31. Obling H, Claesson I, Ebel KD, et al. Renal scars and parenchymal thinning in children with vesicoureteral reflux: a 5-year report of the International Reflux Study in Children (European branch). *J Urol* 1992;148:1653–1666.
32. Chao SM, Saw AH, Tan CL. Vesicoureteric reflux and renal scarring in children—a local perspective. *Annal Acad Med, Singapore* 1991;20:335–339.
33. Jakobsson B, Berg U, Svensson L. Renal scarring after acute pyelonephritis. *Arch Dis Child* 1994;70:111–115.
34. Jakobsson B, Nolstedt L, Svensson L, et al. Technetium-99m-dimercaptosuccinic acid (DMSA) scan in the diagnosis of acute pyelonephritis in children: relation to clinical and radiological findings. *Pediatr Nephrol* 1992;6:328–334.
35. Rushton HG, Majd M. Dimercaptosuccinic acid and renal scarring: a review of experimental and clinical studies. *J Urol* 1992;148:1726–1732.
36. Verber IG, Strudley MR, Meller ST. Technetium-99m-dimercaptosuccinic acid (DMSA) scan as first investigation of urinary tract infection. *Arch Dis Child* 1988;63:1320–1325.

# SPECT Bone Scintigraphy of Anterior Cruciate Ligament Injury

Gary J.R. Cook, Paul J. Ryan, Susan E.M. Clarke and Ignac Fogelman
*Department of Nuclear Medicine, Guys Hospital, London; and Department of Nuclear Medicine, Medway Hospital, Kent, United Kingdom*

This retrospective analysis of SPECT bone scans of the knee was undertaken to define typical bone scan appearances and to assess the sensitivity of this method. We looked at 14 patients, mostly with chronic knee pain, who had anterior cruciate ligament (ACL) tears detected by MRI. **Method:** Of the 14 patients, 10 were referred for bone scanning following injury and 4 complained of chronic knee pain without injury. Planar scans were performed 4 hr after the injection of 750 MBq of $^{99m}$Tc-MDP. Tomographic images were obtained by a 64 × 20-sec acquisition over 360° using a high-resolution collimator. MRI imaging included axial and sagittal, T1 weighted and coronal fast field echo (FFE) sequences. Ten patients also had arthroscopy performed. **Results:** MRI scans showed 6 lone ACL tears and 8 combined with other ligamentous injuries. SPECT scans showed abnormalities in 10 patients in the region of ACL insertions but only 4 planar studies were abnormal. SPECT identified focal activity at the upper (n = 8) or lower (n = 2) insertion of the ACL. Six of 10 arthroscopies confirmed ACL tears, 2 complete and 4 partial. Overall, agreement was found with MRI in 10 of 14 cases and in 8 of 10 with arthroscopy. Abnormalities were identified in 10 of 11 regions of other ligament or bone injury identified by MRI. **Conclusion:** SPECT bone scanning of the knee is superior to planar imaging in detecting ACL injury and is a sensitive technique. Focal activity may be seen at either end of ACL attachment but more commonly at the upper femoral insertion. Knee SPECT may be a valuable examination in suspected ACL injury, particularly if MRI is not available, is equivocal or where clinical signs are absent.

**Key Words:** anterior cruciate ligament; knee SPECT; technetium-99m-MDP

**J Nucl Med 1996; 37:1353–1356**

There is considerable experience with SPECT bone scintigraphy of the lumbar spine with improved sensitivity for the detection of pathology when compared to a planar study (*1,2*). Imaging of the knee with this technique also appears promising but previous studies have been largely confined to the diagnosis of meniscal tears (*3–5*).

Soft-tissue injuries to the knee are generally well demonstrated by MRI. Results for anterior cruciate ligament (ACL) injury vary widely, however, and both false-negatives and false-positives have been described (*6–8*). In addition, MRI is not universally available. Therefore, SPECT bone scintigraphy offers an alternative or complimentary imaging modality which is easily accessible for the investigation of knee pain.

We present a retrospective analysis of SPECT bone scintigraphy of the knee in 14 patients who had ACL tears diagnosed with MRI, together with arthroscopic correlation available in 10 cases, in an attempt to define the typical bone scan appearances and the sensitivity of the method in this type of injury.

