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AVASCULAR NECROSIS ASSOCIATED WITH NAILING OF FEMORAL NECK FRACTURE

Two Cases Examined Pre- and Postoperatively by Tetracycline and Radionuclide Tracer Techniques

BJÖRN STRÖMQVIST & LARS INGVAR HANSSON

Department of Orthopaedic Surgery, University Hospital in Lund, Lund, Sweden

Two patients with femoral neck fractures, one displaced and one undisplaced, are presented. Preoperative intravital staining with tetracycline and Tc-MDP scintimetry both showed intact femoral head circulation while Tc-MDP-scintimetry 1 week after operation showed pronounced circulatory deficiency. Sr^{85}-scintimetry performed at the same time was inconclusive. Segmental collapse was observed radiographically, 8 and 12 months postoperatively. The major vascular injury resulting in avascularity most probably occurred during the procedure of osteosynthesis, and Tc-MDP-scintimetry was found suitable for early postoperative recognition of avascular necrosis in both fractures.

Key words: bone; femur neck fractures; femur neck necrosis; fractures; internal fixation; radionuclide imaging; scintimetry; tetracycline

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Segmental collapse of the femoral head after femoral neck fracture is a true radiographical sign of femoral head necrosis and most often occurs 6–36 months after fracture (Ibsen 1951, Garden 1961, Calandruccio & Anderson 1980). Injury to the retinacular vessels supplying the femoral head is the basic pathogenetic mechanism. It is generally considered that circulatory deprivation occurs at the time of fracture, although other potential threats have been pointed out by Hulth (1956), Bauer et al. (1980) and Lowell (1980).

The healing prognosis after femoral neck fracture can be established 1–2 weeks after internal fracture fixation by means of Tc-MDP-scintimetry (Bauer et al. 1980, Strömqvist et al. 1983a). Deficient femoral head isotope uptake, reflecting femoral head hypovascularity, is associated with healing complications such as redisplacement, non-union and segmental collapse, while normal or increased uptake as compared to the femoral head on the intact side, predicts uncomplicated healing. Sr^{85}-scintimetry, however, cannot demonstrate the hypovascularity associated with healing complications (Asnis et al. 1976, Brümmer et al. 1982).

This report presents two cases where peroperatively increased circulatory injury was the main reason for the postoperative avascularity and subsequent segmental collapse.

METHODS

1. *Tetracycline labelling*

1000 mg tetracycline (Terramycin®) was administered to each patient orally on admission.

At operation, after reaming the nail channel beyond the fracture line, a cylindric biopsy of 5–10 mm length was taken from the centre of the femoral head with a Michelle-biopsy instrument. This specimen was fixed and dehydrated in ethyl alcohol, embedded in methyl-

methacrylate and sectioned into 75 μ thick slices. The sections were examined under reflected light in a fluorescence microscope, and the degree of tetracycline deposition on the bone trabeculae was classified in one of four categories (0–3) (Strömqvist et al. 1981).

2. *Tc-MDP scintimetry*

Scintimetry using Tc-MDP as a tracer was performed preoperatively, on the day after fracture, and 1 week, 4, 8, 12 and 24 months postoperatively. Images were obtained 3–4 h after intravenous injection of 350–370 MBq Tc-MDP using a large field-of-view gamma camera covering the pelvis and the proximal half of both femurs in an AP projection. With a dedicated computer system, regions of interest (ROI) were selected in the femoral head, the fracture region, the trochanter major region and in the shaft of the femur. Uptake per picture element was calculated and compared with a corresponding area in the nonfractured side. The ratio fractured/intact side was obtained and is used in the presentation below.

3. *Sr-scintimetry*

The method and equipment used in this part of the investigation have been described by Sjöstrand (1974). Each patient received an intravenous injection of 100 μCi carrier-free Sr^{85} 2 weeks after operation, and scintimetry of both hips was performed 2 weeks later (Sjöstrand 1974, Brümmer et al 1982). With the patient supine, the neutral position of the hips was fixed with sand bags. An AP radiogram of the hips was obtained immediately before the scintimetry procedure. With the aid of the radiogram, a 24 mm wide area around the nail was identified and the activity values in the trochanter (T), neck (Co) and head (Ca) areas were recorded as well as the corresponding areas of the intact proximal femur on the contralateral side.

