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Evaluation of Knee Joint by Ultrasound and MRI

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Abstract: *Knee injuries are common, especially when taking part in sports persons. Injuries to soft tissues, such as ligaments, cartilage and tendons are commonly encountered. Damage to the bone also can occur.[1] The knee joint is a compound type of synovial joint and due to the lack of bony support, stability of the joint is highly dependent on its supporting ligamentous structures, and therefore injuries of ligaments and menisci are extremely common.[2] T1 or proton density-weighted sequences are most suitable for visualizing the ligamentous anatomy. T2 or STIR sequences with fat saturation are essential to demonstrate bone marrow edema. Disorders best evaluated by MRI include internal abnormalities such as those of cruciate ligaments and menisci, abnormalities of patella and quadriceps mechanism, cartilage and synovium. Bone abnormalities such as osteonecrosis and tumors as well as bone contusions and fractures also may be detected[3] . Indirect or dynamic techniques are generally applied in conjunction with sonography to diagnose anterior cruciate ligament tears (ACL). Sonography can clearly depict the posterior cruciate ligament[4]. Study was conducted using multi-frequency linear array probe for real time B mode scanning and 1.5 Tesla GE MRI Machine using knee extremity circumferential coil. This study included 50 symptomatic patients our hospital with knee joint complaints. MRI was performed to as gold standard to confirm the USG findings. The most frequent knee finding was joint effusion which was seen in 44 (88%) follower by ligament 33(66%), 11 osseous (22%) and 1 muscular (2%). No specific sex predilection was found. The most frequent age group affected in this work was the second decade. majority of the cases were meniscal tears and there were only two cases of meniscal degeneration and one case of meniscal cysts.*

Keywords: *Knee joint MRI, Ultrasonogrphy, Menisci, cruciate ligament, collateral ligament, cysts around knee, joint effusion, degenerative joint disease, bone marrow edema, Osseous and osteochondral injuries*

I. Introduction

A wide variety of MRI pulse sequences can be performed to produce diagnostic quality images. These include T1, proton density, T2, STIR, spin echo, fast (turbo) spin-echo, and gradient-echo sequences, which all have been proven suitable for knee imaging.

Anterior Cruciate ligament is best seen on sagittal, oblique images with slices oriented parallel to the cortex of the lateral femoral condyle[5]. Coronal images show the ACL as a curvilinear fan like structure adjacent to the horizontal segment of PCL, near the medial surface of the lateral femoral condyle. Axial images depict ACL as low signal band that is flattened against the medial surface the lateral femoral condyle. All imaging sequences demonstrate fat at the intercondylar notch.[6,7]

Posterior Cruciate Ligament: Sagittal images best depict the PCL, which appears as a uniformly low signal intensity structure with a nearly horizontal take off at the femoral origin and then an abrupt descent at about 45 degrees to the tibia. The meniscofemoral ligaments of Humphrey and Wrisburg are seen as low signal intensity dots anterior and posterior to the PCL and should not be mistaken for displaced meniscal fragments or an intact PCL in presence of tear.[6,8]

Medial and Lateral Collateral Ligaments: It is best seen on coronal images where it appears as homogenously low signal intensity structure on all pulse sequences. Moderately increased signal intensities may be seen between and superficial and deep fibers and below the superficial fibers at the distal tibial attachment site, where fat is normally interposed [6,9]

Oblique Popliteal Ligament (Posterior Oblique Ligament): It is best seen on coronal and axial images. A coronal oblique plane along it's superoinferior course is optimal for imaging.

The Menisci: Sagittal image: The anterior and the posterior horns of menisci appear as isosceles triangles. The posterior horn of medial meniscus is twice the size of anterior horn. The anterior and posterior horns of lateral meniscus are of same size. The posterior horn of either menisci should never appear smaller than the anterior horn. On both sides, the menisci appear as flat bands. On lateral side, the more central the slices take on bowtie configuration because of smaller radius of curvature.

