Anatomy of the Triceps Surae: A Pictorial Essay

Miquel Dalmau-Pastor, PodD, PT[a], Betlem Fargues-Polo Jr[a], Daniel Casanova-Martínez Jr[b], Jordi Vega, MD[c,*], Pau Golanó, MD[a,d,†]

KEYWORDS

• Anatomy • Surgical anatomy • Gastrocnemius • Gastrocnemius-soleus complex • Soleus • Calcaneal tendon • Plantaris muscle

KEY POINTS

- The triceps surae is a muscular group formed by the gastrocnemius, the soleus, and the plantaris muscles. The gastrocnemius and soleus muscles join to form the calcaneal tendon while the plantaris muscle inserts independently.
- Gastrocnemius and/or triceps surae lengthening is helpful in resolving foot disorders.
- There exist 5 different anatomic levels at which surgical lengthening of the triceps surae can be achieved. Mastering the anatomy of every level is the basis of these surgical procedures.

INTRODUCTION

Since the beginning of the twentieth century, several techniques have been reported for the treatment of triceps surae contracture in patients with cerebral palsy.[1–6] The objective of these techniques was to lengthen this muscle group. However, it was not until the publications by Kowalski and colleagues[7] in early 1999 and DiGiovanni and colleagues[8] in 2002 that interest in the anatomy of the triceps surae gained relevance, owing to the suggestion by these investigators that gastrocnemius contracture

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[a] Laboratory of Arthroscopic and Surgical Anatomy, Human Anatomy Unit, Department of Pathology and Experimental Therapeutics, School of Medicine, University of Barcelona, C/Feixa Llarga, s/n, 08907, Hospitalet de Llobregat, Barcelona, Spain; [b] Anatomy Unit, Biomedical Department, University of Antofagasta, Av. Universidad de Antofagasta s/n (Campus Coloso), Antofagasta 1240000, Chile; [c] Unit of Foot and Ankle Surgery, Hospital Quirón, Plaça d'Alfonso Comín 5, Barcelona 08023, Spain; [d] Department of Orthopaedic Surgery, School of Medicine, University of Pittsburgh, 4200 Fifth Avenue, Pittsburgh, PA 15213, USA
† Deceased
* Corresponding author.
E-mail address: jordivega@hotmail.com

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in the healthy individual is associated with conditions affecting the midfoot and forefoot, such as calcaneal tendon injury, metatarsalgia, plantar fasciopathy, diabetic ulcer, hallux valgus, flat foot, and digital deformity.[8–10]

Therefore, an article on the anatomy of the triceps surae is a key contribution to this special issue on contracture of the gastrocnemius muscle. This article is divided into two parts: one discussing the general anatomy of the triceps surae and one addressing the surgical anatomy of the gastrocnemius, a key area of knowledge for surgeons applying lengthening techniques.

TRICEPS SURAE

The triceps surae is the muscular group that occupies the superficial posterior compartment of the leg and comprises the gastrocnemius, soleus, and plantaris. The junction of the gastrocnemius and soleus forms the longest and most powerful tendon in the human body,[11,12] the calcaneal tendon. The plantaris, which is present in more than 90% of the population,[13–16] can merge with this muscle group to form the calcaneal tendon.

In recent years, the term gastrocnemius-soleus complex has been used to refer to the triceps surae.[17–20] Although the authors agree that gastrocnemius-soleus complex is a more clinical term and that, from a functional perspective, the gastrocnemius and soleus act as a single unit, the International Anatomical Terminology[21] has established the term triceps surae to refer to the group formed by the gastrocnemius and soleus. Therefore, triceps surae is the term used in this article.

Similarly, the calcaneal tendon is usually referred to as the Achilles tendon. However, as this term is not included in the International Anatomical Terminology,[21] calcaneal tendon is the preferred term here.

Gastrocnemius

The gastrocnemius comprises 2 heads, medial and lateral, at its origin. These heads insert proximally in the posterosuperior region of the corresponding femoral condyle (**Fig. 1**). However, the origin of the muscle varies depending on whether one is referring to the medial or lateral head.

Medial head

The medial head of the gastrocnemius originates in a triangular area on the popliteal aspect of the distal epiphysis of the femur. A medial and a lateral origin can be considered. The medial origin comprises a flattened, thick, and resistant tendon that extends over the medial condyle immediately below the insertion of the tendon of the adductor magnus muscle and along the medial supracondylar ridge. The lateral origin, less important, inserts by means of short tendinous and muscle fibers on the popliteal aspect of the medial femoral condyle, at the site of a small eminence known as the medial supracondyloid tubercle[22] (also called the medial supracondylar tubercle), and on the capsule of the knee joint (see **Fig. 1**; **Fig. 2**).

Lateral head

The lateral head of the gastrocnemius muscle originates from a tendon in a fossa situated posterior to the lateral epicondyle and proximal to the insertion of the popliteal muscle tendon in the lateral supracondylar ridge (see **Figs. 1** and **2**). Short tendinous fibers and muscle fibers situated medial to this tendon originate on the capsule of the knee joint and on the popliteal aspect, where a small bony eminence known as the lateral supracondyloid tubercle[22] (also called the lateral supracondylar tubercle) can be observed, albeit less often than on the medial side (**Fig. 3**).

