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A Variant of the First Perforating Artery Passing Immediately below the Quadratus Femoris: a Case Report and a Study of the Territorial Relationship between the Perforating Artery and the Descending Branch of the Medial Circumflexus Femoral Artery

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ABSTRACT **The authors encountered an anatomical variant in which the first perforating artery (FPA) emerged posteriorly immediately below the quadratus femoris muscle. Although the usual medial circumflexus/circumflex femoral artery (MCFA) was coexistent, the variant suggested an intermediate morphology between the FPA and the usual descending branch of the MCFA. Using the observations from 51 lower extremities, we examined configurations of these arteries with special reference to the territorial correlation, i. e., whether the descending branch of the MCFA shows complementary territorial relations with the FPA and, if so, whether there is an intermediate morphology between these two arteries. The MCFA consistently supplied a limited area of the posterior thigh, whereas the FPA varied independently in its territory but consistently was the most dominant of all arteries supplying the region. Consequently, the variant might occur as a result of a muscular variation, and the suggested intermediate morphology was not evident.**

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Key words: Perforating artery, Medial circumflexus femoral artery, Human gross anatomy

1 Introduction

The first perforating artery (FPA), running through the uppermost portion of the adductor magnus (i. e., between the adductor minimus and adductor magnus), is a major feeding artery of the posterior thigh muscles[1]. It is also known that the medial circumflexus/circumflex femoral artery (MCFA) gives off the so-called descending branch, which passes between the quadratus femoris and adductor magnus muscles and supplies the posterior thigh muscles[2] (Fig. 1). However, few descriptions of the descending branch have been published. Moreover, according to recent systems of anatomical nomenclature, the name "descending branch" is omitted and changed into the transverse branch of the MCFA[1,3].

The authors encountered a variant in which the FPA emerged posteriorly immediately below the quadratus femoris muscle. Although the usual MCFA was coexistent, the variant suggested an intermediate morphology between the FPA and the descending branch of the MCFA. Is there another variation showing an intermediate form between them? Does the MCFA play a complementary role with the

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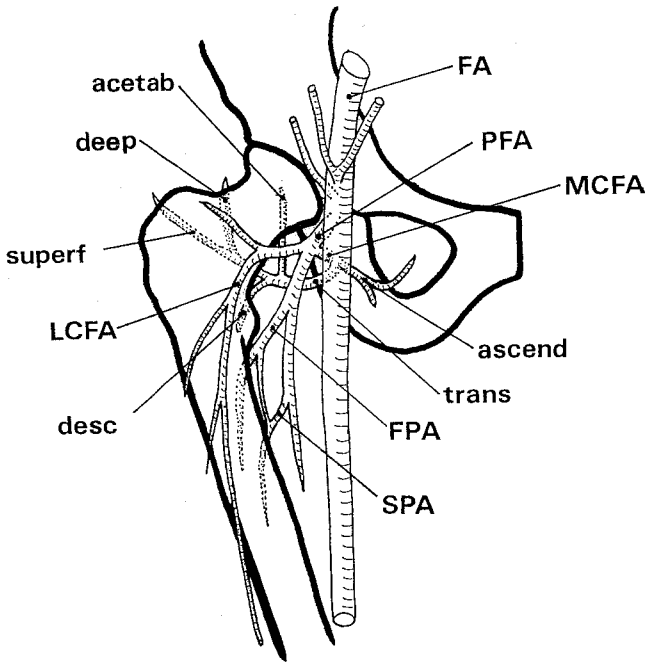

Fig. 1 A "typical" medial circumflexus femoral artery.
From the anterior aspect: The medial circumflexus femoral artery (MCFA) divides into the ascending branch (ascend), the tranverse branch (trans), the acetabular branch (acetab), the descending branch (desc), the deep branch (deep) and the superficial branch (superf). However, this scheme may be one of interpretations of the arterial morphology. FA, femoral artery; FPA/SPA, first/second perforating artery; LCFA, lateral circumflexus femoral artery; PFA, profunda femoris artery.

