ORIGINAL ARTICLE

Tc-99m MDP bone SPECT in the diagnosis of meniscal tears

Muhammad Khalid Bosan[1,*], Hafiz Khusnaseeb[1], Shazia Fatima[2]

[1]Centre for Nuclear Medicine and Radiotherapy (CENAR), Quetta
[2]Nuclear Medicine, Oncology and Radiotherapy Institute (NORI), Islamabad

Abstract

Objective The study was designed to observe the role of SPECT bone imaging for the detection of meniscal tears.

Methods This study was conducted at NORI hospital Islamabad in collaboration with radiology and orthopedic departments of leading hospitals of Islamabad and Rawalpindi. Radionuclide SPECT bone imaging with Tc-99m MDP was performed on the knees of 35 patients with suspected meniscal injuries. After SPECT scanning, the patients had an MRI scan followed by arthroscopy, the gold standard for diagnosis of meniscal injuries. The Fischer's Exact Test was applied to compare the results of M.R.I with arthroscopy. *p*-value <0.05 was considered as significant.

Results The results of SPECT scanning were comparable to MRI imaging in the diagnosis of meniscal tears. The sensitivity was 88% for SPECT scanning and 80% for MRI in diagnosis of meniscal tears on the basis of arthroscopy results. The specificity for MR.I and SPECT was similar for the two diagnostic moalities. However, the accuracy of SPECT scanning was found to be 80.6% compared with 74.2% for MRI for accurate for diagnosis of meniscal tears.

Conclusion There was insignificant difference between the results of MRI and arthroscopy, and SPECT and arthroscopy (*p*-value 0.161 and 0.069 respectively). The overall results reveal that SPECT scanning can be very useful in diagnosis of meniscal tears.

Key words: *^{99m}Tc-MPD, bone SPECT, MRI, meniscal tears, knee joints*

***Correspondence**
Dr Muhammad Khalid Bosan
Nuclear Medicine Department
CENAR
Quetta, Pakistan
Tel: +923342237110
Email: khalidbosan@gmail.com

Introduction

The uptake and retention of the Tc-99m diphosphonate complex in the bones and soft tissues is a function of calcium content of the respective tissues in general [1]. The di phosphonate concentrate in the mineral phase of the bone, which consists of two-thirds crystalline hydroxyapatite and one-third amorphous calcium phosphate. The major factors affecting the accumulation of diphosphonate complexes in the skeleton are the blood flow and extraction efficiency. Bone blood flow is five to thirteen times higher in cancellous bone containing marrow than in the cortical bone as measured with microspheres. Increased blood flow does cause an increase in the uptake, but the process is not linear [2]. Pathological lesions containing woven bone have an increased uptake because of higher extraction efficiency [3].

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Other factors influencing the uptake include capillary permeability, acid base balance, intraosseous tissue pressure, parathyroid hormone, vitamin D and glucocorticoids [4]. Diphosphonates are absorbed on the surface of the bone with particular affinity for sites of new bone formation.

History and physical examination, along with the use of MRI, remain the primary methods of diagnosing meniscal pathology [5]. Tc-99m bone SPECT is also a diagnostic modality for diagnosis of meniscal tears [6]. However, arthroscopy remains the gold standard for diagnosis of meniscal tears. This study was undertaken to investigate and highlight the role and effectiveness of Tc-99m SPECT bone scan in the diagnosis of meniscal tears. The overall objective of this project was to assess the role of radionuclide imaging especially SPECT scanning in the assessment of meniscal injuries.

Subjects and Methods

The patients were selected for SPECT scanning on the basis of a positive history and clinical signs suggestive of meniscal tears. All the patients presented with a complain of knee joint pain with majority having had sports-related injuries. Patients with fractures or morphologic features of fractures of the knee bones were excluded from the study. Patients, who had undergone any surgical or additional invasive therapeutic interventions of the affected knee together with pregnant females were excluded from the study. Patients with any sign of osteoarthritis were also excluded to reduce the number of menisci with possible degenerative changes. These exclusions would help to differentiate meniscal findings due to contusion and degeneration. All the patients included in the study had a recent onset of symptoms with the maximum duration of complaints of not more than 2 months. The final study group comprised of 35 patients.

