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Original Article

The Role of High-Resolution Ultrasound in Evaluation of knee Meniscal Lesions: A Comparative Study to Magnetic Resonance Imaging

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ABSTRACT

Background: Meniscal lesions are the commonest lesions in the knee, and usually caused by athletic activities. Meniscal lesions diagnosis may need costly imaging modalities like magnetic resonance imaging [MRI]. However, MRI is not available in all medical facilities, especially peripheral and rural continents. Thus, there is a need for a readily available imaging tool. Knee ultrasound may be used as diagnostic modality as it is devoid of economic burden of MRI.

Aim of the work: The current work aimed to estimate the diagnostic accuracy of knee ultrasound and to correlate it with the results of MRI for diagnosis of knee meniscal lesions.

Patients and methods: Fourty patients with acute or chronic knee pain, swelling or movement restrictions were included. All were assessed by referral physician and submitted to knee ultrasound and MRI. Then results of ultrasound were correlated with that of MRI and diagnostic accuracy measures of ultrasound were calculated [sensitivity, specificity, positive predictive value [PPV], negative predictive value [NPV] and overall accuracy].

Result: Out of included patients, 28 were males. Their mean age was 36.7 ± 14.4 years [ranged from 15 to 60 years]. The ultrasound detected meniscal tear in 90%, degeneration in 47.5%, Para-meniscal cyst in 25% and discoid meniscus in 40%. The MRI detected meniscal tear in 80%, degeneration in 65%, para-meniscal cyst in 25% and discoid meniscus in 37.5%. For meniscal tear, the ultrasound had 83.3% sensitivity, 50.0% specificity, 93.7% PPV, 25.0% NPV and overall accuracy of 80.0%. Otherwise, the overall accuracy was 75.0% for degenerative changes and 95.0% for para meniscal cyst. Finally, it was 67.5% for discoid meniscus.

Conclusion: Ultrasound has shown reasonable diagnostic accuracy in detecting meniscal lesions. It could be used as a screening tool to prevent unnecessary and costly MRI.

Keywords: High resolution Ultrasound; Magnetic Resonance Imaging; Accuracy; Knee; Meniscal tear

INTRODUCTION

During the past decades, physical and sports activities have been practiced by increasing number of peoples all over the world. This exposes people to higher risk of musculoskeletal injuries [1]. The knee is the most prone joint for such injuries that needs treatment [2]. Menisci are critical for load transmission, stun ingestion, and joint adjustment [3]. Meniscal lesions are the commonest among knee injuries, associated with pain and disability and difficult in clinical diagnosis. The medial meniscus is more common due to its less mobility [4]. The difficulty of diagnosis and diagnostic dilemma are due to overlapping soft tissue structures and more data are required before initiation of treatment [5]. It is important to exactly and conveniently determine the meniscal tear to arrange proper treatment and reduce the tear burden [3].

Ultrasound was used to evaluate musculoskeletal system for nearly more than 25 years without gaining wide acceptance. An interest has been re-emerged in recent years, due to innovations, simplicity, non-invasiveness, rapid performance, wide availability and higher patient acceptance [6]. However, magnetic resonance imaging [MRI] was the gold-standard imaging method for assessment of knee injuries [7]. Some recent studies suggested ultrasound as a reasonable alternative assessment method. One of the main advantages of ultrasound attributed to its multi-planar capabilities. Moreover, it permits proper compression, dynamic assessment and compare right to left sides [8, 9].

Musculoskeletal ultrasound [MSUS] is usually used to assess soft tissue structures and detect fluid collection [10]. MSUS could also guide biopsy, aspiration, and injection of different drugs [11]. Unlike MRI, sonography permits acquisition of dynamic information. In this dynamic pattern of imaging, the patient executes a movement while the sonographer holds the probe relative to an anatomic landmark [12].

AIM OF THE WORK

We conduct this study to correlate role of high frequency ultrasound in evaluation of knee meniscal lesion with MRI. The diagnostic accuracy of ultrasound in relation to MRI did not addressed sufficiently. The current work could add to available evidence.

PATIENTS AND METHODS

This is a prospective study, which involved 40 patients. They were selected and the study had been completed from July 2021 to March 2022. They were 28 males and 12 females. Their age ranged between 15 and 60 years. They were referred to the Department of Radiology, Al-Azhar University Hospital [New Damietta]. The inclusion criteria were any patient with clinically suspected of meniscal lesions, from both genders. On the other hand, patients known to have contraindications for MRI [e.g. an implanted magnetic device, or pacemakers] or patients with previous knee operations, were excluded from the study.