The mean counting rates within the areas of interest were corrected for background activity measured in an area 1 cm proximal to the greater trochanter and 2 cm lateral to the lateral border of the acetabulum. In order to account for individual variations in the metabolism of Sr^{85}, activity values recorded over the fractured hip were expressed as ratios relative to the values recorded over identical areas of interest in the contralateral hip.

*Table 2. Sr^{85}-scintimetry – administration of isotope 2 weeks after operation and scintimetry 2 weeks later. Comparison to Brümmer et al. (1982)**

	Caput	Collum	Troch.
Case 1	1.05	2.79	5.01
Case 2	2.18	6.24	8.62
Uncomplicated healing (n=8)*	1.2±0.3	2.1±0.6	2.0±0.7
Avascular necrosis (n=8)*	0.9±0.3	1.7±0.5	1.7±0.6
Pseudarthrosis (n=4)*	1.0±0.1	1.8±0.4	1.9±0.4

CASE REPORTS

Table 1 presents the femoral head and neck uptake ratios at Tc-MDP-scintimetry in subsequent investigations for both patients. Table 2 shows the Sr^{85} uptake in the femoral head, neck and greater trochanter postoperatively and a comparison to healing course figures, according to Brümmer et al. (1982). In Figure 3, the two lines denote femoral head uptake in subsequent Tc-MDP imaging procedures and the arrows mark the time for radiographical segmental collapse. The shaded area represents femoral head uptake ratio ± standard deviation for 20 fractures healing normally (Strömqvist et al. 1983a).

Table 1. Tc-MDP scintimetry uptake ratios at subsequent investigation

			Months postoperatively				
		Preop.	0–1	4	8	12	24
Case 1	Femoral head	1.01	0.51	1.61	2.07	2.01	4.32
	Femoral neck	1.32	1.57	2.54	2.60	1.93	4.14
Case 2	Femoral head	1.08	0.58	1.16	2.06	2.30	2.65
	Femoral neck	1.85	2.52	2.78	3.78	4.27	4.42

Case 1

An 88-year-old woman, taking medication for hypertension and cardiosclerosis but otherwise healthy, was crossing the street when a rapidly approaching car made her turn around towards the pavement. She slipped and fell, landing on her left hip region and left hand. Radiographs were obtained after admission to hospital and revealed a left-sided displaced femoral neck fracture, type IV according to Garden (1961) (Figure 1 A) as well as a fracture of the distal radius on the same side. Pin traction was applied through the proximal tibia on admission.

On the day of admission, 1000 mg of tetracycline was administered per os for intravital staining of bone. A biopsy from the centre of the femoral head taken during operation was investigated in the fluorescence microscope and showed multiple local depositions on the bony trabeculae as evidence of existing, though reduced, circulation and bone remodelling.

Preoperative Tc-MDP-scintimetry was performed on the day after admission. The isotope uptake in the femoral head on the fracture side equaled that on the intact side (ratio 1.01) and slightly increased uptake was revealed over the fracture line (ratio 1.32) (Figure 1 A).

Two days after fracture, closed reduction, femoral head biopsy (see above) and osteosynthesis with a 4-flanged nail (Rydell 1964) were performed. The postoperative radiograph showed a slight valgus position (Figure 1 B).

Tc-MDP-scintimetry was repeated 1 week after the operation and a marked defect corresponding to the femoral head was noted, ratio 0.51 (Figure 1 B). In the fracture and trochanteric regions, the uptake was about twice that on the intact side.

Sr^{85}-scintimetry showed an increased ratio for the femoral neck (2.79) and trochanteric region (5.01). The ratio for the femoral head was estimated to be 1.05.

