ORIGINAL RESEARCH PAPER

Radio-Diagnosis

COMPARATIVE EVALUATION OF ULTRASOUND AND MRI IN THE DIAGNOSIS OF KNEE JOINT PATHOLOGIES

KEY WORDS: Ultrasound, MRI, Knee joint, Diagnostic accuracy, Meniscus tear, Ligament injury

Dr Manish Bhagat — Professor & HOD, Department Of Radiodiagnosis, Sri Aurobindo Medical College & PG Institute, Indore (M.P).

Dr Diksha Maheshwari* — PG Resident, Department Of Radiodiagnosis, Sri Aurobindo Medical College & PG Institute, Indore (M.P). *Corresponding Author

ABSTRACT

Background: Knee joint pathologies are a major cause of disability, often involving ligaments, menisci, tendons, cartilage, and synovium. MRI is the gold standard for diagnosis, but its high cost, limited availability, and contraindications restrict its use. Ultrasound (USG) offers a non-invasive, inexpensive, and dynamic alternative, though its diagnostic accuracy for different knee conditions needs further evaluation. The present study aimed to assess the diagnostic performance of USG in detecting knee pathologies compared with MRI as the reference standard. **Methods:** A prospective comparative study was conducted on 100 patients presenting with knee pain, swelling, or restricted movement. All underwent high-resolution USG (GE LOGIQ E9) followed by MRI (SIEMENS Magnetom Vida 3T). Agreement was measured using kappa statistics, and sensitivity, specificity, PPV, NPV, and accuracy were calculated. **Results:** USG showed almost perfect agreement with MRI for medial meniscus tears ($\kappa = 0.81$), meniscal cysts ($\kappa = 0.97$), medial meniscal extrusion ($\kappa = 0.99$), MCL tears ($\kappa = 0.87$), Baker's cysts ($\kappa = 0.98$), and osteophytes ($\kappa = 0.93$). High diagnostic accuracy was achieved for joint effusion (89%), medial meniscus tears (93%), osteophytes (97.5%), meniscal cysts, meniscal extrusion, and Baker's cysts (all 100%). Substantial agreement was seen for joint effusion ($\kappa = 0.71$), patellar tendinopathy ($\kappa = 0.76$), and LCL tears ($\kappa = 0.62$). Lower sensitivity was noted for ACL tears ($\kappa = 0.04$), PCL tears ($\kappa = 0.55$), and meniscal degeneration ($\kappa \leq 0.26$). **Conclusion:** Ultrasound is highly accurate for detecting superficial and peri-articular knee pathologies and can serve as a reliable first-line modality. However, MRI remains indispensable for evaluating deep intra-articular structures and degenerative changes.

INTRODUCTION

The knee joint is among the most frequently affected joints in the human body due to its complex anatomy and extensive range of motion. Various pathological conditions involving tendons, ligaments, muscles, synovial membranes, and articular cartilage frequently compromise its function, contributing significantly to pain and joint instability. While conventional radiography is effective in detecting bony abnormalities, it lacks the ability to visualize soft tissue structures. [1,2]

Magnetic Resonance Imaging (MRI) addresses these limitations by offering high-resolution, multiplanar visualization of both osseous and soft tissue components. It is a non-invasive modality that avoids ionizing radiation, making it a preferred tool for comprehensive joint assessment [3,4]. However, MRI remains costly, is not universally accessible—especially in smaller or resource-limited healthcare settings—and presents challenges for claustrophobic individuals or those with metallic implants.

Although knee arthroscopy is recognized as both a diagnostic and therapeutic intervention, its invasive nature and potential complications—such as septic arthritis, deep vein thrombosis, and pulmonary embolism—limit its use in certain cases [5–7]. In contrast, musculoskeletal ultrasound (USG) offers a reliable, non-invasive option for evaluating soft tissue abnormalities, including tendon and ligament injuries, muscle trauma, bursitis, and synovial pathologies. It also enables assessment of neurovascular structures adjacent to the knee [8].

