Acta orthop. scand. *41*, 77–90, 1970

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ARTERIOGRAPHIC FINDINGS IN NECROSIS OF THE HEAD OF THE FEMUR AFTER MEDIAL NECK FRACTURE

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Received 15.xii.69

Today, it is generally accepted that necrosis of the femoral head after neck fracture is due a disturbance of the blood supply of the head. The occurrence of circulatory disturbance has been demonstrated angiographically in neck fractures and necrosis by Müssbichler (1956). He reported on arrested and delayed circulation in the posterior collum branch in fractures and on delayed circulation in 3 out of 4 cases with head necrosis. Lange & Hipp (1959/60) examined 6 cases with necrosis by arteriography. They found a delay of the circulation in the posterior collum branch in 1 case and also noted other findings such as narrowness of the posterior collum branch and non-filling of femoral head vessels, which they thought was pathologic.

The patient materials published to date are, however, too small to provide reliable information about the vascular findings typical of necrosis, nor has a correlation between the angiographic findings and the stage of necrosis been published.

Recent technical developments, such as rapid serial angiography with film changers and the use of catheters, have made possible examination of the hip in different positions and far more detailed and reliable visualization of the arterial circulation. These methods have been applied to the majority of the patient material in the present study, the aims of which are as follow: (1) to confirm or supplement the previously described observations concerning the circulation in the posterior collum branch, (2) to extend the observations to the femoral head vessels, (3) to look for regional vascular changes, and (4) to correlate the arteriographic findings to the stage of necrosis.

The findings in the necrotic hips are interpreted on the basis of the recognition of angiograms from the contralateral unaffected hip as well as of a large material of normal hips (Müssbichler 1970a).

PRESENT INVESTIGATION

Material

Arteriography was carried out on 21 hips with necrosis of the femoral head. They comprised 16 women and 4 men aged 19 to 85 years (median age 60 years). One of them had bilateral necrosis.

Necrosis of the femoral head was diagnosed on generally accepted roentgenologic signs such as increased density of skeletal structure, with or without deformation or fragmentation of the caput.

The findings are specified in Table 1 from which the type and extent of necrosis, the time-lapse from fracture, fracture-healing, and histological findings as well as the results of the angiographic examination are shown.

In 2 cases the changes involved about half the head, whereas in the rest practically the whole head seemed to be involved. Increased skeletal density alone was found in 6 cases. It was associated with deformation of the caput in 3 and with fragmentation as well in 11. In 1 case no skeletal changes could be ascertained as fracture occurred only 3 months before arteriography. In this case, as in 6 others, necrosis was confirmed by histological examination from specimens. In addition to "necrosis" the pathologist also found inflammatory reaction in the bone and connective tissue in 3 cases and granulation tissue in 1 case. All fractures had been nailed. In 10 the nail was extracted, in 6 it had slipped and in 5 its position was unchanged. In 10 cases the fractures were not united with certainty, in another 2 pseudarthrosis was manifest. All patients suffered from severe disorder.

In 10 patients the unaffected contralateral hip was also examined angiographically.

Methods

In 7 cases arteriography was performed by injection of 20 ml of 50 per cent Dijodon (diaethanolamini dijod-pyridon-N-acetas) through a Seldinger canula (Seldinger 1953) into the external iliac artery. A series of 4 films over 12 seconds was exposed.

In all other cases 16 ml of 76 per cent Urografin (Schering AG, a mixture of sodium- and methylglucamine salts of N,N-diacethyl-3,5-diamino-2, 4, 6-trijodbensoeacid in the ratio 10:66) was injected within 2–3 seconds through a polyethylene catheter. In 12 cases the catheter was introduced into the external iliac artery in a proximal direction, in 2 into the deep femoral artery in a distal direction. A series of 1 frame per second for 15 seconds was exposed using the Elema-Schönanders AOT filmchanger. The first film in each series was already exposed before contrast material was injected in order to make application of the subtraction method (Ziedes Des Plantes 1961) possible.

In all examinations the femoral artery was compressed at the thigh by a pressure cuff.

