The surgical anatomy of the blood supply to the femoral head

DESCRIPTION OF THE ANASTOMOSIS BETWEEN THE MEDIAL FEMORAL CIRCUMFLEX AND INFERIOR GLUTEAL ARTERIES AT THE HIP


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The inferior gluteal artery is described in standard anatomy textbooks as contributing to the blood supply of the hip through an anastomosis with the medial femoral circumflex artery. The site(s) of the anastomosis has not been described previously. We undertook an injection study to define the anastomotic connections between these two arteries and to determine whether the inferior gluteal artery could supply the lateral epiphyseal arteries alone. From eight fresh-frozen cadaver pelvic specimens we were able to inject the vessels in 14 hips with latex moulding compound through either the medial femoral circumflex artery or the inferior gluteal artery. Injected vessels around the hip were then carefully exposed and documented photographically.

In seven of the eight specimens a clear anastomosis was shown between the two arteries adjacent to the tendon of obturator externus. The terminal vessel arising from this anastomosis was noted to pass directly beneath the posterior capsule of the hip before ascending the superior aspect of the femoral neck and terminating in the lateral epiphyseal vessels. At no point was the terminal vessel found between the capsule and the conjoined tendon. The medial femoral circumflex artery receives a direct supply from the inferior gluteal artery immediately before passing beneath the capsule of the hip.

Detailed knowledge of this anatomy may help to explain the development of avascular necrosis after hip trauma, as well as to allow additional safe surgical exposure of the femoral neck and head.

It is accepted that the primary blood supply to the femoral head in the adult is the terminal extent of the deep branch (also known as the ramus profundus) of the medial femoral circumflex artery. Standard textbooks describe the additional contribution of the cruciate anastomosis to the blood supply to the hip in general. The vessels contributing to this anastomosis have been variously reported as including the obturator, the lateral femoral circumflex, the inferior gluteal, the superior gluteal and possibly the first perforating arteries in addition to the medial femoral circumflex artery. Recently, Gautier et al reported that the inferior gluteal portion of this anastomosis was “constant” and could potentially provide adequate blood to the femoral head if the medial femoral circumflex artery was damaged. Despite the potential importance of this portion of the cruciate anastomosis, there remains no detailed description of either the course of the inferior gluteal artery in the trochanteric region or of connections between it and the medial femoral circumflex artery.

We performed a series of injections into the medial femoral circumflex artery and inferior gluteal artery in an attempt to delineate precisely the site or sites of connection between the deep branch of the medial femoral circumflex artery and the inferior gluteal artery.

Materials and Methods

We obtained eight fresh-frozen pelves with their hips (Anatomic Gifts Registry, Hanover, Maryland), none of which were known to have hip disease. Two specimens were shared with other researchers, in which only one single side was injected and dissected in each. Bilateral studies were carried out in the six remaining specimens. Thus a total of 14 investigations were performed.

Vascular injections were through either the medial femoral circumflex artery in three specimens and the inferior gluteal artery in 11 specimens. Access to the former was obtained by dissection through the femoral triangle. Angiography was performed in either the superficial or deep femoral artery at the level of...
branching of the lateral femoral circumflex artery at which point the medial femoral circumflex artery was easily identified as exiting posteriorly. Access to the inferior gluteal artery was obtained through either intrapelvic or extrapelvic dissection as it crossed behind piriformis. All the specimens were injected in a standardised fashion after cannulation with a 14-gauge angiocatheter. Industrial liquid rubber compound PMC-780 (Smooth-On, Easton, Pennsylvania) was prepared and coloured with the dye So-Strong (Smooth-On) following the recommendations of the manufacturer and injected using a pressurising cement gun. Once injected the latex was allowed to cure for at least 16 hours in accordance with the manufacturer’s instructions.

