Relationship Between the Middle Genicular Artery and the Posterior Structures of the Knee

A Cadaveric Study

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Background: The middle genicular artery (MGA) is responsible for the blood supply to the cruciate ligaments and synovial tissue. Traumatic sports injuries and surgical procedures (open and arthroscopic) can cause vascular damage. Little attention has been devoted to establish safe parameters for the MGA.

Purpose: To investigate the anatomy of the MGA and its relation to the posterior structures of the knees, mainly the posterior capsule and femoral condyles, and to establish safe parameters to avoid harming the MGA.

Study Design: Descriptive laboratory study.

Methods: Dissection of the MGA was performed in 16 fresh, unpaired adult human cadaveric knees with no macroscopic degenerative or traumatic changes and no previous surgeries. The specimens were meticulously evaluated with emphasis on preservation of the MGA. The distances from the MGA to the medial and lateral femoral condyles were measured. The Mann-Whitney test was used for statistical analysis.

Results: In all specimens, the MGA emerged from the anterior aspect of the popliteal artery, distal to the superior genicular arteries, and had a short distal trajectory toward the posterior capsule where it entered proximal to the oblique popliteal ligament. The artery lay in the midportion between the condyles. The distance between the posterior aspect of the tibia and the point of entry of the MGA into the posterior joint capsule was 23.8 ± 7.3 mm (range, 14.72-35.68 mm). There was no correlation between an individual's height and the distance of the entrance point of the MGA into the posterior joint capsule to the posterior superior corner of the tibia.

Conclusion: The middle genicular artery lies in the midportion between the medial and lateral femoral condyles.

Clinical Relevance: This knowledge is important for the preservation of the blood supply during posterior knee surgical procedures and to settle a secure distance between the posterior aspect of the tibia and the MGA input. This could decrease and prevent iatrogenic vascular injury risk to the MGA.

Keywords: Knee; anatomy; middle genicular artery; vascular anatomy.

A rising problem in orthopaedic surgery is the high-energy trauma that can lead to knee dislocations associated with unstable fractures, floating knees, and deviated articular knee fractures that need immediate surgical intervention.[14,27,33] In some of these injuries, the distorted anatomy makes the surgical approach difficult, and vascular injuries may occur.[13,33] In addition to this, the need for a posterior approach to the knee is less common, and few surgeons feel comfortable accessing this area.[4] This could be explained by the low incidence of posterior knee disorders that require surgery and by the proximity of complex neurovascular structures.[4] A posterior approach to the knee has an increased risk of vascular injury, and greater care should be taken[4,23] as extra-articular injuries to the popliteal artery[17] and the middle genicular artery (MGA)[3,15,24,26,50] have been reported. The direct posterior approach to the knee is essential for open posterior cruciate ligament (PCL) reconstruction, internal fixation of posterior tibial plateau

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fractures, popliteal cyst removal, flexion contracture releases, synovectomy, tumor excision, and foreign body removal,[4] and the main complications reported with these procedures are vascular and neurologic.[27]

The vascular supply to the cruciate ligaments is mostly provided by the MGA, which is a direct branch of the popliteal artery and, in its intra-articular portion, follows the PCL. Although MGA injury is rare,[9,19,44,45] it should not be overlooked as it can occur[45,47] during cruciate ligament reconstruction, meniscectomies, and arthroplasties.[3,46] Consequences to this vascular injury might be a pseudoaneurysm of the popliteal artery,[3,12] an acute arterial occlusion during PCL reconstruction,[50] or persistent hemarthrosis.[8] Vascular injury most often occurs from direct injury by sharp instruments (scalpel, scissors), laceration from motorized devices (shaver, drill), excessive traction (incorrect retractor placement), and overpressure (excessive tourniquet use, infiltration of fluid infusion).[12]

To the best of our knowledge, no previous study has described the MGA and posterior knee anatomy in detail. The purpose of this study was to define the anatomic relationships between the MGA and the surrounding structures to characterize a safe anatomic zone during a posterior knee approach.

METHODS

Sixteen fresh, unpaired adult human cadaveric knees (all from male specimens), with no macroscopic degenerative or traumatic changes and no previous surgeries, were used in this study. The cadavers were obtained from the Death Postmortem Inspection Service at the University of São Paulo after approval from the institution's ethics committee. The knees were stored at –20°C and were thawed overnight at room temperature before testing. The mean age of the donors at the time of death was 48.5 ± 10 years (range, 34-65 years), and the mean height was 1.71 ± 0.5 m (range, 1.66-1.80 m). Before dissection, all specimens were tested for articular range of motion, and full flexion-extension was achieved.

