ORIGINAL RESEARCH

Diagnostic Accuracy of MRI in Knee Meniscus Tear and ACL Injury

Xin Zhang, MM; Jie Zhou, BM; Xiande Jin, BM; Yuhui Ji, MM; Kaile Wang, MM

ABSTRACT

Objective • Knee injuries are very common and may lead to other secondary injuries if effective treatment is lacking. In addition to standardized physical examination, magnetic resonance imaging (MRI) is sometimes considered an aid in the diagnosis of knee trauma. In order to have a more accurate diagnosis of knee injuries, we compared MRI with arthroscopic findings in this study to evaluate the diagnostic accuracy of MRI for meniscal tears and anterior cruciate ligament injuries of the knee.

Methods • One hundred and ten patients with suspected meniscal tears and anterior cruciate ligament injuries of the knee who were admitted to our hospital from June 2020 to June 2022 were selected as study subjects, and the clinical data of the patients were retrospectively analyzed. All patients underwent MRI for preoperative diagnosis, and the sensitivity, specificity, MRI findings, and confirmation of diagnosis were compared and analyzed, and the accuracy of MRI in diagnosing meniscal tears and ACL injuries of the knee was analyzed.

Results • The mean ACL angle was (98.0 ± 5.4) in the MRI group and (118.0 ± 6.8) in the arthroscopic group, the difference between the two groups was statistically significant $P < .05$. The mean L/H value of the ACL was (2.12 ± 0.38) in the MRI group and (1.81 ± 0.19) in the arthroscopic group, which was statistically different between the two groups ($P < .05$). Among the patients, 68 meniscal injuries were found in the MRI examination, including 45 cases of knee meniscal tears and 23 cases of anterior cruciate ligament injuries. The sensitivity, specificity, positive and negative predictive values, agreement rate, kappa value, and Youden index of MRI in diagnosing meniscal tears and ACL injuries were all high.

Conclusions • In terms of sensitivity and accuracy, MRI is an excellent imaging technique for the diagnosis of meniscal tears and anterior cruciate ligament injuries of the knee. (*Altern Ther Health Med.* [E-pub ahead of print.])

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INTRODUCTION

The knee is an important complex joint in the human body, responsible for frequent and complex athletic functions, as well as being the main weight-bearing joint, making knee injuries common.[1] Most of them are caused by inappropriate sports, sports injuries, high falls, and car accidents.[2] Injuries can cause swelling, pain, loss of motion, and even interfere with daily activities, and lack of timely and effective post-injury treatment can lead to knee instability, further accelerating secondary damage to other ligaments, articular cartilage, and other important structures within the joint, causing the onset and progression of knee degeneration.[3] The meniscus is an important structure in maintaining the stability of the knee joint and plays a major role in weight bearing, transmission and distribution of compressive loads, and absorption of external forces.[4] Meniscal injuries are also one of the most common knee injuries and are primarily trauma-induced.[5] According to the literature, the prevalence of meniscal tears in the asymptomatic population is approximately 36%.[6] It is most common in the lateral meniscus in young adults. The incidence of meniscal degeneration with tears increases with age, and injuries to the medial meniscus are more common in middle-aged and older adults.[7] The discoid meniscus is the most common type of meniscus and is prone to a high number of injuries.[8]

MRI has a high resolution of soft tissues and a high spatial resolution, and it is a non-invasive examination method for the diagnosis of knee injuries with a superiority that cannot be achieved by other imaging modalities.[9] A variety of MRI findings have been proposed to identify knee meniscus tears and anterior cruciate ligament (ACL) injuries, including meniscocapsular separation with or without fluid-like signal intensity, peripheral irregularity or tear involving the posterior horn of the medial meniscus, and posteromedial tibial plateau bone marrow edema.[10]

The aim of our study was to map the grading criteria of ACL injuries, to clarify the accuracy of MRI diagnosis of ligament injuries for different numbers of soft tissue injuries, to clarify whether the number of ligament injuries is related to the accuracy of MRI diagnosis of meniscal injuries, and to clarify whether ACL injuries are related to the accuracy of MRI diagnosis of meniscal tears.