Four months after the operation, the patient was seen at follow-up. She was rehabilitated to prefracture status, denying hip problems. Radiographs showed slight compression in the fracture region (Figure 1 C) and Tc-MDP-scintimetry revealed that the femoral head uptake had increased as compared to the previous investigation, ratio 1.61 (Figure 1 C). The isotope uptake in the fracture region had increased further (ratio 2.54).

Eight months after the operation, the patient complained of some weeks of progressing hip pain on walking, localized to the groin. She had pain on rotating the hip and left leg shortening of 1 cm. Radiographically, the fracture had healed and a slight collapse of the apical joint line was noted. The isotope uptake over the femoral head had increased (ratio 2.07).

One year after fracture, the patient regarded her hip pains as minor and the uptake ratios were virtually unchanged (Table 1). Two years after operation, however, the pain on walking had increased severely and pain at rest had begun. Radiographs showed the classical segmental collapse of the apical part of the femoral head with secondary changes of the joint (Figure 1 D). Tc-MDP-scintimetry showed a very high uptake corresponding to the head of the femur (ratio 4.32) and the metabolic hyperactivity in the whole of the proximal femur was noted (Figure 1 D). A total hip arthroplasty *ad modum* Lubinus was performed and the patient was rehabilitated without complications.

Case 2

A 43-year-old platelayer was out walking his dog when he became tangled up in the leash and was pulled to the ground, sustaining a blow to his left hip. Radiographs revealed a fracture of his left femoral neck with slight displacement into valgus, type I according to Garden (1961) (Figure 2 A). No pin traction was applied as the fracture was found to be stable.

One thousand milligrams of tetracycline was administered perorally on the day of admission for bone staining and the biopsy taken from the femoral head peroperatively showed, as in the first patient, evidence of a moderate reduction in vascularization and bone remodelling.

Preoperative Tc-MDP-scintimetry was performed on the day after admission, showing that the isotope deposition in the femoral head was almost equal to the contralateral side, ratio 1.08 (Figure 2 A). The uptake in the fracture region was 1.85 times that on the intact side.

On the following day, nailing was performed without any attempt at reduction. A femoral head biopsy (see above) was taken.

One week after operation, the patient was walking with partial weight-bearing with the aid of two sticks. Radiographical examination was performed (Figure 2 B) as well as Tc-MDP-scintimetry. The femoral head isotope uptake on the left side was now severely reduced, ratio 0.58 (Figure 2 B).

Sr^{85}-scintimetry showed increased ratios for all areas, femoral head 2.18, neck 6.24 and trochanteric region 8.62.

Four months after the operation, the patient was pain-free except for local tenderness around the base of the nail when sitting. Radiographs showed slight fracture compression (Figure 2 C) and Tc-MDP-scintimetry showed signs of femoral head revascularization, ratio 1.16 (Figure 2 C). The patient had by then returned to his work half-time and was working full-time 1 month later.

One year after fracture, the patient sought medical attention because of pain in his left hip. A slight extension defect was noted in the left hip and the patient felt most comfortable with the hip in 60° of flexion and some outward rotation. Radiographs revealed an apical collapse of the joint line with a minor compression (Figure 2 D). Aspiration of the joint was performed, yielding 1.5 ml of clear fluid. Direct microscopy, white cell count, glucose and aerobic as well as anaerobic culture of joint aspirate and blood were all negative.

