https://doi.org/10.48047/AFJBS.6.6.2024.6577-6587

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

A Comparative Study on the Accuracy and Sensitivity of Ultrasound and MRI in Diagnosing Complete Knee Meniscal tears in Patients Referred to Besat Artesh Hospital in Tehran

Hamid Moradi[1]*, Mohammad Reza Azimi Aval[2], Davood Feizi[3], Zahra Sabooni Mameghani[4]

[1]Department of radiology،faculty of radiology, AJA University of medical sciences, Tehran, Iran
[2]Department of radiology, faculty of radiology, AJA University of medical sciences, Tehran, Iran
[3]Department of Orthopedic Surgery, Aja University of Medical Sciences, Tehran, Iran
[4]Department of radiology, AJA University of medical sciences, Tehran, Iran

[*]**Correspondence: Hamid Moradi**

Volume 6, Issue 6, 2024
Received: 03 Feb 2024
Accepted: 06 Apr 2024

doi:10.48047/AFJBS.6.6.2024.6577-6587

Abstract

Background and Purpose: This study was conducted with the objective of comparing the accuracy and sensitivity of ultrasound, as corroborated by MRI findings, in diagnosing complete tears of the knee menisci in patients referred to Army Mission Hospital from March 2022 to September 2023.

Materials and methods

The present study is a cross-sectional analytical investigation. The population under study comprised patients suspected of having medial and lateral knee menisci tears at Besat Artesh Hospital in Tehran. All patients underwent ultrasound examination by a radiologist, followed by MRI, which served as the standard method for diagnosing meniscal injuries. The results of the ultrasound and MRI, indicating the presence or absence of tears and the condition of the medial or lateral meniscus in each patient, were recorded separately. Subsequently, the data were analyzed to determine the sensitivity, specificity, negative predictive value (NPV), positive predictive value (PPV), and accuracy of the ultrasound.

Results: Additionally, the sensitivity, PPV, and accuracy of ultrasound in diagnosing partial meniscus tears were 95.4%, 100.0%, and 95.4%, respectively, and in diagnosing complete meniscus tears, these values were 85.7%, 100.0%, and 85.7%, respectively. Furthermore, the specificity, NPV, and accuracy of ultrasound in diagnosing menisci without tears were 85.2%, 100.0%, and 85.2%, respectively.

Conclusion:Given the high sensitivity and specificity of ultrasound in diagnosing medial and lateral meniscal tears, as well as partial and complete knee meniscal tears, compared to MRI, it can be employed as a primary imaging modality for patients suspected of having meniscal tears.

Keywords: Sonography, Magnetic Resonance Imaging (MIR), meniscus tear, Knee, Sensitivity, Specificity

Introduction

Knee meniscal injuries are common. Twisting injuries are the primary cause of acute meniscal tears. Crescent-shaped pads of fibro-cartilage located between the femoral condyles and the tibial plateau are the two menisci in the knee joint (1-3). Menisci reduce the effect of weight and spread of the force on the knee, stabilize the knee during rotation, and lubricate the knee joint. The outer one-third of the meniscus has a relatively rich blood supply, which is called the red zone. The inner two-thirds lacks a strong blood flow and is referred to as the white zone. The peripheral red area is vascularized by the perimeniscal capillary network (4). This vascular network supplies about 50% of the meniscus in neonates and only 10-30% in adults. Access to this source of blood in the red area causes healing and a better prognosis of non-degenerative tears. In contrast, a tear in an avascular white area has little potential for spontaneous healing (5).

Untreated large complex tears can disrupt the smooth motion of the knee and cause joint effusion. Additionally, it may cause early-onset osteoarthritis. Meniscal injuries can occur separately or along with collateral or cruciate ligament tears. Meniscal tears can be classified as simple or complex. They can also be classified as medial, lateral, or posterior (based on location), traumatic or degenerative, and horizontal, vertical, radial, parrot-beak, or bucket-handle. The meniscus can be torn from the tibia bone at the anterior or posterior end, which is called meniscal root tear (6.) An acute meniscal tear occurs mostly when a person changes his direction in a way that his knee is rotated, while the knee is bent and the same leg is in its place (7). Such a maneuver imposes compressive, rotational, and shearing stresses on the meniscus. When such stresses are excessive, it can cause meniscal tears. Chronic degenerative tears occur in older patients with minimum twisting or stress (8).