Ultrasound can be performed swiftly, even bedside, and both knees may be examined during the same session. Its affordability, portability, and capability for real-time dynamic assessment make it highly suitable for use in community settings and on athletic fields [9]. Furthermore, ultrasound remains unaffected by the presence of metallic implants—a common limitation in MRI. An additional benefit is the ability for radiologists to correlate clinical findings directly with imaging during the examination.

Given the limited published data regarding the diagnostic utility of ultrasound for knee pathologies in the Indian context, this study was undertaken to assess the effectiveness of ultrasound and to compare its findings with those obtained via MRI.

MATERIAL AND METHODS

After obtaining approval from the Institutional Ethical Committee, this prospective comparative study was carried out in the Department of Radiodiagnosis at Sri Aurobindo Institute of Medical Sciences & PG Institute, Indore. A total of 100 patients presenting to the outpatient department (OPD) with a chief complaint of knee pain, with or without swelling, or with restriction of movement following trivial trauma or other symptoms suggestive of underlying knee joint pathology were recruited for the study over a defined period. Those who satisfied the inclusion and exclusion criteria were enrolled in the study after obtaining informed written consent.

Inclusion Criteria:

- Patients presenting with knee pain, with or without swelling.
- Patients with clinical suspicion of meniscal or ligamentous injuries.
- Patients having restricted range of motion at the knee joint following minor trauma.

Exclusion Criteria:

- Patients unwilling to provide consent.
- Claustrophobic individuals.
- Patients with metallic implants.
- Post-operative cases involving the knee.

Methodology

Following consent and clinical screening, all patients first underwent high-resolution ultrasonography (USG) using the GE LOGIQ E9 ultrasound machine, followed by magnetic resonance imaging (MRI) using the SIEMENS Magnetom Vida 3T MRI scanner. In each case, the symptomatic knee was evaluated, and for comparative purposes, the contralateral normal knee was also scanned using ultrasound.

The imaging evaluations were performed by two separate consultant radiologists, each with significant experience in musculoskeletal imaging. One radiologist conducted and interpreted the USG, while the other independently analyzed the MRI findings. Both radiologists were blinded to each other's observations to maintain diagnostic objectivity.

Ultrasound Examination Technique

Ultrasound of the knee joint was performed in both supine and prone positions, with systematic evaluation through anterior, medial, lateral, and posterior approaches. The transducer was positioned in both longitudinal and transverse orientations depending on the anatomical region being examined.

- **Anterior Approach**: Conducted with the patient in a supine position and the knee flexed 20–30 degrees using a pillow under the popliteal fossa. Structures evaluated included the quadriceps tendon, suprapatellar recess, prepatellar bursa, patellar tendon, and anterior cruciate ligament (ACL).
- **Medial Approach**: With the leg externally rotated, the medial collateral ligament (MCL), medial femorotibial joint, medial meniscus, and pes anserinus complex were visualized.
- **Lateral Approach**: Performed with the leg internally rotated. Assessed structures included the lateral femorotibial joint space, lateral meniscus, lateral collateral ligament (LCL), and superior tibiofibular joint.
- **Posterior Approach**: Conducted in prone position with the knee extended. Structures evaluated were the posterior cruciate ligament (PCL), posterior horns of the menisci, semimembranosus bursa, and neurovascular bundle.

In specific anterior knee views, the ACL was evaluated by flexing the knee maximally and placing the probe sagittally over the patellar tendon. Articular cartilage was assessed in the transverse plane at the suprapatellar level.

MRI Protocol

MRI was performed using the SIEMENS Magnetom Vida 3T system, with standard knee sequences in axial, sagittal, and coronal planes. Sequences included T1-weighted, T2-weighted, proton density (PD) with and without fat suppression, and STIR sequences. MRI served as the reference standard for detecting internal derangements of the knee, given that arthroscopy was not performed in all patients.

Statistical Analysis

All data collected during the study were entered and analyzed using Statistical Package for the Social Sciences (SPSS) for Windows, version 21.0 (SPSS Inc., Chicago, IL). To evaluate the level of diagnostic agreement between ultrasonography (USG) and magnetic resonance imaging (MRI), the Kappa (κ) statistic was employed. The strength of agreement was interpreted in accordance with the Landis and Koch classification, where a κ value of 0.01–0.20 indicates slight agreement, 0.21–0.40 denotes fair agreement, 0.41–0.60 represents moderate agreement, 0.61–0.80 signifies substantial agreement, and 0.81–1.00 reflects almost perfect agreement. Furthermore, the diagnostic performance of ultrasound in comparison to MRI was assessed by calculating sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy, considering MRI findings as the reference or gold standard for various knee joint pathologies.