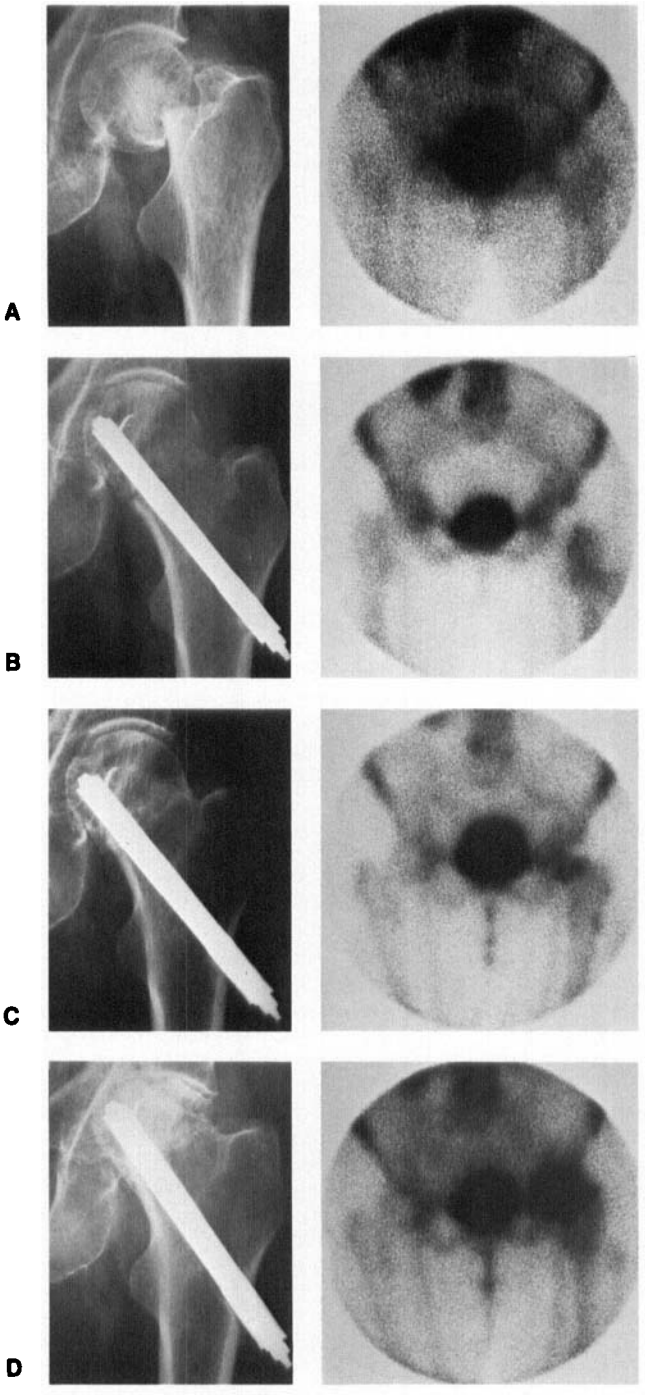

Figure 1 A. Case 1. Preoperative radiograph and Tc-MDP scintimetry.
Figure 1 B. Case 1. Radiograph and Tc-MDP scintimetry 1 week after operation.
Figure 1 C. Radiograph and Tc-MDP scintimetry 4 months after operation.
Figure 1 D. Radiograph and Tc-MDP scintimetry 2 years after operation.

