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The relationship between the deep branch of the medial femoral circumflex artery and the short external rotators and anatomical safety margins: a cadaver study

Medial femoral sirkumfleks arterin derin dalı ile kısa dış rotatorlar arasındaki ilişki ve güvenli cerrahi mesafeler: bir kadavra çalışması

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ABSTRACT

Objective: *The aim of this cadaveric study was to quantitatively characterize the spatial relationship between the deep branch of the medial femoral circumflex artery (MFCA) and the obturator externus (OE), quadratus femoris (QF), and obturator internus (OI) tendons, and to define measurable surgical safety distances for posterior hip approaches.*
Materials and Methods: *Eleven hips from six formalin-fixed adult cadavers without prior hip surgery or major trauma were dissected. Posterior exposure was performed using the Kocher–Langenbeck approach. The deep branch of the MFCA was traced within the QF–OE interval via microdissection. Measurements included the tendon widths of OE and QF, the shortest distance of the deep branch to the OE insertion, the distance of the trochanteric branch to the lower OE and upper QF borders, and the capsular entry point relative to the distal border of the OI conjoint tendon. Distances were measured using a digital caliper with steel pin anatomical references.*
Results: *The mean widths of the OE and QF tendons were 9.0 mm and 30.0 mm, respectively. The deep MFCA branch coursed at an average of 9.2 mm from the OE insertion. The trochanteric branch was located 7.0 mm from the lower OE border and 5.4 mm from the superior QF border. The capsular penetration site was positioned 3.6 mm distal to the distal OI tendon. The deep branch gave an average of four lateral branches prior to capsular entry.*
Conclusion: *The close millimetric proximity of the MFCA deep branch to the posterior short external rotators highlights the need for OE preservation, controlled QF retraction, and medially placed, limited-length conjunct tendon incisions to maintain femoral head vascularity during posterior hip surgery.*

Keywords: *medial femoral circumflex artery, femoral head blood supply, obturator externus, quadratus femoris, posterior hip approach, cadaver study*

ÖZET

Amaç: *Bu kadavra çalışmasının amacı, medial femoral sirkumfleks arterin (MFCA) derin dalı ile obturator externus (OE), quadratus femoris (QF) ve obturator internus (OI) tendonları arasındaki uzamsal ilişkiyi nicel olarak karakterize etmek ve posterior kalça yaklaşımları için ölçülebilir cerrahi güvenlik mesafelerini tanımlamaktı.*
Gereç ve Yöntem: *Önceden kalça cerrahisi veya majör travma geçirmemiş, formalinle sabitlenmiş altı yetişkin kadavradan alınan on bir kalça diseke edildi. Posterior ekspozisyon Kocher–Langenbeck yaklaşımı kullanılarak gerçekleştirildi. MFCA'nın derin dalı, mikrodiseksiyon yoluyla QF–OE aralığı içinde izlendi. Ölçümler arasında OE ve QF tendonlarının genişlikleri, derin dalın OE insersiyonuna en kısa mesafesi, trokanterik dalın alt OE ve üst QF sınırlarına mesafesi ve OI konjoint tendonunun distal sınırına göre kapsüler giriş noktası yer aldı. Mesafeler, çelik pimli anatomik referanslara sahip dijital kumpas kullanılarak ölçüldü.*
Sonuçlar: *OE ve QF tendonlarının ortalama genişlikleri sırasıyla 9,0 mm ve 30,0 mm idi. Derin MFCA dalı, OE insersiyosundan ortalama 9,2 mm uzaklıkta seyretmiştir. Trokanterik dal, alt OE sınırından 7,0 mm ve üst QF sınırından 5,4 mm uzaklıkta yer almıştır. Kapsüler penetrasyon bölgesi, distal OI tendonunun 3,6 mm distalinde konumlanmıştır. Derin dal, kapsüler girişe kadar ortalama dört lateral dal vermiştir.*
Sonuç: *MFCA derin dalının posterior kısa dış rotatorlara milimetrik olarak yakınlığı, posterior kalça cerrahisi sırasında femur başı vaskülaritesini korumak için OE'nin korunması, kontrollü QF retraksiyonu ve medial olarak yerleştirilmiş, sınırlı uzunlukta konjonktif tendon insizyonlarının gerekliliğini vurgulamaktadır.*