RESULTS

A total of 100 patients presenting with complaints of knee joint pain were evaluated using ultrasonography, followed by MRI for confirmatory diagnosis. The maximum number of patients (36) belonged to the age group of 21–30 years (36%), followed by 22 patients in the ≤20 years group (22%). The least number of patients (12) were seen in the >50 years group (12%). Out of 100 patients, 80 (80%) were males and 20 (20%) were females, indicating a male predominance in the study population.

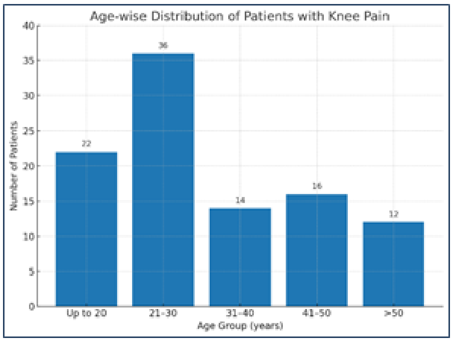

Figure 1. Age-wise Distribution of Patients with Knee Pathologies

On analyzing the pathological findings in this study, joint effusion was the most frequently observed abnormality on ultrasound, detected in 71 cases (71%), followed by osteophytes in 29 cases (29%), medial meniscus tears in 23 cases (23%), and lateral meniscus tears in 12 cases (12%). Other findings on ultrasound included cartilage thinning in 12%, patellar tendinopathy in 4%, PCL tears in 4%, and Baker's cysts in 6%. Ultrasound showed limited ability to detect partial ACL tears, meniscal degeneration, and deep intra-articular lesions.

On MRI, the most common pathology was ACL tear, observed in 36 cases (22 complete, 14 partial; 36%), making the anterior cruciate ligament the most frequently involved structure. MRI also detected joint effusion in 75 cases (75%), medial meniscal tears in 27%, medial meniscal degeneration in 24%, and cartilage thinning in 19%. Additionally, MRI identified PCL tears in 6%, lateral meniscal degeneration in 6%, and Baker's cysts in 7%. MRI consistently outperformed ultrasound in evaluating ligamentous injuries, meniscal degeneration, and cartilage pathology, underscoring its role as the gold standard for comprehensive knee joint assessment. [Table 1]

Table 1: Distribution of Knee Joint Pathologies Identified on Ultrasound and MRI (n = 100)

Knee Pathology	Ultrasound (USG)	MRI
Joint Effusion	71	75
Quadriceps Tendinopathy	0	0
Patellar Fracture	2	1
Patellar Tendinopathy	4	3
Bursitis	1	2
Complete ACL Tear	4	22
Partial ACL Tear	0	14
PCL Tear	4	6
MCL Tear/Sprain	6	5
Medial Meniscus Tear	23	27
Medial Meniscal Degeneration	8	24
Medial Meniscal Cyst	2	2
Medial Meniscal Extrusion	1	2
Lateral Meniscus Tear	12	11
Lateral Meniscal Degeneration	2	6
LCL Tear/Sprain	4	3
Osteophytes	29	27
Cartilage Thinning	12	19
Baker's Cyst	6	7

Agreement between ultrasound and MRI for detecting various knee pathologies is summarized in Table 2. Almost perfect agreement was observed for detecting medial meniscus tear, meniscal cyst, medial meniscal extrusion, MCL tear, Baker's cyst, and osteophytes, indicating high diagnostic reliability of ultrasound in these conditions. Substantial agreement was seen in cases of joint effusion, patellar tendinopathy, and LCL tear, while moderate agreement was noted for lateral meniscus tear, PCL tear, and cartilage thinning. In contrast, only fair agreement was found for medial meniscal degeneration, and slight agreement was recorded for lateral meniscal degeneration and ACL tear, reflecting the limitations of ultrasound in evaluating deep intra-articular structures.

