Original Article

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Radiology Section

Diagnostic Accuracy of Ultrasonography in Evaluation of Knee Injuries with Magnetic Resonance Imaging Correlation

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ABSTRACT

Introduction: While considering the Magnetic Resonance Imaging (MRI) as 'gold standard' for detection of knee ligamentous and meniscal injuries, we are determining the usefulness of High Resolution Ultrasonography (USG) in various knee injuries and correlate the findings of USG with the findings of MRI.

Aim: To evaluate the role of sonography and MRI in patients with meniscal/ligamentous injuries of the knee and study their correlation.

Materials and Methods: This prospective study included 60 patients who were referred to the Radiology Department with clinically suspected meniscal/ligamentous injury of the knee. After detailed clinical examination, high resolution USG examination of the involved knee was performed together with an examination of the contralateral normal knee, followed by MRI of the symptomatic knee in all 60 patients. The MRI findings were considered as final. Sensitivity, specificity, accuracy for sonography in knee injuries was calculated with correlation with MRI.

Results: In the present study, the majority of patients were in age group 26-65 years, 60% were males and 40% were females (of a total of 60 patients). A total of 60 patients were diagnosed as having ligamentous/meniscal tears on USG and MRI. In the diagnosis of meniscal/ligamentous tears, the strength of agreement between USG and MRI was good.

Conclusion: USG of the knee shows promising results in the diagnosis of meniscal/ligamentous tears. A wide availability, cost effectiveness and better tolerability of USG make it a modality of first choice for evaluating knee injuries.

Keywords: Anterior cruciate ligament, Lateral meniscus, Ligaments, Tear

INTRODUCTION

The knee joint is a type of compound type of synovial joint. The ligaments constitute the major supporting framework of the knee joint. Due to limited bony support, stability of the joint is highly dependent upon the ligaments, cartilages, tendons and menisci and the same are more prone to injuries [1,2].

Clinical examination even by the most experienced staff using the strictest of clinical methods is not always enough to diagnose knee injuries. Arthroscopy has been considered as the gold standard for the diagnosis of knee injuries, but is invasive, expensive and requires day surgery admission. MRI is now the non invasive gold standard for the diagnosis of knee injuries but MRI has long examination times, and is expensive [3].

High Resolution Ultrasonography (HRUS) is a becoming a leading imaging modality in the evaluation of the musculoskeletal system as it is readily available and economical. USG evaluates the fibrillar anatomy of muscles, tendons and ligaments. Other advantageous of USG are ability to compress, dynamically assess structures and compare easily with the contralateral side. There have been studies done in the past that evaluated the accuracy of either USG or MRI in detection of knee injuries and only few studies compared these two methods [4,5].

We done double blinded, prospective study to assess the effectiveness of USG in diagnosis of knee injuries and compare the results with MRI.

MATERIALS AND METHODS

This was a prospective study that included 60 patients with knee injuries referred to a Radiology Department of SGRD charitable hospital attached to SGRD Institute of Medical Sciences and Research Sri Amritsar. The study was conducted for a period of one year from October 2016 to October 2017

after getting approval from the ethical committee of the institute. Informed consent from all the patients was taken before inclusion in the study. High resolution, real time USG examination of the involved knee was done together with an USG examination of the contralateral normal knee for comparison in all patients followed by MRI of the symptomatic knee in all patients. The USG and MRI examination was done by two consultant radiologists, one doing the USG and the other consultant radiologist doing the MRI image analysis with both having enough experience in the field of musculoskeletal system and both were blinded to each others' findings. There was no intraobserver variability.

The patients who were clinically suspected of knee ligamentous or meniscal injuries were included in the study. While, patients with contraindications to MRI, those with known or diagnosed fracture/dislocation involving the knee on plain radiography and who had undergone knee surgery for any reason were excluded from the study.

Sonography Technique and Patient Position

Technique and equipment: The sonography was performed using Volison E8 Expert BT09 (Wipro GE) with SP10-16-D wide band linear transducer and frequency of 7-18 Mhz.

Patient position: Patient was examined in supine position with knee flexed in 20°-30° (except for the evaluation of the posterior aspects of the knee, which was evaluated in prone position with the knee extended and anterior cruicate ligament in which 60°-70° flexion of knee was done).

