372-377 *Clinical rheumatology*, 1997, **16**, N° 4

Bone Scintigraphy Equipped with a Pinhole Collimator for Diagnosis of Avascular Necrosis of the Femoral Head

J.F. MAILLEFERT*, M. TOUBEAU**, C. PIROTH*, L. PIROTH***, F. BRUNOTTE**, C. TAVERNIER*

Summary **The objective was to compare the sensitivities for diagnosis of avascular necrosis of the femoral head of bone scintigraphy equipped with a pinhole collimator and with an high resolution parallel collimator. Bone scintigraphy equipped with a pinhole collimator and with an high resolution parallel collimator were performed in 16 patients with bilateral (n=7) or unilateral (n=9) avascular necrosis of the femoral head. Bone scintigraphy equipped with a pinhole collimator documented a photopenic defect in 78.3% of the necrotic hips, while bone scintigraphy equipped with an high resolution parallel collimator documented a defect in 47.8%. There was no false-positive diagnosis of avascular necrosis of the femoral head on either bone scintigraphy equipped with a pinhole or with an high resolution parallel collimator. In conclusion, bone scintigraphy equipped with a pinhole collimator has a greater sensitivity for diagnosis of avascular necrosis of the femoral head than bone scintigraphy equipped with an high resolution parallel collimator.**

Key words **Hip, Necrosis, Radionuclide Imaging, Diagnostic Use.**

INTRODUCTION

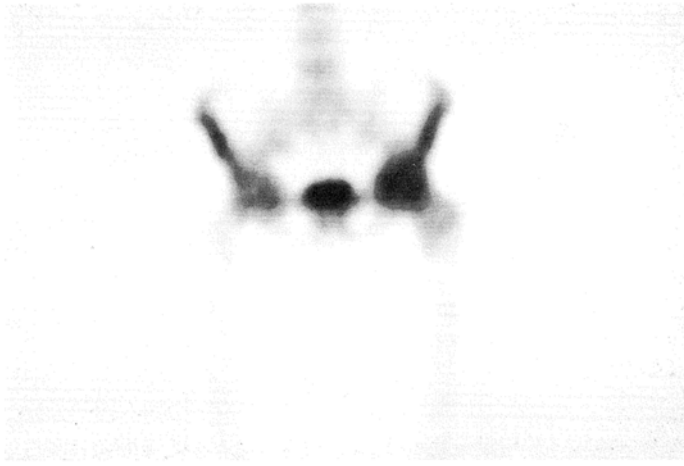
Magnetic resonance imaging (MRI) is the modality of choice for early diagnosis of avascular necrosis of the femoral head (AVNFH). Nevertheless, MRI cannot be performed in patients with cardiac pacemakers, intracranial clips or claustrophobia. These patients can have an unexplained hip pain explored by bone scintigraphy (BS) equipped with an high resolution parallel collimator. A photon deficient defect in the femoral head is a scintigraphic evidence of AVNFH (3). However, a perinecrotic zone increased radiotracer uptake often obliterates the defect and creates difficulties of distinguishing AVNFH from other causes for increased radiotracer uptake (3). The use of a pinhole collimator optimizes resolution in evaluating circumscribes areas. Thus, BS equipped with a pinhole collimator should be a more sensitive indicator of the presence of AVNFH than BS equipped with an high resolution parallel collimator. Consequently, in some institutions, the pinhole collimator is used routinely for evaluation of AVNFH. However, other nuclear medecine departments do not employ this method, and use parallel collimators to detect AVNFH. Although BS equipped with a pinhole collimator has already been studied in comparison with MRI (1,7), this difference in habits may be explained by a lack of comparative studies between BS equipped with an high resolution parallel collimator and with a pinhole collimator.

The aim of this study was to determine the effectiveness of BS equipped with a pinhole collimator in detecting AVNFH and to compare the results of BS equipped with a pinhole and with an high resolution parallel collimator.

