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Original Research Article

Diagnostic Accuracy of Ultrasonography in the Assessment of Anterior Knee Pain

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Abstract

Introduction: Magnetic resonance imaging (MRI) is the gold standard for evaluating anterior knee pain (AKP), but it can be expensive and not readily accessible. Ultrasonography is an affordable and easily accessible alternative that provides dynamic evaluation without major contraindications. It has been shown to effectively diagnose knee joint pathologies like joint effusion, bursal fluid accumulation, and meniscal tears.

Materials and Methods: This cross sectional study included 80 patients with anterior knee pain who had both an ultrasonography and a recent MRI. One radiologist performed all the USG and the other interpreted all the MRIs. Both radiologists had at least 8 years of experience in performing USG and MRI. Diagnostic accuracy of ultrasonography as compared to MRI was analyzed using receiver operating characteristic curve (ROC).

Results: Ultrasonography had an overall diagnostic accuracy of 77.1%, sensitivity of 78.5% and specificity of 70.0% for AKP. It showed high sensitivity in detecting a bipartite patella (100%), infrapatellar bursitis (100%), joint effusion (93.9%), suprapatellar fat impingement (92.3%), and quadriceps tendinopathy (90.0%). However, it had low sensitivity in detecting patellar cartilage defects (0.0%), trochlear cartilage defects (78.9%) and Hoffa's fat pad impingement (70.0%).

Conclusion: Ultrasonography is a valuable diagnostic tool for anterior knee pain (AKP). However, it does have limitations in detecting cartilage defects and Hoffa's fat pad impingement, which can be better visualized using MRI.

Keywords: Accuracy, Anterior Knee Pain, Cartilage Defects, Magnetic Resonance Imaging, Ultrasonography

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Introduction

The knee joint is frequently assessed for internal derangement caused by various injury mechanisms and pathological disorders that result in pain and instability. [1,2] Knee injuries are particularly common and have a significant impact on quality of life, accounting for a substantial portion of musculoskeletal trauma seen in the emergency department. Since the stability of the knee joint relies on ligaments, muscles, tendons, and menisci, it is more prone to injury and should be thoroughly evaluated for anatomical and pathological factors. [3,4]

Anterior knee pain (AKP) is a frequent cause for orthopaedic consultation, but its differential diagnosis can be challenging due to overlapping categories. AKP is more prevalent among young adults, specifically those aged 15-30. It can lead to persistent impairment, limited activity, and a decreased quality of life. [5]

Magnetic resonance imaging (MRI) is a widely used, non-invasive imaging technique considered the gold standard for evaluating various knee pathologies and injuries. It provides detailed visualization of intra-articular knee structures, as well as the extra-articular ligaments, tendons, and periarticular muscles. Unlike other imaging methods, MRI does not involve radiation exposure and offers multiplanar capabilities. However, it can be expensive, may not be readily accessible, and has certain contraindications. [6–8]

Ultrasonography (USG) is a noninvasive, affordable, and easily accessible imaging technique that allows for dynamic evaluation. It is well-received by patients and does not have major

contraindications like MRI. It can even be performed on claustrophobic patients. Several studies have demonstrated that HRS can effectively diagnose knee joint pathologies such as joint effusion, bursal fluid accumulation, meniscal tears, ligament tears, tendon tears, bursitis, occult fractures, and tendonitis. [8,9] Additionally, USG provides high-resolution images of superficial knee joint structures, surpassing the capabilities of MRI in this regard. [10] The purpose of this study was to establish the role of ultrasonography for evaluation of knee joint pathologies, compared with MRI.

Materials & Methods

Study Type: A cross sectional study.

Study Population: This study included all patients who presented for an ultrasonography knee between January 2020 to December 2022 at the Department of Orthopedic and Radiodiagnosis at tertiary care hospital, Gujarat, with anterior knee discomfort and a recent MRI knee.

Study Duration: January 2020 to December 2022

Inclusion Criteria: Patients with a clinically confirmed AKP and scheduled for MRI examination of the knee.