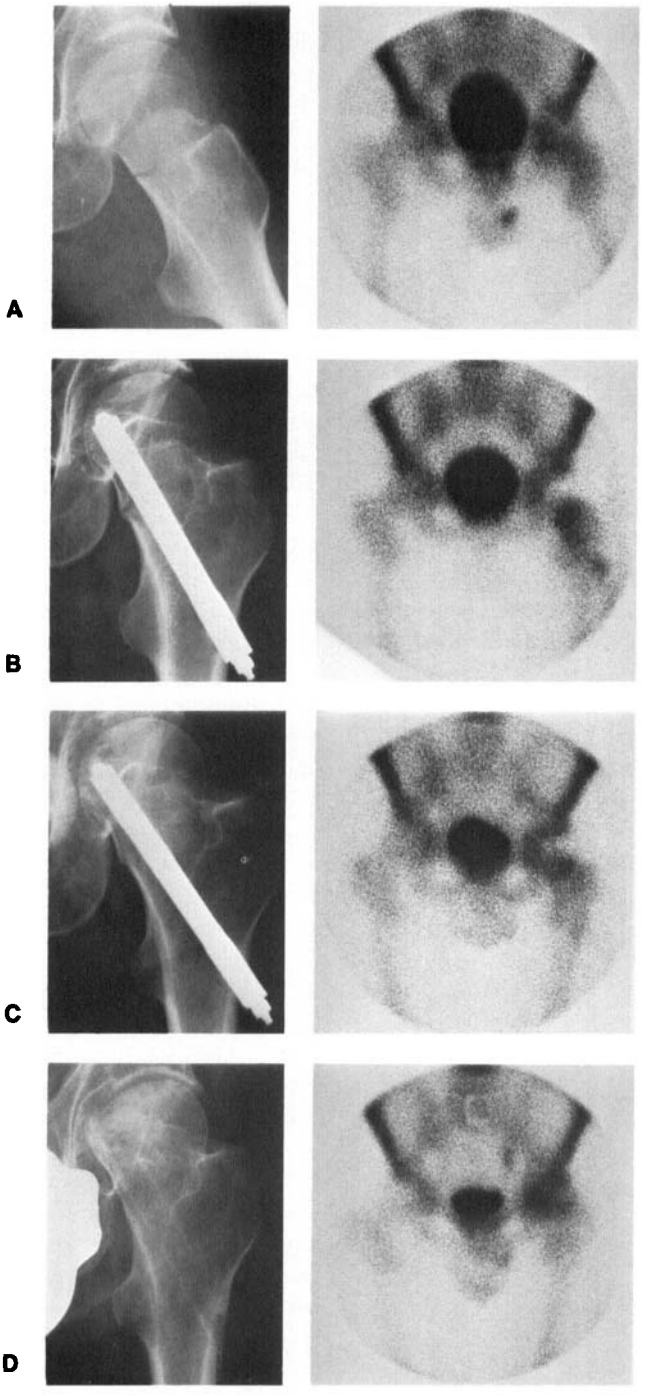

Figure 2 A. Case 2. Preoperative radiograph and Tc-MDP scintimetry.
Figure 2 B. Case 2. Radiograph and Tc-MDP scintimetry 1 week postoperatively.
Figure 2 C. Case 2. Radiograph and Tc-MDP scintimetry 4 months after operation.
Figure 2 D. Case 2. Radiograph and Tc-MDP scintimetry 2 years after operation.

ESR was 100 mm/h and CRP was elevated. The hip joint was aspirated another two times without pathologic findings. The fever and the hip pain subsided without treatment after a few days.

Tc-MDP-scintimetry performed during the hospital stay showed an increase in the femoral head activity (ratio 2.30).

The patient became pain-free and returned to work but the sedimentation rate remained elevated. Nail extraction was performed and further cultures on this occasion also were negative.

Two years after fracture, the segmental collapse was evident with an increasing femoral head isotope uptake, ratio 2.65 (Figure 2 D). The patient, however, was fairly asymptomatic, doing full-time work and had a normal sedimentation rate.

DISCUSSION

The main prerequisite for uncomplicated femoral neck fracture healing is preserved femoral head viability (Hulth 1965, Bauer et al. 1980, Strömqvist 1983), although the age of the patient, the degree of fracture displacement, the quality of fracture reduction, the method of osteosynthesis and the stability of fixation are important factors (Barnes et al 1976, Arnoldi & Lemperg 1977, Lowell 1980, Deyerle 1980).

Three well-documented methods were used for determination of femoral head vitality in the two cases presented, intravital staining with tetracycline (Frost et al. 1961, Hansson 1967, Strömqvist et al. 1981), scintimetry using Sr^{85} (Bauer 1968, Sjöstrand 1974) and Tc^{99m}-MDP (Subramanian & McAfee 1971, Alavi et al. 1977, Strömqvist 1983).

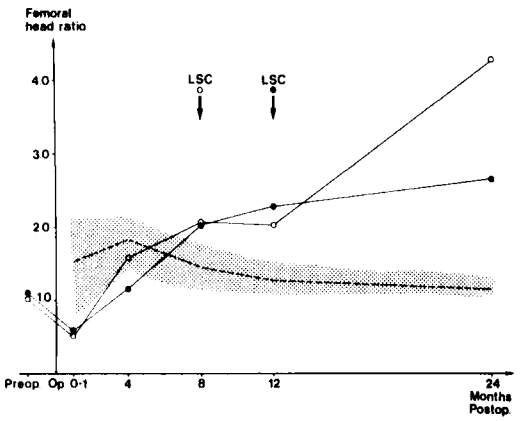

Figure 3. Femoral head isotope uptake in subsequent Tc-MDP scintimetry. ○ denotes case 1, X denotes case 2. Shaded area denotes uptake ratio ± standard deviation for 20 normally healing fractures. Arrows indicate time when radiographical collapse was evident.