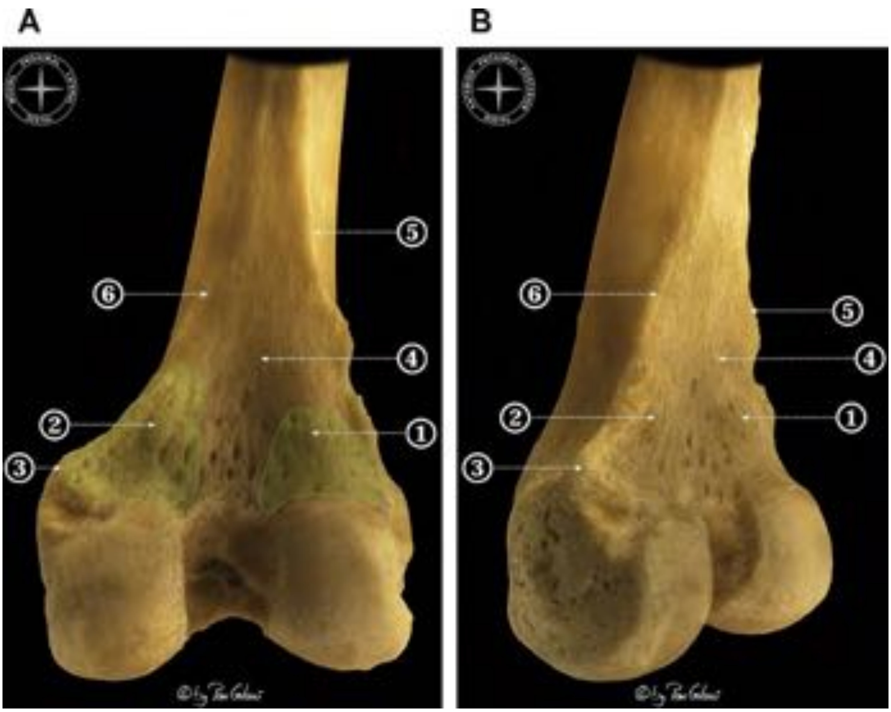

Fig. 1. Posterior (*A*) and posteromedial (*B*) views of the femoral distal epiphysis showing the bony prominences and insertional areas of gastrocnemius muscle (insertional areas of the medial and lateral head of gastrocnemius muscle have been marked in *green*). 1, lateral supracondyloid tubercle; 2, medial supracondyloid tubercle; 3, adductor tubercle; 4, popliteal surface of the femur; 5, lateral supracondylar line; 6, medial supracondylar line. (Figure Copyright © Pau Golanó 2014.)

An accessory ossicle, the fabella, which is found in 10% to 30% of the population, can be found embedded within the tendon of the lateral head (**Fig. 4**).[18] This small sesamoid bone is generally round or oval, with its major axis (5–20 mm) running parallel to the tendinous fibers of the lateral head of the gastrocnemius.[23] It is a casual finding in imaging studies and is usually bilateral.[24] Although the fabella does not generally cause symptoms, it can lead to posterolateral knee pain,[25] and can be fractured[26] or dislocated.[27]

The anterior aspect of the fabella is covered in hyaline cartilage and articulates with the lateral femoral condyle.[25] Its posterior aspect, which is generally convex, is embedded in the tendon and serves as an anchor point for various capsular-ligamentous structures in the posterolateral region of the knee (oblique popliteal ligament, fabellofibular ligament, and arcuate popliteal ligament) (**Fig. 5**).[28] Occasionally an accessory sesamoid bone can be observed on the tendon of the medial head.[12,29]

The medial head is wider and thicker than the lateral head (see **Fig. 2**).

The muscle fibers that originate in these divergent proximal fibers form 2 muscle bellies. As these course distally they converge on themselves, thus delimiting the lower triangle of the popliteal fossa, which is rhomboid in shape. Both muscle bellies are in contact with the posterior capsule of the knee and its reinforcements. The medial head slides across a serous bursa that is generally in direct contact with the joint. This bursa is responsible for the formation of a popliteal cyst (Baker cyst) in cases of