All the dissections were done through an extended posterior approach to the hip. In each case the vessels were dissected to their terminal branches in the trochanteric region to ascertain if the ramus profundus of the medial femoral circumflex artery was perfused. Additionally, the hip capsule was opened to evaluate perfusion of the lateral epiphyseal arteries along the superior aspect of the femoral neck.

Results

Of the 14 possible specimens, 11 were successfully injected through either the medial femoral circumflex artery or the inferior gluteal artery (Table I). There were three technical failures, one due to poor pressurisation and two to failure to cannulate the inferior gluteal artery. Of the successful injections, ten specimens showed a clear anastomosis between the medial femoral circumflex artery and the inferior gluteal artery as documented by retrograde flow in the alternate vessel (Table I).

Retrograde injections into the vasculature of the inferior gluteal artery. In all three medial femoral circumflex artery injections, retrograde flow was observed into the inferior gluteal artery in a characteristic pattern through one to three vessels located either superior or inferior to the conjoined tendon.

Antegrade injections through the inferior gluteal artery. In eight of nine inferior gluteal artery injections a direct anastomosis was observed with the ramus profundus of the medial femoral circumflex artery through a medium-sized vessel of 1 mm to 3 mm in diameter at or about the point where it crossed over the tendon of obturator externus. The pattern of these anastomoses was identical to that seen in those specimens in which filling of the inferior gluteal artery occurred in a retrograde fashion after injection of the medial femoral circumflex artery.

Course of the inferior gluteal artery and description of anastomotic sites. Most of the course of the inferior gluteal artery has been described well in standard texts. In the gluteal region, it descends in the company of the sciatic nerve, sending two to four branches posteriorly and laterally to gluteus maximus, a branch to the sciatic nerve, and branches into the sacrotuberous ligament. In addition, from our latex injections we identified three branches which contributed to the cruciate anastomosis. These ran from posterior-medial to anterolateral on either side of the conjoined tendon. Two of these branches have been reported as the ‘anastomotic’ and ‘articular branches’, respectively in an early edition of *Gray’s Anatomy*. We have attempted to retain that nomenclature for consistency, although the terminology seems to be inappropriate given the distribution which we found. We consider the anastomotic branch to be the piriformis branch described by Gautier et al and the articular branch to be one of two contributions.

The piriformis branch (‘anastomotic branch’) diverged from the main trunk of the inferior gluteal artery at about the level of the superior gemellus. It crossed posteriorly (superficially) to the sciatic nerve in all but one specimen, and continued laterally, running between piriformis and the superior gemellus (Fig. 1). Along the course of this vessel, many small branches were given off passing to the adjacent muscles. Early in its course, a branch was given off which proceeded deeply between piriformis and the superior gemellus to the posterolateral capsule and labrum. In the area of the greater trochanter the piriformis branch split into three or four smaller branches. Some of these arborised to supply the posterior aspect of the tendon of gluteus medius just proximal to the greater trochanter and others coursed posteriorly to the tendon of piriformis. A direct

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Right side</th>
<th>Left side</th>
<th>Anastomosis</th>
<th>Site of anastomosis</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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<td>LFCA*</td>
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<td>Piriformis and capsular branches</td>
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<td>IGA</td>
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</tr>
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<td>IGA</td>
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<td>Inferior gemellar branch</td>
</tr>
<tr>
<td>5</td>
<td>IGA</td>
<td>MFCA</td>
<td>Yes bilaterally</td>
<td>Inferior gemellus, capsular and piriformis branches</td>
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<td>Yes</td>
<td>Capsular branch</td>
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<tr>
<td>8</td>
<td>MFCA</td>
<td>Not injected</td>
<td>Yes</td>
<td>Piriformis branch</td>
</tr>
</tbody>
</table>

* LFCA, lateral femoral circumflex artery
† SGA, superior gluteal artery
anastomosis between the ramus profundus and the piriformis branch (Figs 1 and 2) occurred in five of seven specimens in which an anastomosis was found. Each time such an anastomosis occurred, the piriformis branch travelled posteriorly across the piriformis and conjoined tendons and met the medial femoral circumflex artery in the interval between the inferior gemellus and the tendon of obturator externus.