Table 1. Specification of the patient material and angiographic findings

Time-lapse	3	5	8	10	10	12	18	18	20	24	24	26	33	36	36	36	60	60	65	72	100
Skeletal	-	a	a	a	a	a	ab	abc	abc	abc	a	abc	abc	ab	ab	abc	abc	abc	abc	abc	abc
Extent	-	2	3	4	4	4	2	3	4	3	4	4	4	4	3	4	4	4	4	4	4
Nail	↓	↓	↓	ex	ex	↓	ex	n	n	n	ex	↓	ex	n	ex	ex	↓	n	ex	ex	ex
Not healed	+	+	+	+	-	+	-	-	-	-	+	-	+	-	+	+	+	-	++	++	
Histological	+g		+	+i				+i	+				+i	+							
Posterior collum branch	+	+	+	+	n	n	+	n	n	n	n	n	+++	+	+	+	+	+	+	+	?
Hypervascular	+	+	+	+	-	+	+	+	-	+	+	+	+	-	+	+	+	-	-	-	-
Sup	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Inf	+	+	+	+	+	-	-	+	+	+	+	+	+	-	+	+	-	+	-	-	-
Acet	+	-	-	+	-	+	+	-	-	-	+	-	+	-	+	+	+	+	+	+	+
Teres	-	+	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-

Time-lapse from fracture in months; *Skeletal* changes (a = increased density, b = deformation, c = fragmentation of the caput); *Extent* of the changes (2 = about half of the caput, 3 = almost the whole; 4 = the whole caput); position of the *Nail* (↓ = slipping, ex = extracted, n = unchanged); fractures *Not healed* (+) pseudarthrosis (++); *Histological* findings (+ = necrosis, g = granulation tissue, i = inflammatory reaction, blank = not examined); circulation in the *Posterior collum branch* (n = normal, + = delayed, ++ = occluded as well, ? = questionable); *Hypervascular areas* (+), filling of the superior retinacular (*Sup*), inferior retinacular (*Inf*), acetabular (*Acet*), and ligamentum teres (*Teres*) arteries.

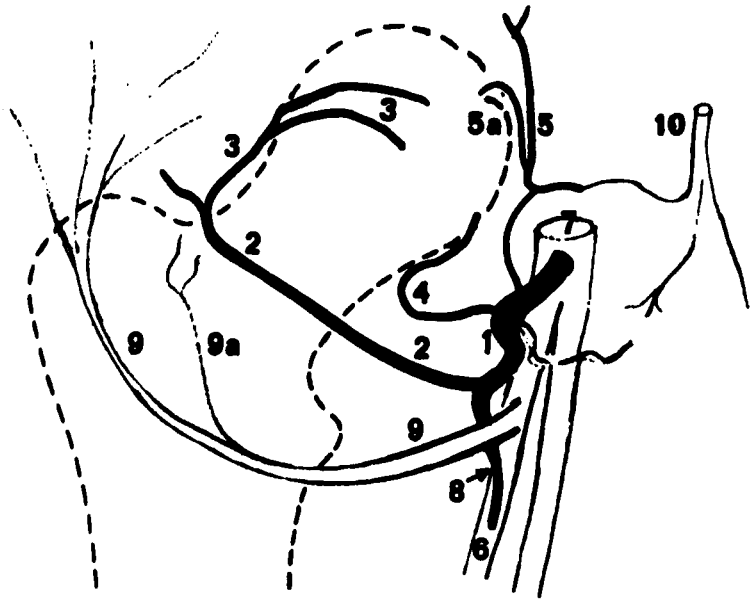

Figure 1. Schematic representation of the vascular pattern of the normal hip. Medial circumflex artery (1), posterior collum branch (2), superior (3) and inferior retinacular (4), acetabular (5), and ligamentum teres arteries (5a); ascending (9) and superior branch (9a) from the lateral circumflex artery. These vessels are derived from the deep femoral (6) and common femoral arteries (7) and the obturator artery (10).

RESULTS

Findings in the Unaffected Hips

In 10 patients the contralateral hip was also examined angiographically with the leg in inward as well as in outward rotation. The arteriographic findings conformed in general to the pattern shown in Figure 1. The posterior collum branch filled in all cases from the medial circumflex artery. No anomalies were noted.

Table 2. Incidence of filling of the femoral head arteries in 10 cases in which both the necrotic and the contralateral unaffected hips were examined by angiography.