For the posterior approach, a 30-cm longitudinal S-shaped incision was made from the lateral aspect of the thigh to the medial aspect of the medial head of the gastrocnemius muscle (Figure 1). The subcutaneous tissue was carefully dissected to accurately identify the short saphenous vein and the medial sural cutaneous nerve to better define the limits of the popliteal fossa.[34] All neurovascular structures and the heads of the gastrocnemius muscle were dissected and removed so that the posterior capsule of the knee could be visualized.

The oblique popliteal ligament (OPL) and the entry site of the MGA were well identified in all specimens. Markers were positioned at the medial side of the lateral femoral condyle, at the lateral side of the medial femoral condyle, at the posterior superior corner of the tibia, and at the entry site of the MGA (Figure 2). To determine these points, a

Figure 1. (A) Posterior approach to the right knee. (B) Posterior view of the knee showing the tibial nerve (T), common fibular nerve (P), medial superficial cutaneous nerve (MSC), lateral superficial cutaneous nerve (LSC), and medial (MH) and lateral (LH) heads of the gastrocnemius muscle.

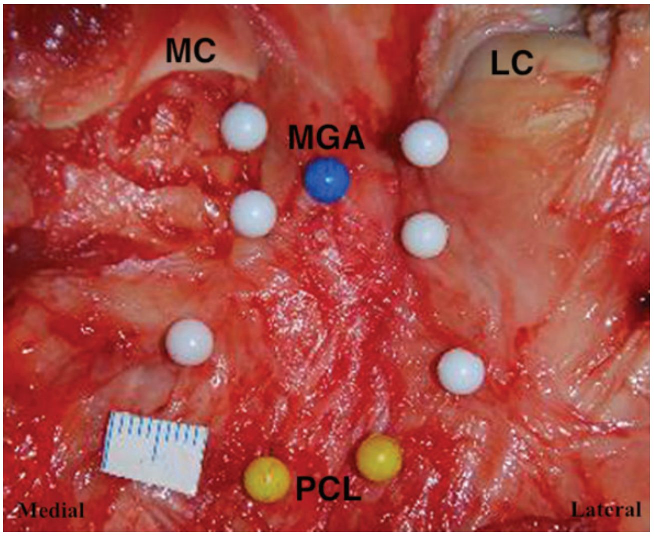

Figure 2. Posterior view of the right knee. The blue marker indicates where the middle genicular artery pierces the posterior capsule; the white markers show the internal contour of the femoral condyles; and the yellow markers show the posterior border of the tibia at the posterior cruciate ligament insertion site.

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micrometer caliper was used to establish the center of the condyles and the center of the tibial plateau. The topographical relationship between the MGA and the posterior structures was evaluated. The distances from the MGA to the medial and lateral notch walls and to the posterior superior corner of the tibia were measured using a digital photograph technique.

Digital photographs were taken using a Nikon D60 camera (Nikon Inc). The lens was positioned perpendicular to the posterior capsule and at a 40-cm distance. A ruler was used to assert the correct distance between camera and capsule, and to calibrate the system, a 1×1–cm^2 marker was used.

Photographs were downloaded to a personal computer, and distances were measured using specific software (Scion Graphics; Scion Corp). Results are shown as mean ± SD. The Mann-Whitney test was used to evaluate differences between both measurements taken. The level of significance was defined as $P < .05$. The correlation between the height and the distance from the MGA to posterior superior corner of the tibia was evaluated using the Spearman test. The Prism Windows 5.03 (GraphPad Software) statistical software package was used for calculations.

RESULTS

After the initial posterior approach, the popliteal artery was the first vascular structure to be visualized. It has a close relationship to the posterior capsule, and its mobilization was difficult due to the presence of the superior genicular arteries and the MGA. In all specimens, the MGA emerged from the anterior aspect of the popliteal artery, distal to the superior genicular arteries, and had a short distal trajectory toward the posterior capsule. The mean distances between the entry point of the MGA and medial and lateral condyles was 12.37 mm (range, 9.76-14 mm) and 12.03 mm (range, 6.67-21.22 mm), respectively. The artery lay in the midportion between both condyles, as no statistical difference between the medial and lateral distances was found ($P = .865$). The distance between the entry point of the MGA and the posterior superior corner of the tibia was 23.76 mm (Table 1). There was no correlation between height and the distance from the MGA to the posterior edge of the tibia (Spearman correlation coefficient, 0.065).

In all specimens, the MGA entered the capsule proximally to the OPL. The OPL was identified in all cases as a thickening of the posterior capsule from the distal-medial to the proximal-lateral direction. The OPL proximal insertion was located close to the direct branch of the semimembranosus tendon and the distal insertion situated posterior to the lateral femoral condyle.