Coronal images: Mid portion of the knee produce best images of bodies of both menisci. They appear triangular and slightly larger laterally than medially. The capsular attachment on the medial side is incorporated in the tibial and medial collateral ligament. A small amount of fat may be interposed between the body of the medial meniscus and the capsule. On posterior coronal cross sections, the posterior horns appear as flat bands. On lateral cross sections, the popliteal tendon courses upward and laterally at 45 degrees. More anteriorly, the anterior horn of lateral meniscus appears as a band like structure. The anterior horn of medial meniscus extends more anteriorly than that of lateral meniscus.[6,10]

II. Aims and Objectives

1) To assess the diagnostic utility of ultrasound and MRI in patient with suspected pathologic lesion of knee joint.
2) To evaluate appearance of various knee joint pathologies on Ultrasound and MRI
3) Assess the accuracy of ultrasound in the diagnosis of knee lesions keeping MRI as the Gold standard.
4) To correlate USG and MRI findings

III. Materials and Methods

50 symptomatic patients suffered knee joint disorders like pain, swelling, locking, limitations of movements and external injury were included in study. After clinical assessment, all patients were subjected to sonographic examination. The diagnosis was confirmed by MR imaging.
They were males & females, with an age range between 11-65years. All the patients are subjected to the

- History taking
- Ultrasonography (US)
- Magnetic resonance imaging (MRI)

1.5 Tesla GE MRI Machine using knee extremity circumferential coil.
We used PHILIPS EnVisor HD and MINDRAY Color Doppler machine with the 7.5 to 12 MHz multi-frequency linear array probe for real time B mode scanning.

Technique for ultrasound examination of the knee joint

- Using the 7.5 MHz linear array probe, the anterior horns of the medial & lateral menisci were examined while the patient was in supine position with 30°-90° flexion of the knee, the transducer was placed in sagittal & coronal planes of the medial & lateral aspects of the knee joint.
- The posterior horns of the medial and lateral menisci were examined while patient was in prone position with some degree of knee flexion obtained by a paper roll placed at lower leg to achieve knee flexion about 20°; A 7.5 MHz linear array probe was placed in sagittal and coronal-oblique planes.

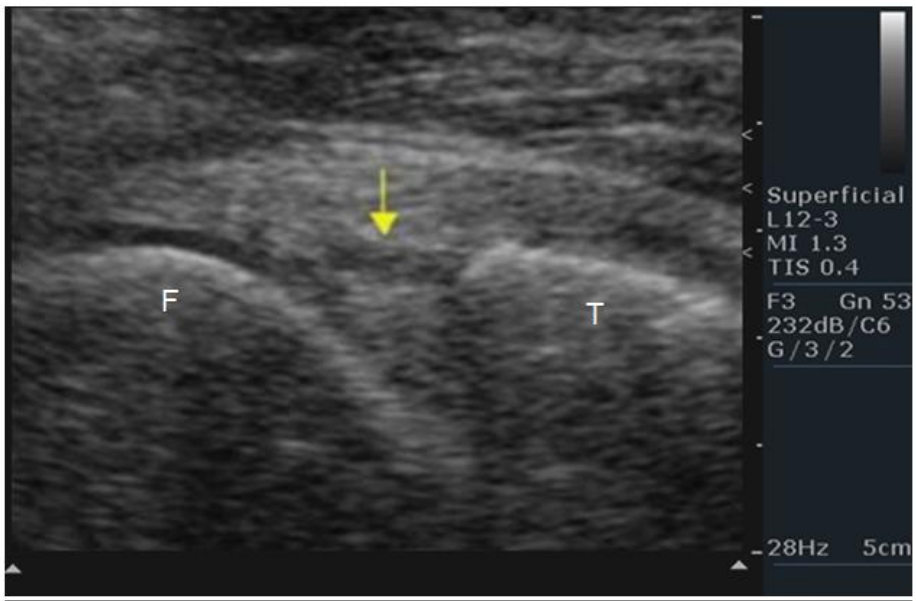


Figure 1- Longitudinal view showing hypoechoic meniscal tear (arrow), Femur(F), Tibia(T)

- For assessment of ACL persons were in supine position with the knee hyperflexed and internally rotated, and then the 7.5-12 MHz linear array probe was positioned longitudinally over the patellar tendon to evaluate distal ACL fibers, then patients were turned to prone position with knee extended and the probe placed transversely in intercondylar fossa to examine the hyperechoic anterior cruciate ligament and the adjacent hyperechoic fat taking the popliteal artery as landmark. In patient group we were depending on the indirect signs. Patients were in prone position with knee extended and the 7.5-12 MHz linear array probe was placed transversely in the popliteal fossa to evaluate hypoechoic hematoma formed in acute injuries. Another indirect sign was assessed. The knee was flexed about 20 ° supported by a paper roll placed at lower leg, the 7.5-12 MHz linear array probe was placed in sagittal plane in medial aspect of the popliteal fossa to measure the distance between medial femoral condyle and the posterior aspect of the tibia at rest and after manual pressure for estimation of the anterior tibial translation seen in chronic injuries.