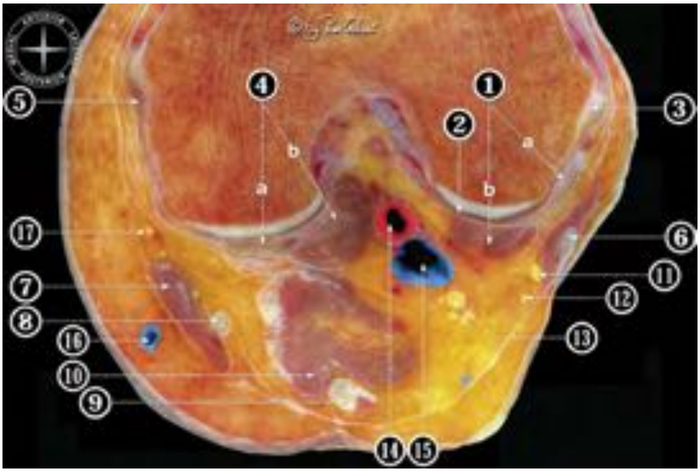

Fig. 2. Transversal section at the level of femoral condyles revealing the proximal insertion of the medial and lateral heads of gastrocnemius muscle (neurovascular structures have been painted with Adobe Photoshop). 1, proximal insertion of the lateral head of gastrocnemius muscle: a. tendinous insertion, b. muscular insertion; 2, knee capsule joint; 3, lateral collateral ligament of the knee joint; 4, proximal insertion of the medial head of gastrocnemius muscle: a. tendinous insertion, b. muscular insertion; 5, medial collateral ligament of the knee joint; 6, biceps femoris muscle; 7, sartorius muscle; 8, gracilis tendon; 9, semitendinosus tendon; 10, semimembranosus muscle; 11, common peroneal nerve; 12, lateral sural cutaneous nerve; 13, tibial nerve and branches; 14, popliteal artery; 15, popliteal vein; 16, great saphenous vein; 17, saphenous nerve. (Figure Copyright © Pau Golanó 2014.)

knee disorder.[28] In addition, the bursa can come into contact with the semimembranosus muscle bursa, thus favoring movement between the bulky tendon and the medial head of the gastrocnemius. The latter is referred to herein as the gastrocnemius-semimembranosus bursa, which may also be associated with the formation of a popliteal cyst (Fig. 6).

A corresponding inconstant serous bursa can also be found at the lateral head.

The muscle bellies finish on the posterior aspect of a wide tendinous lamina, or aponeurosis, which almost completely covers the anterior aspect of the corresponding muscle belly. This lamina, which is in contact with each head proximally, finishes as a single lamina with no muscle fibers at its distal end.[11] At the mid-calf, this aponeurosis joins the tendinous lamina of the soleus distally to form the calcaneal tendon (Fig. 7). The site and mechanism of union between the tendinous laminas play a key anatomic role in gastrocnemius recession.[30,31]

Plantaris

The plantaris, which is absent in 6% to 8% of the population, is found in the superficial posterior compartment of the leg.[13–16] It arises proximally just superior to the lateral condyle, on the lateral supracondylar ridge, proximal and medial to the lateral head of the gastrocnemius, with which it is in close contact (Fig. 8). A small belly measuring 5 to 12 cm emerges from this point[32] and runs distally from lateral to medial crossing the posterior aspect of the knee. At the origin of the soleus, the belly finishes in a long, flat, thin, and almost filiform tendon (approximately 25–35 cm long[32–34]) that varies between 1.5 and 5 mm in width depending on the report (Fig. 9).[16,33,34] This tendon runs down the leg between the bellies of the gastrocnemius and soleus until it reaches

Fig. 3. Posterolateral view of the medial half of the femur distal epiphysis, showing in detail the medial supracondyloid tubercle of the femur. 1, medial supracondyloid tubercle; 2, adductor tubercle; 3, medial supracondylar line; 4, popliteal surface of the femur; 5, medial epicondyle; 6, intercondylar notch (footprint of the posterior cruciate ligament). (Figure Copyright © Pau Golanó 2014.)

the medial border of the calcaneal tendon. Although it has been reported to join the calcaneal tendon, thus contributing to its formation,[32] anatomic studies show that this is not the case[13,34] or that it only joins the calcaneal tendon in very rare cases.[14] The location of the insertion point of the plantaris tendon varies widely. It is most often located in the medial area of the superior calcaneal tuberosity (47%),[13,14,34] anterior and medial to the calcaneal tendon, and thus independent of it (**Fig. 10**). Consequently, it often remains intact in cases of calcaneal tendon rupture. The variable nature of this distal insertion could be due to the loss of the plantar insertion of this muscle, a vestige from when man began to adopt an upright position.[14]

The plantaris can be injured at the level of the musculotendinous junction, either in isolation[35] or simultaneously with a partial rupture of the medial head of the gastrocnemius or soleus.[36]

Soleus

The soleus is the third component of the triceps surae, together with the medial head and the lateral head of the gastrocnemius and the plantaris, when present. The soleus