FPA for blood supply to the posterior thigh? The aim of this report is to examine the variant and to examine these two arteries compared to other specimens in order to obtain a better understanding of the configuration of arterial supply to the posterior aspect of the thigh.

2 Materials and Methods

2. 1 The FPA variant.

The variant was found in the left thigh of a donated female cadaver, aged 72 years, initially examined during a dissection practice course for medical students at Sapporo Medical University in 1998. The variant was noticed after several dissections were performed by students in the investigated region. After that, the specimen was minutely dissected under the naked eye and depicted in drawings. No variation was evident in the same region of the contralateral side of the specimen (see Results, the last paragraph of subsection 3.1 entitled "*The variant case*").

2. 2 Usual distribution of the perforating arteries and the descending branch of the MCFA.

To clarify the usual territorial patterns of these arteries and to compare with the variant case above, 51 lower extremities (11 left and 40 right) from 49 donated cadavers, aged 65–91 years, were examined macroscopically during dissection practice courses at both Sapporo Medical University and Asahikawa Medical University in 1998. Our question was which artery is the descending branch of the MCFA when viewed from the posterior aspect? Sato *et al.*[4] indicated the frequent but small contribu-

tion of the MCFA to the blood supply of the hamstring muscles. We therefore considered a working hypothesis that the descending branch, if present and even if poorly developed, consistently supplied the origin of the hamstring muscles near the ischial tuberosity, and that, if well-developed, the descending branch gave off a longer branch to the origin of the above-mentioned muscles.

The distribution of arteries in the posterior aspect of the thigh was depicted in drawings, and we measured the length and diameter of these arteries. To equalize variations of body size, we defined the arterial territory as the proportional length in which a certain arterial territory occupied between the top of the greater trochanter and the top of the fibular head (the greater trochanter = 0, the fibular head = 100). For instance, if an artery entered the region at the 20-length point, i.e., 20/100 level distal from the greater trochanter, and supplied muscles at the 40, 45, and 50 length-points, its (maximum) territory was indicated as "30 proportional length" (50-20=30). Using this method, we estimated the distribution of each MCFA (its descending branch), FPA, and other perforating arteries, i.e., the second, third and others, including the medial perforating artery so-called by Kato[5] and Yamada *et al.*[6], as the proportion of the region it occupied.

3 Results

3. 1 The variant case (Figs. 2 and 3).

The arterial ramification pattern of the femoral artery nearly correspond to Type I of Adachi's classification[7] in variant side as well as contralateral side.

The profunda femoris artery originated from the femoral artery at a higher position than usual, i.e., just behind the inguinal ligament. The "usual" MCFA issued from the profunda femoris artery at a point 20 mm distal to the origin. The MCFA, 2.7 mm in diameter at its origin, first gave off three small branches to the pectineus muscle. The MCFA ran posteromedially between the iliopsoas and pectineus muscles and then between the obturator externus and adductor brevis muscles. After a 55-mm course from the origin, it gave off a branch to the obturator externus muscle (1.6 mm in diameter) and it proceeded to immediately below the ischial tuberosity. Close to the tuberosity, 65 mm from the origin, the MCFA divided into several muscular branches (1.6-3.3 mm in diameter) and the ascending branch (1.2 mm in diameter). These muscular branches, corresponding to the descending branch (i.e., the transverse branch, see Materials and Methods), supplied the origins of the adductor longus, semimembranosus, and semitendinosus muscles. The ascending branch emerged as a thin branch at the upper margin of the quadratus femoris muscle.

The lateral circumflexus femoral artery arose from the profunda femoris artery at a point 55 mm distal to the origin of the latter. The profunda femoris artery ran downward along the iliopsoas muscle, i.e., between the pectineus and adductor brevis muscles, and then between the adductor magnus and adductor brevis muscles. During its course, the profunda femoris artery gave off several branches to the iliopsoas muscle (0.8-1.4 mm in diameter). The variant FPA, 4.2 mm in diameter at its origin, originated from the profunda femoris artery at a point 110 mm distal to the origin of the latter. The FPA ran between the adductor longus and adductor magnus and then between the adductor magnus and quadratus femoris muscles. The adductor minimus muscle, clearly separate from the adductor magnus muscle in usual specimens, was not observed in this case.