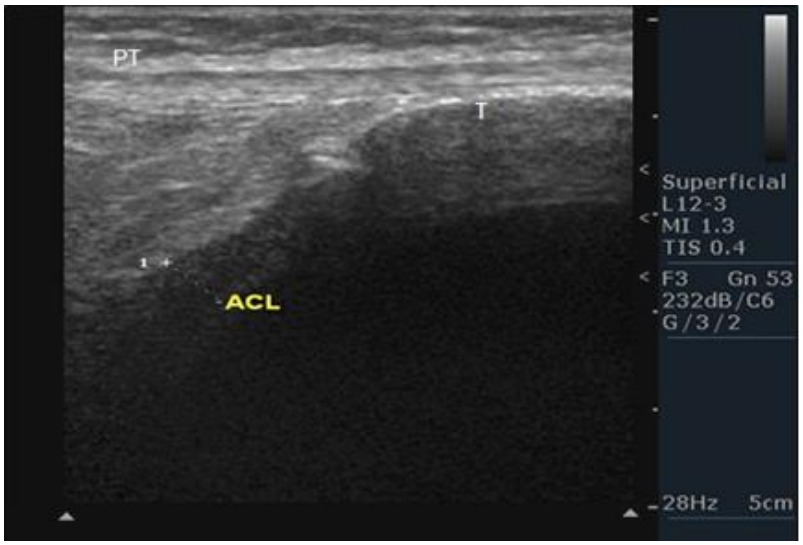


Figure 2- Longitudinal view showing increased ACL thickness, Tibia (T), Patellar tendon (PT)

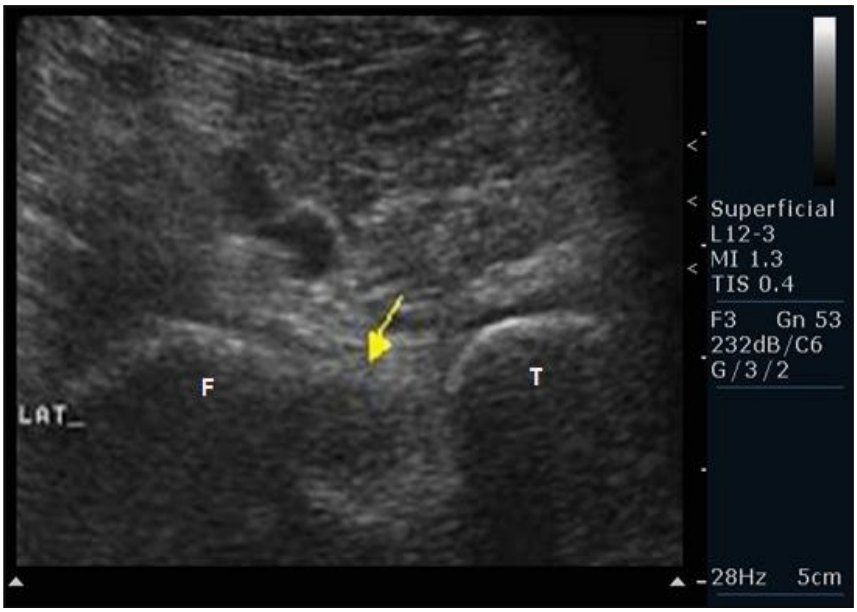


Figure 3- Anterior cruciate ligament hematoma on the inner side of the lateral epidondyle

- The transducer was moved over the midline of the posterior knee to visualize the posterior cruciate ligament. One helpful landmark is the characteristic bone contour of the tibial plateau at the posterior cruciate ligament attachment. The transducer is then rotated slightly to elongate the posterior cruciate ligament.
- Examination of the contra lateral uninjured knee in the same patient attempted routinely for comparison.
- We evaluated the meniscal echogenicity & width while the PCL was evaluated for thickness and echogenicity & ACL was evaluated indirectly for hematoma and anterior tibial translation.