Patients with untreated meniscal tears may complain of locking, sticking, or popping of the knee weeks after the injury. They also may simply report a vague feeling that the knee does not move properly. This feeling of instability is related to proprioception misinformation that occurs when a fragment of the meniscus floats between two articular surfaces. It creates the feeling that the knee is not in its right position. Locking does not mean the complete inability to move the knee, but it means the inability to open the knee fully due to the interference of the torn meniscus (9).

Depending on the type and location of the tear, the accuracy of the physical examination for meniscal tears varies (10). Patients with partial, horizontal, or anterior meniscal tears may have a normal knee examination. These tears often do not interfere with normal knee motion, so they are less likely to cause dysfunction or mechanical symptoms. Multiple positive examination findings in the proposed mechanism make the diagnosis of meniscal injury possible. A set of small observational studies that evaluated using ultrasound for the diagnosis of meniscal tears reported sensitivity from 83 to 100% and specificity from 71 to 89% (11). In these studies, ultrasound was compared with arthroscopy and MRI findings. More studies are needed to determine the overall ultrasound accuracy in the evaluation of meniscal tears. MRI can determine the extent and type of meniscal tear. It is the

most sensitive imaging method for detecting small tears (12). However, an MRI is not necessary in most cases unless surgery is considered. Based on a systematic review, MRI has a sensitivity and specificity of 91.4% and 81.1%, respectively, for medial meniscal tears and 76% and 93.3% for lateral meniscal tears (13).

MRI has shown a limited capacity to determine which tears can be regenerated by surgery ((14-15). In a study on 74 asymptomatic volunteers with no history of knee injury, the presence of meniscal tears in MRI increased from 13% in people aged below 45 years old to 36% in older patients (16).In a population-based sample of 991 subjects, the prevalence of meniscal tears evident on MRI was even higher among patients aged 70 to 90 years so 40% of female and 50% of male subjects showed symptoms. In another study, MRI was performed in both knees of 100 patients with unilateral meniscal tears (18). Fifty-seven patients had meniscal tears on the symptomatic side. Among these 57 patients, 36 patients also had a tear on the asymptomatic side. None of the 43 patients without a meniscal tear on the symptomatic side had an injury on the opposite side. In the study by Elshimy et al. (19) in 2023, the diagnostic accuracy of portable ultrasound (POCUS) in detecting meniscus and collateral ligament injuries compared to MRI was examined. For this purpose, a blind cross-sectional observational study was conducted on 60 patients with suspected clinical injuries in the meniscus and collateral ligament scheduled for arthroscopy or surgery.

These patients underwent POCUS and MRI of the knee before the intervention. The findings of both imaging methods were compared according to the operative and arthroscopy findings. A study by Mohamed Mostafa et al. (20) in 2019 investigated the role of ultrasound in the diagnosis of meniscal tears compared to patients undergoing MRI imaging. In this study, the sensitivity of ultrasound in the diagnosis of meniscal tear was 88.8%, the specificity was 77.2%, and the accuracy was 80.6%. Given what was stated, a comparative study was conducted on the accuracy and sensitivity of ultrasound and MRI in the diagnosis of complete knee menisci tears in patients.

Materials and Methods

This cross-sectional-analytical and double-blind study was conducted on all patients with suspicion of knee meniscal injury referred by an orthopedic surgeon after obtaining the approval of the ethics committee in the research of the Army University of Medical Sciences in 2024. The convenience sampling method was used to select the subjects who had consent to participate in the study. The exclusion criteria included the patient's unwillingness to continue participating in the study, fear of doing an MRI, and doing an MRI in a center other than Baath Hospital. Based on a similar study (21), the required sample size in this study was calculated to be 70 people. In all patients, the study was first explained. After obtaining his consent, his demographic characteristics were recorded. Subsequently, the radiologist student, and professor performed a knee ultrasound on all patients and evaluated regarding for knee meniscal injury. Then, the patient was subjected to MRI as a standard method of examining meniscal injuries and was examined in terms of knee injuries. The results were recorded in a checklist including ultrasound and MRI results (tear or absence of tear, medial

or lateral meniscus injury). Finally, the data were analyzed regarding sensitivity, specificity, NPV, and PPV of ultrasound.

