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Bone single-photon emission tomography in recent meniscal tears: an assessment of diagnostic criteria

P.J. Ryan [1], M. Taylor [2], M. Grevitt [2], P. Allen [2], J. Shields [1], S.E.M. Clarke [1], I. Fogelman [1]

[1] Department of Nuclear Medicine, Guy's Hospital, St. Thomas' Street, London SE1 9RT, UK
[2] Department of Orthopaedics, Guy's Hospital, St. Thomas' Street, London SE1 9RT, UK

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Abstract. Bone single-photon emission tomography (SPET) was performed in 40 patients within 6 months of acute knee injury where internal derangement of the knee was suspected, and the results related to the arthroscopy findings. Scan features with high sensitivity, specificity, and predictive accuracy for a meniscal tear could not be obtained on planar imaging. However, a half-crescent or more of increased tibial plateau activity on transaxial SPET gave a sensitivity of 89%, a specificity of 76%, a positive predictive accuracy of 77% and a negative predictive value of 89%. For longitudinal (bucket handle) tears alone the optimum scan pattern was a full crescent of increased tibial plateau activity with adjacent femoral activity and increased blood pool activity which gave corresponding values of 78%, 94%, 78% and 93%. It is concluded that the inclusion of tibial plateau activity of less than a full crescent and the presence of femoral condyle and blood pool activity in the diagnostic criteria improves the ability of bone SPET to detect meniscal tears. The value of bone SPET in the diagnosis of meniscal tears suggests that it could have a significant role to play in the management of knee injuries.

Key words: Meniscal tears – Single-photon emission tomography – Arthroscopy

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Introduction

An accurate diagnosis is essential to the management of acute knee injuries if the optimal treatment is to be effected and complications and permanent injury avoided. Arthroscopy enables treatment at the same time as diagnosis but is expensive, time consuming and invasive. There is therefore a need for non-invasive diagnostic techniques, particularly to identify those in whom arthroscopy can be avoided. Magnetic resonance imaging (MRI) has been demonstrated to have a high level of accuracy for both meniscal and anterior cruciate ligament tears but may be expensive and not always easily available in parts of the United Kingdom and elsewhere in Europe. Bone scintigraphy with single-photon emission tomography (SPET) has been reported as a promising technique for diagnosing meniscal tears and has the advantage in some centres of lower cost and greater availability [1]. A crescent of increased activity in the tibial plateau has been reported in association with meniscal tears on SPET bone scintigraphy. However, we have noted in such cases that tibial plateau activity may be less extensive and that associated femoral and blood pool activity is frequently present. If bone SPET is to be used to detect meniscal tears, optimum diagnostic criteria are required to evaluate its role. The aim of the present study was to investigate the range of bone SPET abnormalities most useful for the detection of meniscal tears.

Correspondence to: P.J. Ryan

Materials and methods

We examined 40 consecutive patients referred to a specialist knee clinic who were aged 17–50 years and had sustained a knee injury within the previous 6 months. Patients were entered into the study if they had symptoms or signs that warranted arthroscopy for diagnosis or treatment. Following informed consent, patients were examined clinically and investigated with X-rays and two-phase bone scintigraphy with SPET. Arthroscopy was performed by a skilled arthroscopist (P.A.) within 3 months of the scan and 9 months of the original injury. Patients were excluded if they had:

1. Surgery to the affected knee
2. Arthroscopy within previous 6 months
3. Known previous meniscal tears
4. Known previous ligamental tears or injuries
5. Known articular surface lesions
6. Previous fracture or osteochondritis dissecans
7. Degenerative X-ray changes (clear evidence of osteophytes, sclerosis or joint space narrowing)

Bone scintigraphy was performed with 750 MBq technetium-99m methylene diphosphonate with equilibrium images acquired between 1 and 5 min post injection and static images at 3 h. Anterior, posterior, lateral and medial planar views were obtained for 700 K counts each. SPET was performed immediately following the planar views. Images were acquired on a Starcam AC 400 (GE Medical Systems, Milwaukee) with a high-resolution collimator, 360° elliptical orbit, with 64 projections and 20 s per projection. Acquisition was into a 128×128 matrix. Following correction for uniformity, 3-mm transaxial, coronal and sagittal SPET images were reconstructed with prefiltering using a Hanning filter with 0.8 frequency cut-off and back-projection with a Ramp filter.