Anahtar Kelimeler: *medial femoral sirkumfleks arter, femur başı kan akışı, obturator externus, quadratus femoris, posterior kalça yaklaşımı, kadavra çalışması*

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INTRODUCTION

Blood supply to the femoral head is provided by the retinacular, foveal, and intraosseous systems; however, in adulthood, the dominant arterial source for the weight-bearing region is the superior and inferior retinacular arteries arising from the deep branch of the MFCA[1–5]. The foveal branch within the ligamentum teres supplies only the perifoveal area, while the contribution of the lateral femoral circumflex artery and metaphyseal branches is limited in the adult hip [3,5–7].

The deep branch of the MFCA progresses between the obturator externus and the short external rotators outside the capsule, piercing the joint capsule posterolaterally and dividing into superior retinacular branches; this terminal arterial structure reaches the femoral head through subsynovial retinacular structures[8–10]. This fine and superficial arterial network is particularly susceptible to iatrogenic injury during traumatic lesions and posterior surgical approaches[2,3,11–13].

Separation of the short external rotators—particularly transection of the OE tendon—during periacetabular osteotomy, acetabular fracture fixation, or hip arthroplasty via a posterior approach may directly compromise the deep branch of the MFCA ([7,8,14]). Similarly, uncontrolled manipulation of the posterior capsule and retinacular vessels during surgical hip dislocation can lead to decreased femoral head perfusion[10,13,15].

Recent cadaver and imaging studies have detailed the intracapsular course of the superior and inferior retinacular arteries and their distribution at the femoral neck-head junction using a "clock face" reference[9,10,16–18]. However, the extracapsular course of the deep branch of the MFCA outside the capsule and its spatial relationship with the short external rotators have not been sufficiently defined quantitatively at the millimeter level[7–10,17,18].

Therefore, surgically identifiable and measurable safe distances are needed to preserve the MFCA during posterior hip surgery. The aim of this study is to quantitatively evaluate the positional relationship of the deep branch of the MFCA with the OE and QF tendons, the distance of the trochanteric branch from the short external rotators, and the proximity of the capsule entry point to the OI conjoint tendon in adult cadavers.

MATERIALS AND METHODS

This study was performed on six formalin-fixed adult cadavers with no history of surgical intervention, major trauma, or significant deformity around the hip. Four cadavers were male and two were female, and a total of 12 hips were initially evaluated. One hip with technical deformation disrupting anatomical integrity in the posterior trochanteric region was excluded, and analyses were performed on 11 hips. The study was completed in accordance with the approval of the relevant institution's ethics committee (Decision No: 2022/20-24).

All dissections were performed in the prone position and were carried out by an experienced team consisting of two orthopedists and two anatomists. Posterior exposure was performed based on the Kocher–Langenbeck approach [11,13]. After opening the skin and subcutaneous tissues, the gluteus maximus fibers were dissected; the gluteus medius and minimus were retracted posterolaterally, revealing the piriformis, gemellus superior, obturator internus (conjunct tendon), gemellus inferior, and quadratus femoris, respectively.

Figure 1. Visualization of the deep MFCA following a 2.5-cm medial transection of the QF QF:Quadratus Femoris, TM:Trochanter major

Upon reaching the QF level, a standardized dissection protocol was applied, focusing on preserving the deep branch of the MFCA ([8,9,11]). The leg was internally rotated, and the QF muscle was transected transversely approximately 2.5 cm medial to the posterior border of the proximal femur (Figure 1). By extending the incision obliquely, 2.5 cm muscle-tendon cap was left in the distal QF, and the course of the deep branch of the MFCA in the QF–OE groove was safely exposed.