Medial collateral ligament and medial meniscus: For examining the medial compartment of the knee the patient´s leg was rotated externally with slight (20°-30°) flexion of knee. The medial collateral ligament is composed of two layers: a thick hyperechoic fibrillar superficial layer and a thinner deep layer. The medial meniscus is identified as a hyperechoic wedge shaped reflective structure between the femur and the tibia [6].

Lateral collateral ligament and lateral meniscus: For the examination of the lateral compartment of the knee the patient's leg was rotated internally, maintaining a slight (20°-30°) flexion. At this point, the anterior horn of the lateral meniscus and anteriorly the lateral collateral ligament, extending from the lateral femoral condyle to the lateral aspect of the fibular head is seen.

Posterior cruicate ligament: For visualising the posterior knee, the patient was made to lie in prone position with probe placed in the longitudinal plane. PCL appears as a hypoechoic band relative to the surrounding tissue on sonographic examination. The PCL is a homogenous C-shaped structure with uniform echopattern throughout its length. Normal range of thickness of the PCL is taken as 4-8 mm.

Anterior cruicate ligament: The knee joint was flexed to about 70°-80° in sitting position. While siting in front of the patient the ACL was examined by placing transducer on to the anterior aspect of the knee, slightly above the level of the tibial tuberosity and parallel to the Patellar Tendon (PT). The ligament frequently appears as a hypoechoic band but sometimes appears hyperechoic when in motion. In contrast to the soft tissue above the ACL that moves unrelated to the tibia position, the ACL is consistently attached to the tibia.

MR Technique and Protocol

MR scan was carried out on a Philips Gyroscan, Achieva 1.5 Tesla unit. The standard imaging protocol consisted of T1W axial, saggital, PD SPAIR coronal, PD SPAIR sagittal and PD SPAIR Axial [Table/Fig-1].

Sequences	TR	TE	THK	FOV	RFOV	NSA
T1W TSE SAG	450-500	15-25	3.0/0.7	210	80%	2
T1W TSE COR	450-500	15-25	3.0/0.7	210	100%	2
PD SPAIR COR	1500-3000	12-18	3.0/0.7	210	100%	3
PD SPAIR TRA	1500-3000	12-18	3.0/0.7	210	100%	3
PD SPAIR SAG	1500-3000	12-18	3.0/0.7	210	100%	3

[Table/Fig-1]: MRI protocol.

STATISTICAL ANALYSIS USED

The sensitivity, specificity and diagnostic accuracy of USG was determined with MRI correlation using the following formulas-

1. Sensitivity:

$$\frac{\text{True positive results}}{\text{True positive results + false negative results}} \times 100\%$$

2. Specificity:

$$\frac{\text{True negative results}}{\text{True negative results + false positive result}} \times 100\%$$

3. Accuracy:

$$\frac{\text{TP+TN}}{\text{No. of examinations}}$$

RESULTS

The study group comprised of a total of 60 patients with age ranging from 15 to 65 years. The majority of patients belonged to the age group between 26 and 35 years, comprising 36% of all patients [Table/Fig-2]. Men (70%) outnumbered women (30%) and the left knee was involved in the majority of patients (60%).

Evaluation of Anterior Cruciate Ligament (ACL) by ultrasound: Out of 60 cases, 26 cases were positive by USG. Only 18 cases of them proved to be positive by MRI, the other eight cases were negative by MRI.

Out of 60 cases, 34 cases were negative by USG and 29 of them proved to be negative by MRI, the other five cases were positive by MRI.

Age in years	Number of cases	Percentage (%)
< 25	8	13.3
26-35	22	36.6
36-45	14	23.3
46-55	10	16.6
56-65	6	10
Total	60	100

[Table/Fig-2]: Age distribution of patients.

Evaluation of Posterior Cruciate Ligament (PCL) by ultrasound: Out of 60 cases, six cases were positive by USG. Only four cases of them proved to be positive by MRI, the other two was negative by MRI.

Out of 60 cases, 54 cases were negative by USG and 46 cases proved to be negative by MRI, the other eight cases were positive by MRI.

Evaluation of medial meniscus by ultrasound: Out of 60 cases, 18 cases were positive by USG, only 14 cases of them proved to be positive by MRI, the other four cases were negative by MRI.

Out of 60 cases, 42 cases were negative by USG and 38 cases were proved to be negative by MRI. The other four cases were positive by MRI.

