

From the Orthopaedic Research Laboratories (Head: Göran C. H. Bauer, M.D.) and the Orthopaedic Clinic (Head: Sophus von Rosen, M.D.) Malmö Allmänna Sjukhus, University of Lund, Malmö, Sweden.

PREDICTION OF AVASCULAR NECROSIS
FOLLOWING CERVICAL FRACTURE OF THE FEMUR
BASED ON CLEARANCE OF RADIOACTIVE IODINE
FROM THE HEAD OF THE FEMUR

By

B. HOLMQUIST and P.-A. ALFFRAM

INTRODUCTION

Approximately one third of femoral neck fractures result in avascular necrosis of the head of the femur (*Hulth & Johansson 1962*) and about two thirds of the patients with such necrosis suffer considerable invalidity (*Jensenius 1956*). Until to-day efforts to reduce the incidence of avascular manifestations after femoral neck fractures have been relatively unproductive. However, modern techniques for replacing a destroyed femoral head with a vitallium prosthesis supplemented by a reliable method for determining the viability of the femoral head at the time of fracture would be useful in avoiding repeated surgical interventions due to avascular necrosis in these often already debilitated patients.

In 1934 *Phemister* stated that the fate of the femoral head in cases of femoral neck fractures is dependent on the damage to the blood supply and is determined at the time of fracture. During the last two decades assessment of the viability of the femoral head in such cases has been attempted by such methods as venography (*Hulth 1953, 1956, Dahlgren 1959, Hulth & Johansson 1962*), arteriography (*Rook 1953, Müssbichler 1956*), radioactive tracer techniques (*Tucker 1950, Boyd 1951, Arden & Veall 1953, Boyd, Zilversmit & Calandrucchio 1955, Laing*

Financial support was obtained from the *Josiah Macy, Jr., Foundation* and from the *Knut and Alice Wallenberg Foundation*, Stockholm.

& Ferguson 1959, Arden 1960, Johansson 1962, Boyd & Calandrucchio 1963), needle aspiration (Harrison 1962), dye clearance technique (Price 1962), and oxymetry (Woodhouse 1961). Few of these studies compare the long term results with the initial assessment of the blood circulation to the femoral head. In the present study the results of an initial radioactive tracer clearance technique have been related to radiographic follow-up two and one half years or more after fracture.

MATERIAL

Thirty-two unselected patients with recent cervical fracture of the femur were studied. Thirty fractures were nailed immediately after the assessment. Two fractures studied at 7 and 84 days, respectively, after fracture were considered impacted and stable and therefore were not nailed. The age of the patients varied from 43 to 86 years. Roentgenographic follow-up was possible in 25 cases; 22 patients were examined three years or more after fracture and two patients were followed two and one half years. One patient suffered an extensive avascular necrosis of the femoral head during the first year after fracture and was subjected to a Moore arthroplasty. Six patients were dead at the time of follow-up and one patient refused examination.

METHOD

The type of fracture was classified with respect to the displacement of the fracture fragments on initial roentgenograms and the fracture-shaft angle (FSA) on frontal view (Hulth 1956), usually assessed on roentgenograms taken during operation. It was also noted whether or not there was a valgus position after nailing.

At the time of nailing of the fracture intraosseous injection of ^{131}I in sterile isotonic saline was performed by means of a specially designed cannula¹ with a volume of 0.05 ml and a glass syringe containing 0.15 ml of solution (Fig. 1). The cannula was inserted into the femoral head through a lateral approach after reposition of the fracture had been made and the position of the cannula was checked roentgenographically (Fig. 2). 0.10 ml of the solution corresponding to 10 micro-

¹ The authors wish to express their gratitude to *C. M. Berger*, managing director, and *G. Dahl*, chief engineer, AB Malkus Holmquist, Halmstad, for the construction of the cannula used in these studies.

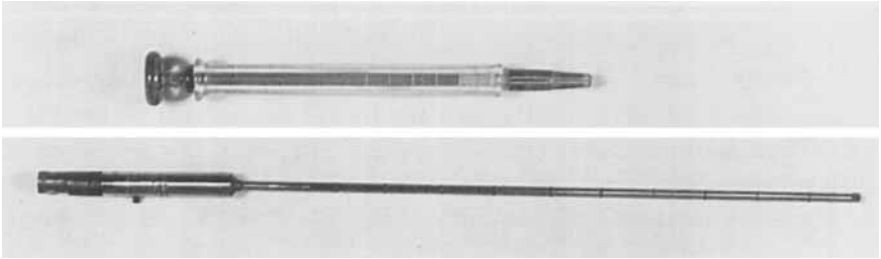


Fig. 1.