The OE tendon was then identified. Since it is known that the deep branch of the MFCA always runs posterior to this tendon, OE tenotomy was carefully planned. The OE was released approximately 2.5 cm medial to the greater trochanter insertion; this distance is consistent with the vessel-tendon relationship reported in the literature and aims to minimize the risk of vascular injury [11].

Following this step, the QF–OE interval was opened, and the deep branch of the MFCA, the region where the trochanteric branch branches off, and the entry line into the capsule were exposed under magnification using microdissection (Figure 2). It was confirmed in all specimens that the deep branch ran closer than 2 cm to the posterior trochanteric border, crossed the OE tendon posteriorly, and entered the capsule immediately distal to the OI insertion[8,11,13].

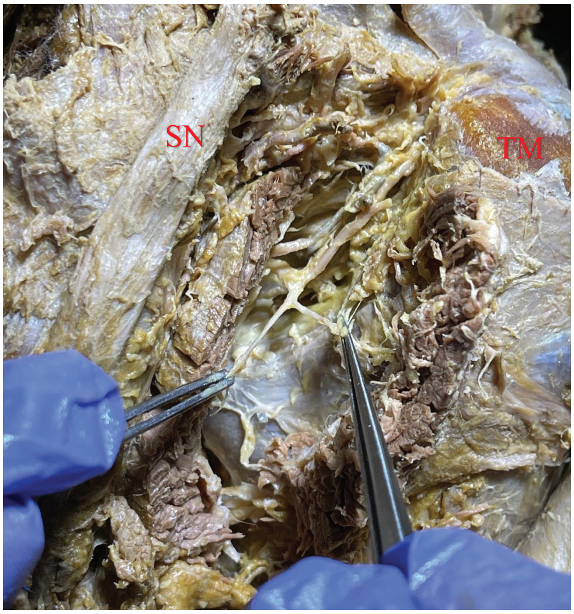

Figure 2. Dissection of the trochanteric and pericapsular branches of the deep MFCA. SN:Sciatic Nerve, TM:Trochanter major

Vascular filling was not applied in this study; the course of arterial structures was followed by microdissection while preserving their natural anatomical planes. Vascular structures were stabilized with fine steel pins at reference points, ensuring standardization of measurements (Figure 3). Intracapsular arterial segments were excluded from evaluation; the focus was on determining the extracapsular topography of the MFCA and its distance from the short external rotators.

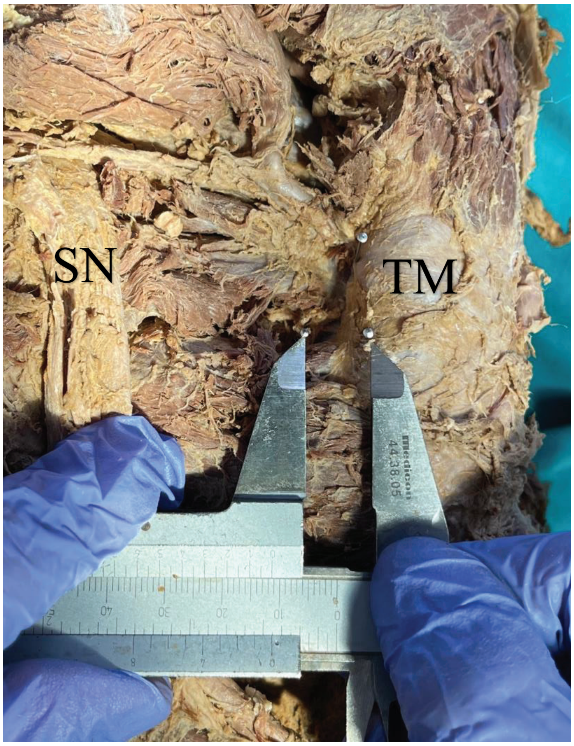

Figure 3. Measurement of MFCA–OE–QF distances using steel pins and a digital caliper.SN:Sciatic Nerve, TM:Trochanter major

