PRE-OPERATIVE AND POSTOPERATIVE SCINTIMETRY AFTER FEMORAL NECK FRACTURE

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In 22 patients with femoral neck fractures ^{99m}Tc -MDP scintimetry was performed before operation and again shortly after operation; in 17 of these patients the investigation was repeated after four months. Six patients with increased uptake in the femoral head before operation and eight with decreased uptake had similar results at the first postoperative investigation. Of eight patients with an intermediate uptake before operation, two showed increased and six decreased femoral head uptake after operation.

It is concluded that for the patients in the group with intermediate femoral head uptake before operation, the operative procedure probably influenced the postoperative blood supply of the femoral head.

Reports of the long-term results after femoral neck fracture are numerous but are difficult to compare because of the heterogeneity of the criteria for evaluation and the variation in follow-up times. The two most important complications, non-union and segmental collapse of the femoral head after fracture healing, should be considered separately. Non-union can usually be diagnosed within a year of the fracture (Banks 1962; Barnes *et al.* 1976); in most series it is rare after undisplaced fractures but occurs in 20 to 30 per cent of displaced fractures (Banks 1962; Barnes *et al.* 1976; Söreide *et al.* 1979; Calandruccio and Anderson 1980). Segmental collapse can develop as late as 17 years after fracture (Massie 1973), but in eight out of 10 patients it is evident radiographically within two years (Brown and Abrami 1964; Massie 1973; Jacobs 1978; Calandruccio and Anderson 1980); it occurs in 10 to 20 per cent of undisplaced fractures and in 15 to 35 per cent of displaced fractures (Banks 1962; Fielding, Wilson and Zickel 1962; Garden 1971; Massie 1973; Bentley 1980; Thorling 1980).

The underlying cause of both non-union and segmental collapse is generally thought to be injury to the blood supply of the femoral head. In addition poor reduction of the fracture and poor stability after fixation may lead to redisplacement and pseudarthrosis (Deyerle 1965; Garden 1971; Massie 1973). Most authors have

assumed that the vascular injury occurs at the moment of fracture and that the fate of the femoral head is decided then (Johansson 1964; Massie 1973; Lucie *et al.* 1981).

In current investigations with a three-year follow-up, it has been shown that deficient vascularity of the femoral head (measured by ^{99m}Tc -MDP scintimetry at one to two weeks after operation) is followed by complications in virtually every case, while normal or increased isotope uptake is associated with uneventful healing (Bauer *et al.* 1980; Strömquist 1983; Strömquist *et al.* 1983c); the prognosis can thus be established by scintimetry within two weeks of operation.

In several cases intravital staining with tetracycline administered pre-operatively has indicated satisfactory femoral head circulation before operation, but scintimetry one to two weeks after operation revealed vascular insufficiency (Strömquist *et al.* 1981). These findings strengthen the hypothesis that additional vascular injury may occur after fracture (Linton 1944; Hulth 1956; Lowell 1980); the handling of the patient, the reduction manoeuvre, traction on the operating table, and the method of osteosynthesis are all potential sources of hazard.

The purpose of the present study was to make a direct comparison between scintimetry before and after operation in patients with intracapsular femoral neck fractures in order to evaluate the possibility of additional vascular injury occurring after the fracture.

MATERIAL AND METHODS

Twenty-four patients, 15 female and nine male, with a mean age of 73 years (range 43 to 92), treated in the departments of orthopaedic surgery, Helsingborg Hospital and the University Hospital in Lund between 1980 and 1982, were investigated. A prerequisite for inclusion in the study was that pre-operative scintimetry would not delay the time of operation. The investigations were

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performed under informed consent. No patients with contralateral hip disease were included.

Pre-operative radiographs revealed that six patients had minimally displaced fractures (Garden Types I and II), four had Garden Type III fractures and 14 had Type IV fractures. In the presentation of results, Garden Type III and IV fractures are grouped together as displaced fractures.

Scintimetry was performed three to four hours after intravenous injection of 330 to 380 megabecquerels of ^{99m}Tc -methylene diphosphonate. Anteroposterior views of the pelvic region were obtained within three minutes. The amount of isotope uptake was estimated with the aid of a dedicated computer system. Regions of interest (ROI) of equal size were selected in the femoral head and neck, in the greater trochanter and in the shaft of the femur on the fractured as well as on the intact side (see Fig. 3). The uptake ratios (fractured: intact side) for these four regions were calculated. Correction for soft-tissue activity was not performed.