Pre-imaging assessment: Detailed proformas were devised for the patients to include a thorough history, relevant examination and reports of previous investigations (if available). X-rays of knee joint for all the referred patients were performed, which were unremarkable with no evidence of bone pathology. The nature of the test was explained to all the patients. SPECT bone scans of the knees were performed in all patients. In addition to SPECT images, planar knee joint images for academic purpose to get any inference at the end of the study were also acquired on 256 x 256 for 400 kcts on anterior and posterior projections (Figure 1).

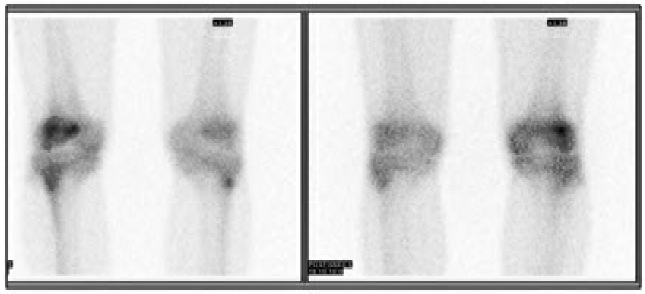

Figure 1 *Planar images of knee joint of a patient with meniscal tear*

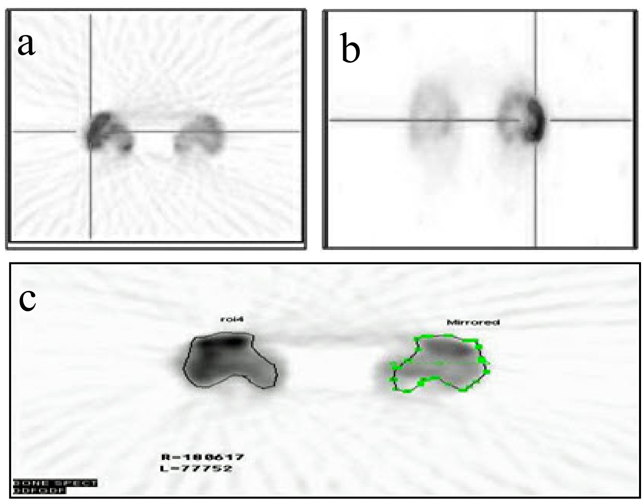

Figure 2 *Bone SPECT images of the knees. A crescentic pattern of uptake is the usual criterion for the scintigraphic diagnosis, especially in trans-axial slices (a). However, posterior horn tears may also be associated with a more focal pattern of accumulation, together with increased equilibrium activity in the adjacent femoral condyle (b) as seen in a meniscal tear. ROIs drawn on summed transaxial images for generating the counts in the regions of interest (c)*

Bone SPECT imaging: Three hours after IV injection of 750 MBq ^{99m}Tc methylene diphos phonate (^{99m}Tc-MDP), anterior, posterior, medial and lateral views of both knees and SPECT images of the knee were acquired. SPECT studies were performed on a dual-head Infinia camera, equipped with low-energy, high-resolution collimators. Images were acquired in a 128 × 128 matrix at 60 steps, 30s each step. The data were processed by filtered back-projection using Hanning 0.9 filters. Images were reconstructed and displayed in all three orthogonal planes.

MRI: All studies were performed using a scanner (IGE Medical Systems, Signa Herza, Milwaukee, WI) with a 1.5 Tesla magnet. The knee was placed in an extended position with approximately 15° of external rotation. The imaging protocol included sagittal multiecho (repetition time msec/ echo time msec, 2,500– 3,600/20–120), coronal T1-weighted (600/12), coronal multiecho (2,500–3,000/ 17–119), and transverse gradient-echo or turbo T2-weighted sequences with a slice thickness of 4.5 mm, no interslice gap, and a matrix of 256 × 256. MRI results were reported by an experienced radiologist in MRI of the knees.

A meniscus was considered torn when an area of increased internal signal intensity was in unequivocal contact with a meniscal articular surface on one or more images. The menisci were assessed as normal or torn. Tears were classified as horizontal, vertical (subdivided into longitudinal and radial), flap, bucket-handle, or complex. A complex tear consisted of two or more tear configurations. The presence of any meniscal contusion was documented. The anterior horn, body, and posterior horn were assessed separately for both menisci. Possible meniscocapsular separation was documented.

