Bone Scintigraphy in Femoroacetabular Impingement

A Preliminary Report

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Abstract Femoroacetabular impingement (FAI) has recently been recognized as a cause of hip pain, labral tears, and cartilage damage in young adults. We determined the sensitivity and specificity of bone scans in diagnosing FAI and describe its findings on nuclear imaging. We prospectively followed 25 patients with hip pain (four bilateral) of greater than 6 months' duration and a positive impingement sign (IS). All patients had plain radiographs and a three-phase bone scan followed by single-photon emission computed topographic (SPECT) images of both hips. We presumed patients had FAI if they had all three of the following findings: hip pain, positive IS, and diagnostic radiographs. Forty-six of the 50 hips had bony abnormalities on radiographs and 26 hips were diagnosed with FAI according to our criteria. Twenty-two of these 26 hips showed an increased uptake on SPECT representing true-positives. There were four false-positives, nine false-negatives, and 15 true-negatives. Sensitivity of

bone SPECT was 84.7%, specificity 62.5%, positive predictive value 71%, and negative predictive value 78.9%. Focal uptake was localized to the superolateral acetabular rim and/or anterolateral femoral head-neck junction consistent with the reported intra-articular cartilage hip damage seen in FAI.

Level of Evidence: Level II, prospective study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

In the past, hip pain in the young adult has been most commonly associated with osteonecrosis and acetabular labral tears [9, 17]. Although the latter occurs in isolation either as a result of trauma or overuse [10, 11], recent investigations have noted the majority of labral tears occur in patients with abnormally shaped femoral heads and/or acetabula referred to as femoroacetabular impingement (FAI) [18, 23, 31]. FAI is caused by premature abutment of the femoral head-neck junction with the acetabular rim. This deformity can lead to acetabular cartilage damage as well as hip osteoarthritis [6]. Early diagnosis before the onset of hip arthritis has permitted surgeons to reshape the femoral head with encouraging short-term clinical results [2, 7, 21, 24].

There are two main types of FAI: (1) cam, which is associated with reduced femoral head-neck offset; and (2) pincer, present with acetabular retroversion with the majority of the patients having both [6, 13]. FAI is diagnosed with impingement signs and limited internal rotation [7] and radiographic signs of femoral head asphericity and/or acetabular retroversion [6, 25]. Additional investigations such as three-dimensional computed tomography and MRI with

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gadolinium arthrography may further characterize femoral head deformity [5] as well as labral abnormalities [16].

The purpose of this study was first to determine the sensitivity and specificity of bone single-photon emission computed tomography (SPECT) in the diagnosis of FAI. Second, we describe the characteristic findings seen on nuclear imaging in the presence of FAI. Third, we asked whether the bone scans would be positive in a group of patients that had a positive impingement test in the contralateral hip despite the absence of symptoms.

Materials and Methods

We recruited 25 consecutive patients with hip pain of more than 6 months' duration with a positive impingement sign (IS, reproducing the patient's groin pain on hip flexion to 90°, internal rotation, and adduction) and radiographic evidence of FAI. The study group included 22 men and three women with a mean age of 33.9 ± 8.4 years. Thirteen patients reported left hip pain, eight right hip pain, and four bilateral pain. All patients had both hips assessed and examined by the senior author (PEB). All 29 symptomatic hips had a positive IS and five additional hips had a positive IS in the contralateral hip despite the absence of symptoms. We diagnosed FAI in 26 hips when all three findings were present: hip pain, positive IS, and abnormal radiographs. We excluded patients with prior hip surgery, previous fracture, and advanced hip osteoarthritis (Tönnis grade greater than 1 [30]). Institutional Ethics Review Board approval and informed consent were obtained before patients' enrollment.

Radiographic examination included anteroposterior pelvis as well as bilateral crosstable lateral and Dunn views of the hips [19]. We assessed femoral head asphericity by

measuring the α -angle (Fig. 1A) [22] and the offset ratio [12] (Fig. 1B). We considered an α -angle greater than 50.5° and/or offset ratio less than 0.15 as diagnostic of FAI [1, 5].