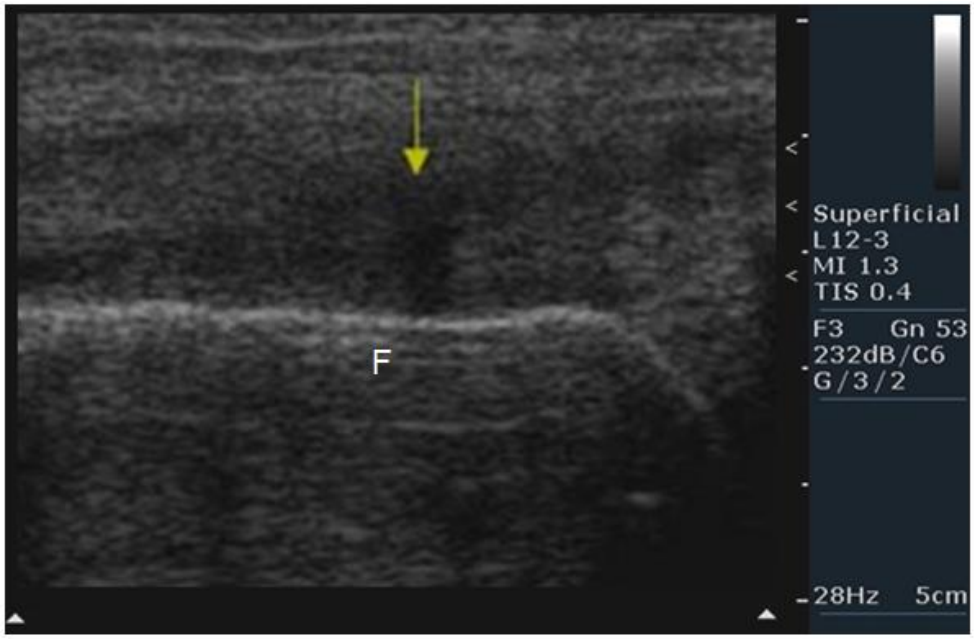


Figure 4- Longitudinal scan showing focal hypoechoic area in medial collateral ligament (arrow) representing tear, Femur (F)

Ultra-sonography(USG) can differentiate meniscal cyst form other cystic or solid masses at the knee join as the ganglion cyst, pes anserine bursa, popliteal cyst and protruded degenerated meniscus. Out of which meniscal cyst was identified in both ultrasonography and MRI. Majority of the tears were those involving the posterior horn of medial meniscus followed by the posterior horn of the lateral meniscus. USG appearances of loose bodies accurately reflect their anatomic structures. The articular cartilage appears as a thin hypoechoic layer, with uniform thickness and regular smooth surface that overlies the thick hyperechoic line corresponding to the subchondral bone. Destructive synovial proliferation, joint effusion and popliteal cysts are recognized to accompany the knee osteoarthritis[11].

IV. Method of Data Analysis

Collected data was presented in the form of tables and diagrams. Sensitivity, specificity and predictive values were calculated. Using data was analysed for finding the significant correlation between MRI knee and arthroscopic findings by kappa statistics.

V. Results

In the present study, the most frequent knee finding was joint effusion which was seen in 44 (88%) follower by ligament 33(66%), 11 osseous (22%) and 1 muscular (2%). No specific sex predilection was found. The most frequent age group affected in this work was the second decade.

Table 1- Age Distribution

Age	**Number of cases**	**Percentage**
11 – 20	7	14%
21–30 (MAXIMUM PATIENTS)	**19**	**38%**
31 – 40	7	14%
41 – 50	12	24%
51 – 60	4	8%
61 – 70	1	2%

Table 2- Knee pathologies

Structures injured	**MRI**	**USG**
ACL	17	16
PCL	4	6
MCL	5	6
LCL	6	5
AHMM	1	1
PHMM	25	23
AHLM	3	2
PHLM	8	6

PARAMENISCAL CYST	1	1
JOINT EFFUSION	44 (5 Hemarthrosis)	44 (5 Hemarthrosis)
FRACTURE/CONTUSION	14	4
ARTHRITIS	5	4
CHONDROMALACIA PATELLAE	2	2
MARROW EDEMA	17	0
POLPLITEAL CYST	7	7
TUMOUR	1	0

Table 3- ACCURACY OF USG

Structure	**Sensitivity (%)**	**Specificity (%)**	**Accuracy (%)**
ACL	82.35	93.94	90
PCL	75	93.48	92
MCL	83.33	97.73	96
LCL	80	97.78	96
AHMM	100	100	100
PHMM	84	92	88
AHLM	66.67	100	98
PHLM	62.57	97.62	92
Meniscal injuries overall	83.87	89.47	86
Parameniscal cyst	100	100	100
Popliteal cyst	100	100	100
Joint effusion	100	100	100
Fracture/Contusion	28.57	100	80
Arthritis	80	100	98
Marrow Edema	0	100	66

The study revealed that the mean accuracy of high resolution ultrasound in the diagnosis of both medial & lateral meniscal injury was 80%, mean sensitivity was 52.5% and the mean specificity was 84.15%. And also ultrasound recorded an accuracy of 83.3 %, sensitivity of 81.2% and specificity of 84.2% in diagnosis of ACL injury. For PCL, its results were as follows:-Accuracy 90 %, sensitivity 50% and specificity 96%.