Femoral head vessels filled	Necrosis 10 cases	Normals 10 cases
Superior ret.	0	7
Inferior ret.	6	5
Acetabular	8	3
Lig. teres artery	1	0

The arteries of the femoral head and the superior and inferior retinacular and the acetabular arteries filled in 7, 5, and 3 cases respectively. The artery of the teres ligament was not visible in any case (Table 2). The angiographic findings were identical in inward and outward rotation and agreed in principal with those obtained from a large material of normal hips (Müssbichler 1970a).

Findings in Necrosis of the Femoral Head

The present study comprised examinations of 21 hips. The examination was carried out in inward rotation of the hip in all cases, while outward rotation was also applied in 14. The latter position was achieved by rotating the lower leg outwardly until the patient reacted from pain. The leg was then fixed in this position on the table by a broad strap.

1. Posterior Collum Branch

The condition of the circulation can be seen from Table 1. The circulation was normal in 7 cases. In 1 of them the posterior collum branch was substituted by an artery originating from the lateral circumflex artery (Figure 8).

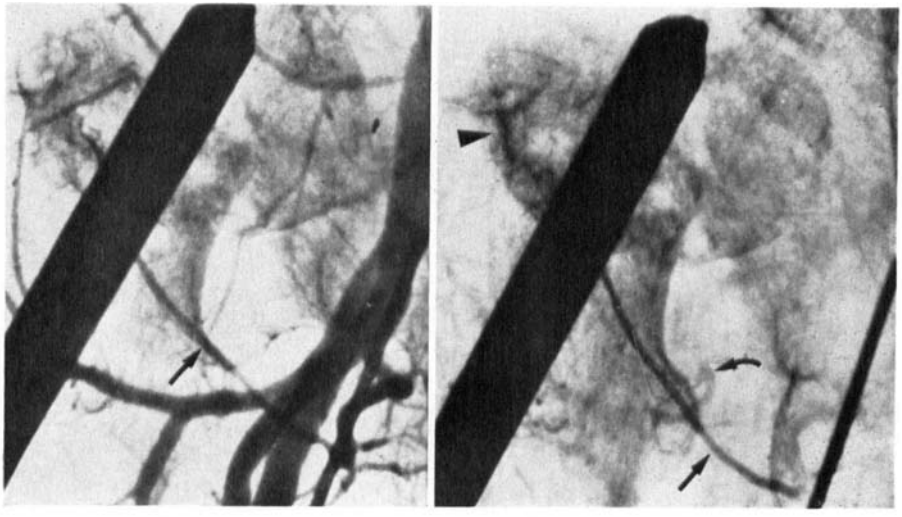

Figure 2. Delayed circulation in the posterior collum branch (↓) in which the contrast medium is pooling in the venous phase (right), vein (↖), hypervascular area (►).

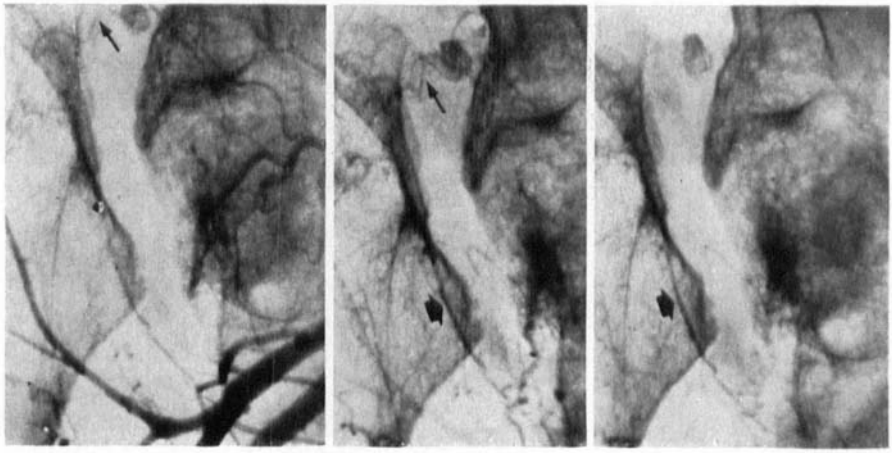

Figure 3. Highly resorbed necrotic head in pseudarthrosis. Three films from one arteriographic series show the contrast medium pooling in the posterior collum branch (◂). Small branches from the lateral circumflex artery bridge over the bone defect at (↓).