The following measurements were systematically recorded during dissection (Figure 4):

• Widths of the OE and QF tendon femoral insertions,

• Shortest distance from the deep MFCA branch to the OE insertion,

• Perpendicular distances from the trochanteric branch to the lower border of the OE and upper border of the QF,

• Number of lateral branches given by the deep branch before reaching the capsule,

• Perpendicular distance of the capsule entrance to the distal border of the OI conjoint tendon,

• Distance of the QF tendon to the trochanter (midpoint and distal end of the tendon),

• Distance of the OI conjoint tendon to the posterior trochanteric bone reference.

Measurements were taken with millimeter accuracy using a digital caliper over steel pin reference points. Each parameter was measured at least twice by two independent observers, and the average value was used in the analysis. Due to the limited sample size and the anatomical-topographical nature of the study, advanced analytical statistical tests were not applied; descriptive statistics (mean, standard deviation, minimum–maximum) were reported.

RESULTS

Of the 11 hips evaluated in the study, seven belonged to male cadavers and four to female cadavers; five were right-sided and six were left-sided. In all specimens, the anatomical integrity of the OE and QF tendons was preserved, and the deep branch of the MFCA could be reliably traced in the QF–OE interval.

The OE tendon width was measured as an average of 9.0 ± 1.0 mm (7.9–10.0 mm), while the QF tendon width was measured as an average of 30.0 ± 4.1 mm (22.4–34.8 mm). The shortest distance of the deep MFCA branch to the OE insertion line was measurable in all hips and averaged 9.2 ± 2.2 mm (5.5–13.2 mm). Furthermore, the relationship of the deep branch to the posterior trochanteric border was consistent in all specimens and was never observed to extend beyond the approximate 2 cm surgical safety margin.

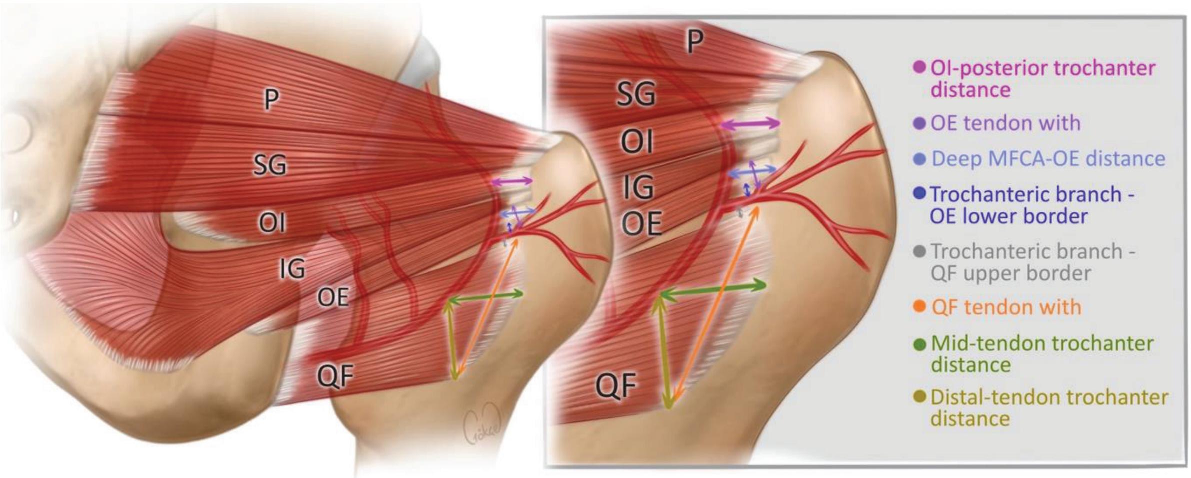

Figure 4. Schematic representation of measurement parameters and reference points recorded during dissection.

