Acta Orthop Scand 55, 430–435, 1984

Preoperative ^{99m}Tc-MDP scintimetry of femoral neck fractures

Preoperative ^{99m}Tc-MDP-scintimetry was performed in 117 patients with femoral neck fractures. Scintimetry was shown to be superior to visual evaluation. The ratio was calculated of the uptake in the femoral head of the fractured side over that in the unfractured side, with compensation for the increased trochanteric femoral activity found on the fractured side. A ratio above 0.90 correlated well with uneventful healing in both undisplaced and displaced fractures. Preoperative scintimetry is of great value in the choice of primary treatment of femoral neck fractures.

Sven Holmberg
Karl-Göran Thorngren

Departments of Orthopaedic Surgery at Danderyd Hospital, S-182 88 Danderyd, Sweden, and at Lund University Hospital, Sweden

Complications after nailed femoral neck fractures are still a challenge to the orthopaedic surgeon. The search for a reliable method of assessing the viability of the femoral head after fracture, and to determine the prognosis, has involved numerous investigations (Tucker 1950, Hulth 1956, Johansson 1964, Müssbichler 1970).

In previous studies where ^{99m}Technetium-labelled compounds have been used to determine femoral head viability after neck fractures, the studies have mainly been performed postoperatively (D'Ambrosia et al. 1978, Bauer et al. 1980, Oda et al. 1980). Recently, Strömqvist (1983) has shown ^{99m}Technetium-methylenediphosphonate (^{99m}Tc-MDP) scintimetry to be of clinical value. Postoperative investigations within 3 weeks could discriminate between fractures with a good prognosis for healing and those prone to complications.

So far, there have been only a few reports on series using ^{99m}Tc-compounds as preoperative prognostic indicators of femoral neck fractures (Meyers et al. 1977, Lucie et al. 1981, Strömqvist 1983), and they lack long-term follow-ups. The main purpose of this study was to determine the prognostic significance of preoperative ^{99m}Tc-MDP scintimetry in the treatment of femoral neck fractures.

Material and methods

This prospective study included 152 patients with 152 intracapsular femoral neck fractures admitted soon after fracture to the Department of Orthopaedic Surgery at the University Hospital of Danderyd, Sweden, from December 1978 through May 1980. Patients with a history of bilateral fractures, endoprosthetic replacement or other pathological conditions of the contralateral hip were excluded from the study.

Treatment

Pin traction was applied immediately on dislocated fractures with the leg resting on a sledge, to start reduction. The fractures were operated on with nailing according to Rydell (1964) in 143 cases, with a Pugh (1955) nail in one case, and in eight cases a primary hemiarthroplasty was performed. Most patients were operated on the same day as the scintimetry was done. The patients were allowed full weight-bearing on the fractured leg from the day after operation.

Tc-99m-MDP scintimetry

The scintimetry was performed on the day of fracture in two patients, on the day after fracture in 76 patients, at 2 days after fracture in 20 patients, at 3 days after fracture in 16 patients, at 4 days after fracture in two patients and at 6 days after fracture in one patient. Each patient was given an intravenous injection of 370 MBq (10 mCi) ^{99}Technetium-

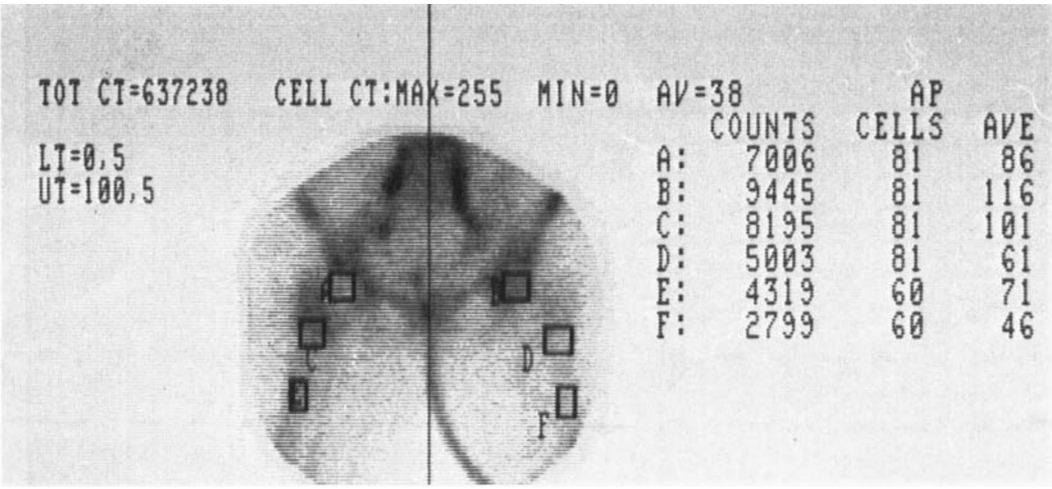

Figure 1. Method of selecting regions of interest (RI) A and B, and regions of interest of reference (RIR) C and D.