Knee meniscus injury in MRI was classified into the following three grades:

Grade 1 - a small focal area of hyperintensity without extension to the joint surface

Grade 2: Linear area of hyperintensity without extending to the joint surface

Grade 2a: linear hyperintensity without extending to the joint surface

Grade 2b: Abnormal hyperintensity in one view reaches the joint surface

Grade 2c: globular wedge-shaped hyperintensity without extending to the joint surface

Grade 3: Abnormal hyperintensity extended to at least one of the joint surfaces (upper or lower) and suggests a meniscal tear

Grades 1 and 2 are defined as partial tears and grade 3 as complete tears.

Finally, after collecting the data, they were analyzed using descriptive indices such as mean, standard deviation, quartiles, frequency, and percentage given the nature of the variables. For inferential analysis, the hypothesis of normality of the variables was first examined (using the Shapiro-Wilk test). In all cases, the two-sided P-value less than 0.05 was the criterion for statistical judgment. SPSS-26 software was used to perform statistical tests. Sensitivity (Sen), specificity (Spe), positive predictive value (PPV), negative predictive value (NPV), and accuracy (Acc) were calculated based on the following definitions.

True positive (TP): A sick person is correctly diagnosed as sick.

False positive (FP): A healthy person is wrongly diagnosed as sick.

True negative (TN): A sick person is correctly diagnosed as sick.

False negative (FN): A sick person is wrongly diagnosed as healthy.

$$Sen = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN}}$$

$$Spe = \frac{\mathrm{TN}}{\mathrm{FP} + \mathrm{TN}}$$

$$PPV = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FP}}$$

$$NPV = \frac{\mathrm{TN}}{\mathrm{FN} + \mathrm{TN}}$$

$$Acc = \frac{\mathrm{TP} + \mathrm{TN}}{\mathrm{Total\ Patients}}$$

Results

In the present study, 70 patients were included in the study based on the inclusion and exclusion criteria. The mean age and interquartile range (IQR) of the patients in this study were 27.5 and 18 years, respectively. The age range of patients in this study was also 17 to 44 years. In this study, 58.6% of patients were male.

Table 1) Determination of Sen, Spe, PPV, NPV, and Acc of ultrasound in the diagnosis of meniscal tear in all patients and separation of meniscus into lateral and medial

Variable	Number of patients	TP	FN	FP	TN	Sen	Spe	PPV	NPV	Acc
All menisci	70	33	3	5	29	6.91	2.85	8.86	6.90	5.88
Medial meniscus	47 (1.67)	23	1	4	19	8.95	6.82	1.85	0.95	3.89
Lateral meniscus	23 (9.32)	10	2	1	10	3.83	9.90	9.90	3.83	9.86

They were examined regarding knee meniscal tears, as shown in Table 1. Among them, 33 patients had positive MRI and true positive ultrasound (TP), 3 patients had positive MRI and negative ultrasound, 5 patients had negative MRI and positive ultrasound, and 29 patients had negative MRI and negative ultrasound. Sen, Spe, PPV, NPV, and Acc ultrasound to detect knee meniscal tears were obtained at 91.6, 85.2, 86.8, 90.6, and 88.5%, respectively. Additionally, based on clinical examinations, 67.1% of the patients were suspected of medial meniscal tear, and 32.9% suspected lateral meniscal tear. The sensitivity, specificity, PPV, NPV, and ultrasound accuracy for diagnosing medial meniscal tears were 95.8, 82.6, 85.1, 95.0, and 89.3%, respectively. Additionally, the sensitivity, specificity, PPV, NPV, and ultrasound accuracy to detect lateral meniscal tears were 83.3, 90.9, 90.9, 83.3, and 86.9%, respectively.

