High-resolution ultrasound (HRUS) evaluation of neurovascular and muscular structures of the Hunter canal

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Purpose

The Adductor Canal (also known as Hunter’s Canal or subsartorial canal) is a relevant anatomical region with many clinical implications. In particular, the adductor canal hiatus is a preferential site for the development of vascular atherosclerotic lesions and may play a role in the pathophysiology of two different (vascular and nervous) entrapment syndromes. In recent years, after the clinical introduction of new sonographic equipment which achieved an effective visualization of peripheral nerves, the Hunter's canal ultrasound (US) anatomy has been revisited by anesthesiologists in order to perform US-guided saphenous nerve block procedures.

The purpose of this study is to describe the US appearance of the Hunter's canal neurovascular content and its boundaries, paying particular attention to the saphenous nerve and its relations with surrounding structures, also identifying those relevant anatomical elements which may be used reference landmarks.
Methods and Materials

We assessed 20 canals (both thighs of 10 healthy volunteers) with an ultrasound scanner equipped with an high resolution linear broadband array (5-12 Mhz) transducer, provided with compound and image optimization software (MyLab™70 XVG, Esaote, Genoa, Italy). All examinations were performed with the patient supine and the leg in external rotation, using a set of scans on axial, axial oblique and coronal oblique planes. The assessment of the adductor canal has been completed with color-Doppler module.
Results

The first scan was performed on an axial plane at the apex of the Scarpa’s triangle, where the sartorius muscle crosses anteriorly the superficial femoral artery. The superficial femoral artery origins in the femoral triangle (Scarpa’s triangle), 2 to 5 cm distally to the inguinal ligament, where the common femoral artery bifurcates originating the deep femoral artery. Then, the superficial femoral artery enters the adductors’ canal, which is in continuity with the apex of the Scarpa's triangle. The division of the common femoral artery was easily assessed on axial US scans as the superficial femoral artery is the most superficial vessel in relation with the deep fascia of the sartorius muscle (Figure1).

Fig.: Figure 1. A) Transducer orientation on the crural region at the apex of the femoral triangle. B) Axial MR section showing the vascular structures at the apex of the femoral triangle which is in continuity with the adductor canal. C) The deep fascia of sartorius muscle is in relation with the anterior aspect of the superficial femoral artery wall. D) Corresponding color-Doppler axial scan. Legend: SaM, sartorius muscle; SupFemA, superficial femoral artery; AddL, adductor longus muscle; RectF, rectus femoris muscle; VasMedM, vastus medialis muscle.
The posteromedial wall of the adductor canal is formed proximally by adductor longus muscle, more distally by adductor magnus muscle and these two muscles are an useful anatomical reference to divide the adductor canal in two segments. The muscular belly of adductor longus, which inserts on the middle third of the linea aspera, becomes progressively thinner caudally. Vastus medialis muscle forms the posterolateral and lateral limits; the deep muscular fascia of sartorius represents the anterior wall. In this proximal part of Hunter's canal the saphenous nerve, which is the largest cutaneous branch of the Femoral nerve, is lateral to the superficial femoral artery and the femoral vein is posterior to the artery. The saphenous nerve was appreciable on axial US scans due to its typical "honeycomb" appearance; on longitudinal US scans the nerve revealed a fascicular echostructure (Figure 2).

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In all subjects a venous vessel, originating from the medial aspect of the superficial femoral vein, was appreciable passing through the intermuscular connective space between sartorius and adductor longus muscles. This venous vessel is a tributary of the great saphenous vein and the color-Doppler module aided its detection (Figure 3).

**Fig.:** Figure 2. A) Transducer orientation on the anteromedial aspect of the thigh. B) Axial oblique US scan showing the neurovascular bundle inside the proximal third of the adductor canal. The saphenous nerve is lateral to the femoral artery; the femoral vein is posterior. The posterior wall is represented by adductor longus muscle. C) Corresponding color-Doppler axial scan showing the "honeycomb" echostructure of the saphenous nerve, adjacent to the arterial wall. Legend: SaM, sartorius muscle; SaphN, saphenous nerve; FemA, femoral artery; Fem V, femoral vein; VasMedM, vastus medialis muscle; AddL, adductor longus muscle.