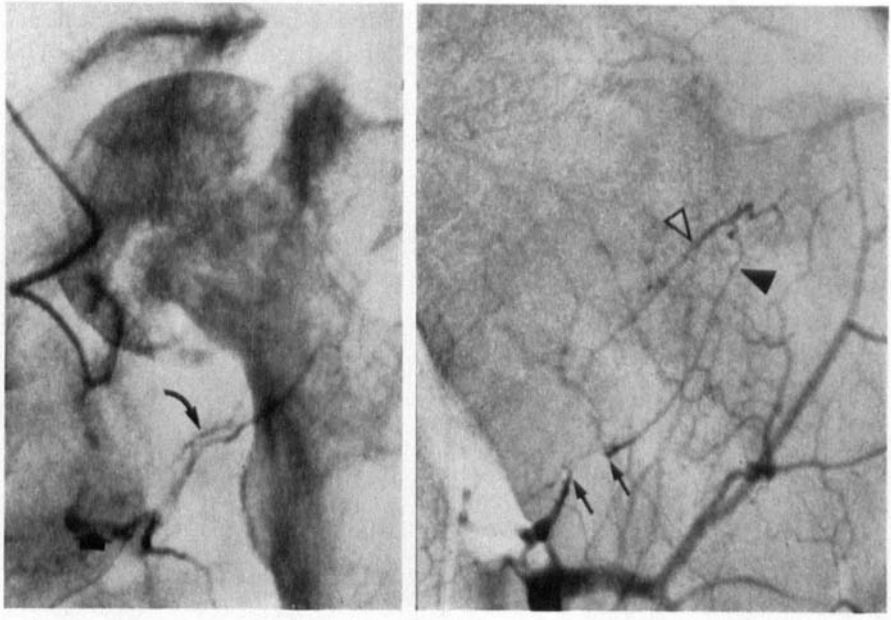

Figure 4. Interruption of the posterior collum branch by a defect (↓↓) in complete necrosis of the femoral head. The peripheral part of the artery (▼) is filled partly by a small by-pass vessel (↷ left) but mostly by the inferior gluteal artery (▽ right). Medial circumflex art. (◂).

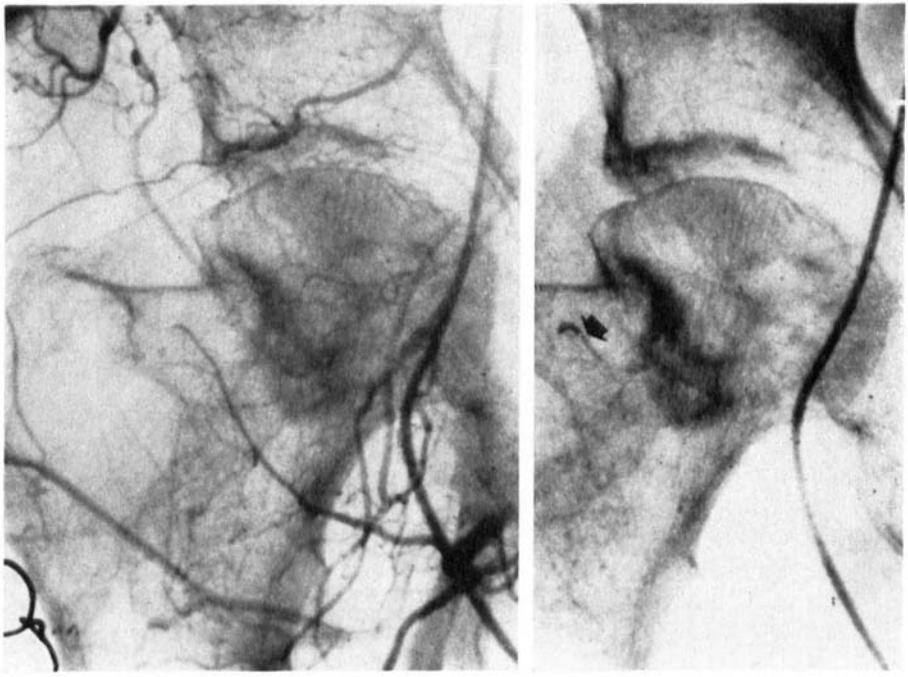

Figure 5. Delayed circulation in the peripheral part of the posterior collum branch (➧) in a case of partial necrosis.