Evaluation of lateral meniscus by ultrasound: Out of 60 cases, 10 cases were positive by USG. Only six cases of them proved to be positive by MRI, the other four cases were negative by MRI.

Out of 60 cases, 50 cases were negative by USG and 41 cases proved to be negative by MRI. The other nine cases were positive by MRI.

Evaluation of Medial Collateral Ligament (MCL) by ultrasound: Out of 60 cases, 11 cases were positive by USG. All 11 cases were proved to be positive by MRI.

Out of 60 cases, 49 cases were negative by USG and 47 cases proved to be negative by MRI. The other two cases were positive by MRI.

Evaluation of Lateral Collateral Ligament (LCL) by ultrasound: Out of 60 cases, 12 cases were positive by USG. 11 cases were proved to be positive by MRI, one case was negative by MRI.

Out of 60 cases, 48 cases were negative by USG and 46 cases proved to be negative by MRI. The other two cases were positive by MRI.

[Table/Fig-3] shows the sensitivity, specificity and accuracy of sonography in meniscal/ligamentous injuries of the knee in correlation with MRI.

Structures	Sensitivity	Specificity	Accuracy
Anterior Cruciate Ligament (ACL)	78.2%	78.3%	78.3%
Posterior Cruciate Ligament (PCL)	33.3%	95.8%	83.3%
Medial Meniscus	77.7%	90.4%	86.6%
Lateral Meniscus	40%	91.1%	78.3%
Medial Collateral Ligament(MCL)	84.6%	100%	96.6%
Lateral Collateral Ligament (LCL)	84.6%	97.8%	95%

[Table/Fig-3]: Sensitivity, specificity and accuracy of ultrasound.

DISCUSSION

USG diagnosis of orthopaedic conditions has gathered pace in recent years. It has become popular because it is safe, quick, inexpensive and fairly reliable. USG diagnosis of knee injuries has been tried in various studies with variable results [6].

In the present study, 36 patients (60%) had injury in the left knee and 24 patients (40%) had injury in the right knee. Thus, the left knee was more frequently involved than the right knee.

The number of males was 42 and the females were 18. This could be explained by the fact that males are more vulnerable to such traumatic knee injury during daily activity and sports injury, while females are more vulnerable to meniscal degeneration resulting from weight bearing due to obesity. This correlates the with the study done by Abdel el Monem S et al., who found that traumatic injuries are more common in men [7].

Diagnostic Criteria for Tears on USG and MRI

Menisci on USG: Partial tear of menisci were diagnosed when hypoechoic or anechoic clefts were seen within the structure [Table/Fig-4a,b].

Complete meniscal tears were diagnosed when a separate fragment was identified or when there was abnormality extending beyond the free edge of the meniscus [8,9] [Table/Fig-5a,b].

Menisci on MRI: Two criteria for diagnosing a meniscal tear are commonly used [10,11]:

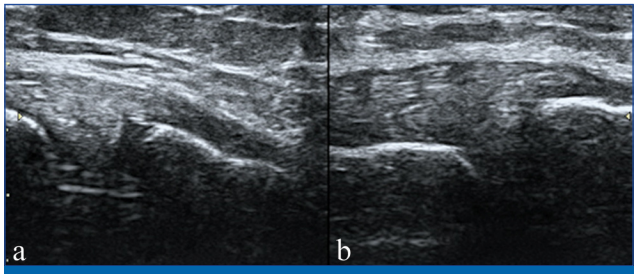
a) Abnormal meniscal morphology;

b) An intrasubstance area of intermediate or high signal intensity that unequivocally extends to the articular surface.

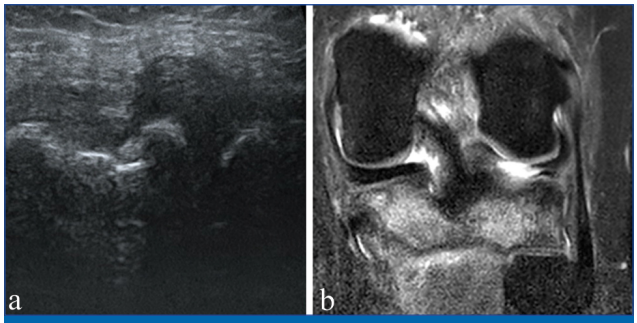
Grade 1: Intrameniscal high signal intensity of irregular or globular appearance that is confined within the meniscus and does not extend to the articular surface.