Arthroscopy protocol: Arthroscopy was performed in the acute phase of injury by three orthopedic surgeons specialized in trauma surgery and knee arthroscopy having more than 10 years of experience. The results of the scans were not known to the surgeon prior to the arthroscopy and the operative findings were recorded in a standard fashion that detailed the internal anatomy of the joint. A tear was considered present if there was a cleavage in the semilunar cartilage that allowed a portion to be displaced from its normal position by the examining probe.

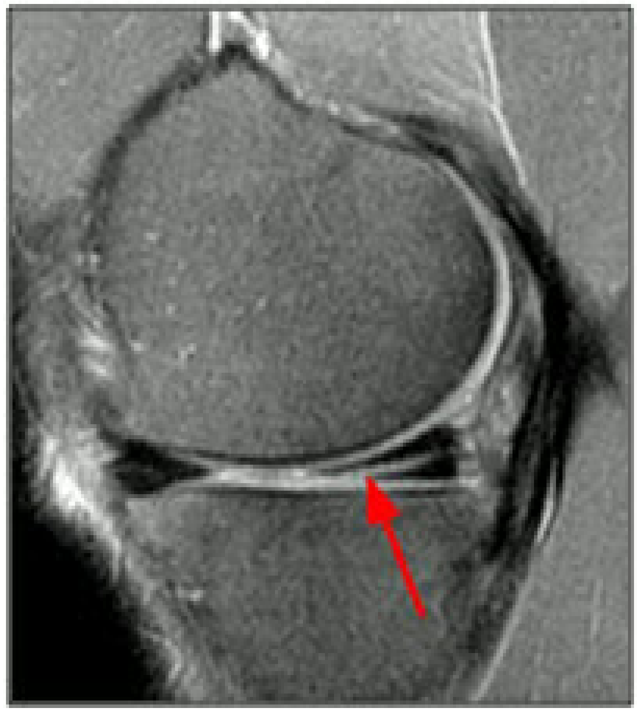

Figure 3 *Evidence of meniscal tear on MRI*

Figure 4 *Arthroscopy of a patient in process*

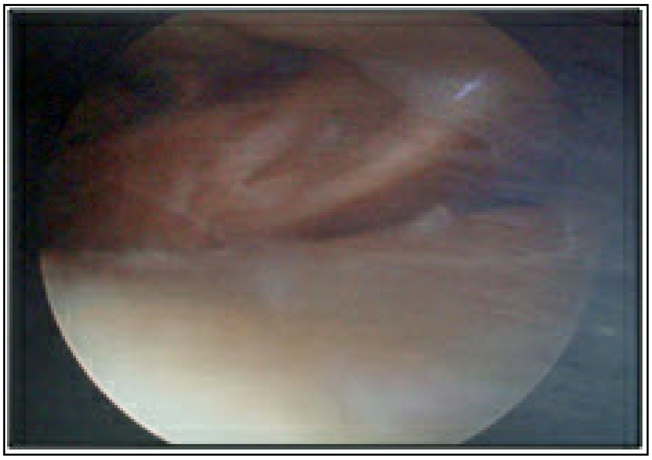

Figure 5 *Meniscal tear on arthroscopy*

Statistical analysis: Statistical analysis of the data was done using SPSS version 17. Descriptive statistics were used to describe the data. Mean and standard deviations were calculated for the age, frequency and percentage for gender and diagnoses on SPECT, MRI and arthroscopy. Sensitivity analysis was carried out for SPECT and MRI separately keeping arthroscopy as the gold standard. Fisher's exact test was applied to compare the results of SPECT and MRI with arthroscopy.

Results

Thirty-five patients, suspected of meniscal injury, were referred to us from orthopedic departments of PIMS, CMH and PAEC hospitals in Islamabad for SPECT scanning of their knee joints. A total of 70 menisci (35 left and 35 right) for 35 patients were assessed. The injury mechanisms were traffic accident in 6 cases, simple fall in 7 cases, sports injuries in 15 cases, and twisting injury in 7 cases. The majority of the patients had sports-related injuries, i.e. trauma to their knee joints while playing cricket, football or hockey. There were 7 female and 28 male patients with a mean age of 30.8 ± 1.5 years (range, 14-46 years). SPECT bone scan was performed for all patients followed by MRI scan at the radiology departments in PIMS and CMH hospitals. This was followed by arthroscopy of the patients' affected knees. Thirty-one out of thirty-five patientshad their arthroscopies done at PAEC, Shifa international hospital, Islamabad, and the CMH Rawalpindi.

