ARTERIAL SUPPLY AT THE FEMORAL HEAD AND ITS CLINICAL IMPORTANCE

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Avascular necrosis of the femoral head is most often seen after fracture of the neck of the femur but it may also be due to slipping of the upper femoral epiphysis, reduction of congenital dislocation of the hip joint, and pyogenic or tuberculous infections of the femoral neck: it is the pathological basis of Perthes' disease. In understanding these problems, accurate knowledge of the arterial supply to the head of the femur is essential. The relative literature is voluminous but contradictory, and this study is presented in an attempt to clarify the subject.

The precarious state of the circulation in the femoral head has been known for many years. Astley Cooper (1822) knew of the blood supply from vessels which passed along the neck, and from small subsidiary vessels in the ligamentum teres. In his day, intracapsular fractures invariably failed to unite unless they were impacted. He claimed that the principal reason for this failure was the "absence of ossific action in the head of the thigh bone when separated from its cervix, its life then being supported solely by the ligamentum teres." Non-union was the dominant problem and inadequacy of blood supply to the femoral head was important only in so far as it affected union of a fracture. Astley Cooper did not distinguish between femoral heads which had some residual blood supply and those which were entirely avascular and necrotic.

With improved methods of immobilisation, union is now achieved in the majority of such fractures. Eyre-Brook and Pridie (1941) reported union in 58.7 per cent. of seventy-five fractures; and Boyd and George (1947) reported union in 86.5 per cent. of one hundred and forty-one fractures. The important remaining cause of non-union is avascular necrosis. It is well established, however, that union may take place even when the head of the femur is avascular. In these circumstances weight-bearing causes fragmentation of the dead bone, or pathological fracture at the junction of dead and living bone. Secondary arthritis is then a frequent complication. Carrell and Carrell (1941), Brailsford (1943), Eyre-Brook and Pridie (1941), and Seddon (1936), noted the high incidence of avascular changes after fracture of the femoral neck in children. Brailsford reported fifteen such fractures, more than half of which showed avascular changes.

Eyre-Brook and Pridie (1941) described the "fracture-shaft angle" and were impressed by the relationship between this angle and the incidence of avascular necrosis. Such necrosis developed in 14.7 per cent. of their patients, and in every case the fracture-shaft angle was less than 37 degrees. Linton (1944) studied 365 intracapsular fractures and presented statistical evidence that fixation with a Smith-Petersen nail increased the incidence of necrosis. This method is widely practised and it is important to determine whether or not insertion of such a nail has harmful effects and, if so, whether they can be avoided.

HISTORICAL REVIEW

The history of investigations into the arterial supply of the femoral head has been reviewed fully by Chandler and Kreuscher (1932), Nordenson (1938), and Wolcott (1943); and in this paper reference will be made only to some of the more important studies. Hyrtl (1846) stated that the vessels of the ligamentum teres were not of nutritional value to the femoral head, but that they spread out upon the surface of the fovea and immediately entered the foveolar veins. Langer (1876) showed by injection that vessels did in fact enter the developing
femoral head through the ligamentum teres and that they were of fundamental importance to the ossific centre. He claimed that variations existed in the adult but that these were secondary changes in which the vessels of the round ligament shrank to unimportance so that cervical vessels took over an almost exclusive supply of the head. Walmsley (1915) examined one hundred round ligaments but never found a vessel of any size; he concluded that arteries of the ligament could convey no more than a trifling amount of blood. Furthermore, he demonstrated by injection that these vessels did not supply the ossific centre in two children aged two years and six years. Kolodny (1925) investigated a number of foetuses, infants, children, and adults, and concluded that the vessels of the ligamentum teres played a certain role in nutrition of the femoral head in the new-born and in children, but that they were of no importance in the adult. Zemansky and Lippmann (1929) came to similar conclusions. Chandler and Kreuscher (1932) examined one hundred and fourteen round ligaments, and made serial sections of six femoral heads, including two in which there had been fractures of the femoral neck. The subjects were adults, averaging forty-eight years. The ligament was absent in only one case and all others contained vessels. In four, the vessels were of pre-capillary size; but the others carried a significant blood supply. In six specimens, serial sections were made of the femoral head and the round ligament, and it was established that there was anastomosis between the arteries of the ligament and those within the head. These observations are significant and they show that, even in the adult hip, the ligamentum teres is a vascular structure. Nordenson (1938) examined one hundred and twenty-nine normal round ligaments. He found that vessels were present in the ligament at all ages, but that with advancing age there was increasing obliteration by arteriosclerosis. Strangely, however, he found that in medial fractures of the femoral neck the foveolar vessels were always large. He suggested that these vessels, even although arteriosclerotic, were capable of hypertrophy, and that this capacity might explain why necrosis of the head was not more common.