Tetracycline deposition on the bony trabeculae after administration is an indication of living osteoblasts and the degree of tetracycline deposition after femoral neck fracture may be used for estimating the vitality of the femoral head (Strömqvist et al. 1981). About one femoral head out of six showed no tetracycline deposition. The remainder showed signs of circulatory reduction of varying degree. However, this reduction was in many cases consistent with intact Tc-MDP uptake in a postoperative scintimetry.

Bone uptake of technetium-labelled phosphates is dependent on the blood flow and metabolic activity (Genant et al. 1974), the uptake probably being connected with bone formation (Greiff 1978) as well as resorption (Bach Christensen & Kroogsgård 1982).

In femoral neck fractures, the intense hypermetabolism preceding segmental collapse was shown by Alavi et al. (1977), while femoral head uptake defects after nailing were noted by D'Ambrosia et al. (1978) and their prognostic significance when detected 1–2 weeks postoperatively was revealed by Bauer et al. (1980). Both patients in this report followed the scintimetric pattern described for healing complications with deficient femoral head activity 1–2 weeks after operation and increasing uptake on later scans. Hypermetabolism in the femoral head in both cases was noted before radiographic evidence of segmental collapse was at hand.

In previous investigations, Sr^{85}-scintimetry has been found useful to register the increased bone formation after fracture (Wendeberg 1961, Asnis et al. 1976, Brümmer et al. 1982), in infected or loose hip prostheses (Sjöstrand 1974) and in infections and malignancy (Bauer 1968). The method has, however, been found unsuitable to register the early avascular phase in femoral neck fractures (Asnis et al. 1976, Brümmer et al. 1982) in contrast to the Tc-MDP technique (D'Ambrosia et al. 1978, Bauer et al. 1980). This investigation was no exception. The somewhat higher ratios found compared to Brümmer et al. (1982) were probably due to the fact that Sr^{85}

was administered somewhat later in the course.

The course of circulatory and metabolic activity changes in both cases are well documented through repeated scintimetric procedures, and the preoperative scintimetric finding is also verified by intravital tetracycline staining. According to the tetracycline biopsy, a moderate circulatory reduction was present in the femoral head on the fracture side for both patients before nailing.

From a recent investigation (Strömqvist & Hansson 1983) it is apparent that according to biopsy findings virtually every femoral neck fracture causes some degree of circulatory reduction. The degree of reduction calculated in the two cases presented here is not inconsistent with an uncomplicated healing course, which, however, the first postoperative Tc-MDP-scintimetry definitely is. It can therefore be deduced that the fates of the femoral heads in both patients were determined not at the moment of fracture but between the pre- and postoperative circulatory investigations.

The results of tetracycline studies, when comparing circulation on admission to hospital to circulation after closed reduction on the operating table, show no significant differences between the two groups (Strömqvist & Hansson 1983) which makes the possibility of vascular injury prior to osteosynthesis improbable.

In conclusion, both cases provide strong evidence that the vascular damage was caused by the osteosynthesis. Flanged nails often produce a marked fracture diastasis when being hammered in, especially in non-osteoporotics (Strömqvist et al. 1983b), and most probably it is here that the irreversible injury is inflicted upon the already strained femoral head circulation.

REFERENCES

Alavi, A., McCloskey, J. & Steinberg, M. (1977) Early detection of avascular necrosis of the femoral head by 99 m technetium diphosphonate bone scan. *Clin. Orthop.* **127**, 137–141.

Arnoldi, C. & Lemperg, R. (1977) Fracture of the femoral neck. II. Relative importance of primary vascular damage and surgical procedure for the development of necrosis of the femoral head. *Clin. Orthop.* **129**, 217–222.