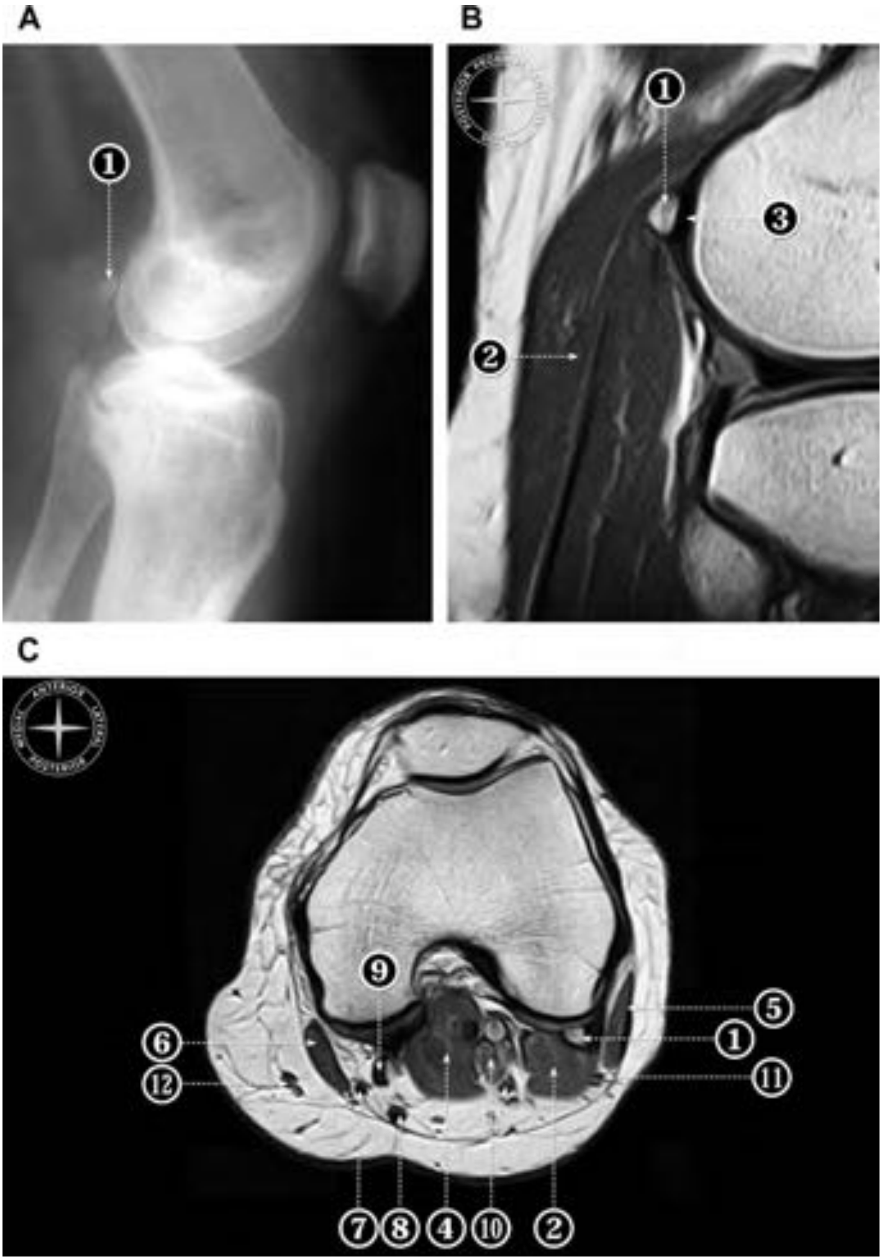

Fig. 4. Os fabella. (*A*) Lateral radiographic view of a right knee with an os fabella. (*B*) Sagittal T1-weighted magnetic resonance (MR) image of the knee showing an os fabella. (*C*) Transversal T1-weighted MR image of the knee showing an os fabella and its relation with surrounding structures. 1, os fabella; 2, lateral head of gastrocnemius muscle; 3, knee joint capsule; 4, medial head of gastrocnemius muscle; 5, biceps femoris muscle; 6, sartorius muscle; 7, gracilis tendon; 8, semitendinosus tendon; 9, semimembranosus tendon; 10, popliteal neurovascular bundle (tibial nerve and popliteal artery and vein); 11, common peroneal nerve; 12, saphenous nerve and great saphenous vein. (Figure Copyright © Pau Golanó 2014.)

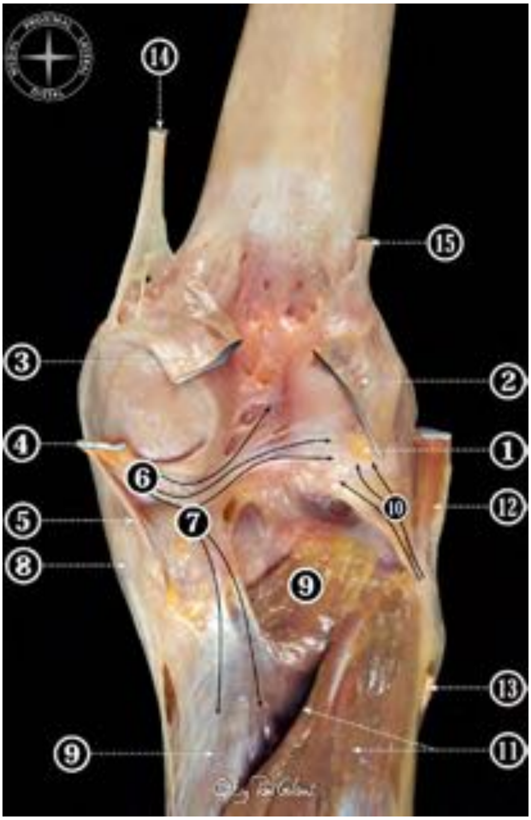

Fig. 5. Dissection of the popliteal region showing the posterior knee joint capsule and an os fabella. Neurovascular structures have been resected. 1, os fabella; 2, lateral head of gastrocnemius muscle (cut); 3, medial head of gastrocnemius muscle (cut); 4, semimembranosus tendon (cut); 5, expansion of the semimembranosus tendon (anterior arm); 6, expansion of the semimembranosus tendon (oblique popliteal ligament, *black arrows*); 7, expansion of the semimembranosus tendon (inferior arm, *black arrows*); 8, medial collateral ligament of the knee joint; 9, popliteus muscle; 10, arcuate popliteal ligament (and *black arrows*); 11, soleus muscle and its tendinous arch; 12, biceps femoris tendon (cut); 13, common peroneal nerve (cut); 14, adductor magnus tendon (cut); 15, lateral intermuscular septum (cut). (Figure Copyright © Pau Golanó 2014.)

is a broad and bulky muscle that lies deep to the gastrocnemius and plantaris and superficial to the muscles of the deep posterior compartment (tibialis posterior, flexor digitorum longus, and flexor hallucis longus muscles), which it covers for most of its course.