Wolcott (1943) investigated the arterial pattern at various ages up to adolescence. He had previously made similar investigations in adults. His conclusions are important: 1) In infants and children the ossifying centre in the developing head of the femur receives its blood supply from capsular vessels which arise from the medial circumflex artery. 2) The ligamentum teres vessels do not enter the head of the femur in children, nor do they contribute to the nourishment of the growing femoral head, except for very small vessels at the site of implantation of the ligament into the foveolar area. 3) Anastomosis between vessels of the ligamentum teres, capsular arteries, and nutrient arteries of the shaft, does not take place until ossification of the femoral head is almost complete, by which time the vessels of the three systems unite by penetrating the thinned area of cartilage at the fovea. 4) The ligamentum teres circulation is closed, so far as the femoral head is concerned, until such anastomosis takes place.

In describing the arrangement present in the adult, Wolcott made these observations: 1) In approximately 80 per cent. of specimens which were injected successfully, even in patients of advanced age, the ligamentum teres carried at least one main artery which penetrated the head of the femur, and anastomosed with vessels entering by way of the capsule. 2) In approximately 20 per cent. of adult specimens in which arteries of the ligamentum teres were injected successfully, the vessels failed to enter the femoral head. In these instances opaque material could be seen to course through the arteries to the foveolar area from whence it was returned through the veins of the ligament.

So far as I know, Wolcott was the first investigator to state that the foveolar vessels increased in size with age. This contrasts with other observations, but it is compatible with observed clinical facts. Schmorl (1924), Hesse (1925), and Santos (1930) presented cases in which the proximal fragment of the head was found alive with only vessels of the ligamentum teres remaining intact.
METHODS OF INVESTIGATION

This study is based on the examination of forty-four femora obtained from fresh cadavers, the ages varying from birth to seventy-seven years. The vessels were injected with barium sulphate, and examined by X-ray after decalcification of the femoral head. The specimens were cleared by Spalteholz’ method which makes the cartilage, fibrous tissue, decalcified bone, and fatty marrow transparent, while the red marrow and vessels containing red cells or barium sulphate remain opaque. Transverse sections were made of thirty round ligaments, close to their femoral attachments. Transverse sections were also made just distal to the articular cartilage of the femoral head in order to confirm the success of the injection, and to corroborate the findings regarding distribution of the vessels about the periphery of the neck. The size of the vessels was assessed by means of an ocular micrometer. An effort was made to measure the lumen of the vessels at their point of entry into the epiphysis, or at an equivalent position in the adult.

RESULTS OF THE INVESTIGATION

Three groups of vessels supply the upper end of the femur, namely the nutrient artery of the shaft, the retinacular or capsular arteries, and the foveolar artery or artery of the ligamentum teres. The term “capsular” is in common use and is quite accurate, but the term “retinacular” stresses the relationship which these vessels have to the retinacular fibres and the periphery of the neck. It also corrects the erroneous view that these vessels run in the substance of the external fibrous capsule and that division of the capsule necessarily impairs the circulation of the femoral head. The term “foveolar,” in place of “artery of the ligamentum teres,” is adopted simply for brevity.
Nutrient artery—The nutrient artery enters the mid-shaft of the femur and may be single or double. The superior branch runs upwards in the medullary cavity and anastomoses with cervical branches of the retinacular arteries. In no specimen from a patient of less than thirteen years of age could I demonstrate nutrient vessels crossing the epiphysial plate from the metaphysis to the epiphysis. However, such an anastomosis could be demonstrated across this zone in several adult specimens. It is not possible to say how frequently this occurs, because the presence of red marrow, or of a dense cloud of capillaries, made visibility poor in some specimens. The anastomosis occurred between vessels of 0.1 to 0.25 millimetres in diameter. It may be supplemented by the inosculation of fine capillary tufts, which appear to belong to both nutrient and retinacular arteries.