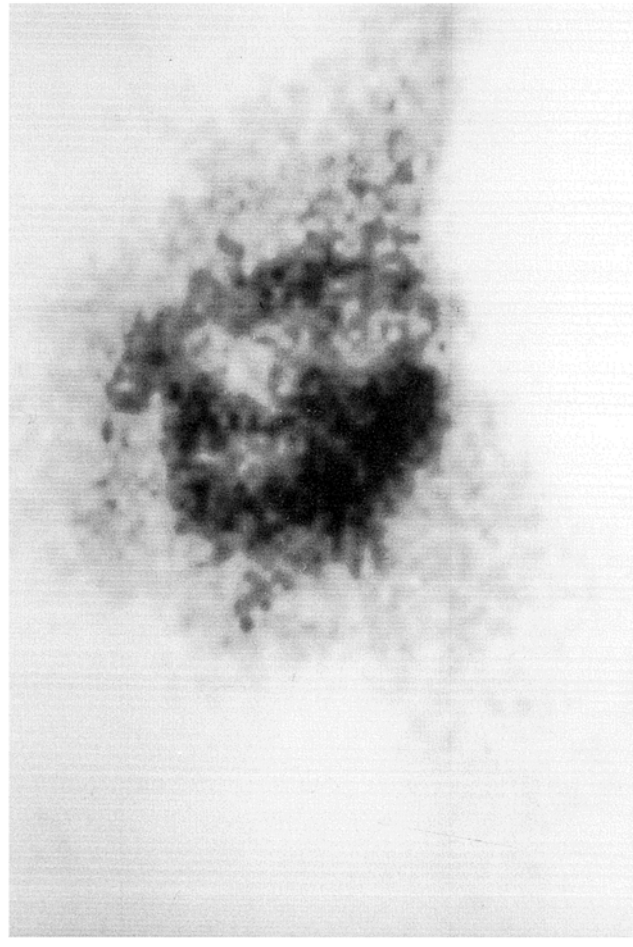
PATIENTS AND METHODS

Sixteen adult patients (13 men, 3 women) with bilateral (n=7) or unilateral (n=9) AVFNH were examined with BS equipped with an high resolution parallel and with a pinhole collimator. Ages ranged from 22 to 73 years (mean=52.4 years ±15.4 SD). Recognized risk factors for AVNFH were identified in 12 cases. Six patients had an history of alcohol abuse and six were treated by long-term corticosteroid therapy (2 of whom were renal

*Department of Rheumatology, CHU Dijon, France.
**Department of Nuclear Medecine, Centre GF Leclerc, Dijon, France.
***Department of Internal Medecine, CHU Dijon, France.



▲ A



B ▶

Fig.1: A 44-year-old man complained of a left hip pain of 2 months duration. X-rays were normal. BS equipped with an high resolution parallel collimator showed a diffuse radiotracer uptake of the left femoral head (figure 1a). BS equipped with a pinhole collimator demonstrated (figure 1b) a defect in the femoral head, surrounded by a zone of increased scintigraphic activity. The diagnosis of AVNFH was confirmed secondarily by histologic examination following total hip replacement.

transplant recipients, 1 was treated with steroids for juvenile chronic arthritis, 1 for chronic bronchopathy, 2 were given intermittent high-dose corticosteroids for non-Hodgkin lymphoma and multiple myeloma). Nineteen out of twenty-three affected hips and a history of a local pain which lasted for 2 weeks to 13 months (mean=4.9 months ±3.2 SD). The 4 remaining hips were asymptomatics.