Grade 2: The signal is linear and does not intersect the inferior or superior articular surface. It may, however, contact the capsular margin at the posterior aspect of the meniscus.

Grade 3: Tears characterised by linear high or intermediate signal intensity that extends to the superior and/or inferior



[Table/Fig-4]: a) USG image depicts normal homogenous echogenicity medial meniscus; b) USG image depicts hypoechoic, displaced meniscus-meniscal tear. (left to right)



[Table/Fig-5]: a) USG image depicts hypoechoic extruded lateral meniscus-meniscal tear; b) PD SPAIR Coronal image shows hyperintense signal intensity in the body and posterior horn of lateral menisus which is reaching upto articular margins-meniscal tear.

articular surface [Table/Fig-5b].

Anterior cruicate ligament on USG: Tears of ACL are considered when there is [12,13]-

(a) Abnormal ligament showing complete interruption of the fibres [Table/Fig-6a-c].

(b) Presence of a hypoechoic collection or hematoma near the origin of ACL. [Table/ Fig-7a,b].

Anterior cruicate ligament on MRI: The signs for anterior cruciate ligament tear include [14]-

a) Discontinuity of the fibers of anterior cruciate ligament.

b) An abnormal contour of anterior cruciate ligament [Table/ Fig-6c].

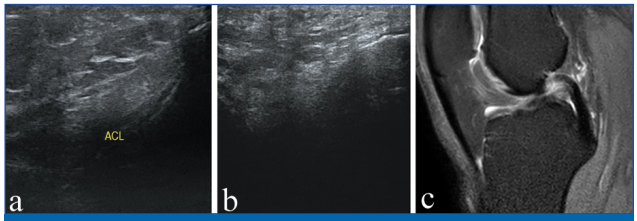
Posterior cruicate ligament on USG: PCL appears as a hypoechoic band relative to the surrounding tissue on sonographic examination [Table/Fig-8].Tear of the PCL were diagnosed as [15]-

(a) Wavy appearance increase in thickness (>10 mm).

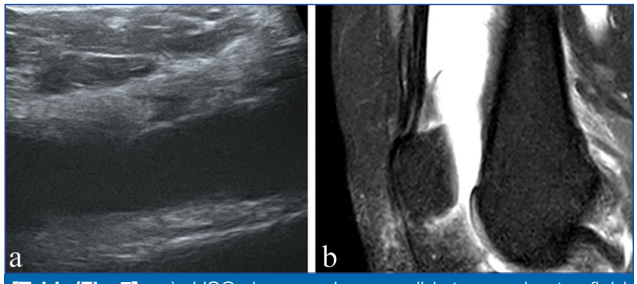
(b) Local indentation of the posterior margin or a wavy or indistinct posterior PCL margin.

(c) Heterogeneous echogenicity.

Posterior cruciate ligament on MRI - Acute tears of the PCL are usually manifested by thickening of the middle portion of the ligament with increased signal on both T1- and T2- weighted images [16].



[Table/Fig-6]: a) USG image depicts normal intact ACL in between the femur and tibia; b) USG image depicting absence of ACL fibres in between the femur and tibia; c) MRI PD SPAIR saggital image shows full thickness tear of the ACL. (left to right)



[Table/Fig-7]: a) USG image shows mild to moderate fluid accumulation in retropatellar region; b) PD SPAIR Saggital image shows moderate fluid accumulation in retropatellar, suprapatellar and in joint cavity. (left to right)

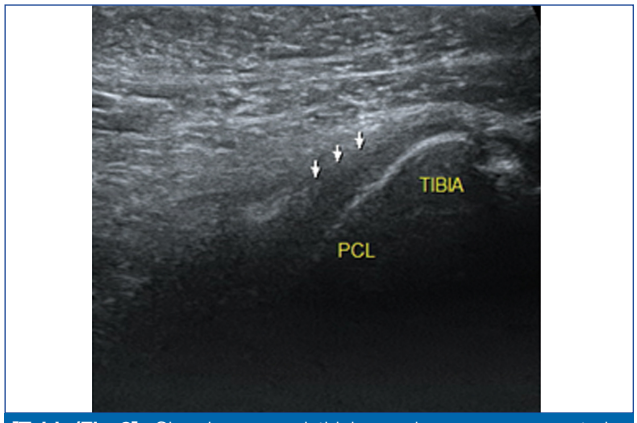
Collateral ligaments on USG - Torn collateral ligaments show thickening and heterogeneously hypoechogenicity in the ligament on USG [2].