We had previously noted that activity in the tibial plateau associated with meniscal tears on transaxial view may vary from a focal area to a full crescent and also that femoral condyle and blood pool activity were sometimes present. These features were therefore evaluated and in addition a comparison performed between planar and SPET imaging. Scans were reported blind to the arthroscopy findings by a nuclear medicine physician familiar with bone scintigraphy with SPET (P.J.R.). Results were compared to the arthroscopy findings and sensitivities, specificities and predictive values derived.

Table 1. Arthroscopic findings in a total of 40 patients

8	Longitudinal (bucket handle) meniscal tears (2 lateral, 6 medial, 1 with patella O.A., 1 with patella and femoral O.A.)
1	Longitudinal and posterior horn tear (lateral bucket handle, medial posterior horn)
6	Posterior horn meniscal tears (all medial)
4	Minor meniscal tears (1 with 2 minor tears, 3 medial, 2 lateral)
1	Frayed meniscal margins
2	Anterior cruciate injuries
1	Collateral ligament injury
1	Patella O.A. alone
2	Patella and femoral O.A.
2	Femoral condylar O.A. alone
1	Loose body with femoral O.A.
11	Normal

O.A.,

Table 2. Optimum sensitivity, specificity and predictive values (%) of bone scintigraphy for meniscal tears

Bone scan activity	Sensitivity	Specificity	+ve pred. value	−ve pred. value
Planar (all tears)	58	62	62	72
Planar (bucket handle)	89	55	36	95
Bone SPET (all tears)	89	76	77	89
Bone SPET (bucket handle)	78	94	78	93

Results

The arthroscopic findings are described in Table 1. Eleven patients had normal arthroscopies. Of the remainder, 19 had meniscal tears, in two of whom they were bilateral. Ten patients had other arthroscopic abnormalities. There were a total of 21 meniscal tears, of which nine were longitudinal (bucket handle), seven were posterior horn tears and five were minor tears not in the posterior horn. Of the longitudinal tears, six were in the medial meniscus and three in the lateral meniscus. All of the seven posterior horn tears were in the medial meniscus but of the minor tears elsewhere, three were medial and two were lateral. One patient had both a longitudinal and a posterior horn tear and another had two minor tears not in the posterior horn.

The effect of the presence or absence of tibial, femoral condyle and blood pool activity on sensitivities, specificities and predictive values for planar and SPET imaging was examined (Table 2). The optimum planar findings for all tears and bucket handle tears alone were the presence of tibial, femoral and blood pool activity. The extent of tibial plateau activity on transaxial SPET, from a focus through to a full crescent and even more extensive tibial activity, was examined. In addition, the presence or absence of adjacent femoral and blood pool activity was noted. Optimum diagnostic criteria for all tears were a half-crescent or more of tibial plateau activity on transaxial view and for bucket handle tears alone a full crescent of tibial plateau activity with femoral and blood pool activity (Table 2). Specificity for all meniscal tears increased as the percentage of a full tibial plateau crescent required for diagnosis increased and with the inclusion of femoral condyle and blood pool activity. A full crescent and femoral condyle and blood pool activity gave a specificity of 95%. However, with such tight diagnostic criteria sensitivity was reduced to 42%. Using a half-crescent of tibial plateau activity for diagnosis, the inclusion of femoral condyle and blood pool activity for all meniscal tears increased specificity by 10% but reduced sensitivity by 20%. However, the inclusion of femoral condyle and blood pool activity for bucket handle tears alone increased specificity by 20% without affecting sensitivity. A separate analysis of medial and lateral menisci showed the optimum diagnostic criteria to be the same as when they were treated together. The strength of the diagnostic criteria was comparable for both menisci.

It should be noted that increased blood pool activity was found in 15 of 19 patients with meniscal tears and eight of nine with longitudinal tears. However, increased blood pool activity was also found in 15 of 21 patients without meniscal tears. In patients without meniscal tears increased activity involving more of the tibial plateau than a crescent was found in four (three normal arthroscopy, one loose body), increased activity involving all components of the knee in three (two anterior cruciate tears, one collateral ligament tear) and normal scans in three. These patterns were not found in those with meniscal tears. Figure 1 shows equilibrium, planar and SPET images from a patient with a right medial meniscal tear with increased blood pool and femoral condyle activity and a full crescent of increased tibial plateau activity. Figure 2 demonstrates three-quarters of a crescent of increased tibial plateau activity on SPET