SPECT bone scan was performed on 35 patients, with 27 of these reported to have meniscal injuries on the basis of crescenteric uptake or focal uptake seen in the region of tibial plateau on SPECT slices, particularly on the transaxial slices. There was a threefold increase in counts recorded on pathological side. No meniscal injuries were reported in 6 patients. All the 35 patients had MRI scan following SPECT studies of their knee joints. All the patients, after having SPECT and MRI scans were referred back to the Orthopedic doctors for further procedures i.e. arthroscopy. Thirty-one out of thirty-five patients had arthroscopy of their knee joints. The parameters for MRI and SPECT scans were evaluated individually and compared, keeping the arthroscopy as the gold standard. See Tables.

Table 1 *Bone SPECT result analysis*

	MRI Positive	MRI Negative	Total
SPECT Positive	23	04	27
SPECT Negative	02	06	08
	25	10	35

Table 2 *Bone SPECT result analysis*

True positives	23
True negatives	06
False positives	04
False negatives	02

Table 3 *SPECT scanning results keeping MRI as standard*

Sensitivity	Specificity	Positive predictive value	Negative predictive value
92%	60%	85.18%	75%

Table 4 *SPECT result analysis arthroscopy as gold standard*

True positives	22
True negatives	03
False positives	03
False negatives	03

Table 5 *SPECT result analysis arthroscopy as gold standard*

Sensitivity	Specificity	Positive predictive value	Negative predictive value	Accuracy
88%	50%	88%	50%	80.6%

Table 6 *MRI results using arthroscopy as gold standard*

True positives	20
True negatives	03
False negative	03
False negatives	05

Table 7 *MRI results using arthroscopy as gold standard*

Sensitivity	Specificity	Positive predictive value	Negative predictive value	Accuracy
80%	50%	87%	37.5%	74.2%

Table 8 *SPECT result analysis arthroscopy as gold standard*

	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Accuracy
SPECT	88%	50%	88%	50%	80.6%
MRI	80%	50%	87%	37.5%	74.2%