Exclusion Criteria:

1. Patients with a history of patellofemoral malalignment
2. Patients who underwent surgeries or previously fractured knee joint
3. Patients who had absolute contraindications to MRI examination
4. Pregnant women, people with hemodynamic instability

The study was performed after getting approval from institutional ethics committee. Initially, we collected 100 consecutive patients. The exclusion process resulted in a final cohort comprised of 80 patients. Written informed consent was taken from each patient. The images were interpreted by two radiologists, each of whom had no knowledge of the imaging findings. One radiologist performed all the USG and the other interpreted all the MRIs. Both radiologists had at least 8 years of experience in performing USG and MRI.

Ultrasonography

Gray-scale and color Doppler ultrasonography of the knee were performed using Aplio 400, Toshiba ultrasound scanner, with a high-resolution, multifrequency linear transducer (7–12 MHz). Patients were positioned in a supine position with the knee comfortably flexed (30–45°) by placing a pillow under the knee. To avoid loss of contact, we used plenty of thick gel. The exam started at the suprapatellar region by scanning in the long axis plane from medial to lateral. The quadriceps tendon was scanned first in both long axis and short axis planes. The trochlear cartilage, as well as the medial and lateral patellar recesses, was examined in various degrees of knee flexions. Long and short axis planes for the patellar tendon were then obtained. The parameters of the color Doppler mode was set to depict the slow flows by using high Doppler frequency, low pulse repetition frequency, minimal wall filter, and high color gain. Focus is positioned just deep to the area of interest. Any suspected lesion, firmness, or tenderness was examined by moving the probe over and around the lesion [14–16].

Dynamic ultrasonography examination executed by changing the degree of knee flexion as well as by medial and lateral movements of the patella was also done. During the ultrasonography examination, the knee was divided into the following entities: (i) the extensor mechanism, i.e., quadriceps tendon, patella, and patellar tendon; (ii) the trochlear femoral articular cartilage; (iii) anterior knee joint recesses (suprapatellar and both medial and lateral recesses); (iv) anterior knee bursa, i.e., subcutaneous prepatellar bursa, subcutaneous infrapatellar bursa, and deep infrapatellar bursa; (v) suprapatellar fat and deep infrapatellar Hoffa's fat pad; and (vi) miscellaneous causes.

All ultrasonography examinations were performed by one highly experienced musculoskeletal radiologist (with over 10 years of musculoskeletal ultrasound experience and had performed > 1000 ultrasound examinations per year). The radiologist was blinded to clinical data. Hypervascularity on color Doppler examinations was used as a marker for patellar tendinopathy, Hoffa's or suprapatellar fat pad impingement, and inflammation.

MRI findings served as the foundation for the patients' final diagnosis. The patients were examined using 1.5T (Siemen's Magnetom Avanto Tim + Dot system). The following images were acquired in the following sequences for knee joint analysis: PD: axial, coronal, and sagittal with 3.5-mm slice thickness and interslice gap of 1 mm; T1W axial and coronal, T2W sagittal and T2 GRE sagittal with 3.5-mm slice thickness and interslice gap of 1 mm; and short tau inversion recovery (STIR) coronal 3.5-mm slice thickness and interslice gap of 1.2 mm. 3D sequences and cine loops were not performed routinely. All MRI images were interpreted by one radiologist with over 8 years of experience. The radiologist was blinded to the clinical history and ultrasound findings.

Statistical Analysis: The data was collected with predesigned proforma and entered in Microsoft Excel 2016. The data was analyzed using Epi info version 7.1.4.0 Continuous data was presented with mean and standard deviation (SD) while categorical data was presented with frequency and percentage.

Diagnostic accuracy of ultrasonography included sensitivity, specificity, positive predictive values (PPV), and negative predictive value (NPV) as compared to MRI for evaluating different anterior knee findings were analyzed using receiver operating characteristic curve (ROC) and judged by the area under the curve (AUC). The agreement between studies of USG and MRI was calculated using the kappa (κ) coefficient. Strength of the kappa coefficient was interpreted in the following manner: 0.01 to 0.20, slight 0.21 to 0.40, fair; 0.41 to 0.60, moderate; 0.61 to 0.80, substantial; and 0.81 to 1.00, near perfect.[11] The p value of less than 0.05 was considered statistically significant.

Result

We included a total of 86 knees from 80 patients including 49 males and 31 females. The mean age of the patients was 35.2 ± 12.1 years. The most common age group was the 31 to 40 year age group, which accounted for 36% of the participants. A total of six patients (7.5%) experienced bilateral anterior knee pain (AKP). The chief complaint was knee pain or disability, which had persisted for no longer than six months.