Retinacular arteries—These vessels arise from the medial and lateral femoral circumflex arteries. There is, however, a brisk extracapsular anastomosis in the region of the trochanteric fossa to which the inferior gluteal, profunda femoris, obturator, and circumflex arteries contribute. The circumflex arteries lie superficial to the distal part of the fibrous capsule and they do not run within its substance; branches of the arteries pierce the fibrous capsule near its lateral extremity and run medially along the neck of the femur, deep to the reflected cuff of synovial membrane. It is in this position that the vessels are associated with retinacular fibres. As a rule they are found in groups, although occasionally a few isolated and separate vessels may be observed.

There are three main groups of retinacular arteries—postero-superior, postero-inferior, and anterior. The first two groups are branches of the medial femoral circumflex artery and they run along the upper and lower borders of the neck of the femur. If one looks at the head and neck of the right femur from the medial aspect (as in Figs. 1 and 2 insets) the postero-superior vessels are found between eleven and two o'clock, and the postero-inferior vessels between five and seven o'clock. Although the groups may extend on to the front of the
neck, they are usually posterior. These two groups are moderately large and quite consistent, the postero-superior group being usually the larger, and occasionally providing the sole supply to the epiphysis. The anterior group is the smallest and least constant; its vessels are branches of the lateral femoral circumflex artery (Figs. 1 and 2). The relative frequency of the groups, and estimations of their sizes, are shown in Tables I to III.

TABLE I
Postero-Superior Retinacular Artery

<table>
<thead>
<tr>
<th>Age</th>
<th>Number of specimens</th>
<th>Postero-superior vessels present</th>
<th>Range of size of vessels</th>
<th>Mean size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children</td>
<td>24</td>
<td>24 (100 per cent.)</td>
<td>0.125-1.875 mm.</td>
<td>0.730 mm.</td>
</tr>
<tr>
<td>Adults</td>
<td>20</td>
<td>20 (100 per cent.)</td>
<td>0.300-1.550 mm.</td>
<td>0.839 mm.</td>
</tr>
</tbody>
</table>

TABLE II
Postero-Inferior Retinacular Artery

<table>
<thead>
<tr>
<th>Age</th>
<th>Number of specimens</th>
<th>Postero-inferior vessels present</th>
<th>Range of size of vessels</th>
<th>Mean size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children</td>
<td>24</td>
<td>23 (95 per cent.)</td>
<td>0.150-0.875 mm.</td>
<td>0.467 mm.</td>
</tr>
<tr>
<td>Adults</td>
<td>20</td>
<td>16 (80 per cent.)</td>
<td>0.150-0.625 mm.</td>
<td>0.410 mm.</td>
</tr>
</tbody>
</table>

TABLE III
Anterior Retinacular Artery

<table>
<thead>
<tr>
<th>Age</th>
<th>Number of specimens</th>
<th>Anterior vessels present</th>
<th>Range of size of vessels</th>
<th>Mean size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children</td>
<td>24</td>
<td>16 (65 per cent.)</td>
<td>0.025-0.825 mm.</td>
<td>0.184 mm.</td>
</tr>
<tr>
<td>Adults</td>
<td>20</td>
<td>5 (25 per cent.)</td>
<td>0.100-0.300 mm.</td>
<td>0.250 mm.</td>
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</tbody>
</table>

TABLE IV
Foveolar Vessels

<table>
<thead>
<tr>
<th>Age</th>
<th>Number of specimens</th>
<th>Number with penetrating vessels</th>
<th>Range of size of vessels</th>
<th>Mean size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children</td>
<td>24</td>
<td>8 (33.3 per cent.)</td>
<td>0.075-0.30 mm.</td>
<td>0.183 mm.</td>
</tr>
<tr>
<td>Adults</td>
<td>20</td>
<td>14 (70 per cent.)</td>
<td>0.075-0.625 mm.</td>
<td>0.328 mm.</td>
</tr>
</tbody>
</table>

The retinacular vessels lie loosely under the synovial membrane, sometimes in mesenteric-like folds of synovial membrane. In their cervical course these vessels supply many branches to the femoral neck which anastomose with the nutrient artery of the shaft. Branches from the superior vessels are particularly numerous and they run a remarkably straight path from their origin to the base of the femoral neck. Despite the attachment of these branches, the mid-cervical parts of the retinacular vessels are quite mobile, in marked contrast to the fixation which may be noted as they approach the articular cartilage.