The soleus has both a fibular and tibial origin. The fibular origin is on the posterior aspect of the head and upper fourth of the diaphysis. The tibial origin is at the inferior border of the soleal line, a bony ridge running obliquely lateral-proximal to medial-distal that is situated on the upper third of the posterior aspect of the tibia, and the posteromedial border of the tibia (middle third) (Fig. 11).

Both origins, which are made of tendinous fibers, merge distally to form a fibrous arch known as the tendinous arch of the soleus, which enables the passage of the tibial nerve and posterior tibial artery and accompanying veins from a superficial position toward the deep posterior compartment (Fig. 12).

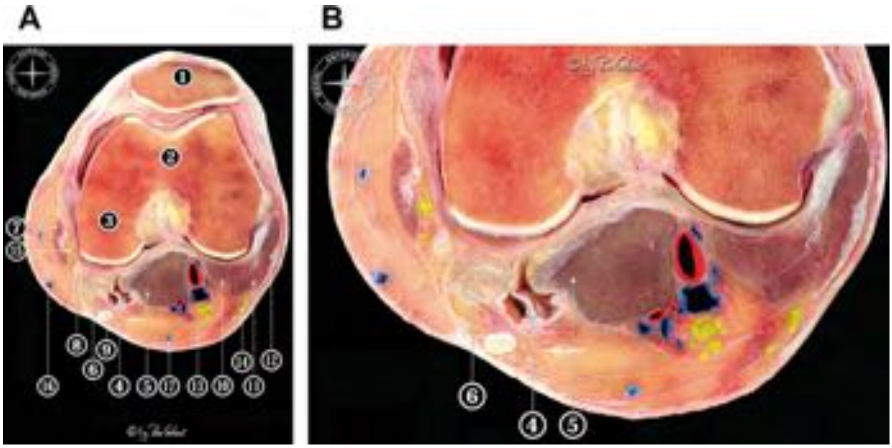

Fig. 6. Popliteal cyst. (*A*) Transversal section at the level of the knee joint showing a popliteal cyst (Baker cyst) at the gastrocnemius-semimembranosus bursa. (*B*) Photomacrography. 1, patella; 2, femur; 3, intercondylar notch; 4, popliteal cyst; 5, medial head of gastrocnemius muscle; 6, semimembranosus tendon; 7, sartorius muscle; 8, gracilis tendon; 9, semitendinosus tendon; 10, lateral head of gastrocnemius muscle; 11, plantaris muscle; 12, biceps femoris muscle; 13, neurovascular bundle (tibial nerve and popliteal artery and vein); 14, common peroneal nerve; 15, saphenous nerve; 16, great saphenous vein; 17, lesser saphenous vein. (Figure Copyright © Pau Golanó 2014.)

The tendinous lamina resulting from the union of these origins gives rise to muscle fibers on both aspects (anterior and posterior). Although most muscle fibers arise from the posterior aspect, some muscle fibers detach from the anterior aspect. Thus, the tendinous lamina is part of the muscle mass and forms the so-called intramuscular aponeurosis of the soleus (Fig. 13). Although the tibial nerve innervates the soleus muscle as a whole, each aspect of the muscle (anterior and posterior) has independent branches.[11,32,37,38]

The muscle fibers that originate on the posterior aspect converge downward to finish on the anterior aspect and on the borders of a new tendinous lamina, known as the insertion lamina. This lamina extends proximally along the posterior aspect of the muscle belly (see Fig. 13). Wide in its proximal part, it gradually narrows until it joins the tendinous lamina from the gastrocnemius to form the calcaneal tendon. The site and mechanics of the union of both tendinous laminas are an important anatomic detail that should be taken into account in the surgical techniques described later.

Lastly, the bipennate fibers arising on the anterior aspect of the tendinous lamina, or intramuscular aponeurosis, finish in another tendinous formation, known as the median septum.[39,40] This thin component, which takes the form of a short septum, originates on the anterior aspect of the aponeurosis (Fig. 14).

The complexity of the muscle fibers, aponeurosis, and innervation of the soleus muscle has motivated studies about its muscular architecture and intramuscular innervation.[37–42]

Calcaneal Tendon

The calcaneal tendon is formed by the union of the soleus and gastrocnemius muscles. It may also include the plantaris (see earlier discussion) (Fig. 15).

Fig. 7. Superficial dissection of the leg and popliteal area showing a posterior view of the triceps surae and its components and surrounding structures. 1, lateral head of gastrocnemius muscle; 2, medial head of gastrocnemius muscle; 3, gastrocnemius aponeurosis; 4, soleus muscle; 5, calcaneal tendon; 6, posterior deep fascia of the leg; 7, biceps femoris muscle; 8, sartorius muscle; 9, gracilis tendon; 10, semitendinosus tendon; 11, semimembranosus muscle; 12, common peroneal nerve; 13, tibial nerve and branches; 14, sural nerve; 15, popliteal artery and vein. (Figure Copyright © Pau Golanó 2014.)