The FPA emerged immediately below the quadratus femoris muscle, as the transverse branch of the MCFA usually does (Fig. 1), and ran laterally along the lower margin of the muscle. This FPA reached the gluteus maximus muscle after giving off a distinct branch to the greater trochanter. Then, the FPA turned abruptly downward to run nearly along and anterior to the sciatic nerve. The FPA supplied most parts of the posterior thigh, i.e., most parts of the adductor longus, semimembranosus,

semitendinosus, adductor magnus and the long head of the biceps femoris muscle, and some cutaneous areas. In the posterior aspect of the thigh, the FPA was distributed over a long area extending from 85 mm to 260 mm distal to the top of the greater trochanter (from 21.5 to 66.5 proportional length). The popliteal artery appeared in the posterior aspect, i.e., in the popliteal fossa, 240 mm distal to the trochanter (61.5 proportional length). At this 240-mm point, the popliteal artery gave off a muscular branch 2.4 mm in diameter, which was the first and only artery supplying the posterior thigh except for the variant FPA and thin small branches of the MCFA. Thus, this variant FPA seemed to be a highly developed case.

After putting forth the FPA, the profunda femoris artery was reduced considerably in diameter, and it ran along the linea aspera between the adductor magnus and adductor longus muscles, this supplying these two muscles. The artery did not reach the popliteal fossa. No perforating artery, other than the variant FPA, was not observed. The so-called medial perforating artery[5,6], which does not perforate the tendinous insertion but runs through the adductor magnus muscle itself, was also absent.

Concerning territorial proportions (see below and Materials and Methods), the variant FPA occupied 44.9% of the length (from 21.8 to 66.7 proportional length) in the posterior thigh, while the descending branch of the MCFA occupied a 2.0% length without overlap in territory and proportional length. The popliteal artery emerged in the popliteal fossa at the 61.5-length point between the greater trochanter and fibular head (average: 63.4, see below).

In the contralateral side of the variant specimens, the profunda femoris artery arose from the femoral artery at a lower position than the inguinal ligament, as usual. The MCFA arose from the profunda femoris, ran through the obturator externus muscle and emerged at the posterior thigh. Its descending branch, that was very short, supplied the most proximal portion of hamstring muscles. Whereas the FPA, arising from the profunda femoris and running between the adductor minimus and magnus muscles, distributed hamstring muscles. The proportional length of the MCFA was 8.1, whereas that of the FPA was 29.8. The popliteal artery appeared in the posterior aspect of the thigh at the 64.9 proportional length.

The comites vein/veins was/were found along all of the arteries described above in both sides of the variant specimen.

3. 2 Usual distribution of the perforating arteries and the descending branch of the MCFA (Tables 1 and 2).

In 25 specimens (25/51, 49.5%), the MCFA supplied small branches to the origin of the hamstring muscles. These branches, such as the descending branch of the MCFA in this study sometimes (18/51) were well-developed enough to supply the proximal portion of these muscles more than 30 mm below the ischial tuberosity. The descending branch emerged below the quadratus femoris muscle at the 18.0-length point on average (range, 7.0-24.0 proportional length) distal to the top of the greater trochanter. The branch ranged from 0.5-3.2 mm in diameter at its emergence; however, distribution was restricted within the 23.0 proportional length of the posterior thigh, even if well-developed. This branch consistently supplied the origin of the semimembranosus muscle and often (40.0%) supplied the entire origins of hamstring muscles. Notably, the lower margin of the MCFA territory usually corresponded to the upper margin of the FPA territory. Thus, the territorial overlap of these two arteries was quite limited. In contrast, we only found the poorly-developed descending branch that we defined in our working hypothesis (see Materials and Methods). Overall, the territory of the descending branch was consistently small (9.7 proportional length at average).