The circulation was delayed in 13 cases. This condition, identical with the previously termed "decreased circulation" (Müssbichler 1956), was characterized by slow emptying of the posterior collum branch. The angiographical symptom was pooling of the contrast medium in the artery continuing after the end of the arterial phase (Figures 2, 3, 5 and 9). In one of these cases the posterior collum branch also seemed to be anatomically obstructed (Figure 4). This type of obstruction looked different from atherosclerotic changes observed by Müssbichler (1970a) as the artery tapered but the walls were regular. In 2 cases with partial necrosis the circulation in the posterior collum branch was delayed in its peripheral part only (Figure 5). In 1 case the condition of the circulation could not be defined as the branch was mostly superimposed by vessels.

When arteriography was carried out in outward rotation of the leg (14 cases), the circulation in the posterior collum branch changed from "delayed" to "arrested" in 4 cases, in all of which the fractures were not healed. This type of circulatory disturbance, also observed in

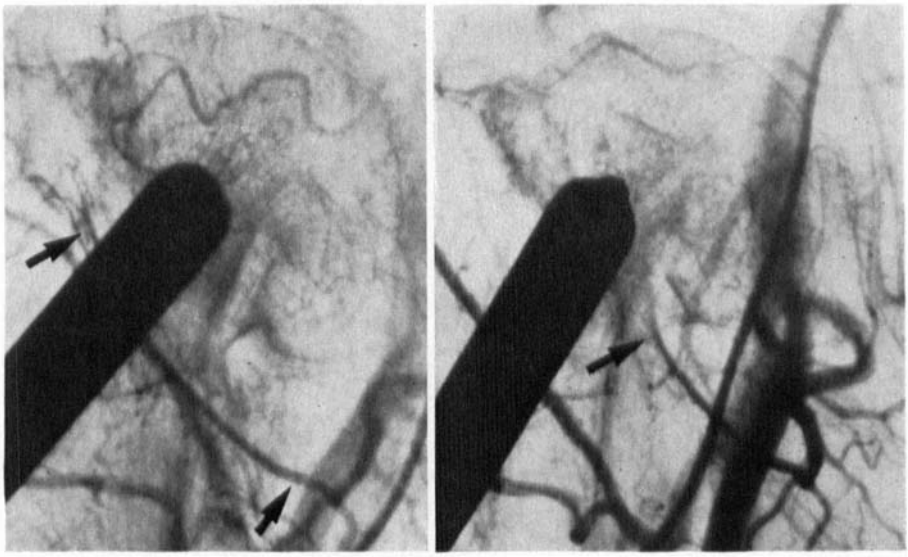

Figure 6. Normal extension of the posterior collum branch (↓) in inward rotation (left); the circulation became, however, arrested in outward rotation (↓ right).

malrotated recent neck fractures (Müssbichler 1970b), was characterized by interruption of the circulation in the posterior collum branch, the extension of which was remarkably reduced on the angiogram (Figures 6 and 9).

2. Femoral Head Vessels

The superior retinacular artery, responsible for the nutrition of the caput, was not filled in any case. The inferior retinacular, acetabular, and ligamentum teres artery filled in 14, 13, and 3 cases respectively.

A striking difference in the filling of the femoral head vessels was found when bilateral examinations comprising 10 necrotic and 10 normal hips were compared (Table 2). It concerned the lack of filling of the superior retinacular artery as well as the increased frequency of filling of the acetabular artery of the necrotic heads. In all cases the inferior retinacular and acetabular arteries were also wider in the necrotic than in the normal hip.

In outward rotation of the hip joint no change in the findings was noted.