A three-phase bone scan was performed followed by SPECT images of the hips. The flow to the hips was acquired anteriorly with a framing rate of 3 seconds per frame for 60 seconds immediately after an intravenous injection of 25 mCi of MDP Tc 99 m. Thereafter, a blood pool image of the hips was acquired anteriorly for 600 K. The delayed planar bone scan views were performed within 3 to 4 hours postinjection. The SPECT study was performed on a dual head camera with each head rotating 180° in a noncircular orbit with continuous acquisition for a total of 64 views or 32 views per head. Each view is acquired for 12 seconds for a total SPECT acquisition time of 15 minutes. Iterative reconstruction software was used to avoid bladder artifact.

All images were recorded on a PACS system with variable intensity display and reported by a board-certified nuclear medicine physician (FR). A positive scan was noted as increased uptake at the acetabulum and/or femoral head-neck junction.

The α -angle and offset ratios are reported as mean $\pm$ standard deviation. We calculated the sensitivity, specificity, and predictive values of the bone scintigraphy in the presence of clinical FAI.

Results

The sensitivity of SPECT bone scintigraphy in the diagnosis of FAI was 84.7% with a specificity of 62.5%, a positive predictive value of 71%, and negative predictive value of 78.9% (Table 1). Of the 50 hips (25 patients), 46

Fig. 1A–B Femoral head asphericity was assessed by measuring (A) the α -angle [22] and (B) offset ratio [12] on a crosstable lateral or Dunn view of the hip. The α -angle is measured by drawing a line between the center of the femoral head and where the anterior head-neck concavity

transects a circle representing the radius of the head. The angle between this line and the longitudinal axis of the femoral neck represents the α -angle. The offset ratio is measured by dividing the anterior offset distance “A” by the diameter of the femoral head “B.”

Table 1. Results of bone scan versus the presence of FAI

Uptake on bone scan	FAI diagnosis	
	Positive	Negative
Positive*	22	9
Negative	4	15

*A positive bone scan represents uptake at the anterosuperior aspect of the acetabulum, the adjacent anterolateral femoral head, or both on the planar bone scan or single-photon emission computed tomographic images; FAI = femoroacetabular impingement.

had reduced femoral head-neck offset with a mean offset ratio of 0.08 ± 0.05 and mean α -angle of $75.8^\circ \pm 12^\circ$. Four hips had a normal offset ratio (0.17 ± 0.03) and α -angle ($45.7^\circ \pm 7^\circ$). Of the 29 symptomatic hips, 26 had a diagnosis of FAI by our criteria and three had normal radiographs. Twenty-two of these 26 hips had increased uptake. Of the 24 hips not meeting our criteria for FAI, 15 had a negative scan representing the true-negatives and nine had a positive scan representing the false-negatives.

The characteristic findings seen on nuclear imaging included an increased focal uptake involving the anterosuperior aspect of the acetabulum, the adjacent anterolateral femoral head, or both on SPECT images (Fig. 2A–D). The blood flow images did not show any measurable changes and only five blood pool images showed increased uptake suggestive of synovitis.

Fig. 2A–D This 26-year-old male patient had a right symptomatic hip. (A) Anteroposterior pelvis and (B) Dunn views of the right hip confirm the diagnosis of femoroacetabular impingement. Bone scintigraphy images show positive uptake (arrow) along the superolateral aspect of the acetabular roof on (C) coronal and (D) sagittal cuts.

Five patients with a positive IS and an abnormal anterior head-neck offset did not have any symptoms in the contralateral hip (Table 2; Fig. 3A–D). Four of these five patients had a positive uptake on bone scan and were therefore among the false-positive results with one now being symptomatic. None of the four hips with normal anterior head-neck offset had a positive bone scan.

