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Radionuclide scintimetry for diagnosis of complications following femoral neck fracture

A scintimetric study using Tc-99m MDP was made of 54 patients with delayed union, nonunion, or late segmental collapse of the femoral head, 4–92 months after femoral neck fracture. In radiographically verified collapse, the radionuclide uptake ratio between the femoral head on the fractured and on the intact side (HHR) was significantly higher than in fractures resulting in delayed union or nonunion. On the basis of scintimetric and radiographic findings, the patients with healing disturbances could be divided into three groups, characterized by the following features: (1) Satisfactory post-reduction position of the fracture without subsequent redisplacement and a high HHR, which as a rule turned out to be delayed union; (2) The same radiographic pattern but with a lower HHR, which in most cases resulted in nonunion; (3) Inadequate reduction or early redisplacement of the fracture with a high HHR, which resulted in nonunion. The fractional precision in discriminating between different types of disturbed fracture healing by means of skeletal scintimetry was 0.86 in this study. This non-invasive and technically simple method would therefore be a valuable complement to radiography in the assessment of healing, more than 4 months after fracture of the femoral neck.

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Impaired vascular supply to the femoral head is the major factor causing late complications after femoral neck fracture (Hulth 1958, 1965, Strömqvist 1983), although the degree of displacement of the fracture has also been discussed in this context (Garden 1971, Massie 1973, Arnoldi & Lemperg 1977, Thorling 1980, Kofoed & Alberts 1980). Radionuclide scintimetry using Technetium-99-m-labelled phosphate compounds as tracers is a non-invasive and technically simple method of assessing femoral head vascularity and vitality.

Most studies of femoral neck fractures utilizing radionuclides have been concerned with the risk of late segmental collapse of the femoral head. Owing to revascularization and remodelling of the initially avascular head, the results of scintimetry are dependent on the time lapse after injury. Many authors (D'Ambrosia et al. 1975a, b, Stadalnik et al. 1975, Asnis et al. 1976, Lucie et al. 1981, Strömqvist 1983) have observed a markedly enhanced radionuclide uptake in the femoral head in fractures with late complications (more than 2 months postoperatively), in contrast to the reduced activity observed in the immediate post-fracture period.

The present study focused on the following questions:

(1) Are there differences in the results of scintimetry when fractures resulting in nonunion and delayed union are compared with those resulting in late segmental collapse of the femoral head?

(2) Can scintimetric assessment of vascularity more than 4 months after femoral neck fracture in combination with clinical and radiographic data provide information about the possible causal relationship between the development of late complications and a) the quality of reduction and b) the vascular supply to the femoral head?

Patients and methods

Patients

The series included 54 patients with Garden Type III and IV displaced femoral neck fractures with clinical and/or radiographic signs of complications 4–92 months after injury. All had been primarily operated

on with reduction and internal fixation of the fracture, in 43 cases with multiple pinning by the Nyström method and in 11 by other multiple pinning or single nail techniques. All patients had pain on weightbearing and radiographic changes consisting in deformity of the weightbearing portion of the femoral head, a still visible fracture line, or progressive resorption of the femoral neck. The average age of the patients was 68 (37–88) years, and 45 were women. In the 49 cases in which the exact date of injury was known, the average delay between fracture and operation was 1.8 (1–7) days. Patients with disorders of the contralateral hip were excluded from the study.

In addition to routine postoperative clinical and radiographic examinations, all patients were included in a scintimetric study and radiographic examination 4–92 months postoperatively.

Scintimetry

Scintimetry of the skeleton was performed 3–4 h following intravenous injection of 400 MBq of Technetium-99m methylene-diphosphonate (Tc-99m MDP), with the patient in the supine position and the hip joints in internal rotation. The distribution of the radionuclide was recorded anteriorly with 400 000 counts over the pelvis and hip joints with a General Electric 400 T or 535 gamma camera equipped with a high resolution large-field 200 KeV collimator. A digital equipment FPF 11/34 Gamma 11 computer system was used for storage and processing of the data, and numerical assessment of radionuclide activity was obtained from the Gamma 11 display screen. The radionuclide uptake was recorded for 2 × 2 pixel regions of interest (ROI) located bilaterally over the upper and lower parts of the femoral head and over the femoral neck. Depending on the degree of magnification, the side of the ROI varied from 6.3 to 4.8 mm. Following determination of the mean value of the uptake levels over the two ROI in each femoral head, the uptake ratio between the femoral head on the fractured and the contralateral side ("head-to-head ratio" = HHR) and that between the femoral head and neck on the fractured side ("head-to-neck ratio" = HNR) were calculated.