From this we can conclude that high resolution ultrasound gives high accuracy & specificity which nearly approaches that of MRI. As regarding its sensitivity, it is of lower comparable value than that of MRI. So it is preferable to use high resolution ultrasound as a preliminary investigation for diagnosis as the patient can avoid performing the high cost MRI unless the patient was proved to be injured and needing MRI.

VI. Discussion

The anterior cruciate ligament is the most commonly injured of the major knee ligaments. In our study the frequency of cruciate ligament injuries was: ACL in patients 17 (34%) and PCL in 6 (12%) patients.

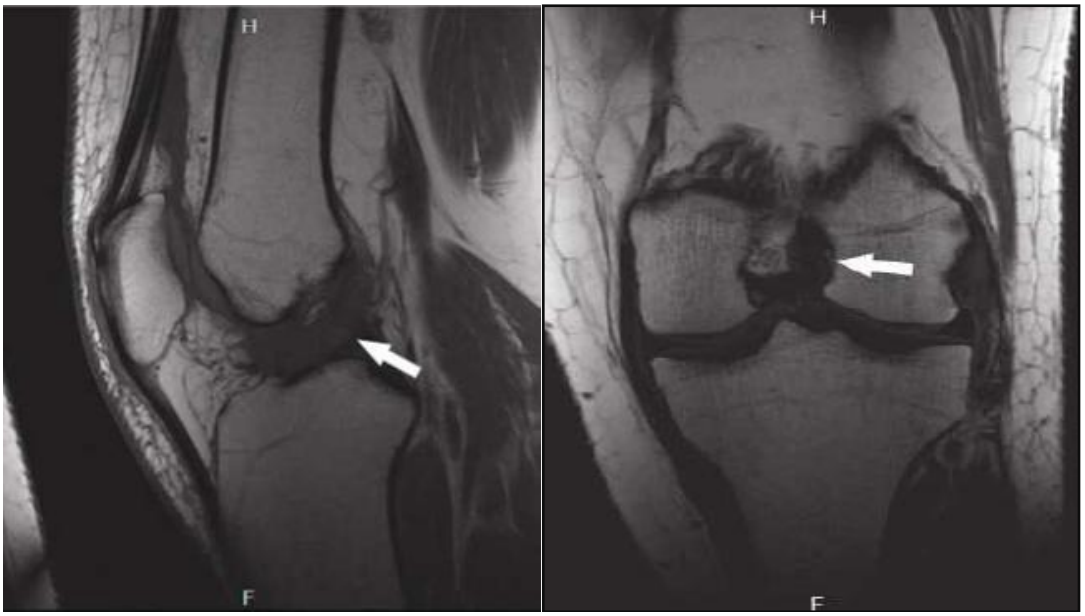


Figure 5 (A) Sagittal PD WI & (B) coronal T1WI show thickened ACL with abnormal signal intensity within its substance s/o tear.

The direct signs of ACL tear on MRI include[12]

- Discontinuity of the fibers of anterior cruciate ligament
- An abnormal contour of anterior cruciate ligament.

The indirect signs of ACL tear on MRI include[6,12]

- Angulation of the posterior cruciate ligament of less than 105^{o},
- Anterior tibial translation exceeding 6mm
- Overhanging posterior horn of the lateral meniscus by 2.5mm
- Deep lateral femoral notch exceeding 2mm in depth
- Segond fracture of the lateral tibia involving the middle portion of the lateral fibrous capsule at the meniscofemoral attachment
- Chip fracture of the posterior tibia
- Rotary bone contusion pattern.
- Irregularity of the free concave edge of Hoffa's fat pad suggestive of synovitis

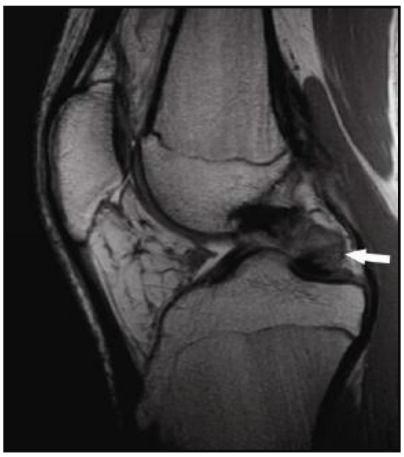


Figure 6- sagittal PD shows complete PCL tear.