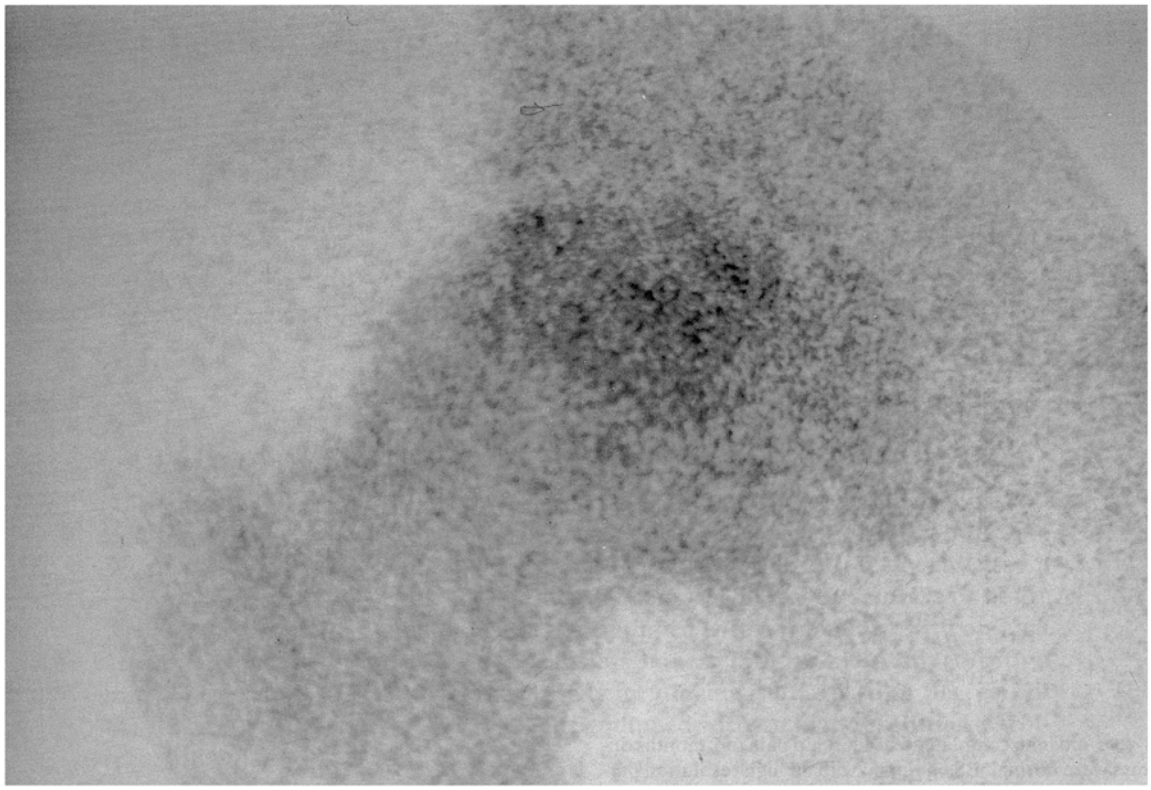
Radiographic staging was performed in all cases. According to Ficat's classification (4), 7 hips were graded with stage I AVNFH (normal plain radiographs), 9 hips with stage II (mottled sclerosis and/or the crescent sign, with no deformity of the femoral head), 6 hips with stage III (progressive deformity of the femoral head), one hip with stage IV (early osteoarthritis). MRI was performed on ten of sixteen patients (with 15 of 23 necrotic hips).

For fifteen affected hips, the final diagnosis of AVNFH was established later by histologic examination, following total hip replacement (14 hips) or core decompression (1 hip). For the 8 remaining necrotic hips, the diagnosis of AVNFH was established by MRI (6 hips) and by the radiological follow-up (2 hips with 9 and 14 months follow-up). For the 9 non-necrotic hips, the diagnosis of AVNFH was excluded by the radiological follow-up in 4 cases (mean follow-up=18.2 months), MRI in 3 cases, MRI and the radiological follow-up in 2 cases.

An additional 4 patients with unilateral painful coxarthrosis were explored with BS equipped with an high resolution parallel collimator, BS equipped with a pinhole collimator, and MRI.

BS was performed following iv injection of 750 MBq of 99m technetium methylene diphosphonate. Three hours later, anterior-view bone scintigrams of the 2 hips were obtained with an high resolution parallel collimator. Later anterior-view bone scintigrams of the 2 hips were obtained using a gamma camera equipped with a pinhole collimator. BS examinations were reviewed by 2 experienced independant examinors (one a rheumatologist, the other a nuclear medecine physician) without benefit of clinical and radiological data. The previously established criteria used for diagnosis of AVNFH was the presence of a photopenic defect in the femoral head.

A.



B.