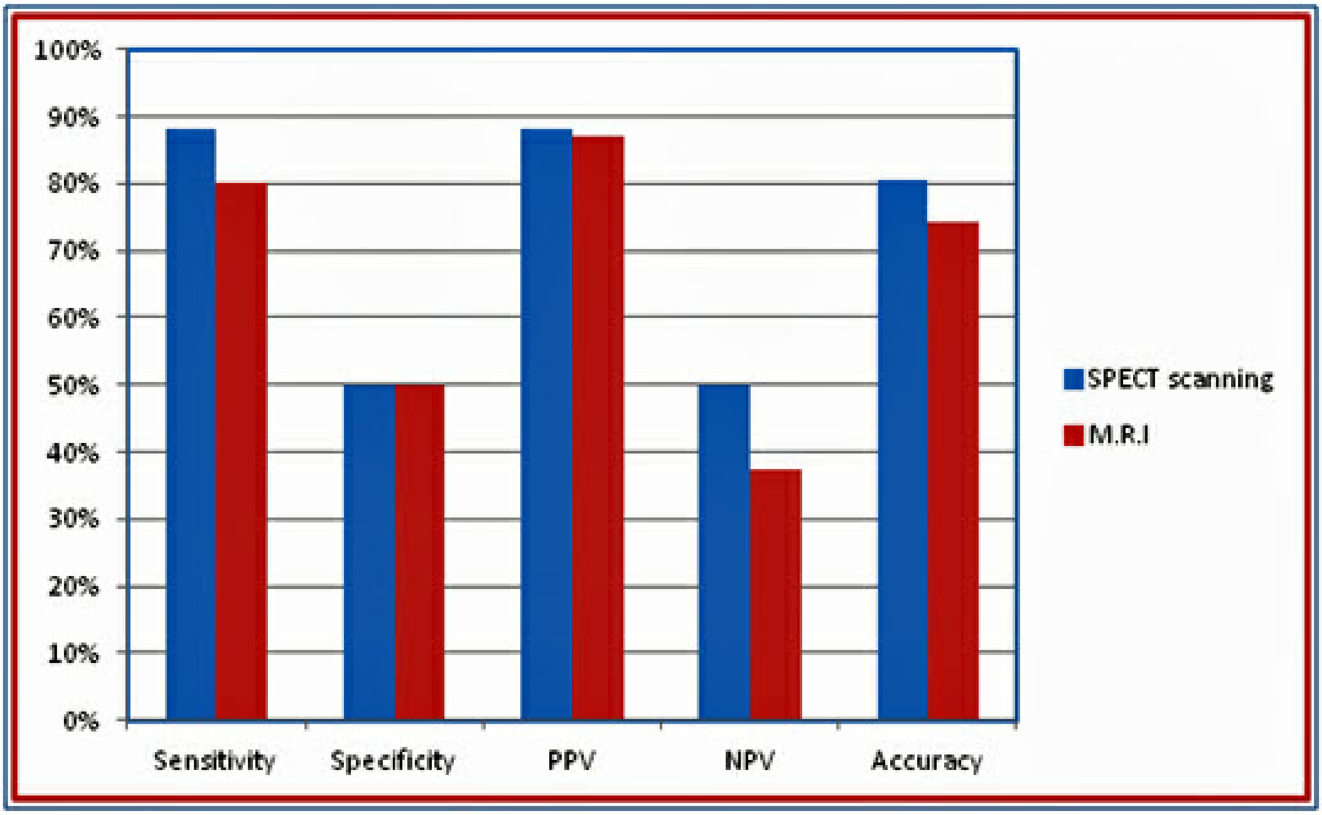

Figure 9 *Comparison of SPECT scanning and MRI*

Fischer's exact test was applied to compare the results of SPECT with arthroscopy. *p*-value <0.05 was considered as significant. There was an insignificant difference between the results of SPECT and arthroscopy as the *p*-value was calculated to be 0.069. There was insignificant difference between the results of MRI and arthroscopy with the *p*-value of 0.161. The sensitivity, specificity, positive predictive value, negative predictive value and accuracy of MRI and SPECT scanning of knee regarding arthroscopy are graphically shown in Figure 9.

Discussion

A significant proportion of patients attending orthopedic out-patient clinics had knee disorders. Antecedent history and clinical examination were facilitated further management of these patients. It is recognized that using clinical examination to exclude meniscal injury is unreliable compared with arthroscopic findings [7]. Although arthroscopy offers the advantage of treating patients at the time of diagnosis, it is more expensive and, as an invasive procedure. It carries the risks associated with anesthesia and additional costs. Therefore, selection of patients for arthroscopy is required. Published evidence suggests that MRI and SPECT scans are useful tools to delineate the lesions pre-arthroscopically [8]. MRI has become the radiologic procedure of choice for the diagnosis of soft tissue derangements of the knees.

This led us to look for alternative modes of investigation. The unreliability of clinical examination and the invasiveness of arthroscopy means that there is a strong need for non-invasive diagnostic tests for the investigation of knee meniscal injuries. However, some authors have reported that bone SPECT is valuable in the preoperative assessment of knee pathologies [9]. MRI has established its role for non-invasive investigation. However, MRI is expensive, time consuming and has a high false-positive rate. SPECT bone scan has proved to be a useful alternative to MRI and also has an important role where MRI is contraindicated. The purpose of this study was to evaluate the role of bone SPECT imaging in a routine clinical setting. Generally, very few studies have directly compared bone SPECT scanning and MRI in the detection of meniscal tears. Most of these reports determined that the spatial resolution of MRI remains superior, but bone SPECT has repeatedly been proven to detect and characterize tears with greater accuracy than MRI [10]. MRI is recognized as the most sensitive and specific non-invasive method of detecting meniscal tears; however, MRI is not yet widely available [11]. Skeletal scintigraphy is more readily available and provides a sensitive and relatively inexpensive means for diagnosing many bone and joint disorders. It has not gained popularity in investigating meniscal damage. Marymont *et al.* [12] claimed that planar imaging was more successful than MRI in identifying tears of the menisci but his results have not been repeated by others. SPECT scanning allows more specific localization of the source of the increased activity [13]. This has also been supported by the research study and the results obtained by Collier *et al.* [14] where SPECT had a sensitivity of 100% and specificity of 63% in the diagnosis of meniscal tears.