Syringe and cannula used in the investigation.

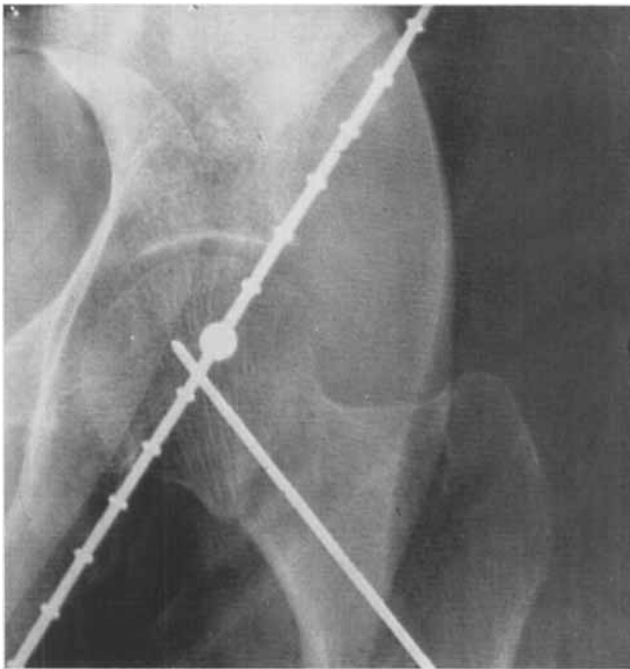


Fig. 2.

Roentgenogram showing cannula in position during examination.

curie ^{131}I was injected and the cannula was immediately washed out by injection of 0.05 ml isotonic saline. At specific time intervals after the injection, the activity over the hip was measured by the equipment described by *Bauer & Wendeborg* (1959). A 12° wide-angle collimator was used throughout the investigation with the aperture of the collimator close to the skin during the measurements. The activity data were

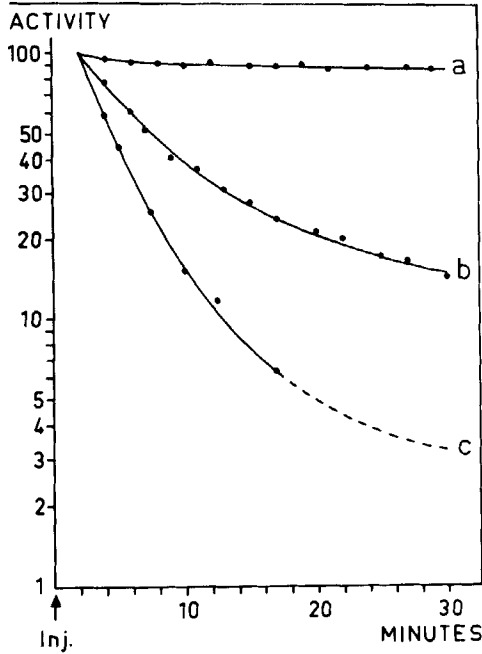


Fig. 3.

Typical disappearance curves.

- a. cervical fracture which resulted in avascular necrosis.
- b. cervical fracture which later healed without signs of avascularity.
- c. traumatic dislocation of the hip.

corrected for back-ground activity which was determined at every measurement. The rate of disappearance of radioactive iodine could then be determined (Fig. 3). The pressure increase within the femoral head due to the injected solutions was arbitrarily assumed to have disappeared after 5 minutes. Therefore the decline in measured radioactivity from 5 to 15 minutes after injection, expressed as per cent of the 5-minutes value, was used as an indicator of the blood circulation to the femoral head.

RESULTS

The roentgenographic results at follow-up with other relevant data are given in Table 1. All measurements but one were made in fresh fractures.

All fractures healed without signs of pseudarthrosis. Roentgenographic evidence of avascular necrosis of the femoral head was pre-

sent in 9 cases. In 2 of these the avascular changes were restricted to the cranial portion of the head, while in the others the changes were diffuse.