## METHOD

### Subjects

Fourteen consecutive patients (9 men, 5 women; aged 25–54 yr; mean age 34 yr) who had ACL tears diagnosed by MRI were included with MRI being used as the standard of reference for ACL tears. All had bone scintigraphy of the knee with SPECT. Ten patients were referred following injury, usually from sports, between 3 wk and 18 mo after the injury. Four patients complained of chronic unilateral knee pain for more than 1 yr without a specific injury being recalled. Ten patients also had diagnostic arthroscopy performed.

In the 10 patients with knee injury, MRI was performed within a median of 2.5 mo (range 0 to 18 mo) of the bone scan. In the 2 patients in whom the interval between bone scan and MRI was greater than 4 mo, one had arthroscopy within 3 mo of the bone scan and the other had MRI within 1 mo of arthroscopy. Both had continued but stable pain throughout this period with no new injuries.

Of the four patients with chronic knee pain without injury, two had an interval of less than 4 mo between bone scan and MRI and the remaining two had a gap of 16 and 18 mo with the MRI predating the bone scan in each case. One is still awaiting arthroscopy and the other had arthroscopy within 2 mo of the MRI.

Two patients had arthroscopic meniscectomy performed after the bone and MRI scans. Two patients have subsequently had ACL prostheses inserted and the remainder have been treated conservatively.

### Scan Interpretation

Bone scans were interpreted by a nuclear medicine specialist (I.F.) with extensive experience in knee bone SPECT. MRI scans had been interpreted by an MRI specialist radiologist. Neither were aware of the others scan results or of clinical or arthroscopic findings.

### Imaging Protocols

*Bone Scintigraphy.* Blood-pool images were taken in the posterior projection 5 min after the injection of 750 MBq $^{99m}$Tc-MDP.

Received June 5, 1995; revision accepted Dec. 13, 1995.
For correspondence or reprints contact: Dr. G.J.R. Cook, Department of Nuclear Medicine, Guys Hospital, London SE1 9RT UK.