Pre-operative scintimetry was performed on the day of operation. If the patient was being treated by skeletal traction, this was retained during imaging. The postoperative investigation was carried out about one week after operation (range 5 to 15 days). Seventeen of the patients had further scintimetry four months after operation.

Patients with displaced fractures were treated by skeletal traction on admission. During the operation an extension table and fluoroscopy were used. All patients, except two, were operated on within two days of admission; these two were delayed for seven and 18 days respectively because of cardiac insufficiency. Closed reduction was performed for displaced fractures and in all cases osteosynthesis was carried out with the four-

Table I. Mean uptake ratios of ^{99m}Tc -MDP ($\pm$ standard deviation) before and after operation

		Site of uptake			
	Number (n)	Femoral head	Femoral neck	Trochanter	Femoral shaft
<i>Before operation</i>					
Undisplaced	6	1.10 ± 0.34	1.72 ± 0.74	1.40 ± 0.10	1.15 ± 0.16
Displaced	16	0.89 ± 0.28	1.36 ± 0.64	1.35 ± 0.30	0.98 ± 0.21
Total	22	0.95 ± 0.31	1.46 ± 0.67	1.36 ± 0.26	1.02 ± 0.21
<i>1 to 2 weeks after operation</i>					
Undisplaced	6	1.14 ± 0.58	3.59 ± 1.36	2.36 ± 0.48	1.45 ± 0.41
Displaced	16	1.07 ± 0.71	2.79 ± 1.08	2.46 ± 0.81	1.26 ± 0.24
Total	22	1.09 ± 0.67	3.01 ± 1.18	2.43 ± 0.73	1.31 ± 0.30
<i>4 months after operation</i>					
Undisplaced	5	1.28 ± 0.86	3.02 ± 1.18	2.16 ± 0.44	1.20 ± 0.32
Displaced	12	1.18 ± 1.11	2.82 ± 1.06	2.44 ± 0.71	1.19 ± 0.28
Total	17	1.21 ± 1.06	2.90 ± 1.16	2.40 ± 0.68	1.20 ± 0.30

flanged nail designed by Rydell (1964). Weight-bearing was allowed from the first day after operation.

RESULTS

Scintimetry. Of 24 patients, one died in the early postoperative period and one patient was excluded because of a very high postoperative uptake in the whole of the proximal femur and adjacent parts of the pelvis. Twenty-two patients remained for comparing scintimetry before and soon after operation.

Femoral head. The pre-operative mean ratio of isotope uptake in the femoral heads (Table I) was 0.95 (range 0.46 to 1.54); in six patients with undisplaced fractures

Fig. 1

Fig. 2

Ratio of uptake by the femoral head in 22 patients. Figure 1—Graph showing the number of patients with low (≤ 0.90), intermediate (0.91–1.10) and high (> 1.10) uptake before operation (above the line) and one to two weeks after operation (below the line). □ = displaced fracture, ▨ = undisplaced fracture. Figure 2—Scatter diagram showing the uptake ratios for the 22 patients before and after operation. ○ = displaced fracture, ● = undisplaced fracture.

Fig. 3

Fig. 4

Pelvic images of a patient with left-sided displaced fracture. Figure 3—Pre-operative scan; the ratio of uptake in the femoral heads is 0.99. The squares indicate the regions of interest (ROI). Figure 4—Nine days after operation the ratio of uptake is reduced to 0.64.

Fig. 5

Fig. 6

Pelvic images of a patient with left-sided displaced fracture. Figure 5—Pre-operative scan; the ratio of uptake in the femoral heads is 0.91. Figure 6—Eleven days after operation the ratio of uptake has increased to 2.48.

the mean ratio was 1.10 (range 0.54 to 1.54) and in 16 patients with displaced fractures it was 0.89 (range 0.46 to 1.45). The postoperative mean femoral head uptake ratio was 1.09 (range 0.53 to 2.70); for undisplaced fractures it was 1.14 (range 0.58 to 2.04) and for displaced fractures 1.07 (range 0.53 to 2.70). These uptake ratios before and after operation can be seen in Figures 1 and 2. All six patients with a pre-operative ratio greater than 1.10 had a satisfactory femoral head uptake postoperatively (range 1.07 to 2.70). All eight patients with a pre-operative ratio of less than 0.90 exhibited defective postoperative values. Of the eight patients in the intermediate group with a pre-operative ratio between 0.91 and 1.10, two showed increased uptake values after operation (1.27 and 2.48 respectively), while the remain-

ing six showed decreased uptake (ratios of less than or equal to 0.90).