Ethical aspects: All the patients before taking any data or doing any imaging techniques, were informed about the study and its aim. Their consent was signed. All collected data were confidential and exclusively used for the research purposes**.**

Methodology: All patients were subjected to detailed clinical history and physical examination [carried out by referring physician] and radiological investigations. The radiological workup included high resolution ultrasound examination magnetic resonance imaging.

Imaging techniques

A. High resolution ultrasound examination: Patient was prepared by full exposure of the knee joint from upper half of the thigh to upper half of the leg. All investigations were carried out by Volsune E6 ultrasound machine using superficial 7-10 MHz transducer. The medial meniscus anterior horn was examined in supine position with 30°-90° of knee flexion. The probe was positioned in sagittal and coronal planes of the medial & lateral knee joint aspects **[Figure 1]**. The posterior horn, on the other hand, of the medial meniscus was examined in prone position with some degree of knee flexion achieved by a paper roll placed at lower leg to achieve a 20º of knee flexion; the transducer was placed in sagittal and coronal-oblique planes. It appears as a homogeneous hyperechoic triangular structure with its apex pointing to the joint. The medial meniscus body was seen deep to the medial collateral ligament [MCL] [13]. The lateral meniscus anterior horn was examined in supine position with 30°-90° knee flexion, the probe was positioned in sagittal & coronal planes of the medial & lateral aspects of the joint. The lateral meniscus posterior horn was imaged in the prone position with knee flexion by a paper roll placed at the lower leg to achieve 20º of knee flexion. The probe was placed in sagittal and coronal-oblique planes **[Figure 2]**. The lateral meniscus has a similar hyperechoic triangular appearance to the medial meniscus on the sagittal view. The popliteus tendon may be seen to run between it and the lateral collateral ligament [LCL] [14].

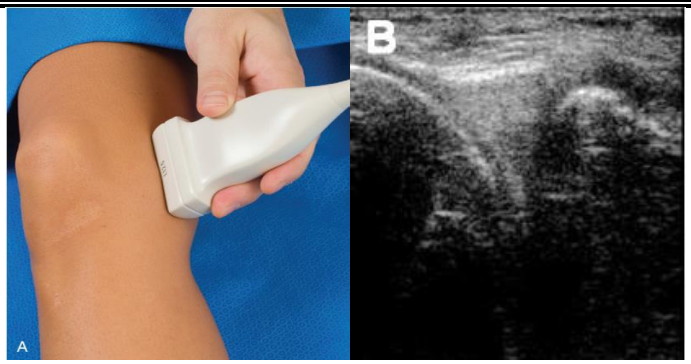

Figure [1]: The patient in supine position to evaluate anterior horn

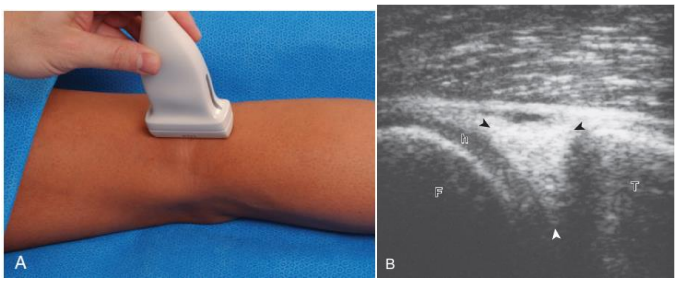

Figure [2]: The patient in prone position to evaluate posterior horn

Meniscal degeneration appears as hypoechic line not reaching the articular surface, while meniscal tear appears as hypoechoic line reaching the articular surface. Simple meniscal cyst appears of clear aspect with posterior enhancement, while complex cyst appears with turbid aspect or fluid-fluid level [14].

B-MRI examination: All metallic objects were removed from the patient's body. The maneuver completed in supine position starting by the feet. The knee was positioned in the knee coil and immobilize with cushions. Cushions were set under the knee for extra comfort. The laser beam localizer was centered over the lower border of patella. The maneuver was completed by Philips, Achieva 1.5 Tesla-XR-Netherlands 2010 magnet. Briefly, while patient in the supine position, the knee had been extended with slight external rotation [10-15°] in an extremity coil to optimize the signal to noise ratio. Images were obtained mainly in the coronal and sagittal planes. The sagittal images were obtained with external rotation of the knee to permit imaging in the ACL plane. Axial images were scanned to study the supporting ligaments around the knee. Routine MRI sequences were used [e.g., turbo spin echo-sagittal proton density, T1 and T2 weighted images as well as coronal short-tau inversion-recovery [STIR] and axial T2 weighted images. Additional sequences were sometimes used as sagittal STIR, coronal T1 or T2 weighted images. These were obtained using a field of view of 16-20 cm, slice thickness of 3-5 mm, and a matrix of 352×320. A skip of [0–20% of slice thickness] was used between imaging sections.