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, with maintained continuity of PCL. Secondary signs such as a lax ligament or persistent increased signal may help diagnose chronic PCL tears

The traditional classification of MCL tears is to grade the damage as first- through third-degree sprain/tear injuries.[13]

- Grade I – Lesions are defined as high signal intensity superficial to the MCL representing edema, with intact MCL fibers.
- Grade II- Lesion in which fluid signal extend partially through MCL, although some fibers remain intact
- Grade III- Lesion with complete discontinuity of the MCL fibers seen along with surrounding edema, consistent with a complete tear

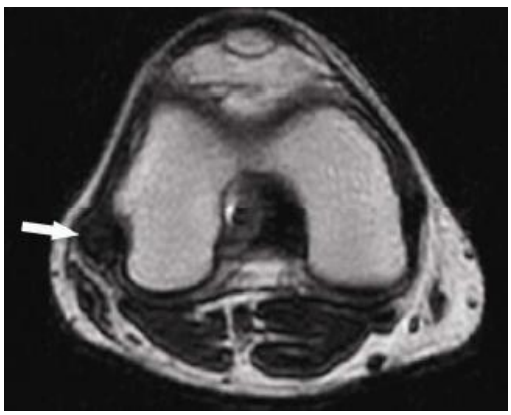


Figure- 7Axial T2WI shows focal thickening of the lateral collateral ligament with bone defectat lateral aspect of the tibial plateau

LCL are associated with other injuries. Lateral collateral ligament injuries are usually classified similarly as medial collateral ligament lesions, using the 3- point grading system as outlined above.

Figure 8- Sagittal PD WI shows abnormal signal intensity in the posterior horn of themedialmeniscus reaching the articular surface s/o horizontal tear of posterior horn of medial meniscus.

Two Diagnostic criteria for diagnosing a meniscal tear are commonly used.[14]

1) Intrasubstance signal: It is graded as follows:

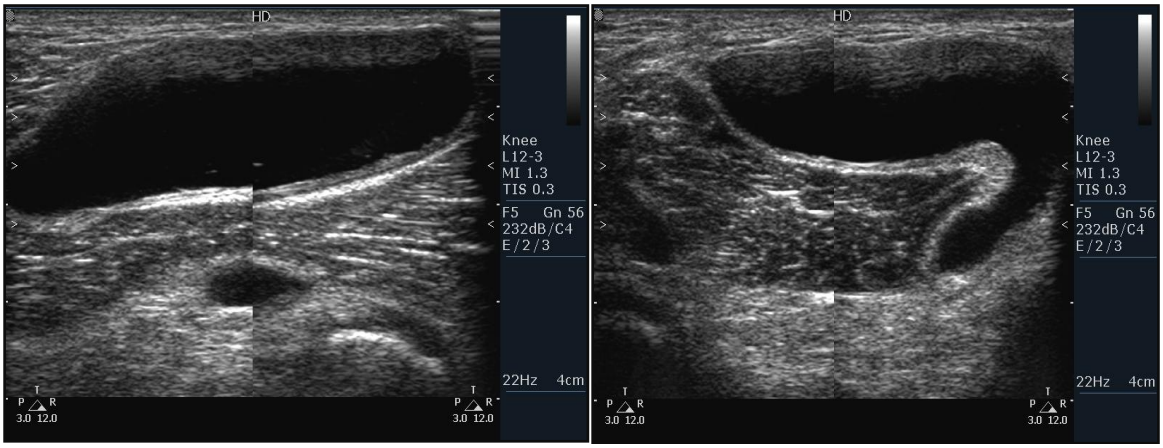
- Grade 1: Intrameniscal high signal intensity of irregular or globular appearance that is confined within the meniscus and does not extend to the articular surface.
- Grade 2: The signal is linear and does not intersect the inferior or superior articular surface. It may, however, contact the capsular margin at the posterior aspect of the meniscus.
- Grade 3: Tears characterized by linear high or intermediate signal intensity that extends to the superior and/or inferior articular surface.
- Grade 4: It is sometimes added to indicate a complex tear with multiple components or fragmentation.

Both grade 1 and grade 2 lesions do not represent a tear, but indicate mucinous and mucoid intrasubstance degenerative change and are usually encountered after the third or fourth decade. In children and adolescents, prominent vasularity may resemble grade 1 or grade 2 lesions.[6]

Figure 9-Sagittal PD WI shows abnormal signal intensity in the posterior horn of themedial meniscus reaching the articular surface …horizontal posterior horn medial meniscus tear.