The scintigrams taken before and after operation in two patients in the intermediate group are shown in Figures 3 to 6; in the first patient the pre-operative femoral head ratio was 0.99 (Fig. 3) which was reduced to 0.64 after operation (Fig. 4); in the second patient the ratio was 0.91 pre-operatively (Fig. 5) and was increased to 2.48 postoperatively (Fig. 6).

Femoral neck. The pre-operative mean isotope uptake at the fracture line (Table I) was 1.46 (range 0.72 to 3.34); for undisplaced fractures, the mean value was 1.72 (range 1.16 to 3.14); and for displaced fractures 1.36 (range 0.72 to 3.34). The corresponding postoperative figures for the total group were 3.01 (range 1.34 to 6.22), 3.59 (range

2.52 to 6.22) and 2.79 (range 1.34 to 5.14) respectively. The pre-operative uptake ratio at the fracture line was above 1.0 in 17 of the 22 patients—in all six undisplaced and in 11 of the displaced fractures. The postoperative uptake in this region showed an increase in all patients.

A comparison between pre-operative and postoperative femoral neck ratios for each individual patient is shown in Figure 7; all fractured femoral necks increased their uptake ratios, most often by a factor of about two. The low postoperative femoral neck uptake ratios are seen among the patients with deficient postoperative femoral head uptake.

Fig. 7

Femoral neck ratio pre-operatively compared with one to two weeks postoperatively in 22 patients. ○ = displaced fracture, ● = undisplaced fracture, ● and ○ = deficient femoral head uptake one to two weeks postoperatively in a displaced fracture and in an undisplaced fracture respectively.

Trochanter. The pre-operative mean trochanteric region isotope uptake ratio was 1.36 (range 0.86 to 1.95); for undisplaced fractures the value was 1.40 (range 1.27 to 1.55) and for displaced fractures 1.35 (range 0.86 to 1.95). The postoperative mean uptake values were 2.43 (range 1.23 to 4.14), 2.36 (range 1.62 to 2.77) and 2.46 (range 1.23 to 4.14) respectively.

Femoral shaft. The pre-operative femoral shaft isotope uptake was 1.02 (range 0.69 to 1.42). The ratio for undisplaced fractures was 1.15 (range 0.96 to 1.42) and for displaced fractures 0.98 (range 0.69 to 1.33). The postoperative values were 1.31 (range 0.89 to 2.14), 1.45 (range 0.96 to 2.14) and 1.26 (range 0.89 to 1.63) respectively.

Scintimetry at four months. Of the 22 patients, two with displaced fractures and postoperative femoral head uptake defects had had total hip replacements within four months of operation because of redisplacement. Two patients with displaced fractures, one with normal and one with deficient femoral head uptake postoperatively, had died; one patient with an undisplaced fracture and deficient femoral head uptake postoperatively had deteriorated seriously because of unrelated disorders. The remaining 17 patients had further scintimetry at four months after operation.

In seven fractures (three undisplaced and four

displaced), all with a femoral head isotope uptake ratio above 1.0 in the early postoperative investigation, the uptake was also increased after four months (range 1.16 to 1.96).

The remaining 10 fractures (two undisplaced and eight displaced) had deficient early postoperative femoral head activity. At four months seven of these had a femoral head ratio above 1.0 (range 1.16 to 2.81). The ratios for the other three fractures were 0.68, 0.89 and 0.94 respectively; these three also had deficient pre-operative femoral head uptake. Figure 8 shows the femoral head ratios at one to two weeks and at four months after operation.

For all 17 patients the uptake in the fracture line was elevated (mean uptake ratio 2.90, range 1.59 to 3.51). No statistical difference (Student's *t*-test) was noted between undisplaced and displaced fractures. All 17 patients showed increased uptake in the trochanteric region (mean ratio 2.40, range 1.11 to 3.57) and all except two also showed a femoral shaft uptake of more than 1.00.

One patient, in whom redisplacement of the fracture necessitated hip arthroplasty 11 weeks after nailing, had scintimetry four months after nailing; the ratio of prosthetic femoral head to intact contralateral femoral head was 0.54.

Fig. 8

Comparison between the ratio of uptake in the femoral heads one to two weeks and four months postoperatively in 17 patients.

DISCUSSION

The present series is a small one, but does not differ in composition from larger series with respect to age, sex and displacement of the fracture (Alffram 1964; Öhman, Björkegren and Fahlström 1969; Ceder 1980).