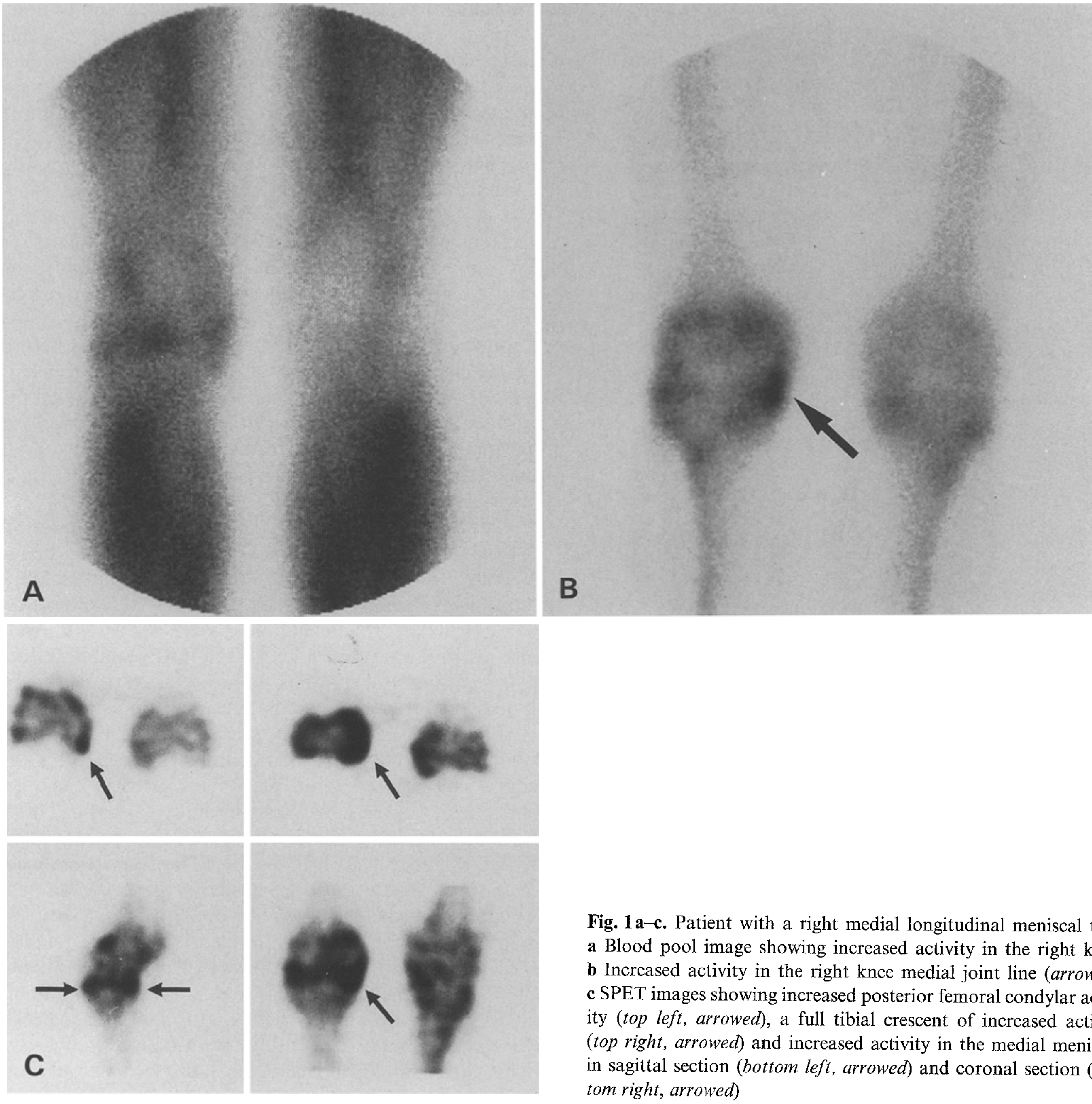

Fig. 1 a–c. Patient with a right medial longitudinal meniscal tear. **a** Blood pool image showing increased activity in the right knee. **b** Increased activity in the right knee medial joint line (*arrowed*). **c** SPET images showing increased posterior femoral condylar activity (*top left, arrowed*), a full tibial crescent of increased activity (*top right, arrowed*) and increased activity in the medial meniscus in sagittal section (*bottom left, arrowed*) and coronal section (*bottom right, arrowed*)

images associated with a meniscal tear and Fig. 3 shows a posterior half-crescent of increased activity associated with a posterior horn tear.