Discussion

The young patient with hip pain can represent a diagnostic dilemma for the general practitioner and orthopaedic surgeon. Early investigation often includes radiographs as well as bone scans or MRI looking for common pathologies of the hip, including avascular osteonecrosis and FAI. We present in this study preliminary experience with the use of this imaging modality in the diagnosis of FAI as well as describe the characteristic findings seen on SPECT images. We specifically (1) determined the sensitivity and specificity of bone single-photon emission computed tomography (SPECT) in the diagnosis of FAI, (2) described the characteristic findings seen on nuclear imaging in the presence of FAI, and (3) asked whether the bone scans would be positive in a group of patients that had a positive impingement test in the contralateral hip despite the absence of symptoms.

Table 2. Bone scan results of a group of five asymptomatic hips that had a positive impingement sign along with an abnormal radiologic evaluation (increased α -angle and/or decreased offset ratio)

Patient number	Age (years)	Impingement sign	α -angle	Offset ratio	SPECT/bone scan
1	38	+	85°	0.021	Head + acetabulum
2	33	+	80°	0.015	Acetabulum
3	48	+	80°	0.085	Head + acetabulum
4	37	+	74°	0.085	Head
5	25	+	63°	0.107	Normal

SPECT = single-photon emission computed tomography.

Fig. 3A–D Dunn's view of (A) right and (B) left hips of a 48-year-old male patient presenting with left hip pain only. Single-photon emission computed tomographic images shown in (C) anterior and (D) posterior coronal views display more uptake (black arrow) along the superolateral aspect of the acetabular roof on the symptomatic left hip compared with the asymptomatic right hip (white arrow).

This study has some limitations as a result of the small number of patients as well as the fact that these patients were preselected, ie, working diagnosis of FAI. For example, we do not know the prevalence of positive bone scintigraphy in the normal population. It also brings to light some of the diagnostic dilemmas facing the physician in the interpretation of bony abnormalities associated with FAI in asymptomatic individuals with or without a positive impingement sign. More specifically, how does one interpret our false-positive bone scans in hips with radiographic findings of FAI but without any clinical symptoms? In our study, four of the five hips with preclinical FAI had positive scans, which accounts for our relatively low

specificity. However, none of the four normal hips (absence of symptoms and no abnormal shape) had a positive uptake. It is important to note, however, that since the conclusion of the study period, one of the four patients with a positive bone scan is now reporting hip pain in the previously asymptomatic hip and is scheduled for surgery.

The characteristic findings of FAI on bone scan showing focal uptake in the superolateral femoroacetabular junction correlate well with the reported intraarticular hip damage (labral tears, cartilage delamination) seen in patients with FAI [5, 6, 14]. Bone scintigraphy has previously been investigated as a screening test before either MR arthrography or arthroscopy for labral tears by Bruce et al. [8].

They reported patients with a labral tear had hyperemia in the blood pool phase and a specific “eyebrow pattern” of uptake along the superior to medial edge of the acetabulum. Furthermore, they also concluded that bone SPECT had a high negative predictive value for symptomatic tears. Because the majority of patients with symptomatic FAI have labral-chondral abnormalities, isolated uptake in the acetabulum could occur in the presence of an isolated labral tear or in association with FAI. Because it is now well recognized that over 80% of labral tears are secondary to FAI, the evaluation of plain radiographs is critical to clearly establish the diagnosis and plan effective treatment because the isolated treatment of labral tears without correction of an underlying structural bony abnormality can compromise the clinical results [18, 31].

Unlike other pathologic conditions of the hip such as hip dysplasia and osteonecrosis, the natural history of FAI has yet to be fully described, and further research is required to determine the best timing of surgery to reduce symptoms and the likelihood of future osteoarthritis. When looking at the natural history of hip dysplasia, Murphy et al. reported a correlation between the severity of dysplasia and the onset of osteoarthritis in the asymptomatic dysplastic hip [20]. With FAI, future longitudinal studies will be required to document if and when the asymptomatic contralateral hips become symptomatic. However, positive bone scintigraphy can be an early indicator of intraarticular cartilage damage that may be present before the onset of symptoms and can therefore provide important clinical information for both the patient and treating physician in terms of counseling. This would be similar to osteonecrosis of the hip, which is present in both hips in over 50% of cases, although the patient is often only symptomatic unilaterally [17]. Finally, although MRI remains the preferred imaging method because of its specificity, it is not widely available worldwide and in some cases such as osteonecrosis of the hip after renal transplantation, SPECT scintigraphy is more sensitive [26].