The inferior anastomotic supply consisted of one or two vessels, one superficial and one deep, both running in the interval between the inferior gemellus and quadratus femoris. We consider that the deeper branch represented the 'capsular branch' described previously, and the more superficial branch the 'quadratus branch' which we have named based on the structures with which the vessels was most intimately associated.
The capsular branch was present in all specimens. It arose from the inferior gluteal artery at about the level of the inferior border of the inferior gemellus, and coursed anteriorly (deep) to the sciatic nerve. It always ramified to supply the proximal capsule and labrum, and continued across the capsule laterally, just cranial to the tendon of obturator externus (Fig. 2). In four specimens this vessel terminated in the lateral portion of the capsule. Equally frequently, it continued transversely and made a direct connection with the ramus profundus at the posteroinferior margin of the capsule of the hip, just cranial to the tendon of obturator externus. In other specimens there was a second, more superficial inferior supply which we have referred to as the quadratus branch. This was quite large bilaterally and crossed quadratus femoris in a retrograde fashion. When present, this branch always travelled directly to the region of the tendon of obturator externus anastomosing in that area with the ramus profundus (Fig. 3). In two specimens, it travelled a noticeably more direct route to the hip capsule than the medial femoral circumflex artery. In these specimens the inferior gemellar branches terminated as the lateral epiphyseal arteries, and the deep branch of the medial femoral circumflex artery appeared to enter the inferior gemellar branch perpendicularly, in a ‘T’ fashion.

In all cases, regardless of which branch of the inferior gluteal artery provided the anastomotic vessel, the anastomosis occurred as the ramus profundus crossed behind and over the tendon of obturator of externus (Figs 2 and 3). This vessel then passed directly under the posterior orbicular fibres of the hip capsule while still on the postero-superior aspect of the femoral neck. Once under the capsule, it coursed subsynovially and obliquely upwards along the femoral neck, and finally split into two to four lateral epiphyseal arteries. We found that the ramus profundus always proceeded beneath the capsule before arriving at the superior aspect of the neck. As the vessel passed deep to the conjoined tendon, it was always protected by a portion of the hip capsule.

In the three examples in which the medial femoral circumflex artery was injected, we also noted latex filling of the medial epiphyseal arteries. This was occasionally noted even
in specimens injected through the inferior gluteal artery. These vessels were found to course in a vincular reflection of the synovial fold at the posteroinferior aspect of the neck. They have been well described previously by Harry and Sevitt and Thompson. We noted one or two vincular vessels which ramified within 3 mm to 5 mm from the physisal scar into four or more terminal epiphyseal vessels. These vessels were distributed along the posteroinferior aspect of the head-neck junction at the five or seven o’clock position, respectively, according to the side of the specimen.

Discussion
Various aspects of the cruciate anastomosis between the inferior gluteal and medial femoral circumflex arteries have been described for at least 100 years. However, the surgical implications have only recently been considered. In the 1918 edition of Gray’s Anatomy, anastomotic connections were described between the internal and external iliac systems through the medial femoral circumflex and the inferior arteries, with the anastomotic branches of the inferior gluteal artery being described as “directed downward across the external rotators, and assist(ing) in forming the so-called crucial anastomosis”. This description has persisted largely unchanged into the 38th edition of this classic text. This ‘crucial’ or ‘cruciate’ anastomosis has many different descriptions. Constant constituents are variously said to be ‘crucial’ or ‘cruciate’ anastomosis has many different descriptions. Constant constituents are variously said to be ‘crucial’ or ‘cruciate’ anastomosis has many different descriptions. Constant constituents are variously said to be ‘crucial’ or ‘cruciate’ anastomosis has many different descriptions.5

Gautier et al most recently mentioned the anastomosis between the inferior gluteal artery and the obturator externus in a report detailing the course of the medial femoral circumflex artery. They noted that there was a consistent blood supply to the femoral head through the medial femoral circumflex artery without any apparent contribution from the lateral femoral circumflex artery. In addition, they described a significant constant anastomosis with the inferior gluteal artery occurring through a branch which they indicated as travelling along piriformis. Without more specific comment on that anastomosis, they stated their belief that it “may be capable of compensating after injury to the deep branch of the MFCA”. Nonetheless, no specific description was offered of the precise location of the anastomotic connections between these two vessels.