The usual profunda femoris artery originated from the femoral artery at a lower position than the

Table 1 Summary of size, location, and territory of arteries

	Number of Specimens	Average Diameter (range)	Territory (proportional length)[1]		
			Upper Margin	Lower Margin	Length of Territory
MCFA[2]	25/51 (49.0%)	1.7 mm (0.5-3.2 mm)	18.0 (7.0-24.0)	27.9 (17.0-33.0)	9.7 (3.0-23.0)
FPA[3]	51/51 (100%)	3.0 mm (1.0-4.8 mm)	27.4 (19.0-36.0)	55.0 (32.5-71.5)	27.1 (5.0-43.5)
Other PA[4]	47/51 (92.2%)[5]	2.0 mm (0.9-4.6 mm)	47.6 (24.0-68.5)	59.0 (33.5-85.0)	10.8 (1.5-34.0)

[1] The proportional length (0=top of the greater trochanter, 100=top of the fibular head) indicates the size and location of the arterial territory.
[2] The descending branch of the medial circumflexus femoral artery (MCFA).
[3] The first perforating artery (FPA).
[4] Perforating arteries (PA) including the medial PA, and excluding the FPA.
[5] The 47 specimens encountered total 104 perforating arteries including the medial PA. The medial PA was found in 33/51 (64.7%) specimens.

Table 2 *Size, location, and territory of perforating arteries*

Perforating[1] Arteries	Number of Specimens	Average Diameter[2] (range)	Territory (proportional length)[3]		
			Upper Margin	Lower Margin	Length of Territory
1 st PA	51/51 (100%)	3.0 mm (1.0-4.8 mm)	27.4 (19.0-36.0)	55.4 (32.5-71.5)	27.5 (5.0-43.5)
2 nd PA	33/51 (64.7%)	2.2 mm (1.3-4.6 mm)	43.6 (24.0-66.5)	56.7 (40.0-81.0)	12.7 (4.0-34.0)
3 rd PA	13/51 (25.6%)	2.2 mm (1.3-3.5 mm)	49.9 (32.5-60.0)	62.3 (40.5-78.0)	12.5 (2.5-22.0)
4 th PA	4/51 (7.8%)	2.6 mm (2.4-2.8 mm)	55.6 (37.0-68.5)	65.4 (47.5-85.0)	12.5 (9.0-16.5)
5 th PA	1/51 (2.0%)	3.0 mm	47.0	62.5	15.5
Popliteal A.	51/51 (100%)	not measured	63.4 (52.0-75.5)	—	—
Post. sup. br.[4]	43/51 (84.3%)	2.0 mm (0.8-3.4 mm)	68.7 (55.5-86.0)	75.0 (60.5-92.5)	7.7 (2.0-13.5)

[1] Perforating arteries running through the tendinous insertion, not including the medial perforating artery.
[2] Average diameter at the entrance into the posterior aspect.
[3] Size and location of the arterial territory are shown by proportional length: 0=top of the greater trochanter, 100=top of the fibular head.
[4] Posterosuperior branch arose from the popliteal artery immediately after the entrance into the superior aspect.

inguinal ligament. The FPA, consistently present, emerged between the adductor muscles at the 27.4 proportional length on average (range, 19.0-36.0) distal to the top of the greater trochanter. The adductor minimus was clearly identified in all specimens examined except for the variant case. The FPA was 3.0 mm in diameter on average (range, 1.0-4.8 mm) at its emergence in the posterior aspect. These diameters seemed not to corelate with those of the MCFA. More than half (34/51) of the FPAs reached the lower half of the region. The FPA frequently (86.2%) supplied hamstring muscles, although its territory was sometimes (13.8%) restricted in one of the hamstring muscles. Whereas it never ran laterally to reach the gluteus maximus muscle and its branch never supplied this muscle. The adductor magnus muscle was not supplied by this artery but by the medial perforating artery (see below) and/or the second and/or third perforating arteries. The territory that it occupied in the posterior thigh was estimated at the 27.5 proportional length on average. This territory usually overlapped that of the second perforating artery, although the FPA varied considerably in the size of its territory (range, 5.0-43.5 proportional length).