methylene-diphosphonate (^{99m}Tc-MDP). Detailed images of the pelvis, including the upper third of both femurs, were recorded 3–4 h after the injection. A gamma camera (General Electric Maxi) with a parallel hole collimator connected to a nuclear data system (Gamma 11 System) was used to allow storage of the images for display and analysis. An X-ray unit (Multi-Imager-7) connected to the computer was used to record the scintigraphic images on X-ray film for visual, qualitative evaluation. Average counts from equally sized regions of interest (RI) over the femoral heads were recorded by the computer. In order to exclude the difference of uptake between right and left femur, another region of interest of reference (RIR) was selected on both femurs at the level of the small trochanter (Figure 1). The RI and RIR comprised a square area of nine by nine or ten by ten elements (pixels) from a 128 × 128 matrix. The quotient of the recorded (A) divided by the expected (A_1) uptake of the fractured side head was named the SH-ratio and expressed as follows:

$$\text{SH ratio} = \frac{A}{A_1}$$

$$\text{where } A_1 = \frac{B \times C}{D};$$

B = average counts in RI of intact side;
C = average counts in RIR of fractured side;
D = average counts in RIR of intact side.

The quantitative evaluation was expressed as a ratio, to two decimal places.

The qualitative evaluation was assigned to five categories, as follows:

1 = strongly increased activity;
2 = increased activity;
3 = bilateral, equal activity;
4 = decreased activity;
5 = strongly decreased or no activity.

Follow-up

Included in the follow-up study were 117 patients out of 152. For reasons given in Table 1, 35 patients were excluded. The remainder comprised 98 females and 19 males with a mean age of 73 (38–99) years. Garden's classification (1961) was used to determine the preoperative fracture displacement, although stages I and II were combined as undisplaced fractures and stages III and IV as displaced fractures. Routine AP and lateral radiographs of the fractured hip were obtained on admission, directly postoperatively and at 6, 12 and 24 months postoperatively or until radiographic evidence of complications such as redisplacement/non-union or segmental collapse (Brown & Abrami 1964) was registered. The average follow-up

Table 1. Reasons for excluding 35 patients from the follow-up study

	No. of patients
Dead	22
Primary arthroplasty	8
Not possible to evaluate scintimetry	3
Refused follow-up	2

period was 26 months for healed fractures, 6 months for redisplacement/non-union and 16 months in the group with segmental collapse.

Statistical methods

The computing was done on a UNIVAC 1100/80 at Lund University Computing Centre. Regression analysis, Student's *t*-test and the Chi-square test with Yates' correction were used. The following levels of significance were used: *** = $p < 0.001$; ** = $0.001 < p < 0.01$; * = $0.01 < p < 0.05$; and NS = $p > 0.05$.

Results

Classification of the fractures according to Garden's system is shown in Table 2. There were 29 undisplaced fractures and 88 displaced fractures.

The range for the time of definite radiographic evaluation was 1–33 months, average 26 months. Most (27/32) of the re-dislocations or non-unions were diagnosed before 12 months had elapsed, whereas the majority (17/20) of the segmental collapses were not obvious until after 12 months. Between 6 and 12 months after fracture, three segmental collapses were diagnosed. When the definite radiographic evaluation was made, 65 patients had a healed fracture in an unchanged position and 32 patients had an early redislocation or non-union. A healed fracture with visible segmental collapse of the femoral head was found in 20 patients. Thus, the ratio uncomplicated versus complicated outcome was 65/52 (Table 3).

The eight patients operated with a primary hemiarthroplasty were all women, with a mean age of 81 years. Seven fractures had complete displacement (Garden stage IV) and one had a moderately displaced (stage III) fracture. The mean ratio for seven of those cases was 0.67, equalling the average for displaced fractures with complications. In one case the ratio was 1.04, representing a normal value.

An arthroplasty had been performed in 34 of the 52 patients with a complicated outcome. Three further patients were scheduled for arthroplasty, four patients did not want any further operation and two were not operated because of their generally bad condition. Nine patients had died before a planned arthroplasty.