Table 2) Determining of Sen, Spe, PPV, NPV, and Acc of ultrasound in the diagnosis of meniscal tears based on gender

Suspected meniscal tear	Number of patients	TP	FN	FP	TN	Sen	Spe	PPV	NPV	Acc
Lateral in males	12 (1.17)	3	2	1	6	0.60	7.85	0.75	0.75	0.75
Lateral in females	11 (7.15)	7	0	0	4	0.100	0.100	0.100	0.100	0.100
medial in males	29 (4.41)	14	1	3	11	3.93	5.78	3.82	6.91	2.86
medial in females	18 (8.25)	9	0	1	8	0.100	8.88	0.90	0.100	4.94
Total in males	41 (6.58)	17	3	4	17	0.85	9.80	9.80	0.85	9.82
Total in females	29 (4.41)	16	0	1	12	0.100	3.92	1.94	0.100	5.96

As seen in Table 2, 58.6% of males and 41.4% of females were suspected of knee meniscal tear. The sensitivity, specificity, PPV, NPV, and ultrasound accuracy in the male population were 0.85, 80.9, 85.0, and 82.9%, respectively. In the female population, they were 100, 92.3, 94.1, 100, and 96.5 %, respectively. In addition, 17.1% of males and 15.7% of females were suspected of lateral meniscal tear. Sensitivity, specificity, PPV, NPV, and ultrasound accuracy in patients suspected of lateral meniscal tear in males were 60.0, 85.7, 75.0, and 75.0.7, respectively. It was 100% in all cases in females. Additionally, 41.4% of males and 25.8% of females were suspected of medial knee meniscal tear. The sensitivity, specificity, PPV, NPV, and ultrasound accuracy in patients suspected of medial meniscal tear were 93.3, 78.5, 82.3, 91.6, and 86.2%, respectively, in males and they were 100.0 88.8, 90.0, 100.0, and 94.4%, respectively, in females.

Table 3) Determining of Sen, Spe, PPV, NPV, and Acc of ultrasound in the diagnosis of meniscal tear based on age groups

Suspected meniscal tear		Number of patients	TP	FN	FP	TN	Sen	Spe	PPV	NPV	Acc
medial	20 <	15 (4.21)	6	0	3	6	0.100	6.66	6.66	0.100	0.80
	20-30	6 (5.8)	2	0	0	4	0.100	0.100	0.100	0.100	0.100
	30 >	26 (1.37)	15	1	1	9	7.93	0.90	7.93	0.90	3.92
Lateral	20 <	14 (0.20)	5	1	1	7	3.83	5.87	3.83	5.87	7.85
	20-30	4 (7.5)	2	1	0	1	6.66	0.100	0.100	0.50	0.75
	30 >	5 (3.7)	3	0	0	2	0.100	0.100	0.100	0.100	0.100
Total	20 <	29 (4.41)	11	1	4	13	6.91	4.76	3.73	8.92	7.82
	20-30	10 (3.14)	4	1	0	5	0.80	0.100	0.100	3.83	0.90
	30 >	31 (3.44)	18	1	1	11	7.94	6.91	7.94	6.91	5.93

Based on Table 3, 41.4% were under 20 years old, 14.3% were 20 to 30 years old, and 44.3% were over 30 years old. The sensitivity, specificity, PPV, NPV, and ultrasound accuracy in the diagnosis of knee meniscal tear in the age group less than 20 years were 91.6, 76.4, 73.3, 92.8, and 82.7%, respectively. In the age group of 20 to 30 years old, they were 80, 100, 100, 83.3, and 90%, respectively. In the age group above 30 years, they were 94.7, 91.6, 94.7, 91.6, and 93.5%, respectively. In addition, 21.4% in the age group under 20 years old, 8.5% in the age group 20 to 30 years old, and 37.1% in the age group over 30 years old were suspected of medial meniscal tear. Sensitivity, specificity, PPV, NPV, and ultrasound