The trochanteric branch was present in all hips. The distance of this branch to the lower border of the OE was determined to be 7.0 ± 2.8 mm (1.8–15.0 mm) on average, while the distance to the upper border of the QF was 5.4 ± 2.2 mm (3.1–9.7 mm). The number of accessory branches arising from the trochanteric segment ranged from 1 to 2, while the total number of lateral branches given off by the deep MFCA branch before reaching the capsule was recorded as 4.1 ± 1.1 (3–6) on average.

It was confirmed in all specimens that the deep branch pierced the joint capsule immediately below the distal border of the OI conjoint tendon; this distance averaged 3.6 ± 1.3 mm (1.9–6.1 mm). The distance of the QF tendon to the trochanteric insertion was found to be 25.6 ± 3.0 mm (21.1–31.2 mm) on average when measured from the midpoint of the tendon and 32.3 ± 3.8 mm (25.3–37.3 mm) when measured from the distal border. The distance of the OI conjoint tendon to the posterior trochanteric bone reference was recorded as an average of 10.8 ± 2.8 mm (7.3–16.0 mm).

Table 1: Anatomical Measurements of the Deep MFCA in the Posterior Hip

Parameter	Mean ± SD	Min–Max
Obturator externus tendon width (mm)	9.0 ± 1.0	7.9–10
Quadratus femoris tendon width (mm)	30.0 ± 4.1	22.4–34.8
Deep MFCA–OE distance (mm)	9.2 ± 2.2	5.5–13.2
Trochanteric branch–OE lower border (mm)	7.0 ± 2.8	1.8–15
Trochanteric branch–QF upper border (mm)	5.4 ± 2.2	3.1–9.7
Branches before capsule	4.1 ± 1.1	3–6
Capsule entry distal to OI (mm)	3.6 ± 1.3	1.9–6.1
Mid-tendon–trochanter distance (mm)	25.6 ± 3.0	21.1–31.2
Distal tendon–trochanter distance (mm)	32.3 ± 3.8	25.3–37.3
OI–posterior trochanter distance (mm)	10.8 ± 2.8	7.3–16

Values are presented as mean ± standard deviation and minimum–maximum range.

DISCUSSION

The quantitative measurements obtained from this cadaveric series illustrate the extracapsular course of the deep branch of the MFCA and its millimetric relationship with the posterior short external rotators. The principal findings include an average deep MFCA–OE distance of 9.2 mm, a 5–7 mm narrow corridor for the trochanteric branch within the QF–OE interval, and the capsular entry of the vessel lying approximately 3–4 mm distal to the OI conjoint tendon. The observation that the deep branch typically gives off around four branches before reaching the capsule suggests that the pericapsular vascular network is richer than traditionally appreciated.

Classic anatomical studies have established that perfusion of the femoral head is primarily supplied by the posterior retinacular branches of the MFCA[1–7]. More recent microdissection and angiographic investigations have provided detailed characterization of the intracapsular retinacular anatomy, yet have offered comparatively limited data regarding the extracapsular topography of the deep branch[8–10,17,18]. Our findings complement this body of knowledge by offering numeric, extracapsular data for surgical reference.

In the work by Gautier et al., the anatomical trajectory of the MFCA was described with the concept of the “trochanteric window,” emphasizing the vessel’s close relationship to the short external rotators [8)]. The average 9.2 mm deep MFCA–OE distance identified in our specimens is consistent with this description and suggests that this anatomical arrangement is preserved across populations. The specification of discrete surgical safety margins — such as 9 mm, 5–7 mm, and 3–4 mm — provides directly applicable reference values for operative planning at the trochanteric level.

Kalhor et al. highlighted the role of the capsular and pericapsular vascular network in acetabular and femoral head perfusion, demonstrating that the anastomoses at the posterior capsule–acetabulum interface are highly susceptible to surgical trauma [9]. In our study, the finding that the deep branch of the MFCA gives an average of four branches before entering the capsule quantitatively reinforces this pericapsular perfusion model. The capsular entry being located only a few millimeters distal to the OI conjoint tendon suggests that excessively medial or deep capsulotomies along this tendon may directly compromise retinacular blood flow.