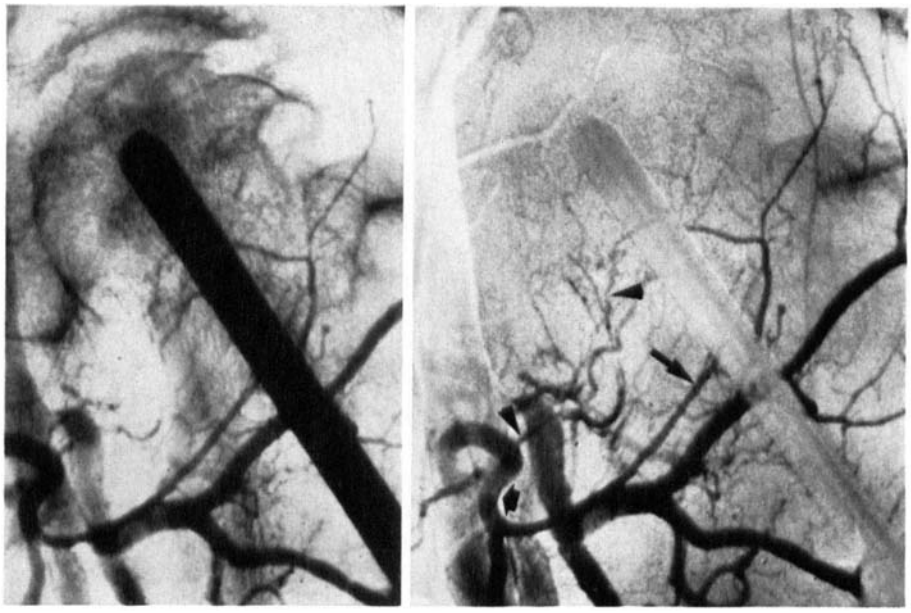

Figure 7. Increased vascularization of the non-necrotic medial segment of the femoral head by a hypertrophic inferior retinacular art. (▼) best visible by subtraction (↓right). Medial circumflex art. (➨), posterior collum branch (↓).

3. Local Hyperemia

An increase in the vascularization could be seen in 14 cases out of the 21. The findings were characterized by local increase of opacity due to an increase in the width and number of arterial branches. The changes resembled the angiographic pattern of hyperemia. They did not seem to be influenced by inward or outward rotation. The hyperemic areas seemed to be localized to:

A. The medial aspect of the femoral head supplied by the enlarged inferior retinacular artery (Figure 7). These findings were seen in 4 cases, in 2 of them opacities were also found over the central Part of the caput. They looked homogenous and were limited to a small area only (Figure 8). In all 4 cases the medial part of the caput supplied by the inferior retinacular artery was relatively free from skeletal changes.
B. The periphery of the areas involved in the fracture, e.g. laterally, superiorly, or inferiorly at the femoral neck (Figures 2 and 9). One of the 11 cases involved was also included in Group A. The

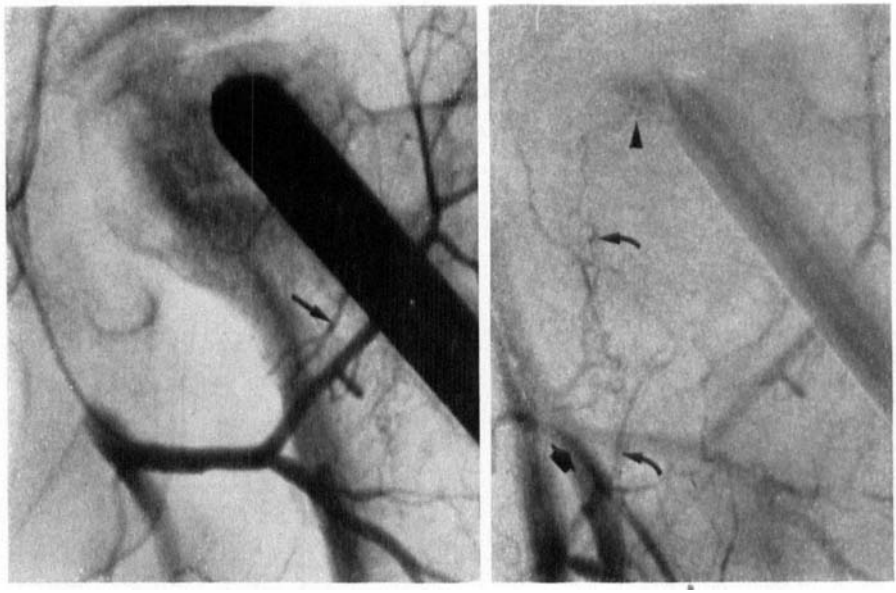

Figure 8. Selective arteriography of the lateral circumflex artery (left) showing a branch (↓) of this artery substituting the posterior collum branch (which otherwise originates from the medial circumflex artery). In the subtraction angiogram (right) the injection was made into the common femoral art. Medial circumflex artery (➧) with an hypertrophic inferior retinacular artery (↰) supplying the medial, non-necrotic portion of the caput. Opacities (▼) originating from the inferior retinacular artery.

hyperemic areas were supplied by one or several of the inferior gluteal, lateral circumflex, inferior retinacular, and medial circumflex arteries. A correlation between the incidence of hyperemia and the stage of necrosis could not be ascertained. In 4 of the cases the pathologist, apart from necrosis, also found reactive inflammation and granulation tissue.

