduce delays, and improve outcomes. E-referral systems linked to pathways enhance coordination without compromising results,(30) standardized approaches reduce waiting times, and regional pathways shorten hospital stays after surgery.(31, 32) Multidisciplinary collaboration further benefits complex cases like spinal metastases,(33) though adoption requires resource investment, adaptation to heterogeneous patient populations, and leveraging high-yield referrer types such as sports physicians and physiotherapy-led services.(34)

The clinical significance of this review lies in providing updated, multi-country evidence supporting MRI as the first-line, non-invasive diagnostic tool for ACL and related knee injuries, with technical refinements offering substantial benefits in detecting partial tears and specific lesion types. Theoretically, it advances the framework of “precision imaging” in musculoskeletal radiology, where protocols are tailored to injury stage, type, and complexity.

However, limitations include heterogeneity in study design, MRI protocols, and injury classification, small sample sizes in some studies, and the fact that arthroscopy—used as the reference standard—may itself miss certain healed or subtle lesions. Future research should focus on standardizing MRI protocols for ACL and meniscal evaluation, conducting longitudinal analyses of injury stage-dependent accuracy, integrating AI-assisted interpretation for subtle lesion detection, performing cost-effectiveness evaluations of advanced MRI protocols, and exploring comparative effectiveness with alternative modalities such as DECT and ultrasound in targeted clinical scenarios.

CONCLUSION

MRI remains a highly sensitive, non-invasive modality for diagnosing ACL and associated knee injuries, with accuracy often surpassing clinical tests and approaching arthroscopy. It performs reliably for complete ACL tears, though sensitivity for partial tears and subtle lesions such as ramp lesions is limited, highlighting the need for protocol refinement, advanced imaging sequences, and adjunct approaches such as machine learning-based interpretation. Comparative studies consistently show MRI outperforming other imaging modalities, while ultrasound retains value in resource-limited or acute settings.

Despite its clinical utility, limitations such as variability in imaging protocols, small sample sizes, and dependence on arthroscopy as a reference standard constrain current evidence. Future research should focus on standardized imaging protocols, longitudinal validation of MRI performance, integration of AI-assisted systems in real-world practice, and comparative effectiveness analyses across diverse populations to optimize diagnostic pathways and improve patient care.

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