(ii) Abnormal Meniscal morphology:

Morphologic changes of the meniscus associated with meniscal tears include blunting of tip of the inner free meniscal edges of the meniscus, displacement of a portion of the meniscus, interrupted appearance of the meniscus and abnormal size of a segment of the meniscus is detached (a bucket handle tear), the remaining peripheral portion appears small and often truncated. The displaced portion usually lies within the intercondylar notch beneath the PCL. Coronal views are helpful in further identifying such displaced fragments. An abrupt change in contour of the meniscus, known as the 'notch' sign, is an important indicator of a meniscal tear. Although the normal meniscal flounce can simulate it, the presence of abnormal intrameniscal signal makes the notch sign a more definite indicator of a meniscal tear.[15]



Figute10 (A)Longitudinal view & (B) - Transverse view showing popliteal cyst with tail

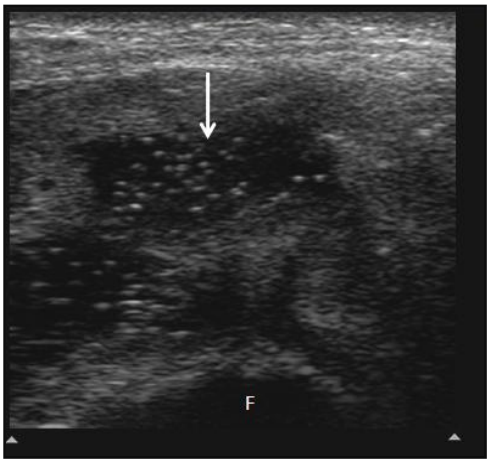


Figure 11- Transverse view joint effusion with multiple internal echoes(Arrow) s/o hemarthrosis, Femur (F)

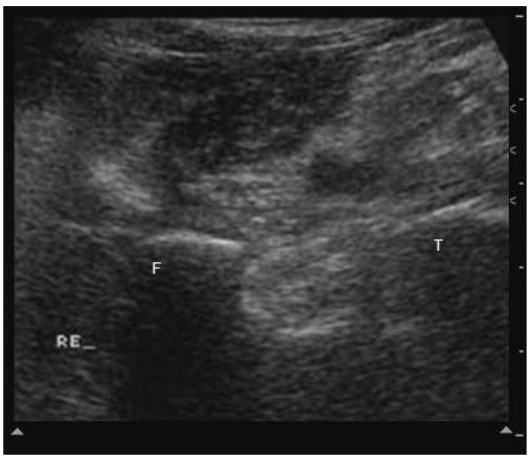


Figure 12- Normal Intercondylar fossa and hematoma transverse

In the present work, one case of meniscal cyst was found , it was easily diagnosed with US and was associated with tear of posterior horn of medial meniscus. It appeared as a well defined sonolucent structure posterior to the medial collateral ligament and related to a tear in the posterior horn of the medial meniscus.

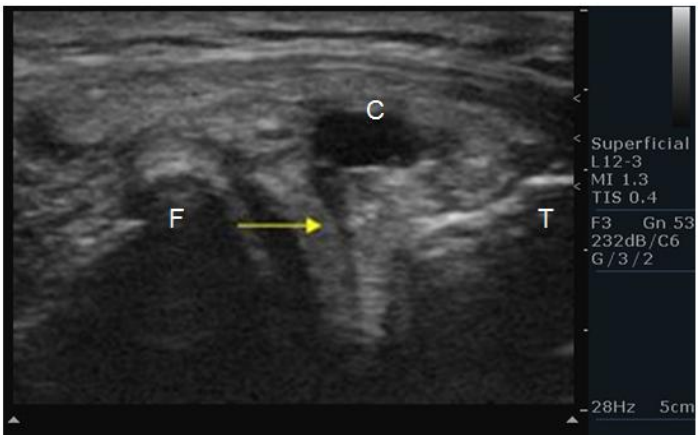


Figure 13- Longitudinal view showing anechoic Parameniscal cyst (C) with hypoechoic tear (Arrow) involving the PHMM, Femur (F), Tibia (T)