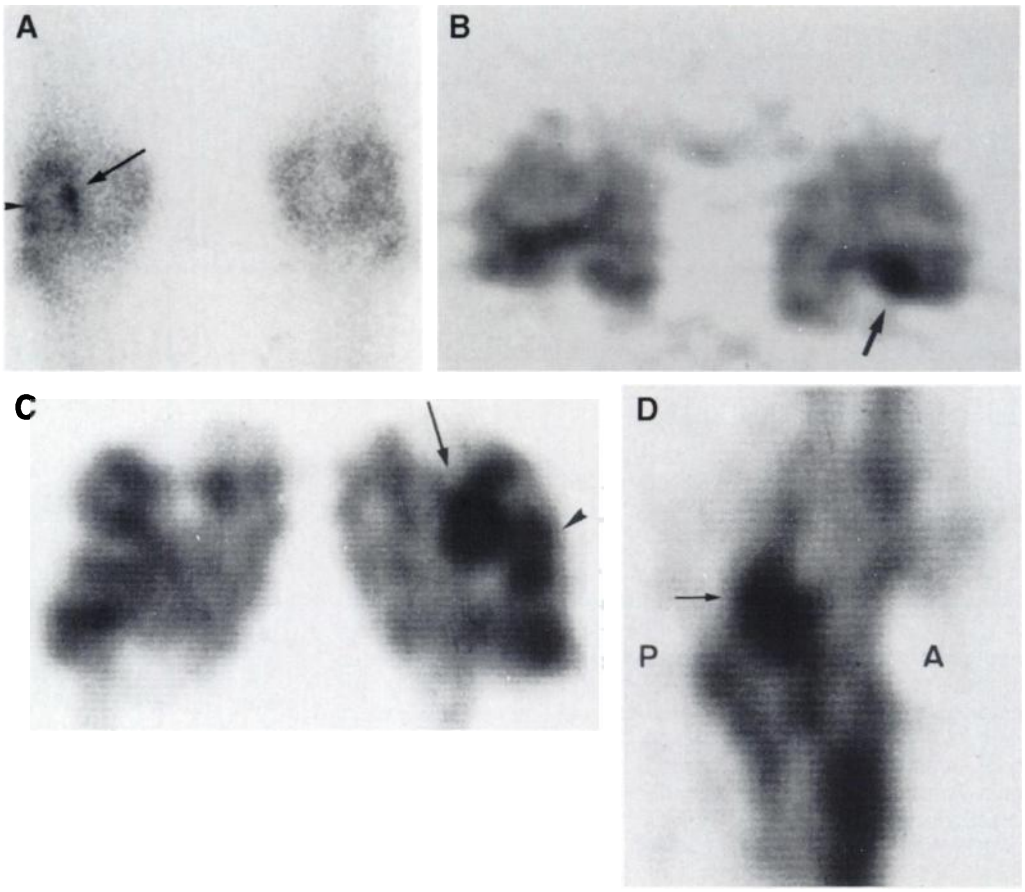


**FIGURE 1.** A 32-yr-old man, 6 mo after injury to the left knee. (A) Posterior planar image shows a focal area of increased activity on the medial aspect of the lateral femoral condyle on the left (arrow), at the site of ACL insertion. (B) transaxial (through the femoral condyles), (C) coronal and (D) sagittal slices show an area of increased activity on the medial aspect of the lateral femoral condyle posteriorly in the position of the upper attachment of the ACL (arrow). Further abnormality is seen in the lateral compartment of the knee (A, C) (arrowheads) corresponding to a lateral meniscal tear which was identified on MRI.

Anterior, posterior and lateral planar scans were performed after 3 hr. Images were acquired for 600 K counts for each view on a large field of view gamma camera with a high-resolution collimator using a 256 × 256 matrix.

Tomographic images were obtained by a 64 × 20 sec acquisition over 360° with a high-resolution collimator. Transaxial, coronal and sagittal slices were displayed on radiographic film after reconstruction using a Hanning 0.9 filter.

*MRI.* Scans were obtained on a 1.5 T Philips Gyroscan S15. Axial and sagittal T1 and coronal fast field echo (FFE) sequences were used.

## RESULTS

All MRI scans were interpreted as showing ACL tears. Eight patients also showed evidence of other soft tissue injury including meniscal tear (n = 7), lateral collateral ligament injury (n = 2) and associated posterior cruciate ligament injury (n = 1). One patient also showed evidence of a subchondral bone infraction to the medial femoral condyle.

Arthroscopy showed complete ACL tears in two patients and partial tears in four patients. One of these patients had an initial arthroscopy which failed to show an abnormality but was subsequently reinvestigated due to persistent symptoms at which time a partial tear was seen. Four patients had no ACL injury seen on arthroscopy. Two patients did not have arthroscopy performed because no clinical evidence of ACL injury existed and symptoms resolved enabling the patient to be discharged from follow up. One patient was lost to follow up and one is awaiting arthroscopy.

Only four planar bone scans showed abnormality in the region of ACL insertion, i.e. either at the lower attachment at the anterior intercondylar area of the tibia or at the upper insertion on the medial aspect of the posterior, lateral femoral condyle. None of these showed an abnormality in blood-pool images. Ten SPECT scans showed abnormality in the regions of ACL attachment. Eight showed a small focus of increased activity on the medial aspect of the posterior, lateral femoral condyle (Fig. 1) and two at the lower tibial insertion (Fig. 2).