Table 1: Characteristics of the patients (n-80)

Characteristics	Frequency	Percentage (%)
Age (year)		
11 to 20	4	4.7
21 to 30	24	27.9
31 to 40	31	36.0
41 to 50	14	16.3
51 to 60	5	5.8
> 60	2	2.3
Mean ± SD	35.2 ± 12.1	
Gender		
Male	49	61.2
Female	31	38.8

Table 2: Number of findings in each knee as detected by ultrasonography and MRI

Findings	USG (n-86)	MRI (n-86)
Normal	21 (24.4%)	12 (14.0%)
Abnormal	65 (75.6%)	74 (86.0%)
Detected number of abnormalities	125	149
Number of findings		
No finding	21 (24.4%)	12 (14%)
One finding	26 (30.2%)	30 (34.9%)
Two finding	24 (27.9%)	25 (29.1%)
Three finding	9 (10.5%)	10 (11.6%)
Four finding	6 (7%)	6 (7%)
Five finding	0 (0%)	3 (3.5%)

Ultrasonography and MRI findings

The ultrasonography detected 125 findings in 86 knees, compared to 149 findings in 86 knees detected by MRI. Ultrasonography revealed 21 (24.4%) knees with no findings compared to 12 (14.0%) knees by MRI. Possible causes of AKP detected by ultrasonography and MRI was shown in Table 3.

Joint effusion was the most common finding (33 patients, 38.4%), while trochlear cartilage defect, superficial infrapatellar subcutaneous edema and synovial plica were reported in 22.1%, 17.4%, and 17.4% respectively. Out of the 33 knees with joint effusion detected by MRI, USG accurately diagnosed 31 cases, with 3 false positives and 2 false negatives for joint effusion. For trochlear cartilage defect: Out of the 19 cases detected by MRI, USG correctly identified 15, with 2 false positives and 4 false negatives. For superficial infrapatellar tissue edema: Among the 15 cases detected by MRI, USG accurately diagnosed 12, with 1 false positive and 3 false negatives. For synovial plica: Out of the 15 cases detected by MRI, USG correctly identified 12, with 1 false positive and 3 false negatives. For patellar tendinopathy: Among the 16 cases detected by MRI, USG accurately diagnosed 14, with no false positives and 2 false negatives. For patellar cartilage defect: Out of the 13 cases detected by MRI, USG did not identify any, resulting in 13 false negatives.

Table 3: Findings detected by ultrasonography and MRI

Causes of AKP	USG	MRI
Joint effusion	34 (39.5%)	33 (38.4%)
Trochlear cartilage defect	17 (19.8%)	19 (22.1%)
Superficial infrapatellar tissue edema	13 (15.1%)	15 (17.4%)
Synovial plica	13 (15.1%)	15 (17.4%)
Patellar tendinopathy	14 (16.3%)	16 (18.6%)
Patellar cartilage defect	0 (0%)	13 (15.1%)
Suprapatellar fat impingement	13 (15.1%)	13 (15.1%)
Hoffa's fat pad impingement	7 (8.1%)	10 (11.6%)
Quadriceps tendinopathy	9 (10.5%)	10 (11.6%)
Infrapatellar bursitis	4 (4.7%)	3 (3.5%)
Bipartite patella	2 (2.3%)	2 (2.3%)

Table 4: Frequency of each finding as detected by ultrasonography compared to MRI

Causes of AKP	USG				MRI	
	TP	FP	FN	TN	Positive	Negative
Joint effusion	31	3	2	50	33	53
Trochlear cartilage defect	15	2	4	65	19	67
Superficial infrapatellar tissue edema	12	1	3	70	15	71
Synovial plica	12	1	3	70	15	71
Patellar tendinopathy	14	0	2	70	16	70
Patellar cartilage defect	0	0	13	73	13	73
Suprapatellar fat impingement	12	1	1	72	13	73
Hoffa's fat pad impingement	7	0	3	76	10	76
Quadriceps tendinopathy	9	0	1	76	10	76
Infrapatellar bursitis	3	1	0	82	3	83
Bipartite patella	2	0	0	84	2	84