Discussion

A high sensitivity and specificity for the diagnosis of meniscal tears has been previously demonstrated with planar bone scintigraphy [2] and further improved with the better localisation available with SPET imaging [1, 3, 4]. In this present study we have refined the diagnostic criteria using SPET. Diagnostic criteria with both high sensitivity and specificity and predictive values were not found on planar imaging in this study. However, using SPET such criteria were found with the optimum being a half-crescent or more of increased activity in the tibial plateau producing a sensitivity of 89%, a specificity of 76%, a positive predictive value of 77% and a negative predictive value of 89%. For longitudinal tears, the most useful bone scan features were a full crescent of tibial plateau activity with adjacent femoral condyle activity and increased equilibrium activity giving respective values of 78%, 94%, 78% and 93%.

In this present study we have analysed patterns of tibial plateau transaxial activity which have included a

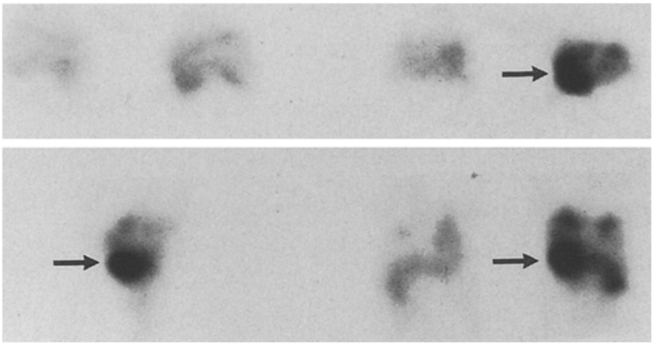

Fig. 2. Patient with left medial meniscal tear. A three-quarter crescent of increased activity is seen on transaxial section of the medial tibial plateau (*top right, arrowed*). There is no femoral condyle activity (*top left*). Activity in the medial tibial plateau is seen in sagittal (*bottom left, arrowed*) and coronal (*bottom right, arrowed*) slices

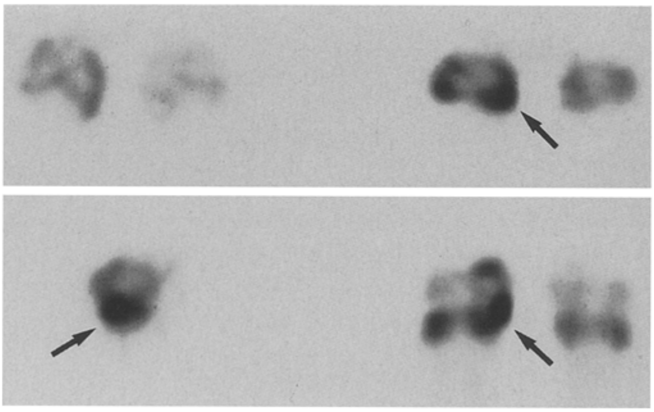

Fig. 3. Patient with a left posterior horn meniscal tear and a half-crescent of increased posterior tibial plateau activity (*top right, arrowed*). Increased tibial plateau activity is also seen on sagittal (*bottom left, arrowed*) and coronal slices (*bottom right, arrowed*) but there is no femoral condyle activity (*top left*)

focus of increased activity in the tibial plateau, partial or full crescents of increased tibial plateau activity and activity that extends beyond the tibial plateau. We have demonstrated that activity less than a full cresent can be commonly associated with meniscal tears. Furthermore, the specificity and negative predicitive value for all tears can be further improved by including the presence of blood pool activity and/or femoral condyle activity, the latter usually posterior, scintigraphic findings associated with meniscal tears that have not been previously described. If the mechanism of increased activity seen on bone scan in meniscal tears is a reaction of the underlying bone, the presence of femoral condyle activity and increased equilibrium activity is not surprising. It should be noted that increased equilibrium activity was also common in patients without meniscal tears and that it is not a helpful diagnostic criterion except in association with tibial plateau activity. Increased activity more extensive than half the tibial plateau on transaxial view was found in four patients, and in none of them was it associated with a meniscal tear. This pattern of activity may be useful in excluding a meniscal tear; it may represent more extensive trauma and/or synovitis. Only three scans were normal and none of these were associated with meniscal tears on arthroscopy.