We were able to produce clear evidence of retrograde flow from the external iliac system, through the medial femoral circumflex artery, into the internal iliac system through the inferior gluteal artery, in all three specimens in which the medial femoral circumflex artery had been injected. The pattern was similar in all three injections, and resulted in filling of the inferior gluteal artery with latex through branches extending from the trochanteric fossa. One branch ran between the superior gemellus and piriformis and the second ran either along the capsule adjacent to the tendon of obturator externus or more superficially between the inferior gemellus and quadratus femoris. We were able to elaborate on those anastomoses through antegrade injections directly into the inferior gluteal artery. This allowed precise determination of the source and sites of any connection between the deep branch of the medial femoral circumflex artery and the inferior gluteal artery. Our dissections established the extent of the ramus profundus and lateral epiphyseal arteries to confirm the hypothesis of Gautier et al that the inferior gluteal artery is able to perfuse the femoral head in the absence of medial femoral circumflex artery inflow. In all successfully-injected specimens with an anastomosis we were able to fill the lateral epiphyseal and also the medial epiphyseal arteries.

Our dissections showed that the ramus profundus stayed close to the level of the tendon of obturator externus in the transverse plane until it ran under the posterior aspect of the hip capsule, the zona orbicularis. The vessel coursed relatively anteromedially along the neck until it reached the posterior capsule, but it never travelled in a significantly-cranial direction, and was never found in the interval between the capsule and the gemelli and obturator internus.

We have hypothesised on the surgical and pathological implications of these findings. Jedral et al described the fetal pattern of the blood supply to the hip as being dominated by the inferior gluteal artery in more than 50% of the cases they examined. In some of our specimens the inferior gluteal artery appeared to be the more dominant vessel in terms of both the direct course of specific inferior gluteal artery branches to the lateral epiphyseal arteries and the many sources of inflow to the ramus profundus from the inferior gluteal artery relative to the single medial femoral circumflex artery source. It may be that some aspect of this variability in fetal development leaves some hips more susceptible to vascular insult in this region. In addition, we believe that our dissections provide a better understanding of the final blood supply to the femoral head. In all seven specimens with an anastomosis, the deep branch of the medial femoral circumflex artery received significant additional inflow from vessels derived from inferior gluteal artery immediately after it crossed the tendon of obturator externus. It may be more accurate to consider the ramus profundus, which is destined to become the lateral epiphyseal arteries, to be a common vessel with input from many sources.
The sequelae of traumatic dislocation of the hip may be better understood based on this concept of the anatomy. It may be that the presence of a proximally-based blood flow at the level of the posterior hip capsule is protective against vascular insult. In the event of a posterior dislocation, such vessels based on the inferior gluteal artery should have more ability to accommodate the extreme displacement of the femoral head. It is apparent from clinical reports that not all posterior dislocations, with or without accompanying fractures, result in avascular necrosis of the femoral head.\textsuperscript{14-16} In these circumstances perhaps it is this added supply to the ramus profundus of the medial femoral circumflex artery which prevents the occurrence of avascular necrosis.

In conclusion, we reliably cannulated the inferior gluteal artery and were thus able to document the precise course and site of anastomoses of branches contributing to the cruciate anastomosis. We found both the occurrence and the site of these anastomoses to be remarkably consistent and located near easily identifiable local landmarks. This information may be relevant in surgical practice to decrease the risk of iatrogenic avascular necrosis during posterior approaches to the hip.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References