In order to evaluate the methodological error in this quantitative assessment of radionuclide uptake in the femoral head, two separate determinations were made in 10 patients.

The average time interval between fracture and scintimetry was 10 (5–27) months for nonunion, 9 (4–21) months for delayed union and 29 (10–92) months for late segmental collapse patients.

In 22 patients with nonunion, a secondary hip arthroplasty was performed on average 12 (5–32) months after fracture, and for seven patients with late segmental collapse 33 (10–94) months after fracture.

Radiographic examination

The AP and lateral views obtained at the time of scintimetry were compared with the initial and subsequent postoperative follow-up radiograms. For five patients the initial radiograms were missing.

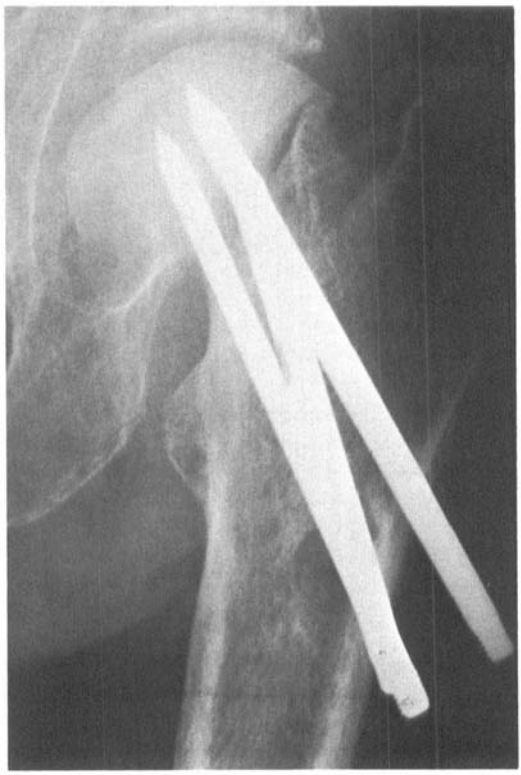
Reduction was defined as inadequate in fractures with a Garden (1961) alignment index of less than 155° or more than 185° in either the AP or lateral view and/or an ad latus displacement of more than one–fourth of the diameter of the femoral neck. In the remainder of fractures, reduction was considered acceptable. Early redisplacement was defined as a loss of reduction with shortening and external rotation of the distal fragment within 2 months postoperatively. Patients with initially adequate fracture reduction and no subsequent redisplacement were classified as belonging to a radiographically favourable group, whereas the remainder were classified as less favourable.

Diagnosis and late complications

The primary diagnosis of late complications was based on radiographic criteria. Thus healing disturbances were defined as a still visible fracture line or more than 10 mm progressive resorption of the femoral neck 4–21 months postoperatively. Late segmental collapse was defined as localized or general deformity of the weightbearing portion of the femoral head after fracture healing.

Table 1. Head-to-head ratio (HHR) and head-to-neck ratio (HNR) (mean ± SD) of radionuclide uptake in relation to final diagnosis and radiographic features

Radiology	Final diagnosis		
	Nonunion (n=26)	Delayed union (n=11)	Segmental collapse (n=17)
Favourable	(n=7)	(n=11)	(n=14)
HHR	1.72±0.35	2.06±0.44	2.70±0.71
HNR	0.89±0.28	1.24±0.49	1.68±0.66
Less favourable	(n=19)	(n=0)	(n=3)
HHR	2.22±0.76	–	3.03±1.04
HNR	0.97±0.35	–	1.71±1.23
All			
HHR	2.09±0.70	2.06±0.44	2.76±0.75
HNR	0.95±0.33	1.24±0.49	1.69±0.73