PATIENTS AND METHODS

Recruitment of Study Participants

One hundred and ten patients with suspected knee meniscus tears and anterior cruciate ligament injuries were selected as the study population. They were admitted to our hospital from June 2020 to June 2022. Among them, there were 58 male and 52 female patients, with their age ranging from 38 to 69 years, with a mean age of (45.02 ± 5.24) years. Inclusion criteria: (1) the presence of joint swelling, pain, instability, and locking by clinical examination; (2) the presence of positive features by anterior-posterior abduction testing, supination and extension testing, axial shift testing, and float testing; (3) voluntary participation in the study and signed informed consent. Exclusion criteria: (1) history of osteoarthritis; (2) intra-articular tumor-like lesions; (3) history of knee surgery associated with rheumatoid arthritis, and missing or incomplete clinical data.

Detection methods

MRI examination. Procedure: Two MRI scanners (manufacturer: Siemens, United Imaging: model: 1.5T, 3.0T superconducting type) were used in our hospital, and the knee phased array surface coil and 1.5T and 3.0T field strength were applied, and the scanning parameters: TE and TR in coronal SE T2WI were set to 90 ms and 2100 ms, respectively, and TE and TR in Philips and United Imaging were set to 18 ms and 540 ms, and TE and TR in aspheric SE. Patients were instructed to lie supine with the lateral femoral arch parallel to the angled canal position, with the lateral and medial pedicles of the femur parallel to the coronal position and the inferior pole of the bone at the level of the center of the coil. Two experienced imaging physicians jointly reviewed and analyzed the images, and assessed the extent of the ACL injury and meniscal tear in the knee. The meniscus was considered normal if it showed a regular and uniform low signal; if it showed a focal high signal within the meniscus and did not extend to the joint surface, the meniscus was considered normal; if the anterior cruciate ligament of the knee showed a low signal band with smooth edges in the coronal and sagittal planes, it was normal. If the anterior cruciate ligament showed a limited band of abnormal signal with good ligament morphology, it was partially torn. While, if the anterior cruciate ligament showed wavy distortion and continuous interruption, it is a complete rupture.[10]

Arthroscopy. The patient was placed in the supine position under lumbar anesthesia and a conventional incision was made on the anteroinferior and posteroinferior knee joints, followed by arthroscopy. The main objective was to observe the morphology, alignment and laxity of the patient's ACL, the texture and morphology of the meniscus and the texture and morphology of the articular cartilage.

Diagnostic criteria

MRI diagnostic criteria: (1) Meniscal tear: Abnormal linear, striated, or stellate fissure-like signals appear within the black meniscus, extending to the articular cartilage surface, and the meniscus is deformed or reduced in size. Cruciate ligament injury: (2) MRI manifestation of cruciate ligament injury: abnormally increased signal or heterogeneous signal changes within the ligament, but parts of the fibers are intact. Arthroscopic diagnostic criteria: (1) Meniscus tear: under direct visualization under the arthroscopy, the posterior horn of the medial meniscus is often obscured by the internal femoral capsule, and the obscured portion is not observable by the arthroscopy, it is necessary to probe the posterior horn with a probe with a blunt hook to determine whether the posterior horn is damaged. (2) Ligament injury: Based on intraoperative findings and physical examination under anesthesia. A complete rupture of the ACL is seen intraoperatively with synovial hemorrhage as the primary manifestation, and the overlying synovial membrane may also be ruptured with white mop-like tissue in the collagen bundle of the ACL. In some partial ACL injuries, the synovial membrane may be intact but there may be evidence of hemorrhage. In a few cases, the diagnosis is unclear and an anterior labral test may be performed intraoperatively. An incomplete rupture may be diagnosed if the continuity of the ACL is intact and only laxity is present. If necessary, arthroscopic examination of the posterior joint space can be performed for the posterior cruciate ligament.

Observed indicators

Sensitivity is the proportion of the number of people in the patient group with positive results by diagnostic tests, and sensitivity = number of true positive cases/ (number of true positive cases + number of false negative cases). Specificity is the proportion of the number of people in the non-patient group with negative results from diagnostic tests, and specificity = number of true negative cases/(number of false positive cases + number of true negative cases).