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**Fig.**: Figure 3. A) Transducer orientation on the medial aspect of the middle third of the thigh. B, C) Two adjacent US axial scans demonstrating the perforating venous branch emerging from the medial aspect of the superficial femoral vein to move medially toward the great saphenous vein which is located in the superficial fascia, between sartorius (anterior) and gracilis muscles (posterior). At this level the posterior wall of the adductor canal is still formed by the adductor longus muscle. D) Corresponding axial MR section showing the great saphenous vein in the superficial fascia. Legend: SaM, sartorius muscle; FemA, femoral artery; FemV, femoral vein; VasMedM, vastus medialis muscle; AddL, adductor longus muscle; PerfBGSv, perforating branch of the great saphenous vein; GSv, great saphenous vein; GraM, gracilis muscle.

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At the origin of this communicating vein, the saphenous nerve is still lateral to the superficial femoral artery but more anterior (Figure 4).
Fig.: Figure 4. Axial US image at the site of origin of the perforating venous branch, tributary of the great saphenous vein. At this level the saphenous nerve is still lateral to the femoral artery. SaM, sartorius muscle; FemA, femoral artery; FemV, femoral vein; VasMedM, vastus medialis muscle; AddL, adductor longus muscle; SaphN, saphenous nerve.

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Caudally the adductor longus muscle belly was still not detectable and the posterior wall of the canal is represented only by adductor magnus muscle, which was considered as the most important reference to guide the US assessment of the distal segment of the canal and of the hiatal region. It is important to remember that the adductor magnus muscle is made of two different parts, defined by the orientation of their fibers. The medial part of the adductor magnus, often called the 'hamstring part', originates from the ischial tuberosity of the pelvic bone and descends almost vertically along the thigh to insert by a rounded tendon into the adductor tubercle on the medial condyle of the distal head of the femur. The most lateral part (adductor part) inserts onto the medial supracondylar line and the medial margin of the linea aspera. The adductor hiatus is a large circular gap located inferiorly between the hamstring and adductor parts of the adductor magnus, which allows the femoral artery and associated veins to pass from the adductor canal to the popliteal fossa posterior to the knee (Figures 5, 6).
Fig.: Figure 5. A, B) Schematic drawing illustrating the boundaries of the proximal and distal parts of the Hunter’s canal. Note that adductor canal hiatus is delimited medially by the longitudinal fibers of adductor magnus muscle and its rounded tendon, laterally by the oblique fibers of adductor magnus. C) Axial MR scan showing the hamstring part (longitudinal fibers) of the adductor magnus with its myotendinous junction and the adductor part (oblique fibers) which inserts via an aponeurosis on the medial margin of the linea aspera. Legend: SaM, sartorius muscle; FemA, femoral artery; FemV, femoral vein; VasMedM, vastus medialis muscle; AddMmtj(rt), adductor magnus myotendinous junction (origin of the rounded tendon); AddMobf, oblique fibers of adductor magnus; MedMla, medial margin of linea aspera; SemimM, semimembranosus muscle; SemitM, semitendinosus muscle; GraM, gracilis muscle.  

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**Fig.**: Figure 6. A, B, C Three axial MR scans showing the myotendinous junction of the hamstring part of adductor magnus, where origins the rounded tendon. Legend: SaM, sartorius muscle; FemVV, femoral vessels; VasMedM, vastus medialis muscle; AddMmtj(rt), adductor magnus myotendinous junction (origin of the rounded tendon); GraM, gracilis muscle; GSaphV, great saphenous vein; AddTub, adductor tubercle.

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In this second segment of the canal (bounded postero-medially by adductor magnus muscle) the saphenous nerve becomes progressively more anterior to the superficial femoral artery while the femoral vein becomes posterior to the artery. A slight "up and down" motion of the transducer on axial planes was helpful in detecting the peripheral nerve when it was not easily cleavable from the surrounding connective tissue of the subsartorial canal. The visualization of the perineurium as a clear hyperechoic interface was very difficult (Figure 7).
**Fig.**. Figure 7. A, B Two axial US scans demonstrating the course of the saphenous nerve which moves from a lateral position to the femoral artery to an anterior position to this vessel near the hiatal region. The saphenous nerve may be identified on axial US scans between the anterior surface of the arterial wall and the deep fascia of sartorius muscle Arrow, saphenous nerve.