Table 2: Diagnostic Agreement Between Ultrasound and MRI For Knee Joint Pathologies

Pathology	Kappa Value (κ)	p-Value	Level of Agreement
Joint Effusion	0.71	<0.001	Substantial
Patellar Tendinopathy	0.76	<0.001	Substantial
Medial Meniscus Tear	0.81	<0.001	Almost Perfect
Lateral Meniscal Tear	0.57	<0.001	Moderate
Medial Meniscal Degeneration	0.26	0.004	Fair
Lateral Meniscal Degeneration	0.18	0.062	Slight
Meniscal Cyst	0.97	<0.001	Almost Perfect
Medial Meniscal Extrusion	0.99	<0.001	Almost Perfect
ACL Tear	0.04	0.542	Slight
PCL Tear	0.55	<0.001	Moderate
MCL Tear	0.87	<0.001	Almost Perfect
LCL Tear	0.62	<0.001	Substantial
Baker's Cyst	0.98	<0.001	Almost Perfect
Osteophytes	0.93	<0.001	Almost Perfect
Cartilage Thinning	0.56	<0.001	Moderate

The diagnostic performance analysis of ultrasound compared to MRI revealed high accuracy for detecting joint effusion (89%), medial meniscus tears (93%), and osteophytes (97.5%). Ultrasound demonstrated excellent sensitivity and specificity (100%) in identifying meniscal cysts, meniscal extrusion, and Baker's cyst, indicating perfect diagnostic concordance with MRI in these conditions. MCL and LCL tears also showed high sensitivity (100%) with overall accuracy exceeding 97%. However, ultrasound showed low sensitivity for detecting degenerative changes, particularly lateral meniscal degeneration (16%) and medial meniscal degeneration (22%), despite high specificity. Detection of cartilage thinning was moderately accurate (88%), emphasizing that while ultrasound is reliable for superficial and periarticular abnormalities, MRI remains superior for intra-articular and degenerative pathologies. [Table 3]

Table 3: Diagnostic Performance of Ultrasound Compared to MRI in Detecting Knee Pathologies (n = 100)

Pathology	Sensitivity(%)	Specificity(%)	PPV (%)	NPV (%)	Accuracy(%)
Joint Effusion	89.3	86.7	94.7	74.2	89.0
Patellar Tendinopathy	100.0	98.0	60.0	100.0	98.5
Medial Meniscus Tear	82.0	97.5	94.5	91.8	93.0
Lateral Meniscus Tear	68.0	92.0	50.0	95.2	89.5
Medial Meniscal Degeneration	22.0	96.5	68.0	77.2	76.0
Lateral Meniscal Degeneration	16.0	97.0	35.0	92.8	91.0
Medial Meniscal Cyst	100.0	100.0	100.0	100.0	100.0
Medial Meniscal Extrusion	100.0	100.0	100.0	100.0	100.0
MCL Tear	100.0	98.5	80.0	100.0	98.8
LCL Tear	100.0	98.0	66.7	98.0	97.5
Baker's Cyst	100.0	100.0	100.0	100.0	100.0
Osteophytes	100.0	96.8	93.1	100.0	97.5
Cartilage Thinning	52.0	98.0	88.0	87.3	88.0

DISCUSSION

Over the past decade, musculoskeletal imaging has seen remarkable advancements, largely due to the evolution of magnetic resonance imaging (MRI) and musculoskeletal ultrasound (USG). Ultrasound, in particular, has gained prominence owing to its real-time, dynamic imaging capabilities and accessibility. MRI, although regarded as the gold standard for evaluating knee pathologies [3,4], is often limited in availability, especially in resource-constrained settings in India, and may be unsuitable for certain patient populations due to cost, length of procedure, or contraindications. In contrast, ultrasound remains an economical, widely available, and non-invasive modality, capable of dynamic evaluation [9]. However, concerns about its diagnostic accuracy persist.

In our study, joint effusion emerged as the most common pathology detected by ultrasound (71%), followed by osteophytes (29%) and medial meniscus tear (23%). Similar findings were reported by Singh B et al. and Yousif et al., where joint effusion was frequently observed on ultrasound [10,11]. Ultrasound showed substantial agreement with MRI for detecting effusion ($\kappa = 0.71$, $p < 0.001$) with high diagnostic performance (sensitivity 89.3%, specificity 86.7%, accuracy 89.0%), consistent with studies by Draghi F et al. and Singh B et al. [10,12].