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Male, aged two months. Spalteholz’ preparation. Ossific centre not present. Postero-superior and postero-inferior retinacular vessels are seen. A curved penetrating foveolar vessel is passing up to the cartilaginous head. The inset is a photograph of the specimen.

Male, aged six months. Fig. 4 shows posterior view of Spalteholz’ preparation. Retinacular vessels are supplying the ossific centre and passing beyond it to the subarticular region. Foveolar vessels are spread out on the surface of the fovea. Three very small vessels pass deep to the surface but do not reach the ossific centre. Fig. 5 shows the oblique view; the superficial distribution of foveolar vessels can be seen. Insets are photographs of the specimens.
The postero-superior group of retinacular vessels do not pierce the epiphysial cartilage; they cross the plate at its periphery and then turn towards the centre of the femoral head. The postero-inferior and anterior vessels often cut the corner of the plate. Within the substance of the head, the retinacular vessels anastomose with each other, and with the nutrient and foveolar arteries if these are present.

**Foveolar artery**—The foveolar artery arises either from the obturator or medial femoral circumflex arteries, or from both. It passes into the acetabulum under the transverse ligament and, after giving off a pulvinar branch to the Haversian fat pad, it runs along the ligament to the femoral head. The foveolar vessel was present in every ligament examined, but the size varied considerably. The important question is whether or not the vessel contributes to the supply of the ossific centre, or to that of the adult head. In eight specimens out of twenty-four, in children up to the age of thirteen years, the artery penetrated the fovea and supplied the deep cartilage of the head or the ossific centre. The vessels were very small and varied from one to five in number (Figs. 7 and 8). The size of these vessels is shown in Table IV. In the other sixteen specimens the vessels spread out over the surface of the fovea like the fingers of an outstretched hand, obviously being concerned solely with supply of the fibrous tissue of the ligament and its attachment to the cartilaginous head (Figs. 4–6).

In adults there was striking alteration in the size and arrangement of the foveolar vessels. They penetrated the osseous head in fourteen out of twenty specimens. In other specimens visibility was poor, owing to red marrow and perifoveolar capillaries, and accurate observations could not be made. It is evident that there is anastomosis in at least 70 per cent. of adult cases, and possibly in more than 70 per cent. As seen in Table IV, the incidence of penetrating foveolar vessels in adults is approximately double that which is found in children, and the diameter of the vessels is increased by 80 per cent. Adult foveolar vessels are illustrated in Figs. 7 and 9.

**DISCUSSION**

There is no dispute as to the existence of three main arterial groups supplying the femoral head. Difference of opinion exists only on the questions of the relative size and importance of the vessels, and the effect which age may have on foveolar vessels. Many diverse views have been expressed. Unfortunately some investigators have failed to publish the factual basis of their studies, so that critical analysis of their papers is of little value. It is generally agreed that retinacular vessels represent the chief arterial supply to the upper femoral epiphysis and the adult head. Discussion is centred upon the relative importance of the foveolar and nutrient arteries. Foveolar vessels appear to be of significance in a minority of children, whereas in adults the vessels are of increasing value. The nutrient vessels are unimportant so far as the epiphysis of the child is concerned but they constitute a supplementary source of supply in some adults. Examination of material from avascular femoral heads has been infrequent. Observations on Perthes' disease and other necrotic lesions in
children are very rare and I can find no reference to injection of the arterial system in these conditions. We have no alternative, therefore, but to resort to hypothesis in attempting to correlate the pathological findings with known facts about the circulation.