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More caudally the femoral artery and vein move progressively in a postero-lateral direction while the saphenous nerve remains anterior, in close relation to the deep fascia of the lateral extremity of sartorius muscle and the anterior wall of a small branch of the femoral artery which was identified as the descending genicular artery for its peculiar course. On US axial scans the gescending genicular artery may be carefully distinguished from a large muscular branch to vastus medialis which arises more proximally from the lateral aspect of the femoral artery.

The progressive separation of the femoral vessels and the saphenous nerve suggested the proximity of the hiatal region but the origin of the descending genicular artery from the superficial femoral artery represented another and more precise landmark on US examination to identify the distal end (hiatal region) of the adductor canal (Figure 8).
**Fig.:** Figure 8. A) Transducer orientation on the antero-medial aspect of the distal third of the thigh. B, C) Two adjacent axial US scans in the lower part of adductor canal where femoral vessels and saphenous nerve separate. The saphenous nerve is adjacent to the descending genicular artery which may not be confused with a large, more proximal, muscular branch of the femoral artery to vastus medialis. Legend: Sam, sartorius muscle; AddM, adductor magnus muscle; VasMedM, vastus medialis muscle; FemAMb, muscular branch of the femoral artery to the vastus medialis; FemA, femoral artery; FemV, femoral vein; DGa, descending genicular artery; AddCr(Vam), adductor canal roof (vastoadductor membrane); SaphN, saphenous nerve.

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The origin of descending genicular artery from the superficial femoral artery was best assessed on coronal oblique US scans. The descending genicular artery gives immediately rise to its saphenous branch, which passes anteriorly to the adductor magnus rounded tendon, piercing the roof of the adductor canal, and moves inferiorly and medially toward the deep surface of sartorius muscle. The descending genicular artery (main trunk) was easily appreciable on axial and coronal oblique US scans, in particular coronal oblique US scans allowed the visualization of its course adjacent to the adductor
magnus rounded tendon. It was impossible to demonstrate the saphenous nerve piercing the vastoadductor membrane accompanied by the saphenous branch of the descending genicular artery (Figure 9).

**Fig.** Figure 9. A) Color-Doppler coronal oblique scan showing the origin of the descending genicular artery which emerges from the lateral aspect of the femoral artery wall. B) Color-Doppler coronal oblique US scan demonstrating the descending genicular artery moving downward to the knee joint anterior to the adductor magnus tendon and posterior to vastus medialis muscle. C) Color-Doppler coronal oblique US scan showing the relation between descending genicular artery and adductor magnus rounded tendon, which forms the medial wall of the adductor canal hiatus. Note the slight deflection of the femoral vessels passing through the adductor canal.
hiatus. Legend: DGa, descending genicular artery; AddMrt, adductor magnus rounded tendon; FemA, femoral artery; FemV, femoral vein; AddMmtj(rt), adductor magnus myotendinous junction (origin of the rounded tendon).

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The subsartorial branch of the saphenous nerve was identified much more caudally, out of the Hunter’s canal, in the medial knee region for its close relation to the saphenous branch of the descending genicular artery, using this arterious vessel as an anatomical landmark, but this was beyond the scope of our study.

The US morphologic examination of the adductor canal hiatus was complex and some anatomical limits of this region were best assessed on coronal oblique scan planes. The medial margin of the hiatus is the adductor magnus tendon, which courses to the medial femoral condyle. The rounded tendon of adductor magnus was easily identified at its enthesis performing a coronal oblique scan, using the adductor tubercle of the medial femoral condyle as an osseous landmark. When the fibrillar echostructure of the adductor magnus tendon was correctly visualized without anisotropic artifact, a slight, progressive cranial motion of the transducer, always in the coronal oblique scan plane, allowed the visualization of the myotendinous junction of the tendon itself. The superficial femoral vessels were appreciable laterally to the myotendinous structure moving in a dorsolateral direction to become popliteal vessels. Adjacent coronal oblique scans, always using the rounded tendon of adductor magnus as a reference, aided the assessment of the region of "deflection" of the femoral vessels which corresponds to the adductor canal hiatus. In the hiatus, the femoral artery is anteromedial to the femoral vein (figure 10).
Fig.: Figure 10. A) Transducer orientation on the medial femoral condylar region. B) Coronal oblique US scan at the adductor tubercle of the medial femoral condyle; the adductor magnus rounded tendon shows the typical fibrillar pattern. C) Color-Doppler coronal oblique US scan at a more proximal level than A revealing the relations between adductor magnus rounded tendon and femoral vessels at the adductor canal hiatus. Femoral vessels may be seen passing through the adductor hiatus. D) Coronal oblique US scan at a level more proximal than B showing the oblique fibers of adductor magnus muscle which spread laterally to insert on the medial margin of the linea aspera and the longitudinal fibers which converge to form the rounded tendon. Legend: AddMrt, adductor magnus rounded tendon; AddTub, adductor tubercle; AddMlf, adductor magnus longitudinal fibers; AddMobf, adductor magnus oblique fibers; SaM, sartorius muscle.