Anterior knee tendons—mainly the patellar and quadriceps tendons—are frequently affected by tendinopathy. In our study, substantial agreement was observed for patellar tendinopathy (κ=0.76), with high diagnostic metrics (sensitivity 100%, specificity 98.0%, accuracy 98.5%), aligning with findings by Khan KM et al., where ultrasound correlated well with MRI and histopathology in patellar tendinosis [13]. No case of quadriceps tendinopathy was identified in our cohort, consistent with its relatively lower incidence.

Meniscal lesions are a major contributor to knee dysfunction and are classified into tears and degeneration. In our study, medial meniscus tears showed almost perfect agreement between US and MRI (κ= 0.81) with sensitivity 82%, specificity 97.5%, accuracy 93%. These findings align with studies by Unlu EN et al., Singh A et al., and Singh B et al. [10,14,15]. However, a study by Ghosh N et al. reported lower specificity (40%) despite 100% sensitivity, possibly due to the use of bedside USG by non-radiologists [16].

For lateral meniscal tears, our study demonstrated moderate agreement (κ = 0.57) with sensitivity 68%, specificity 92%, and accuracy 89.5%. Similar trends were reported in the literature by Singh B, Singh A, Unlu EN, and Wareluck et al., who used either MRI or arthroscopy as the reference standard [10,14,15,17].

Regarding meniscal degeneration, ultrasound showed fair agreement for medial meniscus (κ = 0.26) and slight agreement for lateral degeneration (κ = 0.18). This underperformance has also been noted by Unlu EN et al., who reported low kappa values and emphasized MRI's superiority in detecting degenerative changes [14]. Thus, ultrasound remains limited in differentiating degenerative changes from tears.

Collateral ligament injuries, especially in athletes and trauma cases, are frequently encountered. In our study, MCL tears demonstrated almost perfect agreement (κ = 0.87) with sensitivity 100%, specificity 98.5%, accuracy 98.8%. These results are comparable to those by Singh A et al. and Singh B et al., though slightly better in sensitivity [10,15]. In contrast, Ghosh N et al. reported lower sensitivity (67%) and specificity (83%), possibly due to technique and operator differences [16].

For LCL tears, we observed substantial agreement (κ = 0.62) with diagnostic accuracy of 98%, matching results from Singh

B et al., who reported values of 84.6% sensitivity, 97.8% specificity, and 95% accuracy [10]. These findings reinforce ultrasound's utility in evaluating collateral ligament injuries when performed by skilled operators.

Anterior cruciate ligament (ACL) remains a diagnostic challenge on ultrasound due to its deep oblique orientation and inaccessibility. Despite using both anterior and posterior approaches, ACL was visualized in only 3 patients on USG, compared to 36 ACL tears on MRI (22 complete, 14 partial), reflecting slight agreement ($\kappa = 0.04$, $p = 0.54$). Similar limitations have been described by Singh A et al. and others, although indirect signs and advanced techniques have improved sensitivity in selected studies [15,18–20].

Posterior cruciate ligament (PCL), though more accessible via posterior scanning, remains partially visualized on ultrasound. In our study, PCL tears were identified in 3 patients on USG versus 7 on MRI, showing moderate agreement ($\kappa = 0.55$) and high specificity (100%) but lower sensitivity (42.9%), consistent with findings by Singh B et al., Singh A et al., and Lalitha P et al. [14,15,21]. However, higher sensitivities were reported by Wang C et al. and Lalitha P et al. (75–83.3%) for ultrasound which is in disagreement with our study [21,22].

Baker's cysts were reliably diagnosed on ultrasound with sensitivity, specificity, and accuracy all at 100%, in concordance with studies by Singh B et al. and Ward EE et al. [10,23].