**Relative importance of the retinacular and foveolar vessels in children**—The cartilaginous head and the ossific centre are supplied almost entirely from retinacular vessels, while in a few specimens the foveolar vessels contribute. In the series now reported, foveolar vessels penetrated the deep cartilage or the ossific centre in only eight cases out of twenty-four. Most of the vessels were small, but in view of the size of the femoral epiphysis there was every possibility that they could sustain its life. The evidence indicates therefore that the foveolar vessels never constitute the chief vascular supply to the femoral head in children, but that they are of importance in a minority of cases. If this view is accepted the site of obstructive vascular lesions causing avascular necrosis must be located in the retinacular group of vessels. The foveolar supply may afford additional protection to the ossific centre. The epiphysis in the child is more dependent upon retinacular vessels than is the corresponding area of bone in the adult, thus explaining the greater frequency of avascular necrosis in children.
Legg-Perthes' disease—Although Jackson Burrows (1941) suggested that venous obstruction might be the cause of Perthes' disease, most investigators believe that arterial obstruction of undetermined nature is the probable cause. If injury is the cause of Perthes' disease, vulnerability of the epiphysis to infarction will be greatest when the blood supply is derived largely from the postero-superior vessels. In other words, multiple sources of vascular supply provide a safeguard to the nutrition of the femoral epiphysis; and in contrast, concentration of the vascular supply to one group of vessels constitutes a potential danger. I believe that the postero-superior group of vessels is susceptible to pressure from the acetabular lip and its labrum in positions of forced abduction and external rotation of the hip, and that it is individuals with this pattern of vascular supply who are most prone to Perthes' disease. Congenital dislocation of the hip—Fragmentation of the epiphysis after reduction of congenital dislocation of the hip joint appears to be due to avascular necrosis. It is unlikely that the

changes could be produced by direct trauma; the vessels and the ossific centre lie deeply within the substance of the cartilaginous head and are thus protected from injury. Moreover it is difficult to believe that manipulative reduction would cause extensive damage to extra-capsular vessels supplying the hip joint. Again, I suggest that the postero-superior vessels are the most likely site of vascular damage. Fragmentation has been observed in the sound hip after fixation in full abduction and external rotation, but not when this joint has been left free. The degree of pressure on the vessels trapped between the femoral neck and acetabular margin depends upon the degree of abduction, the prominence of the posterior acetabular lip, and the tightness of the adductor muscles. After manipulative reduction with gentle stretching of the adductor muscles, the femur usually assumes a position of 45 degrees abduction; this may be accepted as a position of safety so far as the retinacular vessels are concerned. When the adductors are very tight, it would seem less dangerous to the circulation in the femoral head to lengthen them by tenotomy than to stretch them forcibly, using the postero-superior surface of the femoral neck as a fulcrum. Epiphyseolysis capitis femoris—Avascular necrosis is not a frequent complication of the type of epiphyseolysis which is gradually progressive. It does occur, however, in the acute traumatic type, and in cases treated by vigorous manipulative or operative reduction. Waldenström (1934) suggested that these changes were due to surgical division or rupture

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of vessels in the ligamentum teres. It is true that foveolar vessels may represent the main vascular supply remaining to the slipped epiphysis. On the other hand, if the retinacular vessels were damaged irreparably in every case of epiphyseolysis, avascular necrosis should occur more frequently. There are several anatomical facts which would explain escape from injury of the retinacular vessels when slipping occurs slowly. Displacement occurs between the epiphysial cartilage and the metaphysis (Waldenström 1930) at a level where the retinacular vessels are still quite mobile, not yet having reached the vicinity of the epiphysial plate. Thus when the epiphysial plate and epiphysis slip downwards and backwards the vessels may escape traction injury, particularly if the slipping is gradual or slight so that they may elongate and accommodate themselves to the new position of the epiphysis. But if the slipping is rapid, or extensive, the vessels are more likely to be damaged. The postero-inferior group of vessels, which are even more mobile than the postero-superior group, are more likely to be injured by forcible manipulative reduction than by gradual stretching due to progressive displacement of the epiphysis.

**Relative importance of retinacular and foveolar vessels in adults**—In the adult, the united epiphysis receives nourishment from additional sources. The retinacular vessels are still predominant, but the nutrient foveolar vessels take over an increasing share. In fourteen of the twenty specimens examined, foveolar vessels penetrated the femoral head and supplied it with a significant amount of blood, thus confirming Wolcott's observations. The foveolar supply is, however, variable: sometimes there is none, but in the majority of cases it is present to a variable extent.

**Fracture of the neck of the femur**—In fractures of the neck of the femur, the fate of the head depends upon the residual vascularity, which is decided at the moment of maximal displacement of the bone. It is obvious that all intra-osseous vessels in the neck are disrupted and that blood supply depends wholly on the retinacular and foveolar vessels. It seems reasonable to assume that displacement of the fragments is greatest when the fracture line is vertical, and least when it is more horizontal, especially when there is impaction of the fragments. The fracture-shaft angle may be accepted as an index of the degree of displacement, and probably therefore as a guide to the likelihood of damage to the retinacular arteries. The statistics of Eyre-Brook and Pridie (1941) suggest that when the fracture-shaft angle is greater than 40 degrees, displacement of the fragments is insufficient to cause disruption of the retinacular vessels.