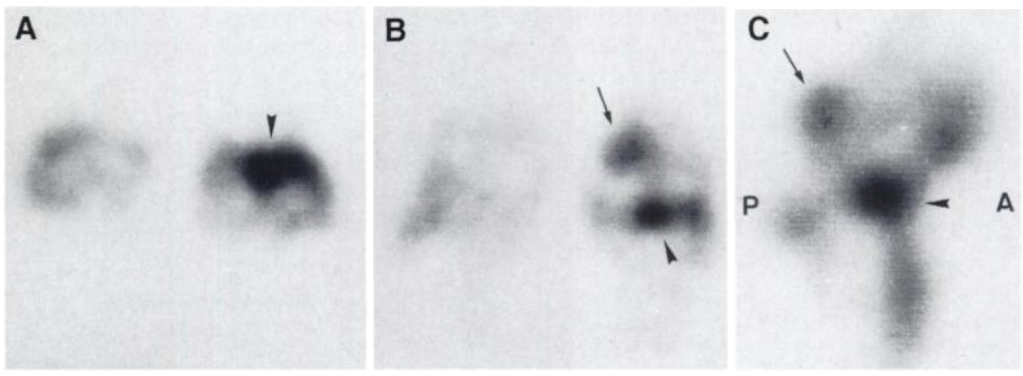


**FIGURE 2.** A 36-yr-old woman, 9 mo after injury to the left knee. (A) Transaxial (through the tibial plateau), (B) coronal and (C) sagittal slices show an area of increased activity in the intercondylar area of the left tibia at the lower insertion point of the ACL (arrowhead). Coronal and sagittal tomograms also show an area of activity on the lateral aspect of the medial femoral condyle at the position of the upper insertion of the posterior cruciate ligament (arrow). Both anterior and posterior cruciate ligament tears were detected on MRI.

**TABLE 1**
Results of SPECT, MRI and Arthroscopic Findings of the ACL in 14 Patients

| Subject | Type | Time of bone scan (mo after injury) | Planar | SPECT U/L | MRI and (mo post-SPECT)* | Arthroscopy and (mo post-SPECT)* | Tear type |
|---|---|---|---|---|---|---|---|
| 1 | Injury | 18 | — | +L | + (0) | −,+ (2 and 17) | Partial |
| 2 | Injury | 1 | — | — | + (2) | — (6) | Not detected |
| 3 | Injury | 11 | — | +U | + (18) | + (3) | Complete |
| 4 | Injury | 0.75 | — | +U | + (2) | + (5) | Partial |
| 5 | Injury | 9 | — | +U | + (1) | + (2) | Partial |
| 6 | Injury | 9 | + | +L | + (15) | + (14) | Partial |
| 7 | Injury | 2 | — | +U | + (4) | Not performed | |
| 8 | Injury | 1 | + | +U | + (4) | + (30) | Complete |
| 9 | Injury | 12 | — | — | + (3) | Not performed | |
| 10 | Injury | 6 | + | +U | + (1) | — (2) | Not detected |
| 11 | No injury | | — | +U | + (4) | — (17) | Not detected |
| 12 | No injury | | + | +U | + (−18) | Not performed | |
| 13 | No injury | | — | — | + (−16) | — (−14) | Not detected |
| 14 | No injury | | — | — | + (3) | Not performed | |

*Time examination performed before (—) or after SPECT.
+ = Abnormal ACL; — = No ACL abnormality; U or L = Abnormality at upper (U) or lower (L) ACL insertion.

In six patients there was not complete agreement between all three modalities. In all but one of these patients, the discordant examination occurred within 3 mo of at least one of the other modalities.

Abnormalities were identified in 10 of 11 regions of other ligamentous and bone injury identified by MRI. A medial meniscal tear, identified on MRI, failed to show an abnormality on bone scan. Arthroscopy with probing subsequently failed to find a tear in this region, however.

Of the four SPECT scans which did not show ACL abnormality, arthroscopy was normal in two and was felt to be not indicated in two, as there was no clinical evidence of ACL tear and symptoms resolved. All six patients with arthroscopically proven ACL tear showed abnormality on SPECT imaging whether the tear was partial or complete. The uptake pattern on SPECT scans (i.e., abnormality at the upper or lower insertion of the ACL) did not appear to bear a relationship to the degree of ACL disruption, however.

Two patients had ACL abnormalities on SPECT and MRI with subsequent negative arthroscopies. Findings are summarized in Table 1.

## DISCUSSION

MRI is generally accepted as being an excellent method for assessing soft-tissue injuries to the knee (*9*), but false-positive studies have been described, particularly in relation to meniscal tears (*10*) but also in ACL injury (*7*). Reduced accuracy in ACL injury is described particularly with partial tears (*8*), and diagnostic arthroscopy is still required (*6*). However, arthroscopy is an operator-dependent procedure and false-negative results are documented (*11*). A true gold standard therefore does not exist, which leaves room for complementary imaging methods.

Although planar and SPECT bone scintigraphy of the knee have been used successfully in patients with meniscal injuries (*3–5*), its use in ACL injury has received scant attention. Murray et al. (*3*) in their assessment of SPECT in 52 patients with acute knee pain, include 10 with arthroscopically diagnosed ACL tear (*3*). Only five showed abnormality, the area of increased uptake being situated at the tibial attachment.