TABLE 1

Case	Sex	Age	Primary displacement	Valgus after nailing	F. S. A.	Interval between fracture and assessment (days)	Interval between assessment and follow-up (mth)	Disappearance (per cent)	Necrosis of head
1	♀	74	++	—	>30	11	12	0.5	total
2	♀	53	—	+	>30	6	48	3.6	total
3	♂	60	+	—	>30	6	52	2.4	total
4	♀	63	+	—	<30	2	40	3.4	total
5	♀	64	+	—	>30	6	61	4.0	total
6	♀	74	++	—	<30	4	40	3.5	total
7	♀	52	—	+	>30	7	52	11.6	partial Not nailed
8	♀	43	++	+	<30	6	51	3.0	partial
9	♂	78	++	—	<30	6	56	4.1	partial
10	♂	61	—	+	>30	6	62	39.0	none
11	♀	55	—	—	<30	8	62	19.1	none
12	♂	57	++	—	<30	4	62	2.2	none
13	♀	48	+	+	>30	4	40	2.1	none
14	♂	55	+	—	>30	6	60	5.3	none
15	♀	56	++	+	<30	1	55	6.3	none
16	♂	74	+	—	<30	7	51	46.6	none
17	♀	79	++	—	>30	4	30	24.2	none
18	♀	76	++	—	<30	4	59	6.7	none
19	♂	66	+	—	<30	4	54	5.6	none
20	♀	83	—	+	>30	84	58	42.7	Malum coxae Not nailed
21	♂	56	+	—	>30	4	55	9.6	none
22	♀	55	—	—	>30	5	36	49.0	none
23	♀	64	+	—	>30	6	55	14.5	none
24	♀	78	++	—	>30	4	58	28.5	none
25	♀	74	+	—	>30	7	30	4.5	none

The decline in radioactivity between 5 and 15 minutes after injection was less than 5 per cent in 8 of the cases that subsequently underwent avascular necrosis. In one case with partial necrosis of the head the disappearance rate was 11.6 per cent. This fracture was impacted in valgus and was not nailed.

Of the 16 cases without signs of avascularity at follow-up the clearance was above 5 per cent in 13 and below 5 per cent in 3 cases. One of

the latter fractures was nailed in valgus and the initial displacement was moderate. Another case, with a disappearance rate of 4.5 per cent, was followed for only 30 months after fracture.

Since 1 of 14 fractures with a disappearance rate above 5 per cent and 8 of 11 fractures with a disappearance rate below 5 per cent resulted in avascular necrosis the reliability of this method is 84 per cent.

The degree of primary displacement, the fracture-shaft angle or the valgus position after nailink could not be demonstrated to influence the occurrence of avascular necrosis in this small series.

DISCUSSION

To-day there are several methods by which the viability of the femoral head can be assessed after a femoral neck fracture, with about the same reliability. By measuring the oxygen tension in the femoral head *Woodhouse* (1961) found a positive correlation in 17 of 19 cases. In evaluable venographies (*Hulth & Johansson* 1962) a correct prediction of the viability could be made in about 80 per cent, and similar reliability was obtained by the different radioactive tests described by *Arden* (1960), *Boyd & Calandrucchio* (1963) and *Johansson* (1964). In these methods, however, one quarter to one third of the tests were not evaluable. By measuring the transport of isotope-tagged red cells to the femoral head *Massie* (1964) predicted total avascularity with almost complete accuracy. In the present series, where no tests were omitted, a correct prediction of the viability of the femoral head was made in 84 per cent of the cases.

A disappearance rate of less than 5 per cent during 10 minutes strongly indicates avascularity of the femoral head whereas avascular necrosis was rare above that level. This is in agreement with the findings of *Laing & Ferguson Jr.* (1959) who in animal experiments found total avascularity in cases with a clearance below 5 per cent 10 minutes after injection and normal blood supply in cases with a clearance above 20 per cent. Between these values the femoral head was partially devascularised.

Injection of large volumes may damage the bone tissue of the femoral head (*Hulth* 1956), and cause increased intraosseous pressure forcing the tracer solution along the cannula into the fracture space resulting in incorrect assessments. Therefore the total volume injected in this method was reduced to a minimum by the specially designed cannula

with a volume of 0.05 ml. The pressure effects of such a small volume injected in this method is certainly negligible.

The position of the tip of the cannula in the femoral head is probably also essential. In case 8 where the cannula was inserted centrally in the head and injection made into probably vascularized bone, there were signs of partial avascular necrosis despite the high disappearance rate of 11.6 per cent. The accuracy of the method can probably be increased by inserting the cannula into the proximal part of the femoral head where partial necrosis is most commonly seen.

The method prolongs the operating time by about 15 minutes. It seems, however, possible to reduce this delay by at least 5 minutes by measuring the disappearance rate during the first 10 minutes from the time of injection.

SUMMARY

In 32 unselected patients with recent cervical fracture of the femur the vascularity of the femoral head was assessed by means of a radioactive tracer clearance technique. 25 patients were followed roentgenographically not less than 30 months. In 21 of these 25 cases the prognosis regarding survival of the femoral head could be correctly predicted.