Collateral ligaments on MRI- Classification of collateral ligament tears include [17,18]-

Grade 1: Lesions are defined as high signal intensity superficial to the MCL/LCL representing edema, with intact MCL/LCL fibers.

Grade 2: Lesions in which fluid signal extend partially through the MCL/LCL, although some fibers remain intact.

Grade 3: Lesions with complete discontinuity of the MCL/LCL fibers seen along with surrounding edema, consistent with a complete rupture.



[Table/Fig-8]: Showing normal thickness homogenous posterior cruicate ligament.

According to Ravichandra G et al., the sensitivity and specificity of USG in diagnosing medial meniscus tear was 62% and 80% and for lateral meniscus it was 23% and 89% respectively [8]. In the present study, the sensitivity and specificity of MRI in diagnosing medial meniscus tears is 58% and 88% and for lateral meniscus is 33% and 92% respectively. USG may be used as a screening tool prior to arthroscopy in selected cases where MRI is a contraindication or is not available or if the patient is not affording [8,19].

Attya MSA conducted a study in which he recorded an accuracy of 83.3 %, sensitivity of 81.2% and specificity of 84.2% of USG in diagnosis of ACL injury [16]. According to study done by Abdel el Monem S and Enaba MM the sensitivity and specificity of USG for ACL tears was 81% and 84% respectively, which were similar to results in present study [7].

According to Wang C et al., sonographic examination had a sensitivity of 83.3%, a specificity of 87.0% and an accuracy of 85.7% in detecting PCL tears [15]. In present study, the accuracy and specificity of USG in diagnosing PCL tears are nearly the same, but however sensitivity is lesser then latter study.

According to study done by Singh B et al., accuracy, sensitivity and specificity of USG in diagnosing medial collateral ligament tears were 96%, 83% and 97% respectively and for diagnosing lateral collateral tears accuracy, sensitivity and specificity were 96%, 80% and 97% respectively [20]. These results are similar to the present study.

[Table/Fig-9] shows the comparison of diagnostic accuracy of USG in detecting tears of present study with other studies.

The results show that USG has a moderate to high diagnostic value for medial and lateral meniscal tears. However, for diagnosing Grade 1 and Grade 2 meniscal tears USG has slightly low diagnostic value.

USG has moderate to high diagnostic value for full cruciate ligament tears and a low diagnostic value for detecting partial cruciate ligament tears.

However, for collateral ligament tears, USG is highly sensitive, specific and accurate investigation. There have been studies done in the past that evaluated the accuracy of either USG or MRI in detection of knee injuries but only few studies compared these two methods. The present study highlights the role of USG as an initial first line of investigation in evaluation of ligamentous/meniscal injuries of the knee. For patients with clinical suspicion of ligamentous/meniscal injury of the knee we recommend high resolution USG as an initial imaging modality of choice. MRI can be suggested as next line investigation for suspicious results of USG and for further evaluation.

LIMITATION

The present study has a limitation of sample size. We recommend that the study should be done on large number of patients as well as at multiple centres.

Studies	MCL	LCL	ACL	PCL	Medial meniscus	Lateral meniscus
Khan Z et al., [3]	-	-	86.6	98	93	98
Abdel el Monem S et al., [7]	-	-	83	90	73	86
Attya MSA [16]	-	-	84	90	73	88
Singh B et al., [20]	96	96	90	92	96	94
Present Study	96.6	95	73.3	83.3	86.6	78.3

[Table/Fig-9]: Comparison of diagnostic accuracy of ultrasound in detecting tears of present study with other studies.

CONCLUSION

Based on our results, it can be concluded that USG is an effective imaging modality that has a positive effect on the management of many patients presenting with knee injuries. Knee USG has high accuracy in diagnosing collateral ligament and meniscal tears. A wide availability, lower cost and better tolerability of USG make it a modality of first choice for evaluation of knee ligamentous and mensical tears. MRI can be reserved for patients with suspicious USG results.

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