Similarly, the emphasis placed by Ganz and colleagues on preserving the short external rotators—particularly the OE tendon—during surgical hip dislocation is well supported by our anatomic findings[13]. The observation that the deep branch of the MFCA consistently travels posterior to the OE in a stable trajectory and remains within a 2-cm corridor from the posterior trochanteric border further underscores the importance of maintaining OE integrity whenever possible. Planning OE tenotomies at a safe medial distance from the trochanteric insertion and limiting their length may represent a practical strategy for preserving vascular continuity.

The trochanteric branch's position within a narrow 5–7 mm zone of the QF–OE interval can be interpreted as an anatomical "warning line." Excessive retraction of the QF or aggressive medial mobilization of soft tissues may exert direct pressure on both the trochanteric branch and the deep MFCA segment in this region. Clinical studies demonstrating improved femoral head oxygenation with modified posterior approaches[21], as well as reports of compromised vascularity due to posterior exposure, reaming, and thermal effects[19,22], support the clinical relevance of these anatomical relationships. Our findings provide a detailed anatomical framework that helps explain these mechanisms.

Likewise, the work by Lavigne et al. demonstrating that the majority of vascular foramina at the femoral head–neck junction are concentrated in the posterosuperior quadrant further underscores the critical importance of the MFCA's posterior branches in femoral head perfusion[18]. The consistent observation in our series that the deep MFCA branch traverses a narrow corridor between the OE and QF suggests that a single fragile vascular axis extends from the trochanteric region to the femoral head—one that must be preserved during posterior hip procedures.

The primary novelty of this study lies in providing quantitative measurements of the extracapsular relationship between the deep branch of the MFCA and the posterior short external rotators, using surgically identifiable tendon and bony landmarks as reference points. To our knowledge, no prior cadaveric series has reported, in such detail, the OE and QF tendon widths, the minimal distance between the deep MFCA and the OE insertion, the precise position of the trochanteric branch within the QF–OE interval, and the proximity of the capsular entry point to the OI conjoint tendon. In this regard, our findings complement the previously described intracapsular anatomy of the retinacular system and provide an extracapsular reference framework that can be directly applied to vessel-preserving strategies during posterior hip approaches.

This study has certain limitations. First, the relatively small number of specimens may not fully capture the entire spectrum of anatomical variation in the MFCA and the short external rotators. Second, the use of formalin-fixed elderly cadavers does not fully replicate the elasticity and vascular turgor of living tissue; therefore, the measured distances should be interpreted with caution when extrapolating to younger or athletic populations. Third, the absence of vascular injection limited the assessment of the caliber and intrakapsular distribution of the terminal retinacular branches. Finally, as real-time perfusion analysis was not performed, the quantitative impact of the defined distances on the risk of femoral head osteonecrosis cannot be directly established. Future studies with larger and more diverse cohorts, supplemented by contrast injection, micro-angiography, or advanced imaging techniques, may better elucidate how these anatomical distances translate to dynamic perfusion in vivo.

CONCLUSION

This cadaveric study demonstrates the millimetric proximity of the deep branch of the MFCA to the posterior short external rotators. The artery courses approximately 9 mm from the OE insertion, 5–7 mm along the QF–OE interval, and only a few millimeters distal to the OI conjoint tendon at its capsular entry, underscoring the necessity of a soft-tissue–preserving approach in posterior hip surgery. In particular, preserving the OE tendon where possible, planning conjoint tendon incisions at a safe medial distance from the trochanteric crest with limited length, and avoiding aggressive retraction within the QF–OE interval may help maintain the posterior retinacular flow to the femoral head. These anatomical findings offer practical and measurable reference points that support vessel-preserving surgical planning in procedures such as the Kocher–Langenbeck approach, surgical hip dislocation, and acetabular fixation.

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