We have shown a greater proportion of abnormal scans in comparison and this could be explained by the differences in the populations studied. Murray et al. (*3*) specifically investigated patients with acute knee injury (2 to 8 wk post-trauma in the majority), whereas our population consisted of 4 patients with chronic knee pain without specific trauma and 10 patients at a median of 7.5 mo (3 wk to 18 mo) following injury. It may be that the more chronic nature of injuries present in some of our population allows time for an osteoblastic reaction to be established at the sites of ACL attachment due to altered joint mechanics. It is also of interest to note that all five patients in the acute injury series showed abnormality at the tibial insertion in contrast to our patients, the majority of whom showed a focal abnormality at the upper femoral attachment. This may again reflect the comparative chronicity of injuries, with bone repair occurring acutely at the site of ligament rupture and in the chronic stage at sites of stress due to altered joint mechanics.

Calculating the sensitivity of SPECT bone scintigraphy in identifying ACL tears is problematic as a true standard for comparison is lacking. However, 100% (6 of 6) of ACL tears detected on both MRI and arthroscopy were shown with SPECT, suggesting that SPECT may be a valuable initial, noninvasive investigation, especially if MRI is unavailable. Overall, agreement was found with MRI in 10 out of 14 cases and in 8 out of 10 with arthroscopy. Of the six patients that showed a discrepancy on one modality, in only one was there a sufficient interval between examinations that could account for the differences observed. In this patient, the discrepant negative arthroscopic result could have occurred due to healing of the ACL in the time interval.

Not surprisingly, the increased contrast resolution of SPECT has allowed more lesions to be detected compared to planar imaging. In addition, we have observed the ability of SPECT to accurately locate sites of other soft tissue and bone injury in association with ACL tears, including posterior cruciate ligament injury, medial and lateral meniscal tears, lateral collateral ligament rupture and associated bone infractions. This is a valuable asset, as associated injuries are common (*11*) and may not be suspected clinically. This enables appropriate management strategies to be chosen and highlights areas for special attention during arthroscopy.

## CONCLUSION

SPECT bone scanning of the knee is superior to planar imaging in detecting ACL injury and is a sensitive examination in a population of patients predominantly with chronic ACL tears. Sensitivity may be dependent on the chronicity of symptoms although acute tears and both partial and complete tears can be identified.

Focal activity at either end of the ACL attachments may be seen, but the more common appearance is of a single, focal abnormality in the medial aspect of the posterior, lateral femoral condyle. This pattern has not been previously reported in patients with acute tears and may therefore occur more frequently in those with chronic symptoms.

SPECT imaging of the knee may be a valuable examination in suspected ACL injury particularly if MRI is not available, if MRI is equivocal or if the clinical signs do not support a diagnosis of ACL tears detected by MRI. In addition, knee SPECT is able to localize other areas of injury within the knee associated with ACL tears.

## REFERENCES


1. Holder LE, Machin JL, Asdourian PL, et al. Planar and high-resolution SPECT bone imaging in the diagnosis of facet syndrome. *J Nucl Med* 1995;36:37–44.
2. Ryan PJ, Evans P, Gibson T, Fogelman I. Chronic low back pain: comparison of bone SPECT, radiography and CT. *Radiology* 1992;182:849–854.
3. Murray IPC, Dixon J, Kohan L. SPECT for acute knee pain. *Clin Nucl Med* 1990;15:828–840.
4. Collier BD, Johnson RP, Carrera GF, et al. Chronic knee pain assessed by SPECT: comparison with other modalities. *Radiology* 1985;157:795–802.
5. Fajman WA, Diehl M, Dunaway E, et al. SPECT for acute knee pain [Abstract]. *J Nucl Med* 1985;26:77.
6. Chissell HR, Allum RL, Keightley A. MRI of the knee: its cost-effective use in a district general hospital. *Ann R Coll Surg Engl.* 1994;76(1):26–29.
7. Reicher MA, Hartzman S, Bassett LW, et al. MRI imaging of the knee. Traumatic disorders. *Radiology* 1987;162:547–551.
8. Le Vot J, Solacroup JC, Leonetti, et al. Correlations between clinical examination, MRI and arthroscopy in acute traumatic knees. *J Radiol* 1993;74:483–492.
9. Mink JH, Levy T, Crues JV. Tears of the anterior cruciate ligament and menisci of the knee: MR imaging evaluation. *Radiology* 1988;167:769–774.
10. Herman LJ, Beltran J. Pitfalls in MR imaging of the knee. *Radiology* 1988;167:775–781.
11. Selesnick FH, Noble HB, Bachman DC, Steinberg FL. Internal derangement of the knee: diagnosis by arthrography, arthroscopy and arthrotomy. *Clin Orthop* 1985;198:26–30.