Osteoarthritic changes such as osteophyte formation, meniscal extrusion, and cartilage thinning can also be evaluated using ultrasound [24-26]. In our study, osteophytes showed almost perfect agreement ($\kappa = 0.93$) with MRI and high diagnostic performance (sensitivity 100%, specificity 96.8%, accuracy 97.5%). These findings were comparable to those reported by Podlipská J et al. [27].

For articular cartilage thinning, ultrasound showed moderate agreement ($\kappa = 0.56$) with sensitivity 52%, specificity 98%, and accuracy 88%. Studies by Podlipská J et al. and Saarakkala S et al. also support the diagnostic value of USG in detecting cartilage changes, though they emphasized that negative USG findings may not rule out early degeneration [27,28].

A key limitation of this study was the relatively small sample size (n = 100) and the single-center setting, which may affect generalizability. Further studies with larger, multicentric cohorts and arthroscopy correlation are recommended for more robust validation of ultrasound's diagnostic utility in knee pathologies.

CONCLUSION

This study demonstrates that ultrasound is an effective, inexpensive, and non-invasive imaging tool for assessing knee joint pathologies, with high diagnostic accuracy for conditions such as joint effusion, Baker's cysts, osteophytes, meniscal cysts, meniscal extrusion, and collateral ligament injuries. In these pathologies, ultrasound showed substantial to almost perfect agreement with MRI, supporting its role as a reliable first-line investigation. Its advantages include portability, dynamic evaluation, and patient acceptability, making it particularly valuable in resource-limited settings or when MRI is unavailable or contraindicated.

However, ultrasound was less sensitive for detecting deep intra-articular lesions, particularly anterior cruciate ligament tears, posterior cruciate ligament injuries, and degenerative meniscal changes, where MRI remains the gold standard. Therefore, while ultrasound can serve as an efficient screening and follow-up modality, MRI should be employed for comprehensive evaluation when clinically indicated. Further multicentric studies with arthroscopic correlation are recommended to strengthen these findings.