RESUME

Chez 32 malades non sélectionnés ayant présenté une fracture cervicale récente du fémur, la vascularisation dans la tête fémorale a été contrôlée au moyen de la technique du traceur radio-actif. 25 malades ont été suivis radiographiquement pendant environ 30 mois. Chez 21 de ces 25 cas, le pronostic par rapport à la survie de la tête fémorale a pu être correctement établi.

ZUSAMMENFASSUNG

Bei 32 nicht ausgewählten Patienten mit frischen Schenkelhalsbrüchen wurde die Blutversorgung des Femurkopfes mittels einer radioaktiven Aufspürungstechnik bestimmt. 25 Patienten wurden nicht weniger als während 30 Monaten nachuntersucht. Bei 21 von diesen 25 Fällen konnte die Prognose hinsichtlich des Überlebens des Oberschenkelkopfes richtig vorausgesagt werden.

REFERENCES

- Arden, G. P. & Veall, M.: The use of radioactive phosphorus in early detection of avascular necrosis in the femoral head in fractures neck of femur. *Proc. Roy. Soc. Med.* 46: 344, 1953.
- Arden, G. P.: Radioactive isotopes in fractures of the neck of the femur. *J. Bone Jt Surg.* 42-B: 21, 1960.
- Bauer, G. C. H. & Wendeberg, B.: External counting of Ca⁴⁷ and Sr⁸⁵ in studies of localized skeletal lesions in man. *J. Bone Jt Surg.* 41-B: 558, 1959.
- Boyd, H. B.: Use of the Geiger counter in estimating the blood supply in the femoral head. *J. Bone Jt Surg.* 33-B: 475, 1951.
- Boyd, H. B., Zilversmit, D. B. & Calandrucchio, R. A.: The use of radioactive phosphorus to determine the viability of the head of the femur. *J. Bone Jt Surg.* 37-A: 260, 1955.
- Boyd, H. B. & Calandrucchio, R. A.: Further observations on the use of P³² to determine the viability of the head of the femur. *J. Bone Jt Surg.* 45-A: 445, 1963.
- Dahlgren, V.: Venography in fractures of the femoral neck. *Acta chir. scand.* 117: 494, 1959.
- Harrison, M. H. M.: A preliminary report of vascular assay in prognosis of the fractured femoral neck. *J. Bone Jt Surg.* 44-B: 858, 1962.
- Hulth, A.: Injection of contrast-medium in the head of intracapsular fractures of the neck of the femur. *Acta Societ. Med. Upsal.* 59: 41, 1953.
- Hulth, A.: Intra-osseous venographies of medial fractures of the femoral neck. *Acta chir. scand. Suppl.* 214, 1956.
- Hulth, A. & Johansson, S. H.: Femoral-head venography in the prognosis of fractures of the femoral neck. *Acta chir. scand.* 123: 287, 1962.
- Jensenius, H.: Osteosynthesis of medial fractures of the femoral neck. *Acta chir. scand.* 111: 222, 1956.
- Johansson, S.: Prognostic assessment in fractured neck of femur using ¹³¹I and venography. *Acta chir. scand.* 123: 298, 1962.
- Johansson, S.: The prognostic value of the radio-iodine test in femoral neck fractures. *Acta Societ. Med. Upsal.* 69: 64, 1964.
- Laing, P. G. & Ferguson, A. B., Jr.: Radiosodium clearance rates as indicators of femoral head vascularity. *J. Bone Jt Surg.* 41-A: 1409, 1959.
- Massie, W. K. & Stevens, D. B.: Avascular necrosis in intracapsular fractures studied. A radioisotops method. *Clin. Orthop.* 32: 187, 1964.
- Müssbichler, H.: Arterial supply to the head of the femur. An arteriographic study *in vivo* of lesions attending fracture of the femoral neck. *Acta radiol.* 46: 533, 1956.
- Phemister, D. R.: Fractures of neck of femur, dislocations of hip, and obscure vascular disturbances producing aseptic necrosis of head of femur. *Surg. Gynec. Obstet.* 49: 415, 1934.
- Price, E. R.: The viability of the femoral head after fracture of the neck of the femur. *J. Bone Jt Surg.* 44-B: 854, 1962.
- Rook, R. W.: Arteriography of the hip joint for predicting end results in intracapsular and intertrochanteric fractures. *Amer. J. Surg.* 86: 404, 1953.
- Tucker, F. R.: The use of radioactive phosphorus in the diagnosis of avascular necrosis of the femoral head. *J. Bone Jt Surg.* 32-B: 100, 1950.
- Woodhuse, C. F.: An instrument for the measurement of oxygen tension in bone. *J. Bone Jt. Surg.* 43-A: 819, 1961.