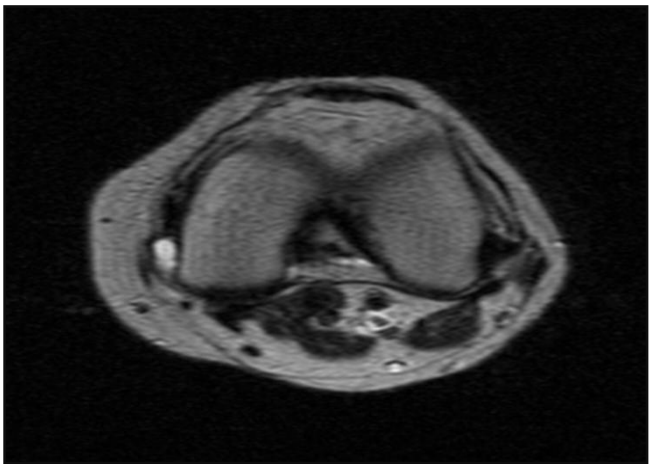


Figure 14–T2W Fat Sat axial image of same patient – Showing Parameniscal cyst

Osseous injuries were detected in 16 cases. 5 fractures were found (10%), 09 (18%) contusion and there was one case of lateral patellar dislocation (2%). The remaining lesions were 2 osteochondral lesions (4%). intraarticular loose bodies were detected with sonography in 2 cases. Osseous loose bodies were found and appeared echogenic with acoustic shadowing with joint effusion. Cartilage loss is regarded as the primary pathological feature of osteoarthritis. In knees with osteoarthritis, secondary synovial osteochondromatosis can be found with formation of chondro-osseous loose bodies due to synovial hyperplasia and metaplasia as a result of synovial rubbing across the osteophytes[16.]

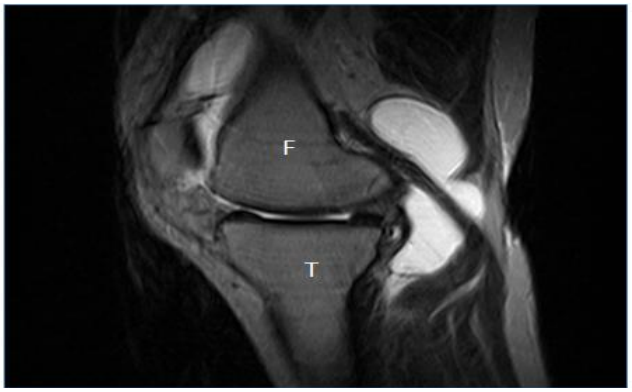


Figure 15–T2W FAT SAG – Showing large popliteal cyst(PC), T-Tibia, F-Femur)

7 cases with baker's cyst were encountered. In all cases, the cyst was associating marked joint effusion. Loose bodies were seen in one cyst and hemorrhage in another one. All bakers' cysts were detected with US examination[17].

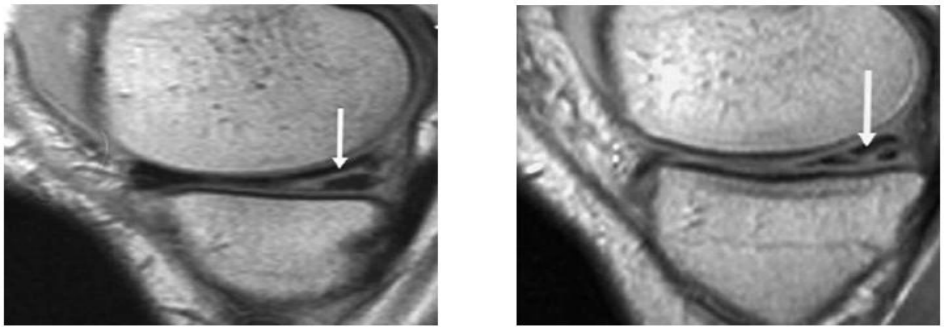


Figure 16- showing a-Linear high signal intensity that intersects the inferior articular surface (arrow) representing a grade 3 lesion.
B-Complex grade 3 tears extending to both the superior and inferior articular surfaces (arrow) Meniscal cyst

VII. Conclusion

The knee joint is one of the most important joints in the human body responsible for weight-bearing and a group of complex movements during ordinary life activities and even in vigorous sports making it susceptible to different traumatic injuries[18]. If there is a patient with history of knee trauma and clinical suspicion of cruciate ligaments and/or meniscal injuries, we recommend starting with high resolution ultrasound examination as screening tool. For negative examinations follow up, if no improvement the second step is MRI examination to rule out cruciate and meniscal injuries[19]. For positive results MRI examination is recommended to prove cruciate ligaments and meniscal injuries and for more details

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