# Pediatric Gastric Emptying: Value of Right Lateral and Upright Positioning


Javier Villanueva-Meyer, Leonard E. Swischuk, Fernando Cesani, Seham A. Ali and Elma Briscoe

*Sections of Nuclear Medicine and Pediatric Radiology, Department of Radiology, University of Texas Medical Branch, Galveston, Texas*



Gastroesophageal reflux and gastric emptying are usually assessed simultaneously with a 1-hr procedure. After ingestion of radiolabeled formula sequential images are gathered when the infant is in the supine position. This position is adequate for gastroesophageal reflux assessment, but delays gastric emptying. **Methods:** We studied 48 children, 1 wk to 2 yr of age, who presented with vomiting or failure to thrive. They received $^{99m}$Tc-sulphur colloid in formula. After completing 1 hr supine imaging we obtained additional abdominal views after changing the position of the infant to right lateral for 30 min, and upright for another 30 min. **Results:** The percent of gastric emptying at 60 min in the supine position was 35% ± 19%. At 90 min, in the right lateral decubitus, the percent gastric emptying was 60% ± 25%. At 120 min, after an upright period, the gastric emptying was 73% ± 20%. In the supine position 19 of 48 patients showed significant emptying (defined as >40% emptying). This increased to 41 of 48 normal studies considering the right lateral position and to 45 of 48 normal studies considering the infant upright position. **Conclusion:** Many patients with delayed gastric emptying show significant emptying just by changing position. We routinely complement gastric emptying studies with delayed views in the right lateral and upright position.



**Key Words:** delayed gastric emptying; pediatric gastric emptying; gastroesophageal reflux; technetium-99m-sulphur colloid

**J Nucl Med 1996; 37:1356–1358**


A concern in infants with recurrent pulmonary infections, failure to thrive and vomiting is the presence of gastroesophageal reflux or delayed gastric emptying. Gastroesophageal reflux is routinely assessed with radionuclide scintigraphy or pH probing (*1,2*). The pH probe is the most sensitive method but the radionuclide method, although less sensitive, is thought to be more physiologic and is widely used (*3*). The association of gastroesophageal reflux and delayed gastric emptying is questionable (*4–6*) but it still is desirable to evaluate both in one study. Many methods have been proposed to measure gastric emptying: ultrasonic examination (*7*); epigastric impedance (*8*) and dual-isotope with combined solid and liquid meal (*9*); and either liquid or formula (*1*). Of all these, the milk scan is the most physiologic, allowing evaluation of gastroesophageal reflux and delayed gastric emptying in one setting. With this procedure formula labeled with $^{99m}$Tc-sulphur colloid ($^{99m}$Tc-SC) is administered to the infant and images in the posterior projection are gathered every minute seeking the presence of gastroesophageal reflux. During the 1-hr acquisition, the infant is in the supine position and gastric emptying is assessed with the results reported as percent emptying or retention at 1 hr or halftime emptying. The variability of these results has been considerable and has cast doubt on the clinical utility of the test in small infants (*3–6,10–12*).

In addition we encountered many discrepancies between radiologic upper gastrointestinal series and nuclear gastric emptying studies. We explored this discrepancy and decided that positioning was a problem. The standard position in upper gastrointestinal studies is right anterior oblique, with the right side of the infant down, this enhances gastric emptying. Also, this is more physiologic because babies are fed in the right lateral semi-upright position.

In this study, at the end of 60 min supine imaging, we gathered two additional views: one after changing the infant to the right lateral decubitus, and another after holding the infant


Received May 22, 1995; revision accepted Sept. 7, 1995.



For correspondence or reprints contact: Javier Villanueva-Meyer, MD, Section of Nuclear Medicine, UTMB, Galveston, TX 77555-0793.