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Conclusion

Neurovascular bundles are often located inside conical or tubular pathways in the human body, which are muscular, osseous, fibrous or mixed in nature. The adductor canal, firstly described by John Hunter in 1786, is a fibromuscular canal which contains the superficial femoral vessels and saphenous nerve along with a variable amount of fibrous tissue [1]. This aponeurotic tunnel is located in the middle third of the thigh and runs from the apex of the femoral triangle (Scarpa's triangle) to an opening in adductor magnus through which the femoral vessels reach the popliteal fossa. It is conical or pyramid-shaped and triangular in section. Its boundaries are represented anterolaterally by vastus medialis, posteriorly by adductor longus and adductor magnus muscles and anteromedially by a strong aponeurosis that extends between the adductors across the vessels to vastus medialis (vastoadductor membrane). Sartorius is anterior [1, 2]. The adductor canal is a relevant anatomical region for many reasons, in particular the hiatal region may be a preferential site for the developing of atherosclerotic plaques and may play a role in two different (vascular and nervous) entrapment syndromes.

The compression of the saphenous nerve at the adductor hiatus is believed to be a possible cause of pain on the medial aspect of the knee [3]. The saphenous nerve neuralgia should be remembered as a differential diagnosis of pain referred to the knee region but this nervous entrapment syndrome is so infrequent that diagnosis is rarely made [3]. Symptoms may be successfully relieved by saphenous nerve block alone or combined with surgical exploration and decompression, especially in those cases with an evident compression at the hiatus [4].

The vascular entrapment syndrome related to arterial compression is much more frequent than saphenous nerve entrapment. It presents as a claudication syndrome during strong physical exercise, typically in young males. The hypertrophy of muscular structure of the adductor hiatus may play an important role in the pathophysiological mechanism [5]. Lower limb arteriography sometimes reveals a short, probably extrinsic, compression of the femoral artery in the distal thigh with few or absolutely no other signs of atherosclerotic lesions at other site. Frequently the arteriography doesn't show any extrinsic compression, this suggesting a dynamic compression mechanism. Definite diagnosis is often made during surgical exploration when a fibrous band is encountered in the interior of the adductor canal or, most frequently, the musculoaponeurotic structures of adductor hiatus encroaches on the femoral artery. This claudication syndrome is relieved by section of the fibrous band and/or adductor hiatus, coupled or not with an autologous or synthetic femoral artery graft. Pathoanatomical findings reveal tunica intima proliferation and tears on the stenosed segment, which may be induced by long-standing, dynamic extrinsic compression [6, 7, 8, 9].
In addiction stenotic and occlusive arterial disease of the femoropopliteal segment is located in the distal part of the adductor canal in 70% of patients with intermittent claudication [10, 11].

Some theories suggest a local mechanical factor, while others suggest that local hemodynamic circumstances facilitate vascular disease in the region of the adductor canal hiatus [12].

According to the mechanical theory, intimal proliferation is caused by continuous microtraumas from the systolic hammering of the arterial wall against the adductor magnus tendon [12]. Others believe that intimal tears are caused by direct compression [6, 8] or traction [13] of the femoral artery in the hiatal region.

According to the hemodynamic theories, plaque formation occurs more frequently because of the "S" shaped curve of the femoral artery [14] or the high incidence of vascular branching in the hiatal region [10].