Femoroacetabular impingement is now recognized as a source of hip pain in the young, active adult as well as a precursor for the development of osteoarthritis [13, 14]. Several authors have reported good to excellent results in the majority of patients treated for FAI either by chondro-osteoplasty of the femoral head-neck junction [2, 7, 24] or pelvic reorientation osteotomy [29]. However, in all of these series, the degree of cartilage damage at the time of surgery negatively influenced the clinical outcome. More importantly, the severity of cartilage damage is in part related to the duration of symptoms [3] and because patients often present with nonspecific groin and/or buttock pain, it is often difficult to confirm a diagnosis of intraarticular hip abnormalities. Burnett and associates [9] reported that, on average, patients with these abnormalities

were misdiagnosed in 33% of cases leading to a substantial delay in diagnosis.

Bone SPECT represents a relatively sensitive test to confirm intraarticular hip abnormalities in the presence of FAI. Physicians ordering bone scintigraphy in the evaluation of unexplained bone and joint pain [27] need to include FAI as part of the differential diagnosis. A positive bone scan should lead to further specialized radiographic examination (MRI with arthrography [4, 28] and/or three-dimensional CT [5]) to rule out FAI, because these investigations can then further aid in surgical planning as well as counseling patients on the prognosis of their hip [15].

References

1. Beaulé PE, Harvey N, Zaragoza EJ, LeDuff M, Dorey FJ. The femoral head/neck offset and hip resurfacing. *J Bone Joint Surg Br.* 2007;89:9–15.
2. Beaulé PE, LeDuff MJ, Zaragoza EJ. Quality of life outcome of femoral head/neck offset correction for femoroacetabular impingement. *J Bone Joint Surg Am.* 2007;89:773–779.
3. Beaulé PE, Schmalzried TP, Campbell PA, Dorey F, Amstutz HC. Duration of symptoms and outcome of hemiresurfacing for hip osteonecrosis. *Clin Orthop Relat Res.* 2001;385:104–117.
4. Beaulé PE, Zaragoza EJ, Copelan N. Magnetic resonance imaging with gadolinium arthrography to assess acetabular cartilage delamination. A report of four cases. *J Bone Joint Surg Am.* 2004;86:2294–2298.
5. Beaulé PE, Zaragoza EJ, Motamed K, Copelan N, Dorey J. Three-dimensional computed tomography of the hip in the assessment of femoro-acetabular impingement. *J Orthop Res.* 2005;23:1286–1292.
6. Beck M, Kalhor M, Leunig M, Ganz R. Hip morphology influences the pattern of damage to the acetabular cartilage: femoroacetabular impingement as a cause of early osteoarthritis of the hip. *J Bone Joint Surg Br.* 2005;87:1012–1018.
7. Beck M, Leunig M, Parvizi J, Boutier V, Wyss D, Ganz R. Anterior femoroacetabular impingement. Part II. Midterm results of surgical treatment. *Clin Orthop Relat Res.* 2004;418:67–73.
8. Bruce W, Van der Wall H, Storey G, Lonegran R, Pitsis G, Paeds D, Kannagara S. Bone scintigraphy in acetabular labral tears. *Clin Nucl Med.* 2004;29:465–468.
9. Burnett SJ, Della Rocca GJ, Prather H, Curry M, Maloney WJ, Clohisy JC. Clinical presentation of patients with tears of the acetabular labrum. *J Bone Joint Surg Am.* 2006;88:327–333.
10. Byrd JW. Labral lesions: an elusive source of hip pain case reports and literature review. *Arthroscopy.* 1996;12:603–612.
11. Edwards DJ, Lomas D, Villar RN. Diagnosis of the painful hip by magnetic resonance imaging and arthroscopy. *J Bone Joint Surg Br.* 1995;77:374–376.
12. Eijer H, Leunig M, Mahomed N, Ganz R. Cross-table lateral radiographs for screening of anterior femoral head-neck offset in patients with femoro-acetabular impingement. *Hip Int.* 2001;11: 37–41.
13. Ganz R, Parvizi J, Leunig M, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. *Clin Orthop Relat Res.* 2003;417:112–120.
14. Ito K, Minka MA 2nd, Leunig S, Werlen S, Ganz R. Femoroacetabular impingement and the cam-effect. *J Bone Joint Surg Br.* 2001;83:171–176.
15. Kim YJ, Jaramillo D, Millis MB, Gray ML, Burstein D. Assessment of early osteoarthritis in hip dysplasia with delayed