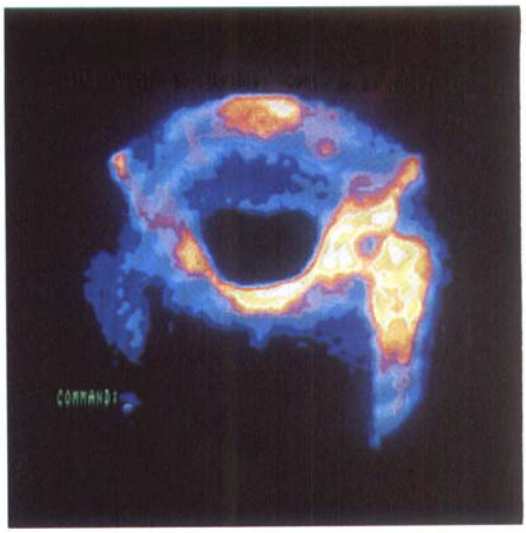


Figure 1. Radiogram of the left hip showing nonunion and scintigram of the pelvis demonstrating only slightly increased activity in the left hip. Head-to-head ratio 1.58.

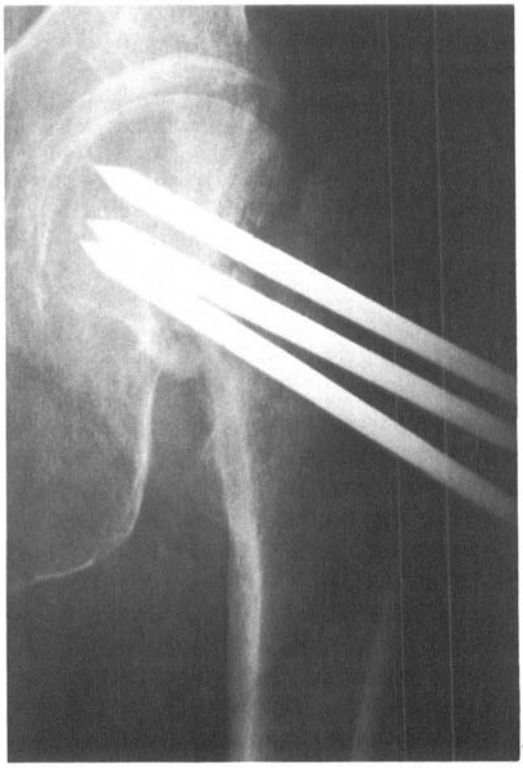


Figure 2. Radiogram of the left hip showing nonunion and scintigram of the pelvis demonstrating enhanced activity in the left hip. Head-to-head ratio 3.08.