Statistical methods

All statistical data in this study were entered into excel, and SPSS 28.0 was used for statistical calculation.

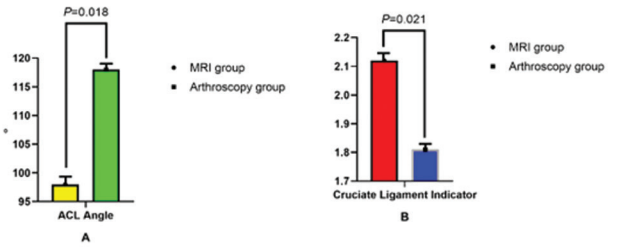
Measurement data conforming to the normal distribution were expressed as Mean ± SD, independent samples *t* test was used, count data were compared by chi-square test, and rank data were compared by rank sum test. $P < .05$ was considered statistically significant.

RESULTS

Bending and flexion index measurement results

Compared with (118 ± 6.8) in the arthroscopic group, the mean ACL angle in the MRI group was (98 ± 5.4), and the difference between the two groups was statistically significant ($P < .05$). The mean L/H value of the ACL in the MRI group was significantly larger than that in the arthroscopic group, with (2.12 ± 0.38) in the MRI group and (1.81 ± 0.19) in the arthroscopic group, and there was a statistical difference between the two groups ($P < .05$). See Figure 1.

Figure 1. Bending and Flexion Index Measurement Results

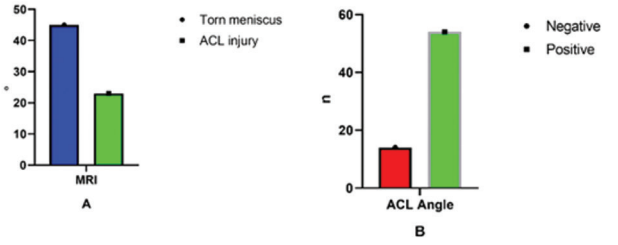


Note: The mean ACL angle was significantly smaller in the MRI group than in the arthroscopic group ($P < .05$). The mean ACL L/H value was significantly larger in the MRI group than in the arthroscopic group ($P < .05$).

MRI and arthroscopic diagnostic results

MRI diagnosis showed meniscus injury in 68 patients, including 45 cases of meniscus tear in the knee and 23 cases of ACL injury. Arthroscopic diagnosis showed meniscal injuries in 68 patients, of which ACL angle was positive in 54 cases and negative in 14 cases. See Figure 2.

Figure 2. MRI and Arthroscopic Diagnostic Results

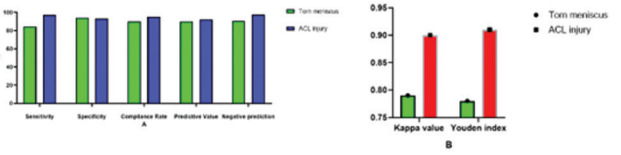


Note: Both MRI and arthroscopy diagnosed showed meniscal injuries in 68 cases. Among them, MRI diagnosed 45 cases of knee meniscus tear and 23 cases of anterior cruciate ligament injury. Arthroscopic diagnosis showed 68 cases of meniscus injury, of which 54 cases were positive and 14 cases were negative.

Evaluation of MRI diagnostic results

The sensitivity, specificity, positive and negative predictive values, compliance rate, kappa value and Youden index of MRI in the diagnosis of meniscal tears and anterior cruciate ligament injuries were all relatively high. See Figure 3.

Figure 3. Evaluation of MRI Diagnostic Results



Note: MRI has high sensitivity, specificity, and positive and negative predictive values for the diagnosis of meniscal tears and anterior cruciate ligament injuries.