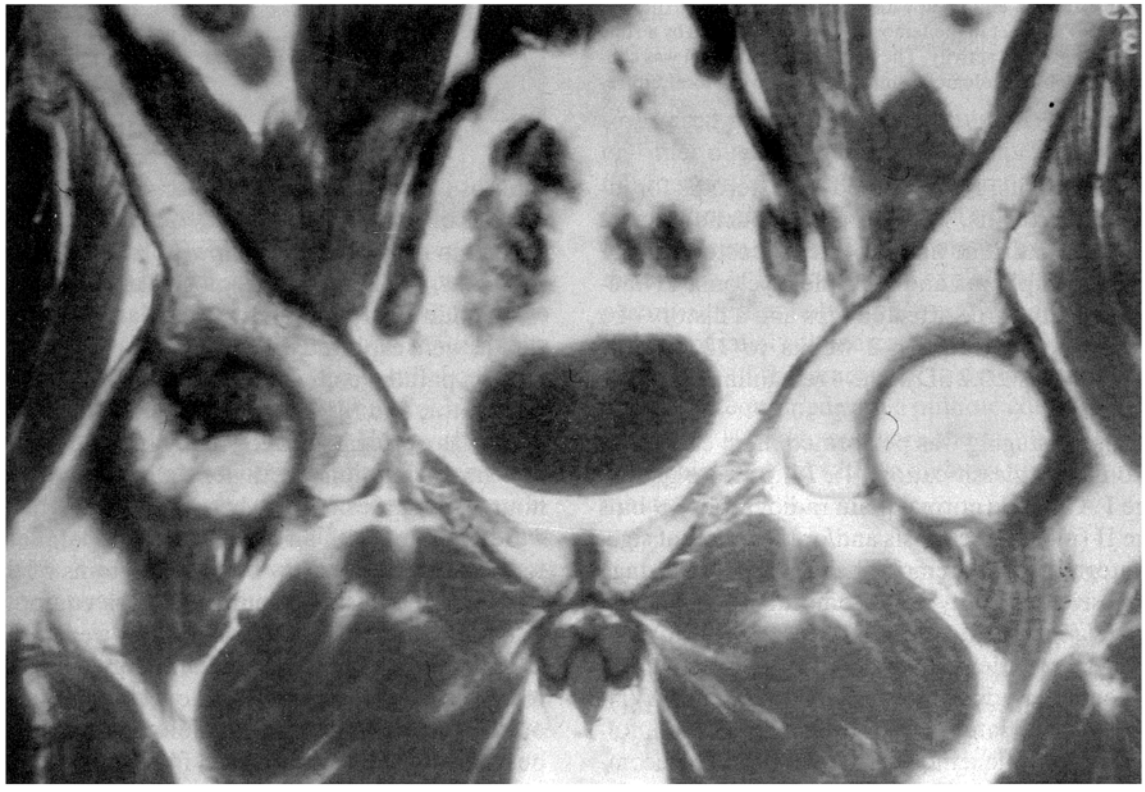


Fig. 2: A 44-year-old man complained of a right hip pain of 13 months duration. X-rays showed mottled sclerosis and radiolucencies in the right femoral head. BS equipped with a pinhole collimator a showed a diffuse radiotracer uptake of the right femoral head (figure 2a). MRI (figure 2b) demonstrated an AVNFH of the right femoral head that was confirmed secondarily by histologic examination following total hip replacement.

Statistical analysis used the Chi-2 squared test with Yates' correction.

RESULTS

BS equipped with a pinhole collimator documented a photopenic defect in 18 out of 23 necrotic heads (78.3%), and a diffuse increased radiotracer uptake of the femoral head in 3. BS equipped with an high resolution parallel collimator showed only 11 defects (47.8%), $p < 0,05$, and 10 diffuse increased radiotracer uptake of the femoral head. When selecting the radiographic early stages (I and II), BS equipped with a pinhole collimator showed a photopenic defect in 11 of 16 AVNFH (68.7%), and BS equipped with an high resolution parallel collimator in 7 of 16 (43.7%), $p < 0,2$. The sensitivity of BS equipped with a pinhole collimator tended to be lower in early stages than in stages III and IV (68.7% vs 100%), but in an insignificant manner. Figure 1-3 show examples of the images obtained with the pinhole collimator.

BS equipped with either pinhole or high resolution parallel collimator failed to show any abnormality in 2 asymptomatic necrotic femoral heads. The two false negatives using BS occured in the asymptomatic hips of 2 patients with bilateral AVNFH. BS equipped with a pinhole collimator and with an high resolution parallel collimator showed a photopenic defect in femoral heads of the painful hips. The contralateral femoral heads were free of scintigraphic abnormalities, but MRI detected an unsuspected AVNFH.

Neither BS procedure detected any abnormality in the 9 contralateral non-necrotic femoral heads. In the 4 patients with painful unilateral coxarthrosis, the 2 procedures documented hyperfixation of the osteoarthritic coxofemoral joint, with no defect of the femoral head, and showed a normal contralateral femoral joint. MRI confirmed the absence of AVNFH.