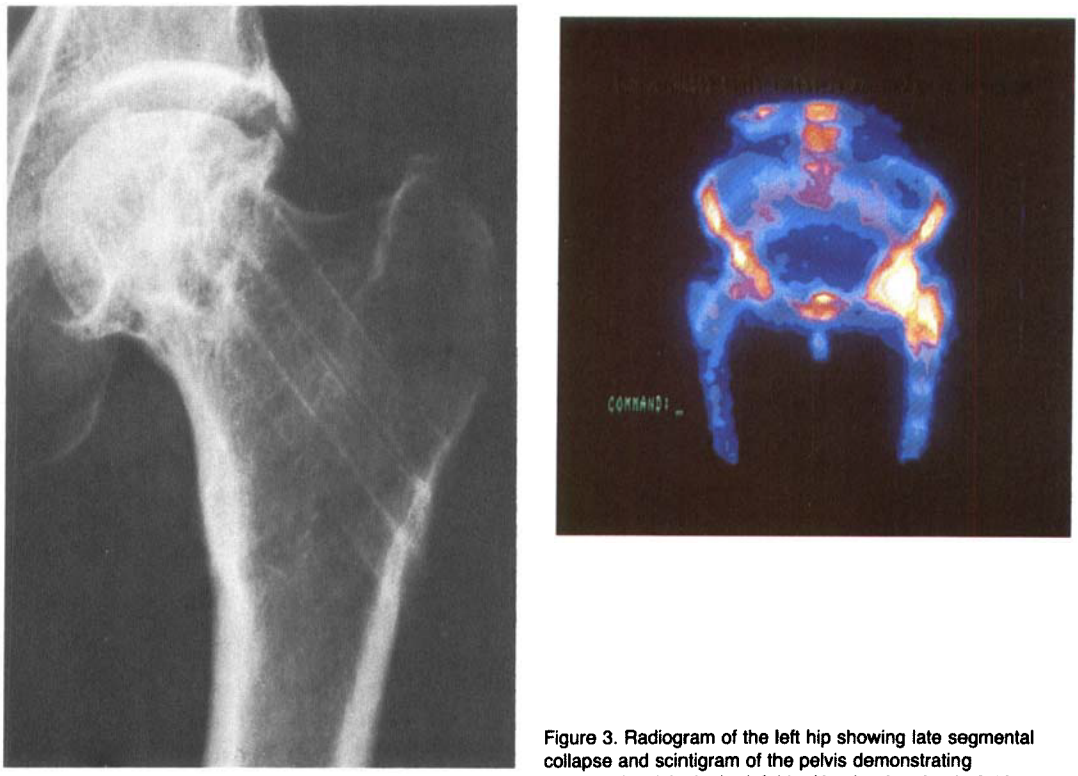


Figure 3. Radiogram of the left hip showing late segmental collapse and scintigram of the pelvis demonstrating enhanced activity in the left hip. Head-to-head ratio 3.18.

Pain on weightbearing was experienced by all 54 patients in the series, but gradually subsided in the 11 patients with delayed union from 4 months postoperatively, and consolidation of the fracture was radiographically verified 10–24 months postoperatively. The final diagnosis of nonunion and late segmental collapse of the femoral head was based on radiographic criteria in combination with continued or recurrent pain on weightbearing, and in 29 cases also on the findings at secondary arthroplasty.

Results

The final diagnosis was nonunion in 26 patients, delayed union in 11, and late segmental collapse in 17. Secondary hip arthroplasty was performed in 29 patients and confirmed the preoperative diagnosis of nonunion in 22 and of late segmental collapse after fracture healing in seven patients.

The methodological error in determining the scintimetric activity, expressed as a percentage of the mean for each ratio, was 10 per cent for the HHR and 18 per cent for the HNR.

The HHR for the entire series was 2.29 ± 0.73 (1.18–3.93) and the HNR 1.24 ± 0.61 (0.47–3.13). The HHR was higher in the group with late segmental collapse than in the nonunion ($p = 0.005$) and delayed union groups ($p = 0.005$). The HNR was lower in the nonunion group as compared to the groups with delayed union ($p < 0.05$) and late segmental collapse ($p < 0.001$) (Table 1).

Patients with less favourable radiography dominated in the nonunion group (19/26), as compared to the groups with late segmental collapse (3/17) and delayed union (0/11) ($p < 0.001$). Analysis of the two uptake ratios showed a difference ($p < 0.05$) in mean HHR between the radiographically favourable (1.72) and less favourable cases (2.22) only in the nonunion group. No corresponding difference was found for the HNR (Table 1).

Three typical sets of radiographic and scintimetric findings were: nonunion with relatively slightly increased activity in the femoral head (Figure 1), nonunion with more enhanced activity (Figure 2), and late segmental collapse with strikingly high activity in the femoral head (Figure 3).

Late segmental collapse could be diagnosed

in all 17 cases at the radiographic examination performed at the same time as scintimetry. On the basis of the available radiographic information concerning the quality of reduction of the fracture, it could be predicted that patients in the favourable group with an HHR exceeding 1.85 would show delayed union, whereas the remainder would not heal. Comparing the resulting preliminary diagnosis with the final one, gave five diagnostic failures out of 54 patients, i.e. a diagnostic precision of 0.91. If cases with late segmental collapse were excluded, there were five diagnostic failures out of 37, equalling a precision of 0.86. The HNR did not contribute additional information of importance to the differential diagnosis and could be excluded from the flow chart (Figure 4).