There were ten menisci that were arthroscopically normal but associated with scintigraphic change. Murray et al. also found scintigraphic changes associated with arthroscopically normal menisci in six patients [1] and Thomas et al. reported in their series of planar scans that five patients had positive images with normal arthroscopies [5]. The cause of this abnormal activity is uncertain but may indicate altered joint mechanics before visible intra-articular pathological change has occurred. Even in patients with meniscal tears the cause of increased activity is unclear, although such an increase presumably represents a reaction of underlying bone since the meniscus is attached to the edge of the tibial plateau.

Clearly, bone SPET as a non-invasive technique for the diagnosis of meniscal tears will be seen as being in competition with MRI. Published work on MRI shows it has a high diagnostic sensitivity and specificity [6–8]. However, this technique does carry a significant false-positive rate (specificity 71%–100%) mainly due to frayed meniscal margins or posterior horn tears, although the latter may not be seen well on arthroscopy [9, 10]. There is also a significant false-negative rate (sensitivity 57%–100%), related mainly to small tears or tears of the free edge but sometimes to large unstable tears [7, 11, 12]. Results from this study cannot be compared directly with MRI due to the selective patient population but in this group bone SPET appears a realistic alternative. Where both are easily available, MRI will probably be used as first choice because of its excellent anatomical detail. However, where MRI is less readily available or substantially more expensive than bone SPET and particularly when there is a large volume of patients, bone SPET may be a useful alternative. Bone SPET could also prove a useful additional non-invasive investigation to MRI where the latter gives equivocal results, and it is possible that bone SPET could be used to screen patients for MRI.

In conclusion, bone SPET provides a useful tool with high sensitivity, specificity and predictive accuracy for meniscal tears in patients with acute knee injuries. Using the appropriate diagnostic criteria it can be used to select those who require arthroscopy. Further work with a larger series and less selective patient population is suggested to confirm this and to investigate other roles for bone SPET of the knees.

References

1. Murray IPC, Dixon J, Kohan L. SPECT for acute knee pain. *Clin Nucl Med* 1990; 15:828–840.

2. Collier BD, Johnson RP, Carrera GF, Isitman AT, Veluvolu P, Knobel J, Hellman RS, Barthelemy CR. Chronic knee pain assessed by SPECT: comparison with other modalities. *Radiology* 1985; 157:795–802.
3. Fajman WA, Diehl M, Dunaway E, Stephenson R, Eisner R, Riggins RS, Berger HJ. Tomographic and planar radionuclide imaging in patients with suspected meniscal injury: arthroscopic correlation. *J Nucl Med* 1985; 26:P77.
4. Marymont JV, Lynch MA, Henning CE. Evaluation of meniscal tears of the knee by radionuclide imaging. *Am J Sports Med* 1983; 11:432.
5. Thomas RH, Resnick D, Alazraki NP, Daniel D, Greenfield R. Compartmental evaluation of osteoarthritis of the knee. *Radiology* 1975; 116:585–594.
6. Fischer SP, Fox JM, Del Pizzo W, Friedman MJ, Snyder SJ, Ferkerl RD. Accuracy of diagnoses from magnetic resonance imaging of the knee. *J Bone Joint Surg [Am]* 1991; 73:2–10.
7. Raunest J, Oberle K, Loehnert J, Hoetzinger H. The clinical value of magnetic resonance imaging in the evaluation of meniscal disorders. *J Bone Joint Surg [Am]* 1991; 73:11–16.
8. Mink JH, Levy T, Crues JV III. Tears of the anterior cruciate ligament and menisci of the knee: MR imaging evaluation. *Radiology* 1988; 167:769–774.
9. Glashow JL, Katz R, Schneider M et al. Double blind assessment of value of magnetic resonance imaging in the diagnosis of anterior cruciate and meniscal lesions. *J Bone Joint Surg [Am]* 199; 71:113–119.
10. Polly DW, Callaghan JJ, Sikes RA et al. The accuracy of selective magnetic resonance imaging compared with the findings of arthroscopy of the knee. *J Bone Joint Surg [Am]* 1988; 70:192–198.
11. Quinn F, Brown TF. Meniscal tears diagnosed with MR imaging versus arthroscopy: how reliable a standard is arthroscopy? *Radiology* 1991; 181:843–847.
12. Tyrell RL, Gluckert K, Pathria M et al. Fast three dimensional MR imaging: comparison with arthroscopy. *Radiology* 1988; 166:865–872.