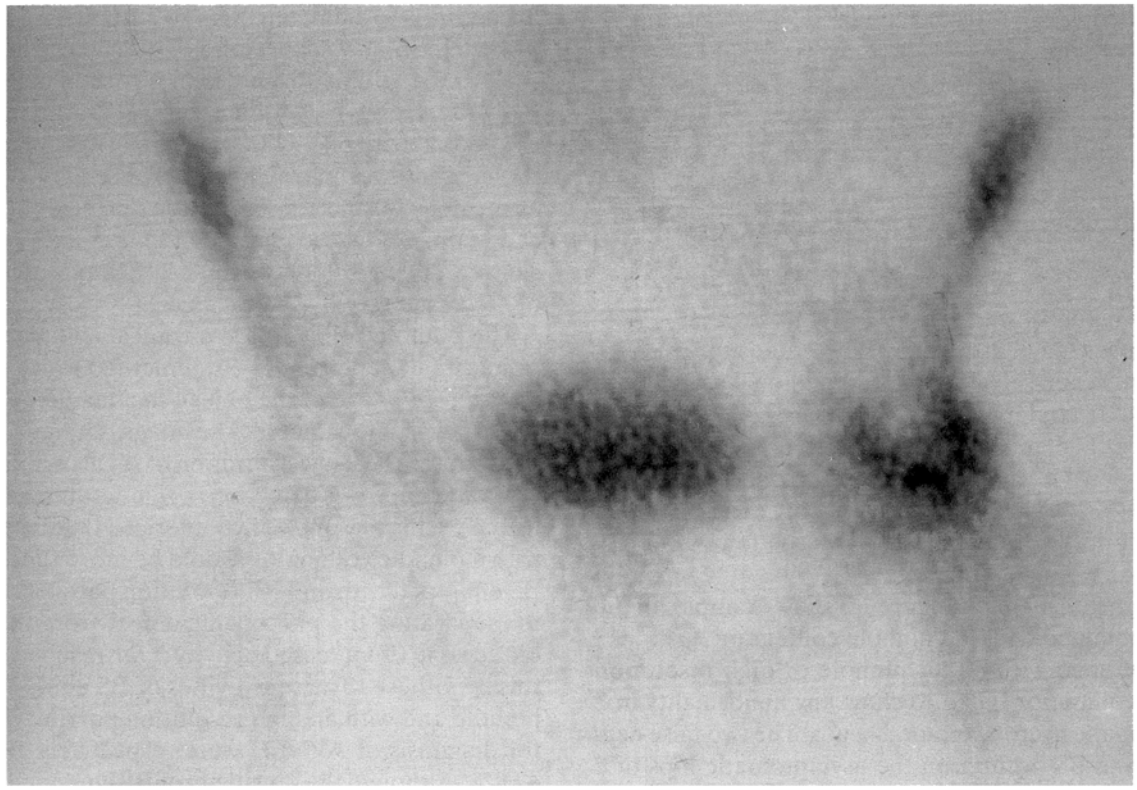
DISCUSSION

Although AVNFH may be suspected on the basis of the history, physical examination and X-rays, special imaging studies are essential for early diagnosis (6,8). Many investigators have demonstrated the usefulness of MRI (1,7,9) and subsequently, MRI has become the modality of choice for early diagnosis of AVNFH. Furthermore, MRI could be useful for predicting the long-term outcome of AVNFH (2,5). However, MRI cannot be performed on some patients, such as those with intracranial clips, cardiac pace makers, or claustrophobia. These patients can have an unexplained hip pain explored by classical bone scintigraphy equipped with an high resolution parallel collimator. Very early in the course of AVNFH, BS may show a photon deficiency in the femoral head, rapidly surrounded by a zone of increased activity (3). However, within a few weeks, the zone of increased activity may obliterate the original defect, and the site shows a uniform high level of activity (6). As long as the defect can be observed, the diagnosis of AVNFH can be made. Once it has been obliterated, physicians can not distinguish between AVNFH and other causes of increased activity.