The calcaneal tendon is the longest and strongest tendon in the human body.[11,12] On average, it can measure up to 2.5 cm in diameter[13] and approximately 15 cm in length.[12] It is also the most frequently injured tendon in the leg (20% of all tendon lesions).[43,44]

The union of the gastrocnemius tendinous lamina to the soleus at mid-calf gives rise to the calcaneal tendon. The contribution of the different muscles to the formation of the calcaneal tendon varies between individuals. Cummins and colleagues[13] observed that the soleus accounts for two-thirds of the tendon in 52% of subjects, both the soleus and the gastrocnemius account for half of the tendon in 35%, and the gastrocnemius accounts for two-thirds of the tendon in the remaining 13%.

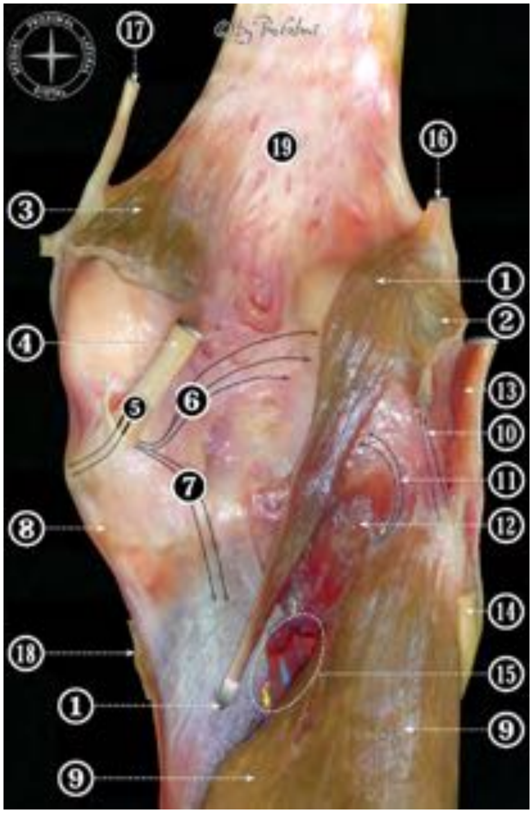

Fig. 8. Dissection of the popliteal region. The lateral head of gastrocnemius muscle has been cut and rejected to show the entire muscle belly of the plantaris muscle. 1, plantaris muscle (*large gray arrow* shows direction of the tendon); 2, lateral head of gastrocnemius muscle (cut); 3, medial head of gastrocnemius muscle (cut); 4, semimembranosus tendon (cut); 5, expansion of the semimembranosus tendon (anterior arm); 6, expansion of the semimembranosus tendon (oblique popliteal ligament, *gray arrows*); 7, expansion of the semimembranosus tendon (inferior arm, *gray arrows*); 8, medial collateral ligament of the knee joint; 9, soleus muscle; 10, fabellofibular ligament (and *gray arrows*); 11, arcuate popliteal ligament (and *gray arrows*); 12, popliteus muscle; 13, biceps femoris tendon (cut); 14, common peroneal nerve (cut); 15, neurovascular bundle passing through the tendinous arch of the soleus; 16, lateral intermuscular septum (cut); 17, adductor magnus tendon (cut); 18, pes anserinus distal insertion (cut); 19, popliteal surface of the femur. (Figure Copyright © Pau Golanó 2014.)

The calcaneal tendon is wide at its origin, although it narrows slightly as it descends, reaching its minimum width at the level of the ankle joint, before widening again and inserting on the calcaneus.[32] The narrowest point results from rotation of the fibers (**Fig. 16**).[13] Consequently, the medial fibers rotate posteriorly and the posterior fibers rotate laterally. The anterior aspect is composed of fibers from the lateral gastrocnemius, and the anteromedial part of the tendon is composed of fibers from the soleus.[45] Torsion of the fibers of the tendon gives it greater mechanical resistance.[46] However, this torsion also creates a poorly vascularized area of stress 2 to 5 cm proximal to its insertion in the calcaneus.[13]

Fig. 9. Overview of plantaris muscle. (Figure Copyright © Pau Golanó 2014.)

Vascularization of the calcaneal tendon has been widely studied.[47–50] It receives its blood supply from the myotendinous junction, the osteotendinous junction, and the paratenon. Vascular supply is via 2 arteries: the posterior tibial artery and the fibular artery. The posterior tibial artery irrigates the proximal and distal sections of the tendon, whereas the fibular artery irrigates the mid-section.[50] The supply from the posterior tibial artery is rich, whereas the mid-section of the tendon, irrigated by the fibular artery, has fewer vessels and therefore a poorer supply.[47]

Sections of the tendons with poor irrigation are more likely to rupture. Therefore, it is no surprise that most ruptures of the calcaneal tendon are in the mid-section.[50]

The bursa of the calcaneal tendon, or retrocalcaneal bursa, is found at the insertion point of the tendon on the posterior aspect of the calcaneus.[51] This bursa, which lies between the calcaneal tendon and the calcaneus, enables proper sliding of the tendon (**Fig. 17**). A second bursa, the subcutaneous calcaneal bursa, is constant and lies between the tendon and the skin (**Fig. 18**).