The correlation between the quantitative and qualitative evaluation is shown in Figure 2. The correlation between the preoperative scintimetry ratio for all the femoral neck fractures and the outcome found after 2 years is shown in Figure 3. A good discrimination between uncomplicated and complicated healing

Table 2. Distribution of femoral neck fractures according to Garden's classification

Stage	No. of fractures	No. of fractures
I	27	29
II	2	
III	37	88
IV	51	

Table 3. Outcome of femoral neck fractures in the follow-up study

	Total	%	Follow-up time Months	Range
Uneventful healing	65	(56)	26	(21–33)
Redisplacement/non-union	32	(27)	6	(1–24)
Segmental collapse	20	(17)	16	(7–26)

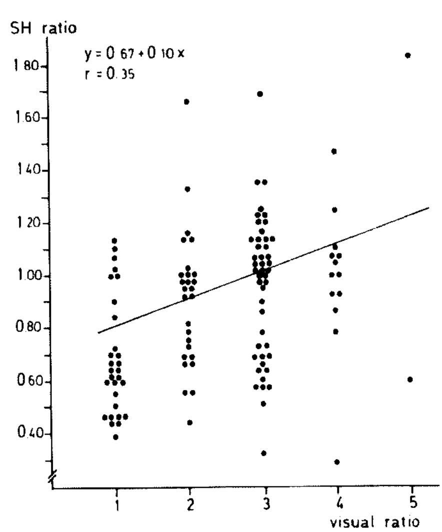

Figure 2. Correlation of SH-ratio and visual evaluation in the follow-up study. For visual grading and SH-ratio, see text.

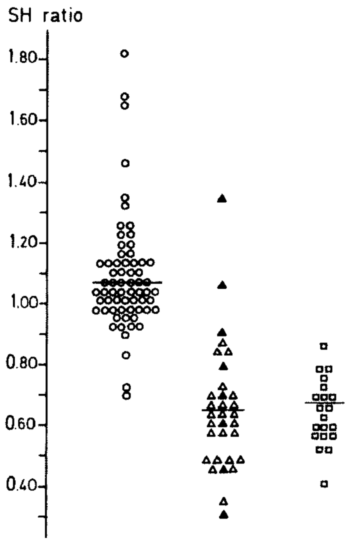

Figure 3. Distribution of SH-ratio according to outcome of the femoral neck fractures in the follow-up study. ○ = uneventful healing, △ = non-union, ▲ = early redisplacement, □ = segmental collapse. For SH-ratio, see text.

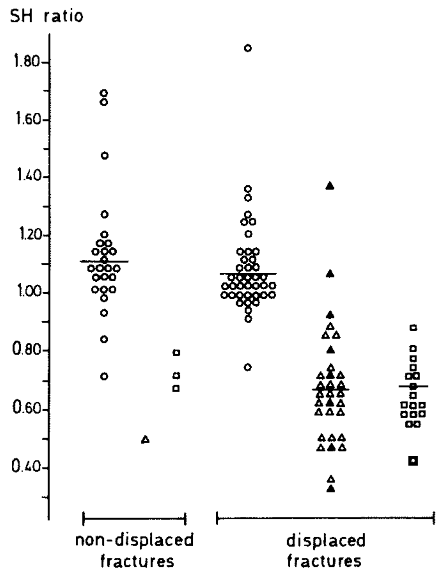

Figure 4. Distribution of SH-ratio for non-displaced and displaced fractures according to outcome of femoral neck fractures. For SH-ratio and explanation of symbols, see Figure 3.

was found, with the majority of uncomplicated patients having a preoperative scintimetry ratio above 0.90. Also, the majority of patients showing a complicated outcome had a preoperative scintimetry ratio below 0.90; below 0.70, only a complicated outcome was found. The mean value for cases with uncomplicated healing was 1.08, for redisplacement/non-union 0.66 and for segmental collapse 0.70. When the fractures were divided according to the radiographic examination into non-displaced and displaced fractures, the same main pattern persisted (Figure 4). The mean values for various subgroups are shown in Table 4. The mean ratio for undisplaced fractures was found to be higher than that for the displaced fractures with corresponding outcome, except for the subgroup redisplacement/non-union, but the difference was not significant for the subgroups. Both for undisplaced and displaced fractures, a significant difference ($p < 0.001$) in mean ratio was found between uncomplicated outcome and redisplacement/non-union or segmental collapse. This was also found for all fractures. In the undisplaced fractures, only four of 29 had a complicated outcome, whereas in the displaced fractures 48 of 88 had a complication ($p < 0.001$).