Statistical Analysis: Data were analyzed using Statistical Package for Social Science [SPSS] version 24 [IBM® Armonk, USA]. Quantitative data were expressed by their means and standard deviations [SD]; while qualitative data were expressed by their relative frequencies and percentages. Sensitivity, specificity, positive predictive value [PPV], negative predictive value [NPV] and accuracy of the ultrasound in relation to MRI [the gold-standard] were calculated by equations, after building 2x2 tables to determine true positives [TP], true negatives [TN], false positives [FP] and false negatives [FN], where sensitivity equals [TP/TP+FN], specificity = [TN/TN+FP], PPV = [TP/TP+FP], NPV = [TN/TN+FN], and accuracy= [TP+TN/TP+TN+FP+FN].

RESULTS

The current work included 40 patients. They were 28 males [70.0%] and 12 females [30.0%]. Their age ranged between 15 and 60 years. Four of them [10.0%] had associated comorbid medical conditions in the form of diabetes mellitus and hypertension. Pain was the commonest clinical presentation [60.0%], followed by trauma [40.0%] and swelling [10.0%] [Table 1].

Results of ultrasound and MRI examinations were presented in table [2]. On ultrasound, tear was the commonest [36; 90.0%], followed by degeneration, discoid meniscus and finally para-meniscal cyst. The same order was reported by MRI with different frequencies.

For diagnosis of tear, the results of ultrasound in relation to MRI revealed that, it had 83.3% sensitivity, 50% specificity, 93.7% PPV, 25% NPV and overall accuracy of 80.0%. otherwise the overall accuracy for degenerative changes was 75.0% and for Para meniscal cyst was 95.0%. Finally, it was 67.5% for discoid meniscus [Table 3].

Figure [3] presented image results of a 40-year-old female patient, complained of right knee pain for 4 months with a history of trauma. By ultrasound [A and B] of the right knee, PHLM showing linear hypoechoic streak reaching the articular surface [Arrows]. MRI showed that, the PHLM showing had signal intensity reaching articular surface at sagittal PD w/fat image [C], and the coronal stair image showing mid-joint effusion. The final diagnosis was grade III meniscal tear of PHLM [flap tear/ fish mouth tear], with mild joint effusion.

Figure [4] presented ultrasound and MRI images of a 50 years old male patients complaining progressive knee left knee pain with no history of trauma. The ultrasound of the left knee PHMM showing horizontal linear hypoechoic streak reaching the articular surface [A]. by MRI, sagittal PD w/fat image, PHMM showing abnormal signal intensity reaching the inferior articular surface [B], and MRI coronal stair image showing encysted fluid collection seen at the medial aspect of the knee joint bursa [C]. The final diagnosis was horizontal degenerative tear of the PHMM, with medial collateral bursa.

Table [1]: Characteristics of studied populations

Variables		Statistics
Gender [No., %]	Male	28 [70.0%]
	Female	12 [30.0%]
Age [years]	Mean ±SD	36.7 ± 14.4
	Min. – Max.	15- 60
Associated chronic diseases [No., %]	None	36 [90.0%]
	Diabetes mellitus and hypertension	4 [10.0%]
Clinical presentation [No., %]	Pain	24 [60.0%]
	Trauma	16 [40.0%]
	Swelling	4 [10.0%]

Table [2]: Results of ultrasound and magnetic resonance imaging

Variables		Statistics
Ultrasound results [No., %]	Tear	36 [90.0%]
	Degeneration	19 [47.5%]
	Para-meniscal cyst	10 [25.0%]
	Discoid meniscus	16 [40.0%]
Magnetic resonance imaging [No., %]	Tear	32 [80.0%]
	Degeneration	26 [65.0%]
	Para-meniscal cyst	10 [25.0%]
	Discoid meniscus	15 [37.5%]

Table [3]: Evaluation of ultrasound results in relation to magnetic resonance imaging results