Knowledge of vascularization of the skin and subcutaneous tissue surrounding the calcaneal tendon is essential in avoiding complications during scarring after surgery. The skin covering the medial and lateral borders of the tendon is better vascularized than that of the posterior aspect. Therefore, it is advisable to avoid incisions on the posterior aspect, because they could lead to complications during scarring.[52]

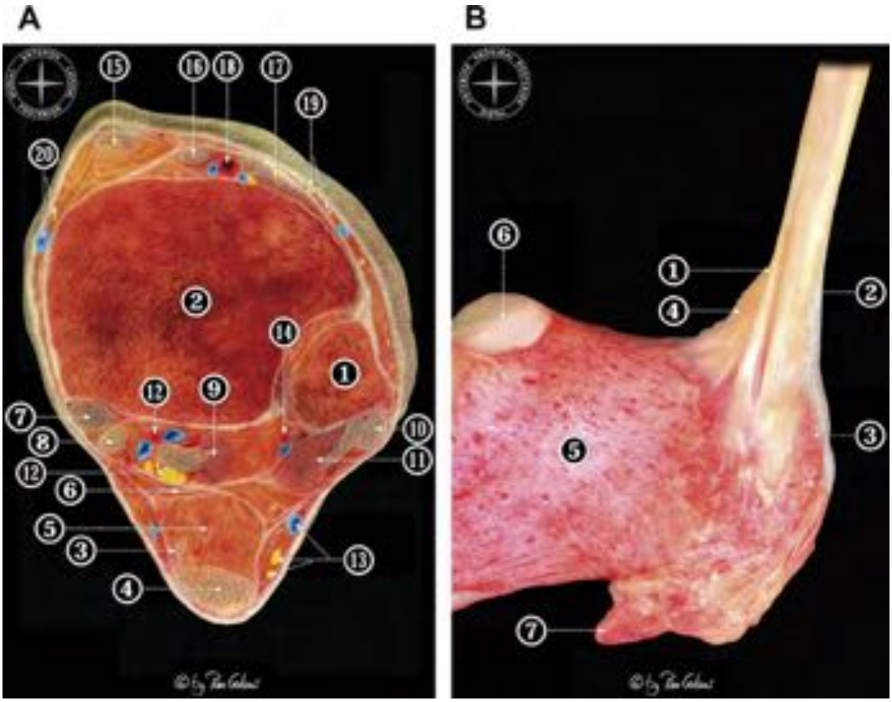

Fig. 10. Plantaris muscle distal insertion. Both preparations show the independent insertion of the plantaris tendon from the calcaneal tendon. (*A*) Transversal section at the level of tibiofibular syndesmosis (neurovascular structures have been painted with Adobe Photoshop). 1, fibula; 2, tibia; 3, plantaris tendon; 4, calcaneal tendon; 5, precalcaneal fat tissue (Kager fat pad); 6, posterior deep fascia of the leg; 7, tibialis posterior tendon; 8, flexor digitorum longus tendon; 9, flexor hallucis longus tendon; 10, peroneus longus tendon; 11, peroneus brevis tendon; 12, posterior neurovascular bundle (tibial nerve, posterior tibial artery and veins); 13, sural nerve and lesser saphenous vein; 14, peroneal artery; 15, tibialis anterior tendon; 16, extensor hallucis longus tendon; 17, extensor digitorum longus and peroneus tertius tendons; 18, anterior neurovascular bundle (deep peroneal nerve, anterior tibial artery and veins); 19, branches of the superficial peroneal nerve; 20, Saphenous nerve and greater saphenous vein. (*B*) Dissection showing the insertion of the calcaneal and plantaris tendons on the calcaneus. 1, plantaris tendon; 2, calcaneal tendon; 3, posterior calcaneal spur; 4, calcaneal tendon bursa; 5, medial surface of the calcaneus; 6, posterior articular surface for the talus (posterior subtalar joint); 7, calcaneal spur. (Figure Copyright © Pau Golanó 2014.)

Incisions made on the lateral aspect of the tendon carry the risk of injury to the sural nerve and lesser saphenous vein; therefore, incisions made on the medial side seem to be the most appropriate.

Innervation

The triceps surae is innervated by branches from the tibial nerve, which provide motor innervation to the popliteal area.

Function of the Triceps Surae

The gastrocnemius and soleus share an insertion tendon in the calcaneus; therefore, they exercise the same function on the foot. Contraction of the triceps surae produces plantar flexion with adduction and medial rotation of the foot.[11] Despite this similarity

Fig. 11. Posterior view of the proximal half of tibia and fibula bones. Fibular and tibial proximal insertions of the soleus muscle are shown in green. Dotted line indicates the tendinous arch of the soleus muscle. 1, tibial proximal insertion of the soleus muscle on the soleal line; 2, fibular proximal insertion of the soleus muscle. (Figure Copyright © Pau Golanó 2014.)

in function, the power of each muscle differs considerably. In their study on muscle balance, Silver and colleagues[53] found the soleus to be the main plantar-flexor muscle of the foot and the most powerful muscle of those crossing the ankle. The soleus provides more than double the plantar-flexor force of the gastrocnemius, whose medial head provides 71% of its force, with the lateral head contributing only a small part to the plantar-flexor force.