Discussion

In clinical practice, radionuclide imaging is widely used to evaluate activity in bone tissue. The two most important factors influencing

Table 4. Mean SH-ratio ± SD in the follow-up study. Number of patients in parentheses. U and R indicate significance versus uncomplicated and redisplaced fractures respectively. For significance levels, see methods

	Uncomplicated healing	Redisplacement/ non-union	Segmental collapse	Total
Undisplaced	1.11±0.21 (25)	0.50 (1)	0.72±0.07 (3) U**	1.05±0.26 (29)
Displaced	1.06±0.17 (40)	0.67±0.20 (31) U***	0.69±0.28 (17) U*** R NS	0.85±0.28 (88)
Total	1.08±0.19 (65)	0.66±0.20 (32) U***	0.70±0.26 (20) U*** R NS	0.90±0.29 (117)

the accumulation of radionuclide agents are the integrity of blood supply and the rate of bone turnover, blood flow being the main factor (King et al. 1977). Thus, a decrease or absence of blood perfusion to a region of bone will influence the uptake of the radionuclide in that region and a "cold" area will be apparent (Georgen et al. 1973, Siegel et al. 1976).

It is evident from the present investigation that ^{99m}Tc-MDP-scintimetry is a powerful method of evaluating the vascular condition in the femoral head after a femoral neck fracture. Good correlation of the SH-ratio above 0.90 and uneventful healing was found, except for three fractures. Similarly for an SH-ratio below 0.90 a complicated outcome was found, such as redisplacement/non-union or segmental collapse in the majority of cases. However, three cases with a ratio below 0.90 healed without complication on X-ray check-up at 24 months. Those cases will be followed further since 20 per cent of late segmental collapses are detected after 24 months (Massie 1973, Calandruccio 1980). When the material was split into non-displaced and displaced groups of the non-complicated cases, somewhat lower mean ratios were seen for the displaced fractures. The difference might be explained by a greater disturbance of the blood supply in displaced fractures (Sewitt 1964, Müssbichler 1970). After reduction of a femoral neck fracture, some improvement of the vascularization has been achieved (Müssbichler 1970). The three false positive cases all had incorrect nailing.

Differences of radionuclide accumulation, with a higher uptake in the femur on the fractured side, could be observed both quantitatively and qualitatively (Figure 1). The explanation of this finding seems to be the hypermetabolism occurring immediately after the injury. This difference was considered and compensated for when the femoral head ratio was calculated, stressing the importance of a region of reference in preoperative scintimetry of femoral neck fractures.

The regions of interest and ratio calculation used in the present investigation have been compared (Holmberg et al. 1984) to those used in postoperative ^{99m}Tc-MDP scintimetry of femoral head circulation (Strömqvist 1983). The SH-ratio as used here was found to discriminate best in these preoperative, early investigations.

The correlation of qualitative and quantitative evaluation found here was inferior to that of Strömqvist (1983), who reported a good correlation. This could partly be explained by the facts that many different radiologists evaluated the present scintigrams, and that some of the scintigrams were evaluated from polaroid pictures. The most important outcome of this correlation study was, however, the inexactness of visual evaluation compared to numerical evaluation. Thus, numerical evaluation of radionuclide images should be carried out.

Non-union is very seldom seen in non-displaced fractures, but it is the most common complication in displaced fractures, amounting to 15–35 per cent according to previous investigations (Banks 1962, Garden 1971, Arnold et al. 1974, Barnes et al. 1976). A somewhat different pattern has been reported regarding the incidence of segmental collapse. In non-displaced fractures, the frequency is 10–20 per cent and in displaced fractures 15–30 per cent (Massie 1973, Barnes et al. 1976, Bently 1980).

In the present study only one of the non-displaced fractures resulted in non-union, but as many as 35 per cent (31/88) of the displaced fractures developed redisplacement/non-union. Since early displacement of nailed fractures can mainly be referred to as technical failure (Söreide et al. 1979), eight fractures with this complication might be excluded, reducing the rate of non-union to 26 per cent, which is comparable to previous investigations. Segmental collapse occurred in 3/29 of the non-displaced fractures and in 17/88 of the displaced fractures. As compared to findings reported in previous studies, even these figures agree well.

This study has demonstrated that preoperative scintimetry is a powerful diagnostic and prognostic tool to determine the viability of the femoral head at an early stage.

Acknowledgements

This study was financially supported by the insurance companies Folksam and Skandia, by Stockholms läns landsting and by the Swedish Medical Research Council (Project 17X-2031).

References

Arnold, W. D., Lyden, J. P. & Minkaff, J. (1974) Treatment of intracapsular fractures of the femoral neck. *J. Bone Joint Surg.* **56**-A, 254–262.

Banks, H. H. (1962) Factors influencing the result in fractures of the femoral neck. *J. Bone Joint Surg.* **44**-A, 931–964.