DISCUSSION

This study has described the anatomy of the middle genicular artery and that it lies in the center of the femoral condyles. The intra-articular path of the middle genicular artery was described in 1968 by Scapinelli,[40,41] and its importance has long been referenced in the literature.[5,20,32,35,39,43]

TABLE 1
Mean Distance Between the Entry Point of the MGA and Other Anatomic Structures[a]

Distance From MGA, mm	Medial Condyle	Lateral Condyle	Posterior Edge
Mean	12.37	12.03	23.76
Range	9.76-14	6.67-21.22	14.72-35.68
SD	2.26	4.71	7.35

[a]MGA, middle genicular artery.

The MGA is a direct branch of the anterior surface of the popliteal artery and originates 3 to 5 cm proximal to the articular line, usually as a single branch but an accessory artery may exist.[40,41] According to Scapinelli,[40,41] it follows distally, between the popliteal artery and the posterior capsule, for 1.5 to 2.5 cm, where it crosses the posterior capsule through the oblique popliteal ligament near the lateral femoral condyle, becoming intra-articular. After this, it follows the PCL and emits branches to this structure as well as to the ACL and ends at the vascular plexus of the anterior genicular arteries.[39,41] Contrary to these findings, this study has shown that the artery is equidistant to both femoral condyles and lies above the OPL. The middle geniculate artery forms an angle of 15° to 30° with the popliteal artery when the knee is extended, but this angle is close to 90° when the knee is flexed over 90°.[39] In addition, the greater the knee flexion angle, the greater the distance between the posterior capsule and the PCL insertion site[2]; also, the distance between the MGA and the posterior aspect of the tibia increases with greater knee flexion. To the best of our knowledge, there are no previous publications that describe the medial-lateral dislocation (coronal displacement) of the artery that occurs with the change in knee flexion angle near the joint line.

The incidence of vascular lesions among patients undergoing elective orthopaedic surgery is 0.005% (very rare).[49] Wilson et al[49] reported that pseudoaneurysms were the second most common type of vascular injury, occurring in 11% of cases, and they acted as arranged hematomas with internal arterial flow. Another form of clinical presentation is recurrent hemarthrosis and/or pulsatile mass after the surgery.[38] The proper diagnosis of pseudoaneurysm can be difficult, delayed, and obscure,[38] and pseudoaneurysms can be a source of functional disability and late recovery[38,49] and can be caused by a nicked artery by extensive synovectomy or direct damage of the genicular arteries during surgical manipulation.[11,21] The majority of studies that describe this complication are case reports related to the genicular arteries[11] and its branches: medial inferior[10,28,29] and medial superior.[8,22,30] We believe that 1 reason to underestimate vascular injuries (including MGA) is the lack of knowledge of the vascular anatomy; 1 traditional anatomy textbook has failed to add recent information on the genicular arteries.[37]

Although a neurovascular injury during knee surgery is rare, its consequences can be serious. It may hinder patients' rehabilitation and prognosis due to limited function and possible amputation in addition to the legal issues that may arise.[19] Knee vascular injuries can occur due to local intraoperative manipulation in the immediate or late postoperative period. Common injuries are laceration, pseudoaneurysm, thrombosis, and arteriovenous fistulas secondary to iatrogenic trauma from inappropriately placed retractors or direct vascular injury (cut by sharp instruments, vessel avulsion, thermal injury, plunging drill bits), anomalous anatomy and scar tissue due to previous surgery, malpositioned implants and fixation devices, periarticular calcification, or ossification.[36] The MGA can be placed at risk during open posterior knee surgery (open reduction internal fixation [ORIF] medial plateau fractures, ORIF PCL avulsion fracture fixation, cyst/tumor removal, PCL reconstruction, posterior synovectomy) due to iatrogenic trauma from inappropriately placed retractors or direct vascular injury (sharp instruments, vessel fragility, thermal injury, plunging drill bits). In cases of unrecognized or iatrogenic MGA damage in open surgery, the lack of ligation of the MGA can be associated with an increase of morbidity due to ischemic events, thromboembolic problems, and a negative impact on the functional outcome due to soft tissue disturbance caused by blood extravasation.[31] This is correlated with the inconsistent information related to complications during femoropopliteal bypass surgery, and the overall morbidity can reach 37%.[48] Familiarity with the anatomy of the MGA can decrease the incidence of "never events," unplanned reoperations, and readmissions.[7,42]