A comparison between pre-operative and postoperative ratios of isotope uptake in the femoral heads

revealed that eight patients had deficient uptake before operation (a ratio below 0.90) and that they all retained this pattern at the first postoperative investigation (Fig. 2). A postoperative ratio below 1.00 is almost invariably followed by complications associated with avascularity (Strömqvist 1983; Strömqvist *et al.* 1983c). Thus, the end result for these fractures was determined at the time of the injury. Of these eight fractures, one was undisplaced.

Six of the fractures (three displaced) had pre-operative femoral head uptake exceeding 1.10. These fractures showed a satisfactory isotope uptake after operation which was consistent with uncomplicated healing. With a satisfactory pre-operative femoral head blood supply, the risk of intra-operative damage and of postoperative deficiency of uptake seems small.

The remaining eight fractures had a pre-operative femoral head ratio between 0.90 and 1.10. Two of these were undisplaced. Postoperative scintimetry showed an increased femoral head uptake in two patients with displaced fractures, while the remaining six had deficient femoral head uptake and are destined for complications. For this group with intermediate uptake pre-operatively, the operative procedure probably determined the outlook. Of the six fractures with reduced postoperative uptake, it is notable that two were undisplaced. This supports the findings of Linton (1944), Öhman *et al.* (1969) and Bentley (1980) that there is a higher incidence of post-traumatic femoral head necrosis in operated than in unoperated undisplaced fractures.

An investigation of pre-operative femoral head circulation using intravital staining with tetracycline (Strömqvist *et al.* 1981; Strömqvist 1983) showed no differences between those in which tetracycline was administered before operation and those in which it was given on the operating table after closed reduction but before nailing. This would indicate that the procedure of fixation was itself the probable cause of the vascular damage.

The results of Hansson-nailing compared with Rydell-nailing regarding postoperative isotope uptake by the femoral head have shown the former method to be significantly better (Strömqvist *et al.* 1983a). The technique of inserting the Hansson nails, which minimises operative trauma, has probably saved many of the femoral heads with intermediate circulation before operation.

The pre-operative femoral head uptake has been studied with ^{99m}Tc -sulphur-colloid by Meyers, Telfer and Moore (1977) and with ^{99m}Tc -MDP by Lucie *et al.* (1981). A very high incidence of primary avascularity was noted in both these investigations. In the former, the clinical outcome did not correspond to their figures (less than 70 per cent) and this was ascribed to the muscle-pedicle graft operation performed. In the latter investi-

gation, the majority of patients underwent primary total hip replacement and femoral head avascularity was judged histologically. However, it is not unlikely that many of the defects of femoral head uptake diagnosed in these two investigations belong to the intermediate group described above and might, with an atraumatic technique of osteosynthesis, have healed without complications.

In accordance with earlier findings (Bauer *et al.* 1980), the majority of patients with isotope defects in the femoral head one to two weeks after operation show increased femoral head activity four months later; in this present investigation seven out of 10 showed such an increase. Whether this increase in activity represents femoral head revascularisation or merely reflects hyper-metabolism in surrounding acetabular areas is not known, but it is hoped that this will be determined by means of emission tomography (Strömqvist *et al.* 1983b). This increase in uptake by the femoral head, however, does not influence the long-term prognosis (Strömqvist 1983).

Rosenthal, Hill and Chuang (1976) noted that ^{99m}Tc -phosphate rapidly accumulates in fracture regions. In this present investigation, the pre-operative scintimetry, which was performed between one and three days after fracture, detected more than 75 per cent of fractures, including one in which radiographic identification was uncertain. The uptake of ^{99m}Tc -MDP in the fracture region was studied postoperatively by Oda *et al.* (1980); a higher uptake was noted in the group of patients who developed non-union compared with those who healed normally. The present series will be followed up and the definitive figures for non-union and segmental collapse will be presented later. In contrast to previous findings (Oda *et al.* 1980) it was obvious that the fractures with a bad prognosis were those with only a moderate increase of uptake at the fracture line (Fig. 7). The uptake at the fracture line may reflect variations in the vascularity of the femoral neck and thus be a prognostic factor *per se*. It is also possible that differences in this uptake merely reflect the metabolic status of the proximal fragment, that is the femoral head. If so, it is reasonable to suppose that the femoral head ratio would be a better prognostic indicator (Fig. 2).

In conclusion this study showed one group of patients whose femoral head circulation after a fracture of the femoral neck was well preserved both before and after operation. Another group had a severe femoral head uptake defect pre-operatively as well as postoperatively. For a third group with intermediate pre-operative values, the postoperative outcome differed widely; it seems logical to presume that this is the result of further injury to the blood supply during operation. The incidence of complications in this group might be reduced by an operative technique inflicting a minimum of trauma to the circulation of the femoral head.

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