[n = 40]	Tear	Degeneration	Para-Meniscal cyst	Discoid meniscus
True positive	30 [75.0%]	17 [42.5%]	9 [22.5%]	9 [22.5%]
True negative	2 [5.0%]	13 [32.5%]	29 [72.5%]	18 [45.0%]
False positive	6 [15.0%]	2 [5.0%]	1 [2.5%]	7 [17.5%]
False Negative	2 [5.0%]	8 [20.0%]	1 [2.5%]	6 [15.0%]
Sensitivity	83.3%	68%	90%	60%
Specificity	50%	86.7%	96.7%	72%
PPV	93.7%	89.5%	90%	56.3%
NPV	25%	61.6%	96.7%	75%
Accuracy	80%	75%	95%	67.5%

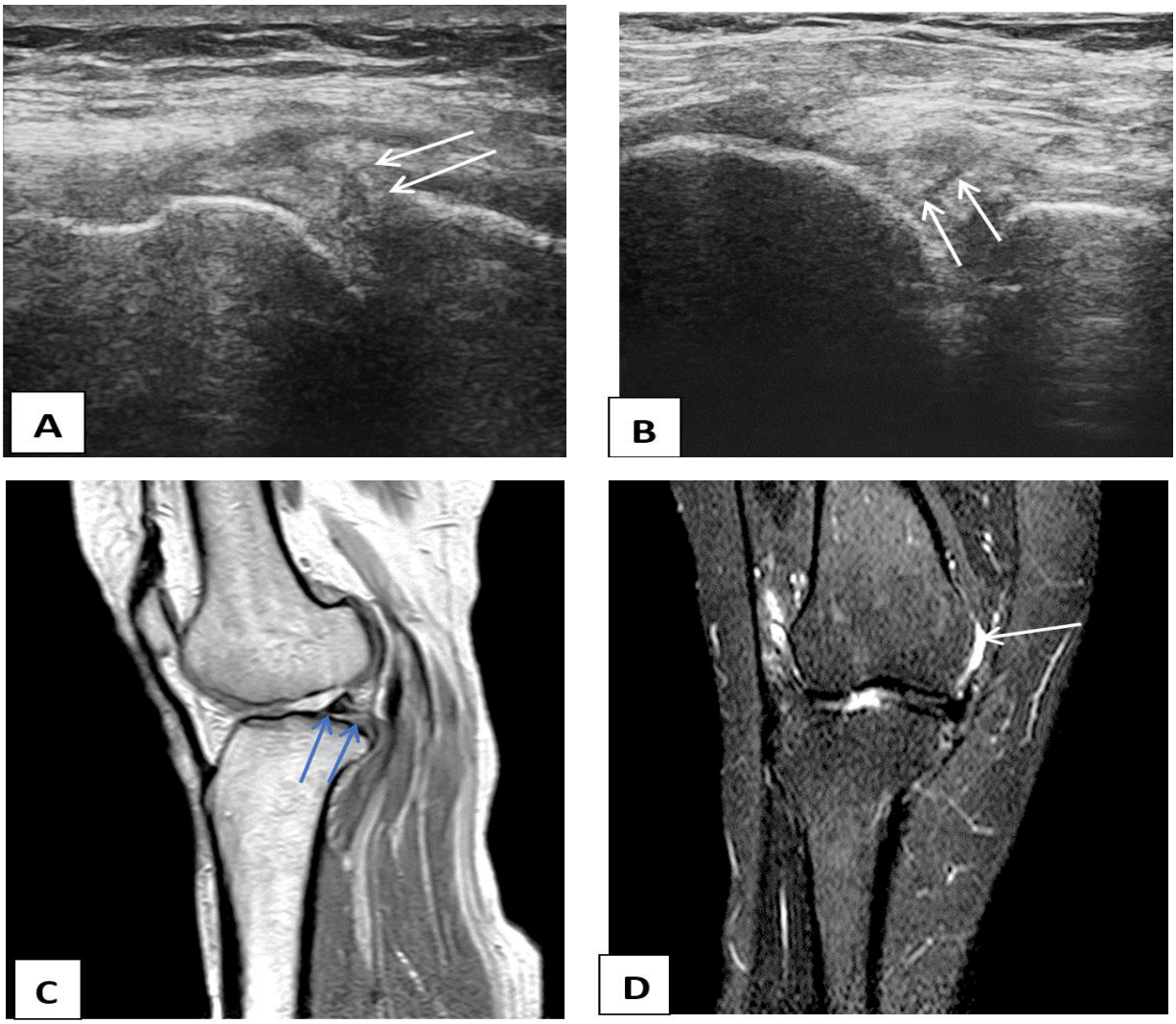

Figure [3]: Ultrasound and MRI examinations of the right knee showing grade III meniscal tear of PHLM [flap tear/ fish mouth tear], with mild joint effusion