accuracy in the diagnosis of medial meniscal tear of the knee in the age group of less than 20 years were 100.0, 66.6, 66.6, 100.0, and 0.80%, respectively. In the age group of 20 to 30 years, they were 100.0% in all cases, and in the age group above 30 years, they were 93.7, 90.0, 93.7, 90.0, and 92.3%, respectively. In addition, 20.0% in the age group below 20 years, 5.7% in the age group 20 to 30 years, and 7.3% in the age group above 30 years were suspected of lateral meniscal tear. Sensitivity, specificity, PPV, NPV, and ultrasound accuracy in the diagnosis of lateral meniscal tear in the age group less than 20 years were 83.3, 87.5, 83.3, 87.5, and 85.7%, respectively. In the age group of 20 to 30 years, they were 66.6, 100.0, 100.0, 50.0, and 75.0%, respectively. In the age group above 30 years, they were 100% in all cases.

Table 4) Determining of Sen, PPV, and Acc of ultrasound in the diagnosis of meniscal tear based on the tear grade in MRI

Meniscal tear	Number of patients	TP	FN	FP	TN	Sen	PPV	Acc
partial medial	17 (1.36)	16	1	0	0	1.94	0.100	1.94
Complete medial	7 (8.14)	7	0	0	0	0.100	0.100	0.100
partial lateral	5 (7.21)	5	0	0	0	0.100	0.100	0.100
Complete lateral	7 (4.30)	5	2	0	0	4.71	0.100	4.71
Partial	22 (4.31)	21	1	0	0	4.95	0.100	4.95
Complete	14 (0.20)	12	2	0	0	7.85	0.100	7.85

Table 4 is based on positive MRI results in patients. Thus, FP and TN are zero since MRI is negative in both cases. Therefore, only the sensitivity, PPV, and ultrasound accuracy to detect tears detected in MRI were calculated based on the tear grade (partial and complete) since MRI findings should be positive in patients to diagnose a partial or complete tear. The sensitivity, PPV, and ultrasound accuracy in diagnosing partial tears of the medial meniscus were 94.1%, 100.0%, and 94.0% respectively, in the diagnosis of complete medial meniscal tear, they were 100.0% in all three cases, in the diagnosis of partial medial meniscal tears, they were 100.0% in every 3 cases, and in the diagnosis of complete lateral meniscal tear, they were 71.4%, 100.0%, and 71.4%, respectively. In addition, the sensitivity, PPV, and ultrasound accuracy in the diagnosis of partial tears of all menisci (medial and lateral) were 95.4, 100.0, and 95.4%, respectively, and in the diagnosis of complete tears, they were 85.7, 100.0, and 85.7%, respectively .

Table 5) Determining of Spe, NPV, and Acc of ultrasound in the diagnosis of meniscus without tears based on MRI findings

Meniscus	Number of patients	TP	FN	FP	TN	Spe	NPV	Acc
Healthy medial	23	0	0	4	19	6.82	0.100	6.82

Healthy lateral	11	0	0	1	10	9.90	0.100	9.90
Total	34	0	0	5	29	2.85	0.100	2.85

Table 5 is based on negative MRI results in patients, confirming the absence of meniscal tears. Accordingly, the specificity, NPV, and Acc of ultrasound in the diagnosis of meniscus without tears in all patients in this study were 85.2, 100.0, and 85.2%, respectively. In the medial meniscus, they were 82.6, 100.0, and 82.6%, respectively. In the lateral meniscus, they were 90.9, 100.0, and 90.0%, respectively.

Discussion and Conclusion

The present study compared the accuracy and sensitivity of ultrasound and MRI in the diagnosis of complete knee menisci tears in patients referred to Besat Artesh Hospital in 2024. According to a systematic review, MRI has sensitivity and specificity of 91.4% and 81.1% for medial meniscal tears and 76% and 93.3% for lateral meniscal tears, respectively (13). In the present study, the sensitivity, specificity, PPV, NPV, and ultrasound accuracy in the diagnosis of medial meniscal tears were 95.8, 82.6, 85.1, 95.0, and 89.3%, respectively. They were also 3 83.9, 90.9, 90.9, 83.3, and 86.9%, respectively, in the diagnosis of lateral meniscal tears. Unlike the previous studies, this study examined the diagnostic value of ultrasound in the diagnosis of partial and complete knee meniscal tears.