Hypervascularization was not, however, noted in 7 cases, in all of which the femoral head was completely necrotic.

DISCUSSION

In experiments on rabbits necrosis could be produced by blockage of the blood circulation by "ligation of the femoral neck" by Rokkanen (1962). Arrested and/or delayed circulation was also demonstrated angiographically in medial neck fractures (Müssbichler 1956, Hipp

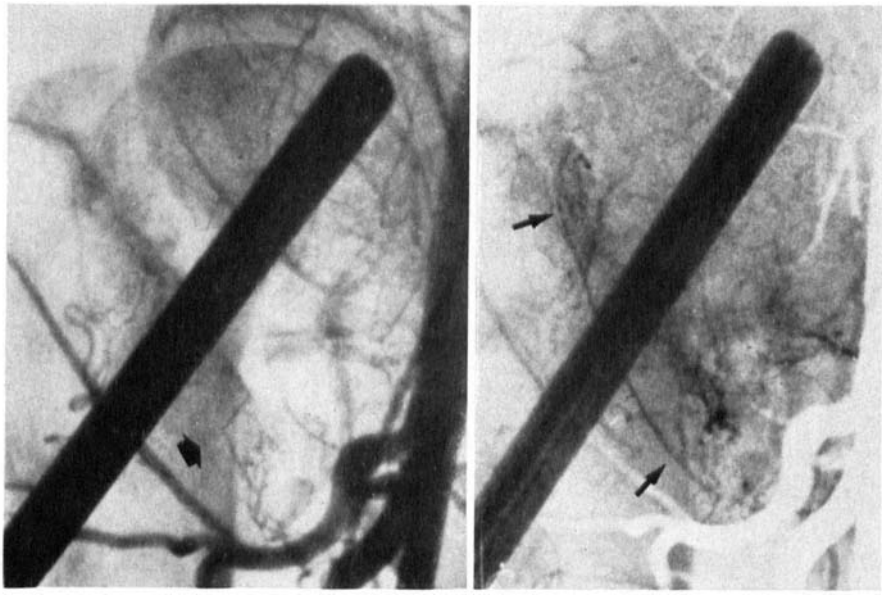

Figure 9. Arrested circulation in the posterior collum branch at (➧) in an outwardly rotated unhealed fracture (left). In inward rotation (subtraction, right) the extension of the branch is normalized but the contrast medium is pooling. In addition to that, increased vascularization along the fracture area at the neck is present.

1962, Brugger 1963). In follow-up studies a close relation between recent fractures with arrested circulation and development of necrosis was observed by Brünner et al. (1967) and Müssbichler (1970b). The results of all these studies emphasize the vascular etiology of necrosis after neck fracture.

Lange & Hipp (1959/60) reported on angiography of 6 cases with necrosis of the head of the femur. They found a delay of the circulation in the posterior collum branch in 1 case, in addition they noted in some cases that this artery or the superior retinacular or some of the other femoral head arteries were small, narrow, incompletely filled, or not filled at all. Hipp (1962) also presents similar findings. Only as regards "delayed circulation in the posterior collum branch" do the results of the examinations of these authors agree with those from a previous study (Müssbichler 1956) and the present examination. The other findings are, in my opinion, completely unspecific and should not be associated with necrosis as they can also be present in normal hips (Müssbichler 1970a).