The pinhole collimator is a conical collimator with a small circular aperture (3-5 milimeters) which produces an inverted image of the object, in a manner analogous to photographic cameras. The image obtained is magnified, allows a better visualization of small organs or structures and improves detection of scintigraphic abnormalities. For this reason, we hypothesized that BS equipped with a pinhole collimator should be more sensitive than BS equipped with an high resolution parallel collimator for separating the photopenic defect from the perinecrotic zone of increased activity. Our results confirmed this hypothesis. The sensitivities of BS equipped with a pinhole and with an high resolution parallel collimator for diagnosis of AVNFH were respectively 78.3% and 47.8%. Although the sensitivity of BS equipped with pinhole collimator tended to be lower in stages I and II, similar results were found when selecting such radiologic early stages but the difference was not statistically significant, due possibly to the few cases studied. There were no false-positive diagnoses of AVNFH on BS equipped with a pinhole collimator. Nine patients had only a unilateral AVNFH and 4 patients with coxarthrosis were free of AVNFH. BS did not show any defect in these non necrotic femoral heads. These results suggest that BS equipped with a pinhole collimator is a sensitive and specific procedure for diagnosing AVNFH. Beltran et al (1) reported similar sensitivity of BS equipped with a pinhole collimator. However, the diagnostic criteria (increased or decreased activity in the femoral head) were different from ours. Mitchell et al (7) reported a lower sensitivity for BS equipped with a pinhole collimator. In their study, a cold defect was seen in 10 out of 41 necrotic hips. However, a large porportion of the lesions was examined following core decompression. Such a decompression could have modified the findings of BS. In these two studies, comparison between BS equipped with an high resolution parallel and with a pinhole collimator was not performed.

Other scintigraphic procedure has been studied to ameliorate the detection of the photopoenic defect. The single photon emission computed tomography (SPECT) has been shown to be a highly accurate imaging modality for the diagnosis of AVNFH (3). The advantage of

A.



B.

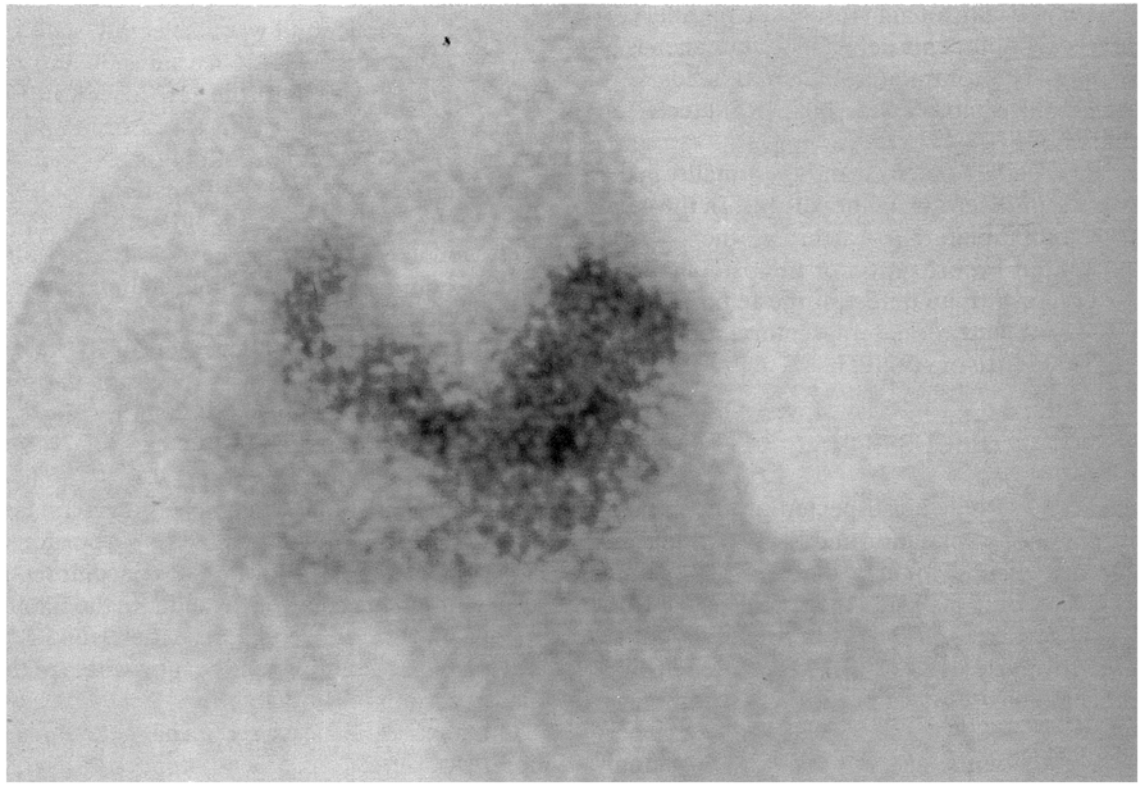


Fig. 3: A 57-year-old man complained of a left hip pain of 6 months duration. BS equipped with an high resolution parallel collimator (figure 3a) and with a pinhole collimator (figure 3b) documented a defect in the left femoral head, surrounded by a zone of increased radiotracer uptake. The diagnosis of AVNFH was confirmed secondarily by histologic examination following total hip replacement.