The popliteal artery and its posterosuperior branch seemed to be the critical factor that could cause the territory of the FPA to change. The posterosuperior branch, one of the superior muscular branches in Gray's Anatomy[1], arose from the popliteal artery immediately after its entrance into the popliteal fossa. The popliteal artery entered into the popliteal fossa at the 63.4 proportional length on average

(range, 52.0–75.5). In six cases where there was a higher entrance of the popliteal artery (greater than the 60 proportional length from the trochanter) with its posterosuperior branch, the territory of the FPA was reduced considerably to 17.0 proportional length.

The number of total perforating arteries varied in specimens (one to four per specimen). The medial perforating artery[5,6] was found often (33 of 51 specimens; one to four per specimen). These arterial configurations, including the FPA and MCFA, are summarized in Tables 1 and 2. Notably, the territories of the lower perforating arteries (second, third, and others) entirely or partly overlapped each other. Overall, the distinct territorial proportion of the FPA indicated that it was the most dominant artery in this region.

In two cadavers in whom we examined both sides of the lower extremities, the arterial configuration of one side, e.g., the proportional territory of the FPA and total number of perforating arteries, was similar to that of the contralateral side. Finally, the femoral artery ramification pattern was also examined according to Adachi's classification[7]: Type I, 60.0%; Type II, 12.5%; Type III, 17.5%; Type IV, 7.5%; Type VIII, 2.5%. However we could not find any relation between the territorial proportion of the perforating arteries and the ramification pattern.

4 Discussion

At the beginning of this study, we hypothesized that the variant FPA that emerged posteriorly immediately below the quadratus femoris muscle implied an intermediate morphology between the FPA and MCFA. However, the usual MCFA was found to be coexistent. After additional observations in another 51 normal lower extremities, we found neither similar variants nor a complementary territorial relation between the two arteries. Nevertheless, we confirmed our working hypothesis as to the identification of the descending branch of the MCFA; it emerges just anteriorly to the origin of the hamstring muscles near the ischeal tuberosity and supplied limited proximal areas of these muscles. We also demonstrated systematically the territorial variation and relation of certain arteries using the proportional length method. We found that the FPA enlarged or reduced its territory irrespective of the morphology of the descending branch of the MCFA. The territory of this branch was restricted within a small proximal area: the territories of both arteries did not overlap. The MCFA might never replace the FPA, and vice versa. The complementary territorial relation between the popliteal artery and perforating arteries, however, was evident. The MCFA appears to be not absolutely critical in clinical terms, due to the possible collateral blood supply from the inferior gluteal and obturator arteries, even though the MCFA is regarded as one of the several feeders of the femoral head and neck[8]. The FPA is also considered to be noncritical due to the presence of several perforating arteries[1], and it has no relation to the origin of the profunda femoris artery.

The MCFA consistently supplied a limited area of the posterior thigh, whereas the FPA supplying area varied, but the FPA consistently was the most dominant of all arteries in the region except for the popliteal artery. Is the present variant a missing link between two different arterial configurations? As an example of a systemic abnormality caused by a basic developmental error, a strange variant without similar reported examples seemed to occur in the arterial system[9]. But in general, we hardly believed that a certain arterial variant would occur singlely without any similar examples in other specimens that would suggest gradual changes between the variant and usual form. Moreover, Ohuchi[10] suggested that the adductor minimus variation was not so rare. Consequently, the present variant might occur as a result of a muscular variation, e.g., in a poorly developed adductor minimus or in the absence of muscle separation between the adductor magnus and minimus muscles, and the suggested intermediate morphology of the artery was not found.