Asnis, S., Shoji, H. & Bohne, W. (1976) Scintimetric evaluation of complications after femoral neck fractures. *Clin. Orthop.* **121**, 149–156.

Bach Christensen, S. & Kroogsgard, O. W. (1981) Localization of Tc-99m MDP in epiphysial growth plates of rats. *J. Nucl. Med.* **22**, 237.

Barnes, R., 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. (1968) The use of radionuclide in orthopaedics. Part 10. Radionuclide scintimetry of the skeleton. *J. Bone Joint Surg.* **50-A**, 1681–1709.

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

Brümmer, R., Hansson, L. I., Mortenson, W. & Sjöstrand, L. O. (1982) ^{85}Sr-scintimetry in femoral neck fracture. *Arch. Orthop. Traum. Surg.* **101**, 47–51.

Calandruccio, R. A. & Anderson, W. E. (1980) Postfracture 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 (1978) Scintigraphy in the diagnosis of osteonecrosis. *Clin. Orthop.* **130**, 139.

Deyerle, W. M. (1980) Impacted fixation over multiple resilient pins. *Clin. Orthop.* **152**, 102–122.

Frost, H. M., Villanueva, A. R., Roth, H. & Stanisavljevic, S. (1961) Tetracycline bone labelling. *J. New Drugs* **1**, 206–216.

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

Genant, H. K., Bautovich, G. J. & Singh, M. (1974) Bone seeking radionuclides: an *in vivo* study of factors affecting skeletal uptake. *Radiology* **113**, 373–382.

Greiff, J. (1978) Autoradiographic studies of fracture healing using ^{99}Tc^{m}- Sn-polyphosphate. *Injury* **9**, 271–277.

Hansson, L. I. (1967) Daily growth in length of diaphysis measured by oxytetracycline in rabbit normally and after medullary plugging. *Acta Orthop. Scand.* Suppl. 101.

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

Hulth, A. (1965) Prediction of the viability of the femoral head in femoral neck fractures. *Acta Chir. Scand.* **129**, 72–80.

Ibsen, B. (1951) Necrosis capitis femoris post fracturam colli femoris veri et fracturam pertrochantericam. Thesis. Munksgaard, Copenhagen.

Lowell, J. D. (1980) Results and complications of femoral neck fractures. *Clin. Orthop.* **152**, 162–172.

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

Sjöstrand, L.-O. (1974) Radionuclide scintimetry in total hip arthroplasty. Thesis. Lund.

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

Strömqvist, B., Brismar, J., Hansson, L. I. & Palmer, J. (1983a) ^{99m}Tc-MDP scintimetry after femoral neck fracture – a three-year follow-up. *Clin. Orthop.* In press.

Strömqvist, B., Ceder, L., Hansson, L. I. & Thorngren, K.-G. (1981) Vitality of the femoral head after femoral neck fracture evaluated by tetracycline labeling. *Arch. Orthop. Traumat. Surg.* **99**, 1–6.

Strömqvist, B. & Hansson, L. I. (1983) Femoral head vitality after femoral neck fracture – comparison between pre- and peroperative tetracycline labeling. *Arch. Orthop. Traumat. Surg.* **101**, 251–257.

Strömqvist, B., Hansson, L. I., Palmer, J., Ceder, L. & Thorngren, K. G. (1983b) Scintimetric evaluation of nailed femoral neck fractures with special reference to type of osteosyntheses. *Acta. Orthop. Scand.* **54**, 340–347.

Subramanian, G. & McAfee, J. G. (1971) A new complex of 99m-Tc for skeletal imaging. *Radiology* **99**, 192–196.

Wendeberg, B. (1961) Mineral metabolism of fractures of the tibia in man studied with external counting of Sr^{85}. *Acta Orthop. Scand.* Suppl. 52.

Correspondence to: Björn Strömqvist, Department of Orthopaedic Surgery, University Hospital in Lund, S-221 85 Lund, Sweden.