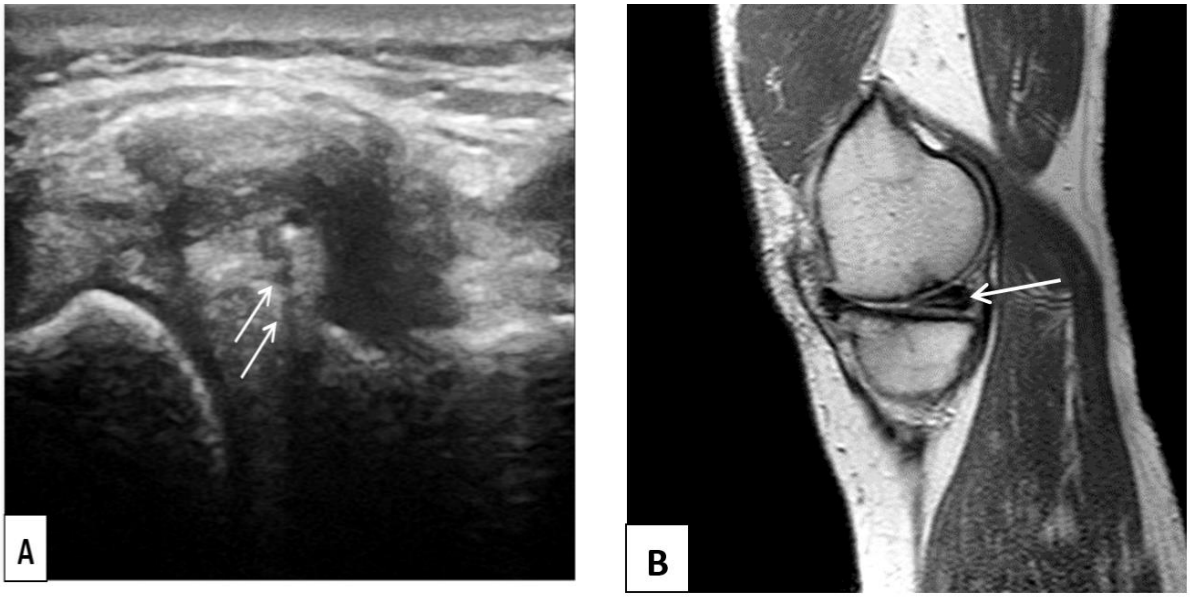

Figure [4]: Ultrasound [A] and MRI [B and C] images of a 50 years old male, showing horizontal degenerative tear of the PHMM, with medial collateral bursa

DISCUSSION

Sports and physical injuries witnessed significant increase during the past decades, with increased risk of musculoskeletal injuries due to direct trauma [15]. Meniscal lesions are the common and most painful conditions with marked disability and difficult clinical diagnosis [4].

Ultrasound gained wide acceptance and used for imaging of different tissues and organs in traumatic, inflammatory and degenerative conditions. In addition, it is able to monitor joints, ligaments, muscles and cartilaginous disease conditions [16]. However, its diagnostic accuracy against gold-standards are not fully investigated. Thus, the current study had been carried out to investigate this point. Results showed high proportion of male gender [70.0%], which in line with Nasir [17] who reported 78% of their patients were males. This could be explained vulnerability of males to more trauma during daily or sport activities. But females are at higher risk for weight-bearing meniscal degeneration due to obesity.