SPECT is to provide images of the radioactive distribution in three-dimensions, but it requies a good cooperation from the patient who must remain immobile for 45 minutes (compared to the 15 minutes acquisition time of BS equipped with a pinhole collimator). An additional limitation is early filling of the bladder.

This study was not conducted to compare BS equipped with a pinhole collimator and MRI. Subsequently, MRI was not performed in all patients. MRI has been shown to be more sensitive than BS equipped with a pinhole collimator for diagnosis of AVNFH (1). In our series, MRI detected 5 necrotic hips not demonstrated by BS equipped with a pinhole collimator (diffuse increased radiotracer uptake in the femoral head 3 times, no abnormality in the femoral head 2 times). Subsequently, we do not advocate the use of BS equipped with a pinhole collimator instead of MRI for diagnosis of AVNFH, but we suggest that BS equipped with a pinhole collimator could be an alternative to MRI when this procedure cannot be performed or when its results are not clear-cut. Moreover, BS equipped with an high resolution parallel collimator is considered to be a useful technique for patients who do not have risk factors for necrosis or as a screening device for those in whom involvement of multiple joints is suspected (8). In such patients, BS equipped with a pinhole collimator could be added to the BS equipped with an high resolution parallel collimator.

In conclusion, we have shown that BS equipped with a pinhole collimator has a greater sensitivity for diagnosing AVNFH than BS equipped with an high resolution parallel collimator. BS equipped with a pinhole collimator could be an alternative to MRI when this procedure cannot be performed or when its results are not clearcut.

REFERENCES

1. Beltran J, Herman LJ, Burk JM, Zuelzer WA, Clark RN, Lucas JG, Weiss LD, Yang A. Femoral head avascular necrosis: MR imaging with clinical-pathologic and radionuclide correlation. Radiology 1988; 166: 215-20.
2. Beltran J, Knight CT, Zuelzer WA, Morgan JP, Shwendeman LJ, Chandnani VP, Mosure JC, Shaffer PB. Core decompression for avascular necrosis of the femoral head: correlation between long-term results and preoperative MR staging. Radiology 1990; 175: 533-6.
3. Collier BD, Carrera GF, Johnson RP, Isitman AT, Hellman RS, Knobel J, Finger WA, Gonyo JE, Malloy PJ. Detection of femoral head avascular necrosis in adults by SPECT. J Nucl Med 1985; 26: 979-87.
4. Ficat RP. Idiopathic bone necrosis of the femoral head: early diagnosis and treatment. J Bone Joint Surg 1985; 67-B: 3-9.
5. Lafforgue P, Dahan E, Chagnaud C, Schiano A, Kasbarian M, Acquaviva PC. Early-stage avascular necrosis of the femoral head: MR imaging for prognosis in 31 cases with at least 2 years followup. Radiology 1993; 187: 199-204.
6. Mankin HJ. Nontraumatic necrosis of bone (osteonecrosis). New Eng J Med 1992; 326: 1473-9.
7. Mitchell DG, Rao VM, Dalinka MK, Spritzer CE, Alavi A, Steinberg ME, Fallon M, Kressel HY. Femoral head avascular necrosis: correlation of MR imaging, radiographic staging, radionuclide imaging, and clinical findings. Radiology 1987, 162: 709-15.
8. Mont MA, Hungerford DS. Non-traumatic avascular necrosis of the femoral head. J Bone Joint Surg 1995; 77-A: 459-74.
9. Seiler JG, Christie MJ, Homra L. Correlation of the findings of magnetic resonance imaging with those of bone biopsy in patients who have stage-I or II ischemic necrosis of the femoral head. J Bone Joint Surg 1989; 71-A: 28-32.

Received: 11 October 1996.
Revision-accepted: 7 January 1997.
Correspondence to: JF MAILLEFERT, MD,
Service de Rhumatologie, Hôpital Général, 3 rue du Fb Raines, 21 000 DIJON, FRANCE.