- gadolinium-enhanced magnetic resonance imaging of cartilage. *J Bone Joint Surg Am.* 2003;85:1987–1992.
16. Leunig M, Werlen S, Ungersbock A, Ito K, Ganz R. Evaluation of the acetabular labrum by MR arthrography. *J Bone Joint Surg Br.* 1997;79:230–234.
 17. Mankin HJ. Nontraumatic necrosis of bone (osteonecrosis). *N Engl J Med.* 1992;326:1473–1479.
 18. May O, Matar WY, Beaulé PE. Treatment of failed arthroscopic acetabular labral débridement by femoral chondro-osteoplasty. A case series of five patients. *J Bone Joint Surg Br.* 2007;89:595–598.
 19. Meyer DC, Beck M, Ellis T, Ganz R, Leunig M. Comparison of six radiographic projections to assess femoral head/asphericity. *Clin Orthop Relat Res.* 2006;445:181–185.
 20. Murphy SB, Ganz R, Muller ME. The prognosis in untreated dysplasia of the hip. A study of radiographic factors that predict the outcome. *J Bone Joint Surg Am.* 1995;77:985–989.
 21. Murphy SB, Tannast M, Kim Y-J, Buly RL, Millis MB. Débridement of the adult hip for femoroacetabular impingement. Indications and preliminary clinical results. *Clin Orthop Relat Res.* 2004;429:178–181.
 22. Notzli HP, Wyss TF, Stoecklin CH, Schmid MR, Treiber K, Hodler J. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. *J Bone Joint Surg Br.* 2002;84:556–560.
 23. Peelle MW, Della Rocca GJ, Maloney WJ, Curry MC, Clohisy JC. Acetabular and femoral radiographic abnormalities associated with labral tears. *Clin Orthop Relat Res.* 2005;441:327–333.
 24. Peters CL, Erickson JA. Treatment of femoro-acetabular impingement with surgical dislocation and débridement in young adults. *J Bone Joint Surg Am.* 2006;88:1735–1741.
 25. Reynolds D, Lucas J, Klaue K. Retroversion of the acetabulum. A cause of hip pain. *J Bone Joint Surg Br.* 1999;81:281–288.
 26. Ryu JS, Kim JS, Moon DH, Kim SM, Shin MJ, Chang JS, Park SK, Han DJ, Lee HK. Bone SPECT is more sensitive than MRI in the detection of early osteonecrosis of the femoral head after renal transplantation. *J Nucl Med.* 2002;43:1006–1011.
 27. Sarikaya I, Sarikaya A, Holder LE. The role of single photon emission computed tomography in bone imaging. *Semin Nucl Med.* 2001;31:3–16.
 28. Schmid MR, Notzli HP, Zanetti M, Wyss TF, Hodler J. Cartilage lesions in the hip: diagnostic effectiveness of MR arthrography. *Radiology.* 2003;226:382–386.
 29. Siebenrock KA, Schoeniger R, Ganz R. Anterior femoro-acetabular impingement due to acetabular retroversion. Treatment with periacetabular osteotomy. *J Bone Joint Surg Am.* 2003;85:278–286.
 30. Tonnies D. Normal values of the hip of the hip joint for the evaluation of x-rays in children and adults. *Clin Orthop Relat Res.* 1976;119:39–47.
 31. Wenger DE, Kendall KR, Miner M, Trousdale RT. Acetabular labral tears rarely occur in the absence of bony abnormalities. *Clin Orthop Relat Res.* 2004;426:145–150.