Barnes, R. J., Brown, J. T., Garden, R. S. & Nicoll, E. A. (1976) Subcapital fractures of the femur. *J. Bone Joint Surg.* **58**-B, 2–24.

Bauer, G., Weber, D. A., Ceder, L., Darte, L., Egund, N., Hansson, L. I. & Strömqvist, B. (1980) Dynamics of technetium-99m methylenediphosphonate imaging of the femoral head after hip fracture. *Clin. Orthop.* **152**, 85–92-

Bently, G. (1980) Treatment of non-displaced fractures of femoral neck. *Clin. Orthop.* **152**, 93–101.

Brown, J. T. & Abrami, G. (1964) Transcervical femoral fracture. *J. Bone Joint Surg.* **46**-B, 648-663.

Calandruccio, R. A. & Anderson, W. E. (1980) Post-fracture avascular necrosis of the femoral head. *Clin. Orthop.* **152**. 49–84.

D'Ambrosia, R. D., Shoji, H., Riggins, R. S., Stadalnik, R. C. & De Nardo, G. L. (1978) Scintigraphy in the diagnosis of osteonecrosis. *Clin. Orthop.* **130**, 139.

Garden, R. S. (1961) Low angle fixation in fractures of the femoral neck. *J. Bone Joint Surg.* **43**-B, 647–663.

Garden, R. S. (1971) Malreduction and avascular necrosis in subcapital fractures of the femur. *J. Bone Joint Surg.* **53**-B, 183–197.

Georgen, T. G., Alazraki, N. P., Halpern, S. E. et al. (1973) "Cold" bone lesions: A newly recognized phenomenon of bone imaging. *J. Nucl. Med.* **15**, 1120.

Holmberg, S., Mesko, L., Strömqvist, B. & Thorngren, K.-G. (1984). Evaluation in ^{99m}Tc-MDP scintimetry of femoral neck fractures. In preparation.

Hulth, A. (1956) Intra-osseous venographies of medial fractures of the femoral neck. *Acta Chir. Scand.* Suppl. 214.

Johansson, S. (1964) The prognostic value of the radio-iodine test in femoral neck fractures. *Acta Soc. Med. Ups.* **69**, 64–69.

King, M. A., Klipper, R. W. & Weber, D. A. (1977) A model for local accumulation of bone imaging radiopharmaceuticals. *J. Nucl. Med.* **18**, 1106.

Lucie, R. S., Fuller, S., Burdick, D. C. & Johnson, E. M. (1981) Early prediction of avascular necrosis of the femoral head following femoral neck fractures. *Clin. Orthop.* **161**, 207–214.

Massie, W. K. (1973) Treatment of femoral neck fractures emphasizing long term follow up and observations on aseptic necrosis. *Clin. Orthop.* **92**, 16–62.

Meyers, M. H., Telfer, N. & Moore, T. M. (1977) Determination of the vascularity of the femoral head with technetium 99m-sulphur-colloid. *J. Bone Joint Surg.* **59**-A, 658–664.

Müssbichler, H. (1970) Arteriographic investigation of the hip in adult human subjects. *Acta Orthop. Scand.* Suppl. 132.

Oda, S., Sakakida, O., Maeda, T. & Tatsuzawa, Y. (1980) Evaluation of femoral neck fracture healing in man by serial 99m Tc-diphosphonate scintimetry. *J. Jpn. Orthop. Assoc.* **54**, 101–110.

Pugh, W. L. (1955) A self-adjusting nail-plate for fractures about the hip joint. *J. Bone Joint Surg.* **37**-A, 1084–1093.

Rydell, N. (1964) Osteosynthesis of medial column fractures with the "spring-loaded nail". *Acta Orthop. Scand.* **35**, 149–157.

Sevitt, S. (1964) Avascular necrosis and revascularisation of the femoral head after intracapsular fractures. *J. Bone Joint Surg.* **46**-B, 270–296.

Siegel, B. A., Donovan, R. L., Alderson, P. O. et al. (1976) Skeletal uptake of 99m Tc-diphosphonate in relation to local bone blood flow. *Radiology* **120**, 121.

Söreide, O., Mölster, A. & Raugstad, T. S. (1979) Internal fixation versus primary prosthetic replacement in acute femoral neck fractures: a prospective randomized clinical study. *Br. J. Surg.* **66**, 56–60.

Strömqvist, B. (1983) Femoral head vitality after intracapsular hip fracture. *Acta Orthop. Scand.* Suppl. 200.

Tucker, F. R. (1950) The use of radioactive phosphorus in the diagnosis of vascular necrosis of the femoral head. *J. Bone Joint Surg.* **32**-B, 100–107.