In 1998, Ryan *et al.* studied 100 patients with undiagnosed knee pain by clinical examination, MRI, SPECT bone scintigraphy and arthroscopy. Using arthroscopy as a gold standard, both MRI and SPECT scanning showed high diagnostic ability to detect meniscal tears, with respective sensitivity rate, specificity rate, and positive and negative predictive accuracies of 80%, 71%, 84% and 71% for MRI and 84%, 80%, 88% and 76% for SPECT. Some meniscal tears were detected by MRI alone (n=5), or SPECT alone (n=8) [15]. The authors found that the comparable diagnostic ability of SPECT bone scintigraphy implies that it can be used successfully when MRI is unavailable or unsuitable. This study prompted an editorial by Ryan in Nuclear Medicine Communications that advocated the application of SPECT scanning, when MRI is unavailable or unsuitable [16]. Most recently Vellala *et al.* assessed the role of single photon emission computed tomography bone scan for the diagnosis of knee lesions in routine clinical practice in 40 patients [17]. The sensitivity of SPECT scans in detecting medial meniscal and lateral meniscal was 77% and 14%, respectively. The specificities for the same structural lesions were high at 89% and 94%, respectively. These investigators concluded that SPECT bone scan appears to be useful in the diagnosis of knee pathology in routine practice and in selecting patients for arthroscopy, especially most useful for the diagnosis of medial meniscal tears. There was also a study conducted by Grevitt *et al.* and they compared SPECT bone scan results with arthroscopy as the gold standard. They concluded that the overall sensitivity of SPECT was 77%, specificity 74%, NPV 65%, PPV 83% and accuracy 76% [18].

In this study we had thirty five patients. A total of 70 menisci, including 35 left and 35 right menisci, in 35 patients were assessed. The number of patients was limited due to time constraints. The injury mechanisms were traffic accident in 6 cases, simple fall in 7 cases, sports injuries in 15 cases, and twisting injury in 7 cases. Majority of the patients were having sports related injuries i.e. had trauma to their knee joints while playing cricket, football and hockey. The patients were 7 female and 28 male, with a mean age of 30.8 ± 1.5 years (range, 14-46 years). Patients were evaluated for any bone fracture or degenerative arthritis by orthopedic doctors before sending patients to us for SPECT bone scan. These patients were not included in the study. We did SPECT bone scan on all patients followed by MRI of their affected knees. Later on the arthroscopies of the patient's affected knee were done. Thirty-one out of thirty-five had their arthroscopies done. First of all we analysed the bone SPECT results and then MRI and the results of both scans were compared keeping arthroscopy as the gold standard. The sensitivity, specificity, positive predictive value and negative predictive value of bone SPECT scan and MRI were evaluated.

The results revealed higher sensitivity and specificity of SPECT scan and MRI in comparison to the study conducted by M. Saghari *et al.* [19] in which SPECT scan was directly compared with MRI with sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of the bone SPECT as 78, 88, 80, and 86 %, respectively keeping MRI as the gold standard. Their study demonstrated that MRI was only slightly superior to SPECT for detection of meniscal tears. However, the difference did not reach statistical significance. The results of MRI and SPECT bone scanning were compared keeping arthroscopy as the gold standard.