REFERENCES

1. Kumar Yadav P, Jain S, Batham IK, Gupta A, Swaika S. Imaging of Knee Joint Pathologies: A Comparative Study of Ultrasound and Magnetic Resonance Imaging. J Med Sci Health 2022; 8(3):222-228
2. Veerendra K Sharma, Trishdeep Singh Grewal. Sonographic Evaluation of Pathologies of Knee Joint with MRI Correlation. Int J Med Res Prof. 2020 Mar; 6(2): 26-33. DOI:10.21276/ijmrp.2020.6.2.008
3. Yaqoob J, Alam MS, Khalid N. Diagnostic accuracy of Magnetic Resonance Imaging in assessment of Meniscal and ACL tear: Correlation with arthroscopy. Pak J Med Sci. 2015;31:263-8.
4. Navali AM, Bazavar M, Mohseni MA, Safari B, Tabrizi A. Arthroscopic evaluation of the accuracy of clinical examination versus MRI in diagnosing meniscus tears and cruciate ligament ruptures. Arch Iran Med. 2013;16:229-32.
5. Ward BD, Lubowitz JH. Basic knee arthroscopy part 3: diagnostic arthroscopy. Arthrosc Tech. 2013;2:503-5.
6. Friberger Pajalic K, Turkiewicz A, Englund M. Update on the risks of complications after knee arthroscopy. BMC Musculoskelet Disord. 2018; 19:179.
7. Salzler MJ, Lin A, Miller CD, Herold S, Irrgang JJ, Harner CD. Complications after arthroscopic knee surgery. Am J Sports Med. 2014;42:292-6.
8. Jacobson JA. Knee ultrasound. In: Jacobson JA, editor. Fundamentals of musculoskeletal ultrasound, 2nd edition. Philadelphia, PA: Elsevier Saunders; 2013;212-56.
9. Patil P, Dasgupta B. Role of diagnostic ultrasound in the assessment of musculoskeletal diseases. Ther Adv Musculoskelet Dis. 2012;4:341–55.
10. Singh B, Pawar K, Kachewar S, Ghule S. Evaluation of knee joint by ultrasound and MRI. IOSR Journal of Dental and Medical Sciences. 2016;15:122-31.
11. Yousif EA, Ahmed BH, Abdella AA, Ali QM. Knee joint diseases diagnosed by ultrasound and magnetic resonance imaging. Sudan Med Monit. 2014;9:1-4.
12. Draghi F, Urciuoli L, Alessandrino F, Corti R, Scudeller L, Grassi R. Joint effusion of the knee: potentialities and limitations of ultrasonography. J Ultrasound. 2015;18:361-71.
13. Khan KM, Bonar F, Desmond PM, Cook JL, Young DA, Visentini PJ et al,. Patellar tendinosis (jumper's knee): findings at histopathologic examination, US, and MR imaging. Victorian Institute of Sport Tendon Study Group. Radiology. 1996;200:821-7.
14. Unlu EN, Üstüner E, Şaylısoy S, Yılmaz Ö, Özcan H, Erden I. The role of ultrasound in the diagnosis of meniscal tears and degeneration compared to MRI and arthroscopy. Acta Med Anatol 2014;2:80-87.
15. Singh A, Mangat I, Thukral C, Gupta K. Ultrasonography in evaluation of knee injuries with magnetic resonance imaging correlation. International Journal of anatomy, radiology and surgery. 2018;7:50-5.
16. Ghosh N, Kruse D, Subeh M, Lahham S, Fox JC. Comparing Point-of-care-ultrasound (POCUS) to MRI for the Diagnosis of Medial Compartment Knee Injuries. J Med Ultrasound. 2017;25:167-72.
17. Wareluk P, Szopinski KT. Value of modern sonography in the assessment of meniscal lesions. Eur J Radiol. 2012 Sep;81(9):2366-9.
18. Khan Z, Faruqui Z, Ogyunbiyi O, Rosset G, Iqbal J. Ultrasound assessment of internal derangement of the knee. Acta Orthop Belg. 2006;72:72-6.
19. Grzelak P, Podgórski MT, Stefa czyk L, Domlalski M. Ultrasonographic test for complete anterior cruciate ligament injury. Indian J Orthop 2015;49:143-9.
20. Skovgaard Larsen LP, Rasmussen OS. Diagnosis of acute rupture of the anterior cruciate ligament of the knee by sonography. Eur J Ultrasound 2000;12:163-7.
21. Lalitha P, Reddy B.H, Reddy K.J, Kumari, V.S. Ultrasound evaluation of normal and abnormal posterior cruciate ligament- a prospective study materials. Pak J. Radiol. 2010;20:125-9.
22. Wang C, Shih T, Wang H, Chiu Y, Wang T. The accuracy of ultrasonographic examination of injured posterior cruciate ligament. J Med Ultrasound. 2009;17:187-92.
23. Ward EE, Jacobson JA, Fessell DP, Hayes CW, van Holsbeeck M. Sonographic detection of Baker's cysts: comparison with MR imaging. AJR Am J Roentgenol. 2001;176:373-80.
24. Koski JM , Kamel A, Waris P, Waris V, Tarkiainen I, Karvanen E et al. Atlas- based knee osteophyte assessment with ultrasonography and radiography: relationship to arthroscopic degeneration of articular cartilage. Scand J Rheumatol. 2016;45:158-64.
25. Riecke BF, Christensen R, Torp-Pedersen S, Boesen M, Gudbergsen H, Bliddal H. An ultrasound score for knee osteoarthritis: a cross-sectional validation study. Osteoarthritis Cartilage. 2014;22:1675-91.
26. Nogueira-Barbosa MH, Gregio-Junior E, Lorenzato MM, Guermazi A, Roemer FW, Chagas-Neto FA, et al. Ultrasound assessment of medial meniscal extrusion: a validation study using MRI as reference standard. AJR Am J Roentgenol. 2015;204:584–8.
27. Podlipská J, Guermazi A, Lehenkari P, Niinimäki J, Roemer FW, Arokoski JP, et al. Comparison of diagnostic performance of semi-quantitative knee ultrasound and knee radiography with MRI: oulu knee osteoarthritis study. Sci Rep. 2016;6:22365.
28. Saarakkala S, Waris P, Waris V, Tarkiainen I, Karvanen E, Aarnio J et al. Diagnostic performance of knee ultrasonography for detecting degenerative changes of articular cartilage. Osteoarthritis Cartilage. 2012; 20:376-81