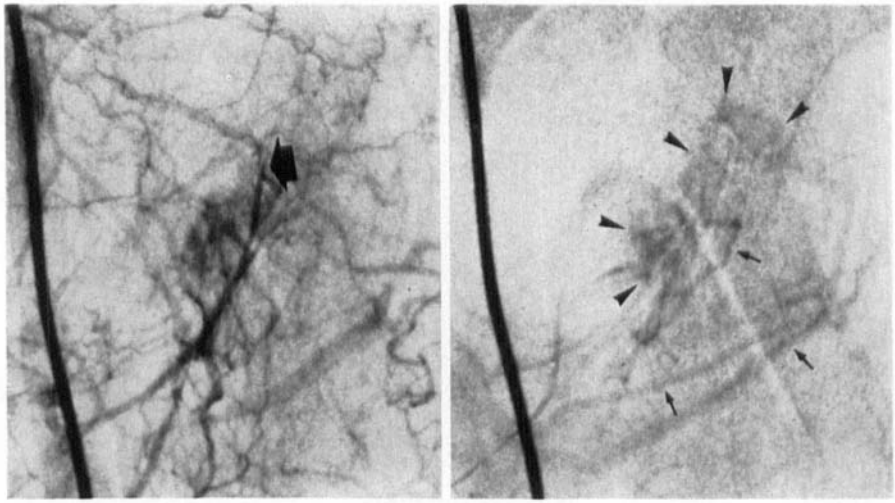

Figure 10. Subtraction angiograms of a case with necrosis and non-united fracture with arrested circulation in the posterior collum branch (◂) in outward rotation of the leg, and hypervascularity (▼) in the fracture area drained by veins (↓right).

In addition to delayed circulation in the posterior collum branch previously described in necrosis, the following findings were recognised in the present investigation: non-filling of the superior retinacular artery in the *whole* necrosis material, widening of the other femoral head vessels which partly filled with increased frequency, and finally hypervascular areas.

Delayed circulation in the posterior collum branch is not in principle different from that seen in recent fractures before as well after nailing (Müssbichler 1970b). The only difference might be that in recent fractures the circulation is delayed mostly in the peripheral part of the artery whereas the whole posterior collum branch is usually involved when total necrosis is manifest. In the two cases with partial necrosis, however, the circulation was delayed peripherally only. It may thus be concluded that delayed circulation is primarily caused by the fracture but progresses simultaneously with necrosis.

Delayed circulation is probably due to impairment of the flow in the terminal portion of the posterior collum branch and/or its main branch, the superior retinacular artery. The involvement of this artery is indicated by its total lack of filling throughout the *whole* necrosis material as well as in all patients with recent fractures that later developed necrosis (Müssbichler 1970).

The condition of arrested circulation in the posterior collum branch provoked by outward rotation of the leg in cases with necrosis and non-united fracture is very like that observed in recent malrotated fractures. The findings in the necrosis material stress heavily the role which malrotation of fractures may play in generating a severe circulatory disturbance in the posterior collum branch.

In a histological study of necrotic femoral heads from rabbits Slätis & Rokkanen (1966) found a hypervascular regeneration process taking place across a soft tissue bridge from the neck to the head. Sewitt (1964) examined human femoral heads histologically and microangiographically. In all of his 25 specimens the upper, lateral section of the head was totally avascular (this area is mostly supplied by the superior retinacular artery under normal conditions). He also observed hypervascular areas which, histologically, represented a re-vascularization process in and around the fovea, the lower, medial segment of the caput, and across the fracture.

The hypervascular areas found in the present investigation may be identical with the findings described by Slätis & Rokkanen and Sewitt. The findings also agree as regards their location and the fact that they were in no case observed at the lateral, superior section of the head. This typical location of the changes makes it unlikely that infection or other conditions are the underlying cause of hypervascularization.

SUMMARY

21 cases with necrosis of the femoral head were examined by arteriography. In contrast to the conditions present in normal hips the following changes were found in necrosis:

1. The circulation in the posterior collum branch was delayed in 13 cases. In 1 of them the artery was also obstructed.

2. In none of the cases was the superior retinacular artery filled.

3. Filling of the acetabular and ligamentum teres artery was increased in frequency. The arteries were widened as also was the case with the inferior retinacular artery.

4. In 14 cases areas of increased vascularization were found near the fracture area. These areas were supplied by branches of the inferior retinacular artery or other arteries of the hip. The findings might be due to a process of revascularization of the femoral head.

5. In the 7 cases in which hypervascular areas were not observed the whole femoral head was necrotic.

6. When angiography was performed in outward rotation of the leg, the circulation in the posterior collum branch became arrested in 4 of the cases in which the fracture was not healed.

The difference between the angiographic findings from femoral head necrosis and unaffected hips was significant.

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