The sensitivity of SPECT bone scan was 88% in comparison to 80% sensitivity of MRI. Our study revealed higher sensitivity of bone SPECT than the MRI and this fact was also stated by Ryan *et al.* in their studies who had reported 80% and 88% sensitivity of MRI and SPECT bone scanning respectively compared to arthroscopy. They had also reported high false positive rate for MRI and our study also supports this fact. Vellala *et al.* had also reported high sensitivity for SPECT bone scanning in detecting meniscal tears. The reported reasons for high false positives of MRI are numerous. False positives can also occur with healed meniscal tears or post operative menisci, in which abnormal signal extending to the surface remains on standard MR imaging sequences [20]. Truncation artifact can also be a cause of false positives. Radially orientated collagen ''tie'' fibers, which have linear intermediate signal within the meniscus and myxoid degeneration can also simulate tears. The lateral inferior genicular artery can simulate a tear of the lateral meniscus, and the normal concavity of the peripheral aspect of the meniscus can mimic a horizontal tear on peripheral sagital images caused by a volume-averaging artifact. The meniscal attachments of the meniscofemoral ligaments can simulate a tear in the posterior horn of the lateral meniscus. The popliteus tendon adjacent to the posterior horn of the lateral meniscus can also be a source of error because of fluid tracking along the intraarticular portion of the tendon [21]. The medial and lateral oblique meniscomeniscal ligaments and the anterior meniscofemoral ligament of the medial meniscus can also simulate tears [22]. The specificity of Bone SPECT scanning and MRI came out to be similar i.e. 50%. However earlier studies had reported higher specificity for bone SPECT, though the difference did not reach statistical significance. The possible reason for higher specificity of earlier studies could be the expertise in reporting and large number of the patients. The positive predictive value and negative predictive values for bone SPECT and MRI were 88%, 50% and 87%,37.5% respectively. All these parameters are consistent with the results of earlier studies. There were two patients who were reported negative on MRI but they were reported to have meniscal tears on SPECT scanning and arthroscopy. It is not yet well determined that why some tears are missed by one modality and are detected by the other. The reason for this non-detection of meniscal tears in these two patients on MRI could be the other associated ligamentous injuries as these two patients had torn ligaments of knee joint as well and another possible reason could be the issues related to reporting and misinterpretation by lesser experienced radiologists. There was one patient who was reported negative on SPECT scanning and MRI but had meniscal injury on arthroscopy. The possible reason for non- detection of meniscal tear in this case on both SPECT scanning and MRI, may be the small size of this tear, long history and its location in posterior horn. Quinn *et al.* had stated that the common false negatives at MR imaging include small meniscal tears and abnormalities involving the meniscal free edge [23]. However, it seems that in the presence of high clinical suspicion and negative MRI results, bone SPECT can be helpful with detecting MRI negative tears.

The Fischer's exact test was applied to compare the results of MRI with arthroscopy. *p*-value <0.05 was considered as significant. There was insignificant difference between the results of MRI and arthroscopy in one hand and and SPECT and arthroscopy other hand with the *p*-value of 0.161 and 0.069 respectively.

In our study, SPECT bone scan results are compatible with MRI when results of both were compared to arthroscopy. The majority of meniscal lesions reported on SPECT scanning were also seen on MRI. We had thirty one patients who had undergone all three procedures, i.e. bone SPECT, MRI and arthroscopy. When we compared the bone SPECT results with MRI considering arthroscopy as gold standard, the results of bone SPECT scan were even slightly better than the MRI. This is also supported by the other studies done on the same topic [24]. The major limitation of this study was the limited number of patients. In this regard further studies having large number of patients are suggested. Both MRI & bone SPECT have various relative advantages and disadvantages. In general, bone SPECT is less costly than MRI because it involves lower capital equipment costs. Bone SPECT is also widely available. The limitation with the use of SPECT scan is the radiation exposure. Magnetic resonance imaging has some advantages over SPECT scanning of the knees too. Most significantly, it gives anatomical details and no ionizing radiation is used but it is more expensive than bone SPECT and in general, MRI has more contraindications and scheduling difficulties. These facts in addition to the results produced in this study indicate that bone SPECT and MRI are both valuable advanced imaging techniques. However, bone SPECT can be helpful when more better accuracy is desired and when MRI results are either inconclusive or contradict with other clinical data. Bone SPECT should be performed if MRI is negative. There are clinical evidences of meniscal tear and incidental finding of meniscal tears when bone scan is being done for some other pathology. Also bone SPECT is available alternative when MRI is unavailable, unsuitable or contraindicated. This approach must be addressed in larger series of patients and a larger prospective study should be performed to confirm these data and approach.

Conclusion

Bone SPECT of knee can be helpful for the diagnosis of meniscal lesions in selecting patients for arthroscopy. Our study revealed high sensitivity and specificity of the bone SPECT scan for meniscal lesion and it suggests that this is a valuable technique to evaluate meniscal knee pathology. The accuracy of bone SPECT in diagnosis of meniscal lesions was also comparable to MRI. In light of the results of this study, MRI and bone SPECT scans can be complimentary to each other in a given clinical situation. This is supported by the results of our study. In conclusion, the lower cost of bone SPECT compared with MRI suggests that it should be the preferred mode of investigation in some clinical situations. Our results suggest that bone SPECT can be valuable and helpful for detecting meniscal tears of the knee, especially when MRI is unavailable, contraindicated and if there is a long waiting period for MRI. An incidental finding of meniscal injury can also be made during bone scanning. However, bone SPECT does not provide the anatomical detail that can be obtained with MRI. Further blinded studies, of considerably larger sample size, would be useful to assess the role of bone SPECT scan in the diagnosis of knee pathology in routine clinical practice.

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