Diagnostic accuracy of ultrasonography

The overall diagnostic accuracy of ultrasonography in detecting abnormal findings in AKP patients was 77.1%. It had a sensitivity of 78.5% and a specificity of 70.0%. The PPV was 92.9%, and the NPV was 39.6%. Ultrasonography showed the highest sensitivity of 100% in detecting a bipartite patella and infrapatellar bursitis. It had a sensitivity of 93.9% for joint effusion, 92.3% for suprapatellar fat impingement, 90.0% for quadriceps tendinopathy, and 87.5% for patellar tendinopathy. For synovial plica, the sensitivity was 80.0%, specificity was 98.6%, PPV was 92.3%, NPV was 95.9%, and accuracy was 96.5%. However, the sensitivity for patellar cartilage defect was 0.0%, specificity was 100.0%, NPV was 84.9%, and accuracy was 84.9%.

ROC curve analysis

The ROC curve analysis of ultrasonography's overall diagnostic accuracy showed an AUC of 0.87 ($p < 0.001$). The Kappa agreement between USG and MRI was good ($k = 0.67$). Table 4 summarizes the ROC curve and Cohen Kappa analysis for each finding. When comparing USG to MRI, the ROC curve analysis for detecting abnormal findings in AKP patients revealed the highest diagnostic accuracy in detecting quadriceps tendinopathy (AUC = 0.96), followed by joint effusion (AUC = 0.95) and suprapatellar fat impingement (AUC = 0.94). However, the diagnostic accuracy was lower for detecting Patellar cartilage defect (AUC = 0.55).

Table 5: Diagnostic accuracy of ultrasonography findings using MRI as the gold reference standard

Causes of AKP	Sn	Sp	PPV	NPV	Accuracy	Kappa agreement	AUC
Joint effusion	93.9	94.3	91.2	96.2	94.2	0.88	0.95
Trochlear cartilage defect	78.9	97.0	88.2	94.2	93.0	0.79	0.88
Superficial infrapatellar tissue edema	80.0	98.6	92.3	95.9	95.3	0.83	0.89
Synovial plica	80.0	98.6	92.3	95.9	96.5	0.87	0.89
Patellar tendinopathy	87.5	100.0	100.0	97.2	97.7	0.92	0.93
Patellar cartilage defect	0.0	100.0	NA	84.9	84.9	0.01	0.55
Suprapatellar fat impingement	92.3	98.6	92.3	98.6	97.7	0.91	0.94
Hoffa's fat pad impingement	70.0	100.0	100.0	96.2	96.5	0.81	0.82
Quadriceps tendinopathy	90.0	100.0	100.0	98.7	98.8	0.94	0.97

Infrapatellar bursitis	100.0	98.8	75.0	100.0	98.8	0.85	0.98
Bipartite patella	100.0	100.0	100.0	100.0	100.0	1.00	1.00
Over all	78.5	70.0	92.9	69.6	77.1	0.67	0.87

Discussion

AKP is a common reason for knee-related orthopedic consultations. The differential diagnosis for AKP is currently unclear and overlapping. Despite its prevalence, the nature and causes of AKP are still poorly understood. It's important to properly assess the anatomy and pathology of the ligaments, muscles, tendons, and menisci that stabilize the knee joint, as they are prone to injury. [11]

The patient's history and physical exam are crucial in figuring out the cause of AKP. Imaging tests complement the examination and help provide an accurate diagnosis. MRI is the preferred imaging method for knee evaluation. Ultrasonography has grown in popularity because it is rapid, easy, affordable, and can evaluate the soft tissues in the knee's anterior aspect, which may be the major source of pain. [5]

Our study primarily comprised individuals aged 31 to 40 years (36.0%), with a mean age of 35.2 years. Basha et al. [5] examined 155 knees from 143 patients, with 55.9% male and a mean age of 33.6 ± 13.9 years. Males constituted 61.2% of the sample. Similar gender distribution and mean age were reported by Singh et al. [11] (75.8% males, mean age 32.9 years), aligning with prior research by Khan et al. [12]

In our study, joint effusion was the most frequent finding (38.4%), followed by trochlear cartilage defect (22.1%), and superficial infrapatellar subcutaneous edema (17.4%). Singh et al. [11] found knee joint effusion to be prevalent (83.5%), along with medial meniscal tear (41.7%) and osteophytes (30.1%). Similarly, Basha et al. [5] noted joint effusion as the primary observation (38.1%), followed by trochlear cartilage defect (20.6%) and superficial infrapatellar subcutaneous edema (20%).