In literature the is only one paper about US anatomy of the adductor canal and it is a morphological study about US location of the adductor canal hiatus [15]. The US examinations were performed with an old generation 5-MHz mechanical-sector scanning head with a focal distance of 3.0 cm. More recently the introduction into clinical practice of sonographic equipment with high-resolution transducers, together with the development of new, increasingly sophisticated postprocessing algorithms to optimize image resolution, has led to an increased use of high-resolution ultrasound in assessment of the peripheral nervous system, including the saphenous nerve. In recent years large interest is arising in regional

anesthesia and pain medicine fields for the ultrasound-guided block of the saphenous nerve at different levels in the adductor canal [16-18]. This increasingly interest is related to continuing challenge of providing sensory anesthesia of the lower extremity without impairing disposition (quadriceps muscle weakness) of the ambulatory surgery patient. saphenous nerve block is essential for complete anesthesia of the foot and ankle because it represents the terminal branch of the posterior division of the femoral nerve and provides sensory innervation to the medial, anteromedial and posteromedial aspects of the lower extremity from the distal thigh to the medial malleolus.

The first of these peripheral anesthesiology works emphasized the importance of correct saphenous nerve detection in Hunter's canal when performing a peripheral nerve block using an ultrasonographic in-plane approach and avoiding unintentional puncture of major vessels [16]. In this work the Author asserted that the saphenous nerve can often be imaged where it pierces the vastoadductor membrane, but this first work was lacking of a complete and detailed US iconography of the anatomical basis for this anesthesiologic procedure.
More recently in a descriptive prospective study about the feasibility and efficacy of real-time ultrasound-guided block of the saphenous nerve in the adductor canal, Manickam and coll. asserted that during the examination of the lower third of the thigh using axial US scans the femoral artery was seen "diving" deep and progressively moving away from the anterior muscle plane (sartorius and vastus medialis muscle); this area was identified as the adductor hiatus and the peripheral block location was selected 2 to 3 cm proximally in the distal adductor canal [17]. It is important to note that with this procedure the sensitive block corresponded to the distribution of both the sartorial and infrapatellar branches of the saphenous nerve. Another, more selective, approach to saphenous nerve block is described by Horn and coll. using the saphenous branch of the descending genicular artery as a reference structure for US-guided peripheral nerve block out of the adductor canal [18].

In our anatomical study we pointed out the presence of some important anatomical landmarks to standardize the examination technique of the adductor canal.

We divided the Hunter's canal in three segments: the first part (proximal) is that segment of the canal where the posterior wall is formed by adductor longus muscle; the second part is bounded posteriorly by adductor magnus and the third part is the hiatal region. In the first part of the canal we observed the constant presence of a perforating venous vessel which connects the superficial femoral vein with the great saphenous vein. In all subjects of our examinations the saphenous nerve at the apex of the Scarpa's triangle is lateral to the superficial femoral artery and becomes more anterior near the emergence of the communicating vein, which may represent an Hunterian perforator [19; 20]. In the distal part of the second segment the nerve is clearly appreciable between the anterior aspect of the arterial wall and the deep fascia of sartorius muscle, which is the more anterior boundary (Figure 11).
Fig.: Figure 11. A, B, C The saphenous nerve at three different levels in the Hunter’s canal. Legend: SaM, sartorius muscle; arrow, saphenous nerve.

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The hiatal region was identified by the origin of the descending genicular artery. The descending genicular artery arises just proximal to the adductor opening and immediately supplies a saphenous branch. It then descends posterior to vastus medialis and anterior to the rounded tendon of adductor magnus, to reach the medial side of the knee, where it anastomoses with the medial superior genicular artery (Figures 12; 13).
Fig.: Figure 12. A, B Two MDCT angiography axial slices of the thigh in a patient with severe atherosclerosis of the femoral artery demonstrating the origin of the descending genicular artery and its bifurcation which gives rise to the saphenous branch. Legend: SaM, sartorius muscle; FemA, femoral artery; DescGA, descending genicular artery; SbDGA, saphenous branch of the descending genicular artery; VasMedM, vastus medialis muscle; AddMlf(hp), adductor magnus longitudinal fibers (hamstring part); AddMmtj(rt), adductor magnus myotendinous junction (origin of the rounded tendon).