It is difficult to estimate the frequency with which the adult femoral head can be nourished fully by the foveolar artery. There is a variable foveolar supply in 70 per cent. of cases, the vessels being capable of maintaining the nutrition of the whole femoral head in some cases (Schmorl 1924, Hesse 1925, Santos 1930), and of no more than a limited area near the fovea in others. In the other 30 per cent., loss of the retinacular supply would be expected to cause avascular necrosis.

One patient who died four months after fracture of the femoral neck showed the importance of the foveolar vessels. There was complete disruption of the retinacular vessels but the foveolar vessels were intact. The medial third of the head was alive; the other two-thirds, which had died, was already revascularised fully from the living segment and new bone was being laid down on the dead trabeculae. There is of course abundant evidence that, in the adult, complete regeneration is slow and usually incomplete, especially when the avascular fragment is large (Phemister 1939). Only when there are large foveolar vessels is vitality of the head likely to be maintained to a degree compatible with a good end-result. It must not be forgotten, however, that proper reduction and immobilisation of the fracture may also assist in revascularisation of the proximal fragment. Clearly, every effort should be made to avoid damage to the foveolar arteries.

**Avascular necrosis due to the Smith-Petersen nail**—There is no direct evidence as to the way in which the foveolar supply may be affected by a Smith-Petersen nail. Linton (1944) suggested
that there was significant difference in the incidence of necrosis as between cases treated by means of a Smith-Petersen nail and those immobilised by Nystrom's three small nails. Avascular necrosis occurred in 39.5 per cent. of fractures treated by the massive nail and only in 9.3 per cent. of fractures immobilised by small nails. The explanation seems to be obvious. Any object driven into the bone near the fovea may disrupt the foveolar vessels. Furthermore, in so far as the anterior part of the head usually receives its blood supply from the posterior set of retinacular vessels, a large centrally placed object may sever intra-osseous arteries. The foveolar vessels are most prone to damage if the nail is near the fovea and with its tip flush with the articular surface. Nystrom's nails, and Austin Moore's pins, are inserted more peripherally than the Smith-Petersen nail and their bulk is dispersed; for this reason they are likely to cause less damage. The risk of a Smith-Petersen nail may perhaps be reduced by inserting it eccentrically and avoiding the foveolar area.

Traumatic dislocation of the hip joint—There is little evidence as to the incidence of vascular damage in traumatic dislocation of the hip joint. Kleinberg (1944) reported a case in which the foveolar vessels were still patent after such injury, but in the majority of cases the ligamentum teres must be ruptured so that there can be no vascular supply to the femoral head from foveolar vessels. The incidence of avascular necrosis must depend first upon the frequency of damage to retinacular vessels, and then upon the incidence of anastomosis between these vessels and the nutrient arteries. In children no nutrient vessel was detected crossing the epiphysial line from the metaphysis to the epiphysis. In some adults, however, there was such anastomosis. Thus, avascular necrosis after traumatic dislocation of the hip joint, due to rupture of the retinacular vessels in cases where there is no adequate anastomosis between these vessels and the nutrient artery, must be expected to occur more frequently in children than in adults.

**SUMMARY**

1. The arterial supply of the upper end of the femur has been studied in twenty-four children and twenty adults.
2. The arterial system was demonstrated by injection of radio-opaque material, with Spalteholz' method of clarification, and histological section of the neck and ligamentum teres.
3. The upper end of the femur is supplied by the nutrient artery of the shaft, the retinacular vessels of the capsule, and the foveolar artery of the ligamentum teres.
4. The retinacular vessels consist of three separate groups: postero-superior, postero-inferior, and anterior. These vessels are the chief supply to the epiphysis and femoral head at all ages.
5. The foveolar artery constitutes a small and subsidiary blood supply to the femoral epiphysis. In this series, it penetrated the cartilaginous or osseous head in 33 per cent. of young specimens and 70 per cent. of adult specimens. The foveolar vessels increase in size with age.
6. The site of the vascular pathology in various lesions of the femoral head is considered.

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