DISCUSSION

Knee meniscus injury is a relatively common and frequent sports injury.[11] One study found that patients with congenital knee laxity were much more likely to develop a knee meniscus injury than normal individuals.[12] In addition, degeneration and injury to the lateral cartilage of the knee meniscus are relatively more common in patients with congenital abnormalities of the knee meniscus.[13] MRI is the best method for evaluating articular cartilage because it can image all parts of the body at multiple angles and planes with high resolution, and can more objectively and specifically visualize anatomic tissues and adjacent relationships in the body, as well as evaluate soft tissue injuries and fluid collections.[14,15] MRI has a high sensitivity for edema and hemorrhage and can clearly show the injury in multiple planes to aid in the clinical assessment of the extent of the disease and subsequent treatment.[16,17] They form a fibrous layer of cartilage and tendons that work together to stabilize a knee joint.[18] They are located on the medial and lateral articular surfaces of the tibial plateau and may be divided into medial and lateral meniscus, both thick on the outer surface and thin on the inner surface.[19]

The intact meniscus presents as a homogeneous low signal on MRI, with triangular anterior and posterior angles of the meniscus bilaterally in the dislocated position, and synovial fluid infiltration when meniscal injury causes degeneration and tears.[20] Infiltration within the degenerated and torn meniscus confines water molecules to the subdivided interfacial region, increasing proton density in this region while presenting a high signal in the low-signal meniscus.[21] The rotation of the tibia around the fixed femur during knee flexion and abduction exposes the meniscus, which is highly susceptible to injury when external forces are applied during this time.[22] In general, medial meniscus tears occur primarily in the lower portion of the posterior horn, and the lateral meniscus is prone to transverse and oblique tears.[23] Literature reports that the majority of ACL tears are reported to occur in the middle segment and 70% are complete.[24] In the acute phase, due to the disruption of the ligament as well as hemorrhage and edema, several direct signs of ligament tears may be seen on MRI, as evidenced by the invisibility of the normal ACL in the asplenic and coronal planes.[25] In the chronic phase, when the hemorrhage and edema have resolved, and also due to the bridging of the fibrous coagulation scar, it may sometimes resemble normal ligaments or only show abnormalities in the ligament corridor and alignment, such as thickening irregularities and

angulation of the ligaments, while the ligament signal is often not abnormal.[26] Therefore, the presence or absence of edema within the ligament and adjacent tissues is the primary basis for differentiating acute from chronic injuries.[27] In contrast, the MRI diagnosis of chronic ACL tears relies primarily on the abnormalities of the ligamentous corridor and alignment.[28]

MRI diagnosis of meniscal tears is mainly based on the sagittal plane in combination with the coronal plane, which shows high signal as well as artifacts of normal knee structure related to false negatives. Thus MRI scans are susceptible to volumetric effects and technical limitations.[29] However, magnetic resonance imaging (MRI), being a non-invasive diagnostic procedure, possesses the capability to effectively direct the clinical monitoring of patients, particularly those necessitating surgical intervention, and can provide a more precise evaluation of the pathology and alterations in patients prior to undergoing surgery.[30]

MRI can produce false negatives and false positives in the diagnosis of ACL rupture. Reasons for false negatives: Mild partial ACL injuries do not show significant abnormalities on MRI and are difficult to diagnose. Bridging of fibrous pockmarks in the chronic phase may resemble a normal ligament.[31-33] Reasons for false positives: The ACL fibers are damaged while the synovial membrane outside the ligament is intact, so the ligament damage is not detected arthroscopically and the diagnosis is missed. There is no damage to the ACL but the signal is abnormally high due to mucinous degeneration or eosinophilic red degeneration within the ligament. The ligament is sprained but not torn, and the result is an abnormal increase in signal within the ligament.[20]

There are some limitations to our study. First, we used a retrospective analysis, which has its limitations because many cases with the same characteristics and conditions were not included. In addition, some may argue that arthroscopy is not the gold standard of care for certain areas of meniscal injury. However, the involvement of one or two surgeons may minimize human error. For ligamentous injuries, especially multiple ligamentous injuries, arthroscopy is more variable because there is more space, and the arthroscope has easier access to the ACL tear, making the posterior knee structures more visible.

In conclusion, magnetic resonance imaging has good application in the diagnosis of knee meniscal tears and anterior cruciate ligament injuries, and the sensitivity and accuracy of MRI are high.

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AUTHOR DISCLOSURE STATEMENT

The authors have no potential conflicts of interest to report relevant to this article.

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XZ and KW designed the study and performed the experiments, JZ and XJ collected the data, JZ, XJ and YJ analyzed the data, XZ and KW prepared the manuscript. All authors read and approved the final manuscript.

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