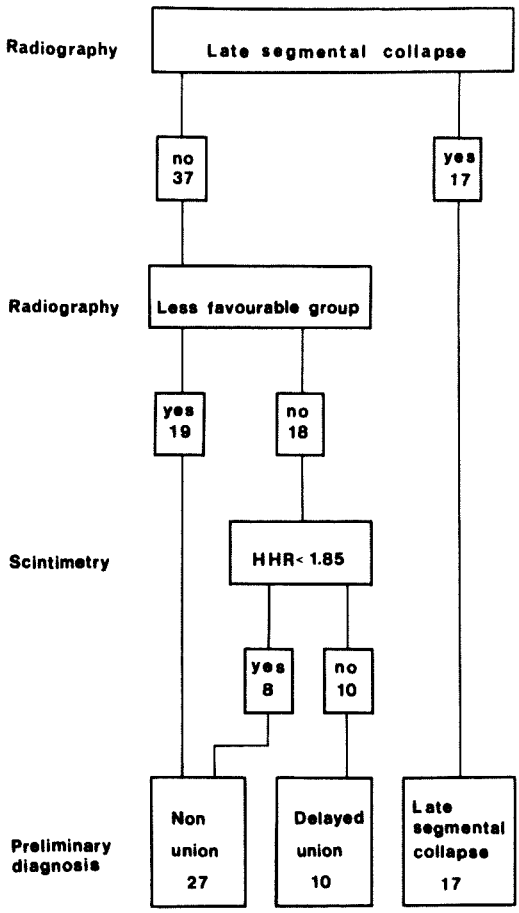


Figure 4. Flow chart illustrating the degree of prognostic precision obtained by combining radiography and scintimetry to differentiate between the diagnostic alternatives nonunion, delayed union and late segmental collapse. Maximal discrimination limit for the head-to-head ratio (HHR) was 1.85.

Discussion

Postoperative serial scintimetry of femoral neck fractures has shown increasing femoral head activity with time (Bauer et al. 1980) in fractures resulting in nonunion and late segmental collapse (Strömqvist 1983). In the present study of more than 4-month-old fractures with manifest or suspected complications, all patients had a higher radionuclide uptake in the femoral head on the fractured side as compared to the intact side. Since the level of activity may be influenced by radionuclide uptake in the surrounding acetabular bone, an HHR of more than 1 does not inevitably indicate a viable femoral head. The higher HHR in patients with late segmental collapse as compared to the nonunion and delayed union groups must be judged with caution, as the former group of patients was included in the study and examined by scintimetry on average 19 months later than the latter groups. However, although this to some extent may explain the difference between the groups, the strikingly high HHR demonstrates that major parts of the femoral head had been revascularized when hip pain recurred and the collapse was radiographically verified.

After the exclusion of patients with late segmental collapse, three groups could be identified, characterized by the following features: (1) satisfactory post-reduction position of the fracture without subsequent displacement, and high HHR and HNR; (2) the same radiographic pattern but lower HHR and HNR; (3) inadequate reduction or early redisplacement of the fracture, high HHR and low HNR. In the first group most fractures gradually healed. Both uptake radios were high, indicating a viable head. The second group had a lower HHR and HNR than the first group, although the differences were not significant, possibly due to the limited number of patients in this group. Most of the fractures in this group resulted in nonunion, and on the basis of Arden's (1960)

and Strömqvist's (1983) findings it would seem that an insufficient vascular supply might be the main reason for this. Although the patients in the third group had a higher HHR than those in the second group, their fractures did not heal either. The high mean ratio in this third group suggested vascularity of the femoral head, but the larger standard deviation may indicate greater heterogeneity with different degrees of vascular supply to the femoral head. Mechanical factors, such as impaired fracture stability and inadequate apposition between the fragments, would consequently seem to contribute to a greater extent to nonunion in this group.

As the time interval between injury and scintimetric study was the same for the groups of delayed union and nonunion, a flow chart was constructed to predict whether or not a fracture would subsequently unite. The diagnostic precision of discriminating between different types of disturbed healing was 0.86 in these two groups. Scintimetry thus seems to be a useful prognostic complement to radiographic examination: a fracture will unite if femoral head circulation is preserved and adequate reduction maintained, even when the fracture line is still visible or progressive resorption of the femoral neck is observed more than 4 months after injury.

The methodological error in calculating the HHR in this study was of the same magnitude as reported by Hansson (1982) and Strömqvist (1983). The 10 per cent error of the ratio in relation to the mean ratio mainly depends on the location of the regions of interest selection to record the activity distribution. The error of the method was small compared to the differences in isotope uptake discussed here.

A prospective study is in progress to clarify further the relative significance of vascular and mechanical factors in the development of complications following femoral neck fracture.

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