Vascular injury can also occur during PCL reconstruction,[24,50] which can be performed by means of a double- or single-tunnel technique or by an inlay technique, and all of these approaches require extensive knowledge of the posterior region of the knee, including the relationship between posterior structures and the MGA. Some authors have advocated for the preservation of remnant fibers during PCL reconstruction to augment graft incorporation, keep the synovial coverage, and maintain mechanoreceptors and blood circulation.[16] Accurate knowledge of MGA location can aid surgeons in applying this technique and avoiding unnecessary vessel injury. The greatest risk to this artery occurs during open procedures with a posterior approach, but there is also a risk of injury during arthroscopy. The main risks occur in procedures that include posterior capsulotomy or synovectomy in which a secondary injury by traction may occur. We believe that there is no risk of injury to the artery when the posteromedial and posterolateral portals are used, as these are far from the artery. Nonetheless, there is a risk of injury when the transseptal portal[1] is used, and injury can occur indirectly by traction or directly when there is an injury to the posterior capsule. Avulsion of the MGA is possible, particularly given its shorter length and larger diameter in some knees (Figure 3). The transseptal portal is safe when performed with the knee at 90° of flexion, a common position during knee arthroscopy.[25] If the knee is positioned at 30°, the rate of knee neurovascular injury will increase, including MGA injury.[25] Another technical point consists in performing the transseptal portal from the medial to the lateral direction to decrease the rate of knee vascular injury.[18] Another recommendation during open surgery consists of the release (or detachment) of the capsule in the tibial portion, which is less vascularized than the femoral portion, preserving the MGA.[18]

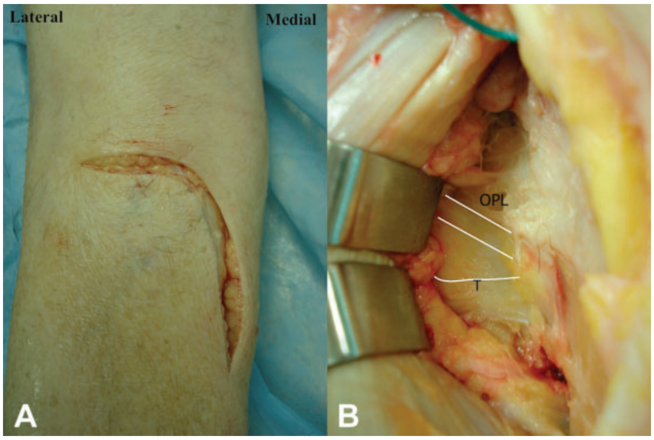

Figure 3. (A) The posteromedial approach to a left knee. (B) Deep-knee dissection showing the possibility of reaching the tibial insertion site (T) of the posterior cruciate ligament while preserving the middle genicular artery and using the oblique popliteal ligament (OPL) as a limit.

Because of the increased incidence of ischemic events occurring in the medial femoral condyle, it has been hypothesized that this region has poor vascular supply,[47] and avascular necrosis of the medial femoral condyle has been reported as a complication of PCL surgery.[6] Etiologic factors include drilling the femoral tunnel too close to the articular surface, which may disturb the nutrient vessels (including MGA),[35] and extensive soft tissue dissection over the medial femoral condyle during open surgery, which may compromise the vascular supply. Accurate femoral tunnel placement in PCL reconstruction, leaving an adequate bone bridge between the tunnel and the articular surface, can prevent this complication as well as correct soft tissue dissection, preserving the main blood vessels.[6,35] This is a particular concern in combined medial collateral ligament and PCL reconstructions or multiple ligament surgeries that require several tunnels in the femoral condyles. Meticulous dissection should always be performed in an attempt to safeguard the vascular structures.

Little attention has been given to the MGA in previous descriptions of the direct posterior approach.[4] Our findings have established that the distance between the posterior aspect of the tibia and the point of entry of the MGA is 23.8 ± 7.3 mm (range, 14.72-35.68 mm). This information is helpful in preoperative planning, as it allows the surgeon to decide on the best surgical approach, depending on the injury.[4] During surgery, this information can help avoid iatrogenic vascular damage to the MGA, especially in procedures that do not require the use of a tourniquet, such as open reduction for posterior knee fractures or those associated with knee dislocations with devitalized soft tissue.[27,33]

Unnecessary bleeding adds to morbidity, cost, and hospital length of stay.[27]

Nonetheless, this study has limitations. There was a small sample size, and all anatomic variations were probably not evaluated. Also, MGA vessel diameter and common trunks were not measured.

The clinical relevance of this study is that it recommends a secure distance between the posterior aspect of the tibia and the entrance point of the MGA into the posterior joint capsule. This may aid surgeons during posterior knee surgical procedures.

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