Ultrasound was able to diagnose 83.3% of meniscal tears. It had specificity of 50%, PPV of 93.7%, NPV of 25% and accuracy of 80%. In line with these results, Mahdy *et al.* [18] on 15 patients, reported on the ultrasound sensitivity in the diagnosis of medial and lateral meniscal injuries. The sensitivity of AHMM was 100%, sensitivity of PHMM was 77.78%, sensitivity of AHLM was 100% and sensitivity of PHLM was 100%. Overall sensitivity was 88.24%. Another study of Rohren *et al*. [19] showed that, the sensitivity, specificity, PPV, NPV of high-resolution US to detect meniscal tear were 91.2%, 84.2%, 95.4% and 76.2% respectively. In addition, Akatsu *et al*. [20] included seventy patients for the assessment of the accuracy of a high-resolution ultrasound. The sensitivity was 83.3%, specificity of 50%, PPV of 93.7%, NPV of 25% and accuracy of 80%. Also, in the study of Imdad and Anjum [21], 125 patients were included, 71.2% were males. Sensitivity of meniscal injury were 81.3%, and specificity 38%, PPV was 66.3% and NPV was 57.6%. Elsayed *et al*. [22] included a total of 100 patients examined by high-definition US and undergo to MRI examination of the knee joint. The diagnostic performance of US compared to MRI showed that, the sensitivity reached [89.1%], specificity [72.2%], PPV [90.1%], NPV [70.1%], and accuracy [84.7%].

Regarding meniscal degeneration in the current study, ultrasound had the sensitivity of 68%, specificity of 86.7%, PPV of 89.5%, NPV of 61.6% and accuracy of 75%. These results are in agreement with Mostafa *et al*. [3] who examined sensitivity of ultrasound in detecting meniscal degeneration and reported sensitivity of 63.64%, specificity was 88.89%, while accuracy was 70.97%.

the ultrasound for para-meniscal cyst in the current work revealed sensitivity of 60%, specificity of 72%, PPV of 56.3%, NPV of 75% and accuracy of 67.5%. The Study of Darwish and Kamel [23] included 73 patients with knee swelling, associated pain and osteoarthritis. US identified 50 cases with cystic lesions [31 had synovial cysts, 24 were popliteal, 15 were ganglion, and 4 meniscal cysts], with overall 89.0% diagnostic accuracy. However out of 58 patients with confirmed knee cysts diagnosed with MRI, 50 were obtained by ultrasound. The sensitivity and specificity were 86.2% and 100% respectively. Also, in the study of Sorrentino *et al*. [24], ultrasound was able to elicit

the meniscal cysts in 49 out of 52 cases. The sensitivity, specificity, and accuracy of ultrasound in the diagnosis of meniscal cysts were 97, 86, and 94%, respectively, with a PPV of 94% and NPV of 92%. Sorrentino *et al*. [24] found that ultrasound had a sensitivity, specificity, PPV, and NPV of 94.23%, 100%, 100%, and 94.54%, respectively, for the diagnosis of meniscal cysts.

These results regarding Para-Meniscal cyst are different than the current study and this could be explained in the light of smaller sample size of 40 patients with exclusion of patients with previous knee operations.

In the current work, ultrasound for discoid meniscus revealed the sensitivity of 90%, specificity of 96.7%, PPV of 90%, NPV of 96.7% and accuracy of 95%. In line with these results, Yang *et al*. [25] included 21 men and 69 women [unlike the current work], with a mean age of 38.5 years. The parallel diagnostic test's sensitivities were 97.8% and specificity were 88.9%, which is suitable for screening of discoid lateral meniscus [DLM]; the series diagnostic test's specificity were 98.9% and sensitivity were 76.7%, which can be used to confirm the diagnosis of DLM.

Due to its advantages [e.g., wide availability, multiplanar capability, and its reasonable cost, high resolution ultrasound has been widely used to assess meniscal tears of the knee joint, with an 70.0% overall accuracy or more. The use of convex transducers, which able to fit in the anatomic concavity of the popliteal fossa, ultrasound achieves a 100% sensitivity and a 95% specificity in meniscal tears diagnosis. The PPV was reported to be 95% and 93% for the medial and lateral menisci, successively, and the NPV was 100% [26].

MRI was the gold standard for cystic and non-cystic soft-tissue conditions [23]. However, ultra-sound has many advantages over MRI. It is already available for use even in the primary clinic, dynamically and in real time, as shown in our study, it has the power to demonstrate physiological movements, and is simpler and more cost effective than MRI.

The limitation of the current work included small sample size [40 patients]. However, we could recommend starting with ultrasound as a screening tool. For negative examinations, follow-up, if no improvement, the second step is MRI to rule out different meniscal injuries. Future studies with large sample size are recommended to confirm these results.

In conclusion, ultrasound is a safe and an effective imaging method that can be suitable as a screening test for conditions associated with knee pain. It is a cheap, widely available with no contraindications. Thus, it should be the used as the first modality of choice in the assessment of knee pain, specifically in patients with contraindications to MRI.

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