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Fig.: Figure 13. A, B Two MDCT angiography reconstructed sagittal images of the same patient of Figure 12 showing the bifurcation of the descending genicular artery, its saphenous branch and the relations between the descending genicular artery and the rounded tendon of adductor magnus. Legend: SemimM, semimembranosus muscle; FemA, femoral artery; DescGA, descending genicular artery; SbDGA, saphenous branch of the descending genicular artery; VasMedM, Vastus medialis muscle; AddMmtj(rt), adductor magnus myotendinous junction (origin of the rounded tendon); AddTub, adductor tubercle; AddMrt, adductor magnus rounded tendon.

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The descending genicular artery, below the origin of the saphenous branch, runs inferiorly along with the adductor magnus tendon to the medial region of the knee. Using the color-Doppler module the descending genicular artery may be identified anteriorly to the rounded tendon of adductor magnus as a pulsatile vascular structure. At this level the femoral vessels were seen moving deeply in a postero-lateral direction toward the popliteal fossa. The saphenous nerve separates from the femoral vessels and accompanies the descending genicular artery toward the roof of the adductor canal, which here is represented by the vastoadductor membrane, appearing on US axial scans as a double hyperechogenic line. This fascia is formed by tendinous fibers which spread laterally from the rounded tendon of the adductor magnus toward the vastus medialis and end in the medial intermuscular septum and it may be pierced by the saphenous nerve and the descending genicular artery [20]. However this aponeurotic structure is not dissociable in vivo on US images from the deep muscular fascia of sartorius and adductor magnus muscles and a more precise anatomical correlation should be performed by US examination of a dissecting room preparation. Unfortunately it was impossible to demonstrate the saphenous nerve, accompanied by the saphenous branch of the descending genicular artery, piercing the vastoadductor membrane, probably due to problems of correct insonation related to its oblique course. However, in all examinations, the small saphenous branch of the descending genicular artery was appreciable passing through the roof of the adductor canal applying the color-Doppler module.

We found that the adductor canal hiatus anatomical limits were best assessed by coronal oblique US scans. The most important reference landmark is the adductor magnus rounded tendon which forms the medial wall of the adductor opening and attacks to the adductor tubercle of the medial femoral condyle. The descending genicular artery was easily appreciated anterior to the rounded tendon using the color-Doppler module. The superior limit of the Hunter’s canal hiatus is represented by the oblique fibers of the adductor part of adductor magnus muscle, which insert on the medial margin of the linea aspera. The deflection site of the superficial femoral vessels were correctly assessed in all subjects of our examination by coronal oblique scans, using the adductor magnus myotendinous junction or the rounded tendon itself as a reference landmark.
In conclusion HRUS technique was able to depict Hunter's canal boundaries and its neurovascular content with high anatomical detail in all subjects of our study. In addition we found several anatomical structures in the adductor canal which may be regarded as US reference landmarks for a standard US assessment of this region.
**Fig. 0:** Figure 11. A, B, C The saphenous nerve at three different levels in the Hunter's canal. Legend: SaM, sartorius muscle; arrow, saphenous nerve.

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Fig. 0: Figure 12. A, B Two MDCT angiography axial slices of the thigh in a patient with severe atherosclerosis of the femoral artery demonstrating the origin of the descending genicular artery and its bifurcation which gives rise to the saphenous branch. Legend: SaM, sartorius muscle; FemA, femoral artery; DescGA, descending genicular artery; SbDGA, saphenous branch of the descending genicular artery; VasMedM, vastus medialis muscle; AddMlf(hp), adductor magnus longitudinal fibers (hamstring part); AddMmtj(rt), adductor magnus myotendinous junction (origin of the rounded tendon).

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Fig. 0: Figure 13. A, B Two MDCT angiography reconstructed sagittal images of the same patient of Figure 12 showing the bifurcation of the descending genicular artery, its saphenous branch and the relations between the descending genicular artery and the rounded tendon of adductor magnus. Legend: SemimM, semimembranosus muscle; FemA, femoral artery; DescGA, descending genicular artery; SbDGA, saphenous branch of the descending genicular artery; VasMedM, Vastus medialis muscle; AddMmtj(rt), adductor magnus myotendinous junction (origin of the rounded tendon); AddTub, adductor tubercle; AddMrt, adductor magnus rounded tendon.

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