The results revealed that the sensitivity, specificity, and ultrasound accuracy in the diagnosis of partial meniscal tears were 95.4, 100.0, and 95.4% respectively, and they were 85.7, 100.0, and 85.7%, respectively, in the diagnosis of complete meniscal tears. Furthermore, the specificity, NPV, and ultrasound accuracy in diagnosing meniscus without tears in all patients in this study were 85.2%, 100.0%, and 85.2%, respectively. In addition, the impact of age on ultrasound diagnosis was investigated in this study. Patients in three age groups, less than 20 years old, 20 to 30 years old, both of which are common ages for sports injuries, and over 30 years old were examined. In the study by Alizadeh et al. (22), patients in the age group of younger and equal to 30 years and the age group of above 30 years were examined. The mentioned study only examined the presence of tears in the medial meniscus, but the present study investigated medial and lateral meniscal tears.

The sensitivity, specificity, PPV, NPV, and ultrasound accuracy in the diagnosis of medial meniscal tear in the 30-year-old group were 100, 88.9, 96.5, 100, and 97.3%, respectively, and 83.3, 71.4, 92.6, and 81.1%, respectively, in the <30-year-old group. In the present study, the sensitivity, specificity, PPV, NPV, and ultrasound accuracy in the diagnosis of medial meniscal tear were 91.6, 76.4, 73.3, 92.8, and 82.7%, respectively, in the age group under 20 years, and they were 80, 100, 100, 83.3, and 90.0%, respectively, in the group of 20 to 30 years old and 94.7, 91.6, 94.7, 91.6, and 93.5% in the age group over 30 years. Thus, ultrasound with the same accuracy as MRI can be used in diagnosing medial and lateral meniscal tears.

Several factors can be involved in the differences in the ultrasound accuracy in the diagnosis of meniscal tears. First, the increased rate of mucoid degeneration in the meniscus may cause heterogeneous echogenicity. This may be misdiagnosed as a tear. However, abnormal signal extension to the articular surface can be a diagnostic clue. Second, the

reduction in the cartilage thickness may lead to the narrowing of the joint space, limiting the field of vision during ultrasound. Finally, marginal osteophytes around the knee may create posterior shadows, limiting the penetration of the ultrasound beam. Thus, it provides an inappropriate view of the deep parts of the meniscus.

However, Wareluk et al. (2011) (23) conducted a prospective study of 160 knees in 80 patients (42 females and 38 males) with a mean age of 36.2 years and a range of 16 to 70 years. All patients underwent ultrasound and arthroscopy. The data of subjects in three different age groups (<30 years, 30-50 years, and <50 years) were analyzed. The overall sensitivity, specificity, positive predictive value, and negative predictive value of ultrasound examination in meniscal tear assessment were 85.4%, 85.7%, 67.3%, and 94.4%, respectively. The highest sensitivity (more than 90%) was obtained in the medial menisci. In addition, age, gender, body mass index, weight, physical activity, mechanism of injury, and time elapsed since the injury did not significantly affect the usefulness of ultrasound. Both knee joints were examined in all patients in the present study. The joints of the injured knee were compared with the asymptomatic knee of the opposite side to understand the sonographic appearance and to more accurately define the normal anatomical features of the meniscus.

The primary limitation of our study was the relatively small number of patients. It is recommended that future studies consider arthroscopy as the diagnostic standard for meniscal tears, and accordingly, calculate and compare the sensitivity, specificity, PPV, NPV, diagnostic ultrasound accuracy, and MRI. Although our study is experimental, it provides potentially important findings for the diagnosis of medial and lateral meniscal tears. Based on our results, ultrasound is more sensitive and specific for meniscal tear diagnosis compared to MRI. Thus, ultrasound is recommended as an effective initial examination in people suspected of medial and lateral meniscal injuries with partial or complete tears.

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