In our study, ultrasonography identified 125 findings in 86 knees, while MRI detected 149 findings in the same number of knees. Ultrasonography revealed no findings in 21 knees (24.4%), compared to 12 knees (14.0%) by MRI. Artul et al.[13] found 34% of ultrasonography reports to be negative and 66% positive. Similarly, Basha et al. [5] reported normal findings in 29% (45 knees) of ultrasonography reports and 16.8% (26 knees) of MRI reports.

In our study, ultrasonography had a sensitivity of 93.9% and specificity of 94.3% in detecting joint effusion. Ultrasonography is sensitive in detecting knee joint effusion with minimal detectable amounts as low as 7 to 10 ml. However, there were some cases where minimal effusions near the anterior cruciate ligament were missed and timing discrepancies with MRI led to false-positive results. Various studies reported varying degrees of sensitivity and specificity, ranging from 79.1% to 100%. [5,11,13–16]

In our study, ultrasonography had a sensitivity of 78.9% and specificity of 97.0% for trochlear cartilage defect with 2 false positives and 4 false negatives. The false negatives primarily occurred due to deeply located defects in the intercondylar fossa, while all patellar cartilage defects were missed due to obscuration by the patellar shadow during ultrasonography. The patellar cartilage isn't usually assessed by ultrasound as it's shaded by the patella. Ultrasonography has a sensitivity range of 62.2% to 71.9% and a specificity range of 90.5% to 98.4%, according to Cao et al. [17] and Basha et al. [5]

In this study, ultrasound had 80.0% sensitivity for detecting subcutaneous edema. Another study by Basha et al.[5] showed that ultrasound had a sensitivity of 77.4% for detecting subcutaneous edema. In this study, ultrasound showed 80.0% sensitivity and 98.6% specificity in detecting synovial plicae. Synovial plica syndrome in the knee is often overlooked, with the most common plica being the infrapatellar plica, followed by the suprapatellar plica, and the most symptomatic being the medial patellar plica.[24] According to Basha et al.'s study, ultrasound had a sensitivity of 78.5% and specificity of 100% for detecting synovial plicae.

Ultrasonography had an overall diagnostic accuracy of 77.1%, sensitivity of 78.5% and specificity of 70.0% for AKP. It showed high sensitivity in detecting a bipartite patella (100%), infrapatellar bursitis (100%), joint effusion (93.9%), suprapatellar fat impingement (92.3%), and quadriceps tendinopathy (90.0%). However, it had low sensitivity in detecting patellar cartilage defects (0.0%), trochlear cartilage defects (78.9%) and Hoffa's fat pad impingement (70.0%). Ultrasonography missed a significant number of lesions, including all 13 patellar cartilage defects, 4 out of 19 trochlear cartilage defects, and 3 out of 10 Hoffa's fat pad impingement cases. Ultrasonography can be used for diagnosis and screening in AKP, but MRI is recommended if patellar cartilage, trochlear cartilage defects and Hoffa's fat pad impingement are suspected or ultrasonography results are negative. In the study of Basha et al.[5], Ultrasonography had an overall sensitivity of 85.3% and specificity of 100% for AKP. It showed high sensitivity in detecting a bipartite patella (100%),

joint effusion (91.5%), quadriceps tendinopathy (87.5%) and suprapatellar fat impingement (84.2%). However, it had low sensitivity in detecting patellar cartilage defects (0.0%), Hoffa's fat pad impingement (66.7%) and Infrapatellar bursitis (66.7%).

Conclusion

Ultrasonography is a useful tool for diagnosing AKP, as it accurately detects conditions like bipartite patella, infrapatellar bursitis, joint effusion, suprapatellar fat impingement, and quadriceps tendinopathy. However, it has limitations in detecting patellar cartilage defects, trochlear cartilage defects, and Hoffa's fat pad impingement. While MRI is considered the gold standard, ultrasonography can serve as a quick screening and assessment method for the anterior knee when MRI is unavailable or contraindicated.

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