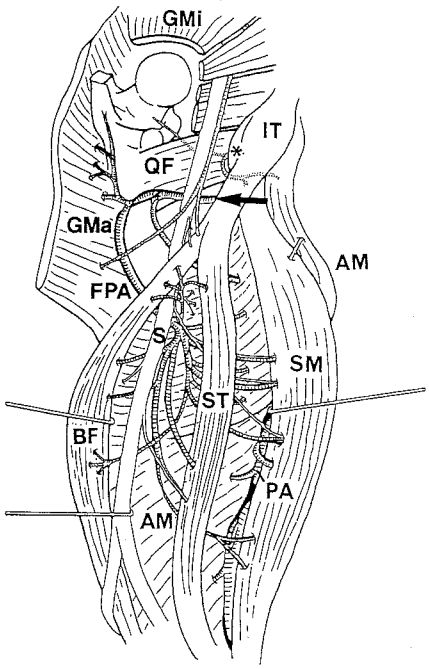

Fig. 2 A well-developed first perforating artery emerging immediately below the quadratus femoris muscle.
From the posterior aspect: Note that the arterial entrance into the posterior aspect is immediately below the quadriceps femoris muscle (QF). The popliteal artery (PA) also appears at a relatively upper level. Comites veins are shown by thick black ink along the first perforating artery (FPA, arrow) and PA. Asterisk, the poorly-developed medial circumflexus femoral artery (MCFA); AM, adductor mugnus muscle; BF, long head of the biceps femoris muscle; GMa, gluteus maximus muscle; GMi, gluteus minimus muscle, PA, popliteal artery; PF, piriformis muscle; S, sciatic nerve; SM, semimembranosus muscle; ST, semitendinosus muscle.

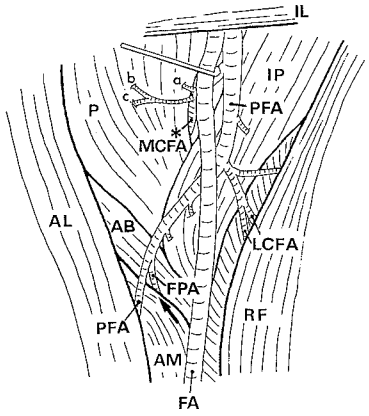

Fig. 3 The ramification pattern of the femoral artery.
From the anterior aspect of the specimen shown in Fig. 2: Note the proximally-converged origin of the profunda femoris artery (PFA). The medial circumflexus femoral artery (MCFA, asterisk) is not thin near its origin (2.7 mm in diameter) if it was compared with the distal course in the posterior aspect (Fig. 2). The MCFA gives off three small branches (a, b, c) to the pectineus muscle (P). Arrow, the well-developed first perforating artery (FPA, 4.2 mm in diameter); AB, adductor brevis muscle, AL, adductor longus muscle; AM, adductor magnus muscle; FA, femoral artery; IL, inguinal ligament; IP, iliopsoas muscle; LCFA/MCFA, lateral/medial circumflexus femoral artery; P, pectineus muscle; RF, rectus femoris muscle.

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内側大腿回旋動脈下行枝と貫通動脈の分布域に関する研究：第1貫通動脈が大腿方形筋の直下を通る1変異例を中心に

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内側大腿回旋動脈（MCFA）の下行枝は時によく発達し，大腿後面を下方に向かって大腿後部の筋に広く分布すると言われている．しかし過去に明確な記載はなく，しかも下行枝という名称自体が用いられなくなっている．著者らは1998年の本学解剖学実習において，第1貫通動脈がMCFA下行枝のごとく大腿方形筋の直下を通り，大腿後面に広く分布する1変異例に遭遇した．この例では通常のMCFAも存在していた．この異変から著者らは，下行枝という概念の重要性を認識するとともに，貫通動脈に代ってMCFA下行枝が発達していく一連の変異系列を仮定し，51脚の下肢について大腿後面の動脈分布を詳細に検討した．その結果，MCFA下行枝は，坐骨結節に接してその内側前方から大腿後面に出現し，ハムストリングの起始部に分布する比較的恒常的な枝であることが明確になった．しかし，MCFAの領域拡大（下行枝の出現と分布域拡大）には限界があり，一方で第1貫通動脈の形態は非常に安定していた．さらに，第1貫通動脈の発達程度は，（MCFAではなく）第2以下の貫通動脈と膝窩動脈の変異に依存していた．比較的少数例の検索とは言え，今回遭遇した変異は動脈の変異ではなく，小内転筋の欠損と見なす方が妥当であると考えられた．