The gastrocnemius also crosses the knee joint, and its contraction leads to flexion of the knee. The flexion force of the gastrocnemius is greater when the knee joint is fully extended.[54] It was traditionally believed that the gastrocnemius and the soleus helped to push the body forward during walking[55]; however, recent studies show that this may not be the case. It seems that the function of the triceps surae during walking has more to do with control of balance and indirect modulation of walking speed.[56] In addition, the soleus acts as a peripheral vascular pump.[57]

Given their function in the foot, it seems logical to consider that the soleus and gastrocnemius enable maximal plantar flexion of the foot and the tiptoe position. However, some investigators state that the plantar aponeurosis plays a fundamental role in this movement, mainly owing to a system that integrates the calcaneal tendon with

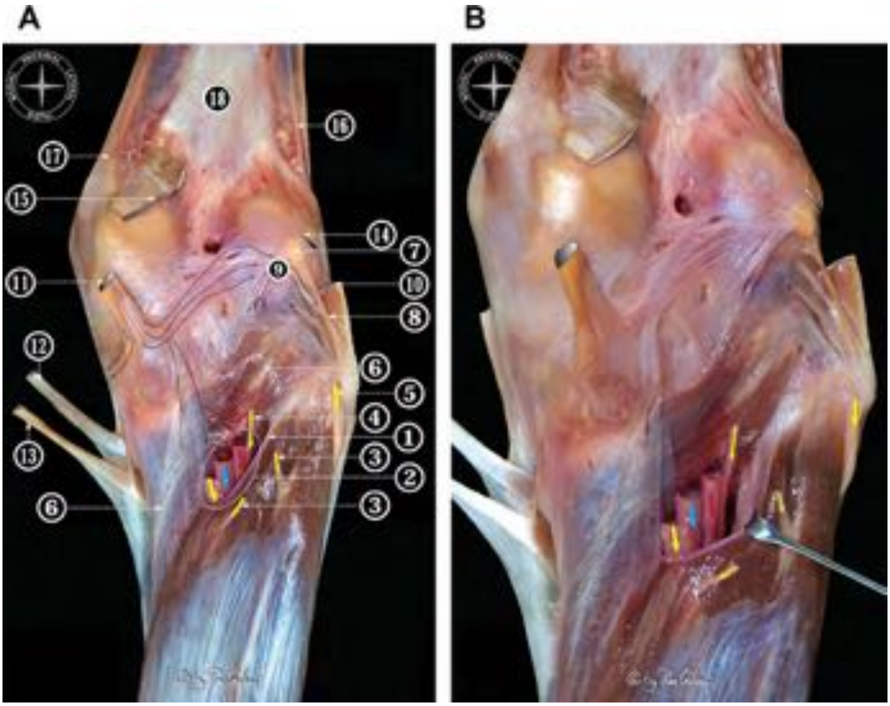

Fig. 12. Dissection of the popliteal region showing the proximal insertion of the soleus muscle and the passage of the neurovascular bundle trough the tendinous arch of the soleus (gastrocnemius muscle has been resected). (*A*) posterior view of the popliteal region. (*B*) posteromedial view (photomacrography) of the popliteal region (surgical instrument is retracting the tendinous arch of the soleus muscle); 1, tendinous arch of the soleus muscle; 2, neurovascular bundle (posterior tibial vein, posterior tibial artery, tibial nerve); 3, motor branches of the tibial nerve entering the soleus muscle (cut) (posterior part of the soleus has usually 2 or 3 motor branches[37]); 4, motor branch for the anterior aspect of soleus and flexor hallucis longus muscles (cut); 5, common peroneal nerve (cut); 6, popliteus muscle; 7, os fabella; 8, fabellofibular ligament; 9, arcuate popliteal ligament; 10, biceps femoris tendon (cut); 11, semimembranosus tendon (cut) and its expansions (*gray arrows*); 12, gracilis tendon (cut); 13, semitendinosus tendon (cut); 14, lateral head of gastrocnemius muscle (cut); 15, medial head of gastrocnemius muscle (cut); 16, lateral intermuscular septum; 17, adductor magnus tendon; 18, popliteal surface of the femur. (Figure Copyright © Pau Golanó 2014.)

structures on the sole (plantar fascia and plantar intrinsic foot muscles) with transmission of forces through the calcaneus. This system was first described by Arandes and Viladot in 1953, and is known as the Achilles-calcaneal-plantar system.[58]

Achilles-Calcaneal-Plantar System

The Achilles-calcaneal-plantar system comprises the calcaneal tendon, the posteroinferior portion of the calcaneus and its trabecular system, the plantar aponeurosis, and the plantar intrinsic foot muscles (**Fig. 19**).

Several investigators have demonstrated continuity between the fibers of the calcaneal tendon and the plantar aponeurosis[51,59]; however, this continuity was only obvious in the fetus and gradually diminished with age until adulthood, when it disappeared, leaving only periosteum between the tendon insertion and the plantar

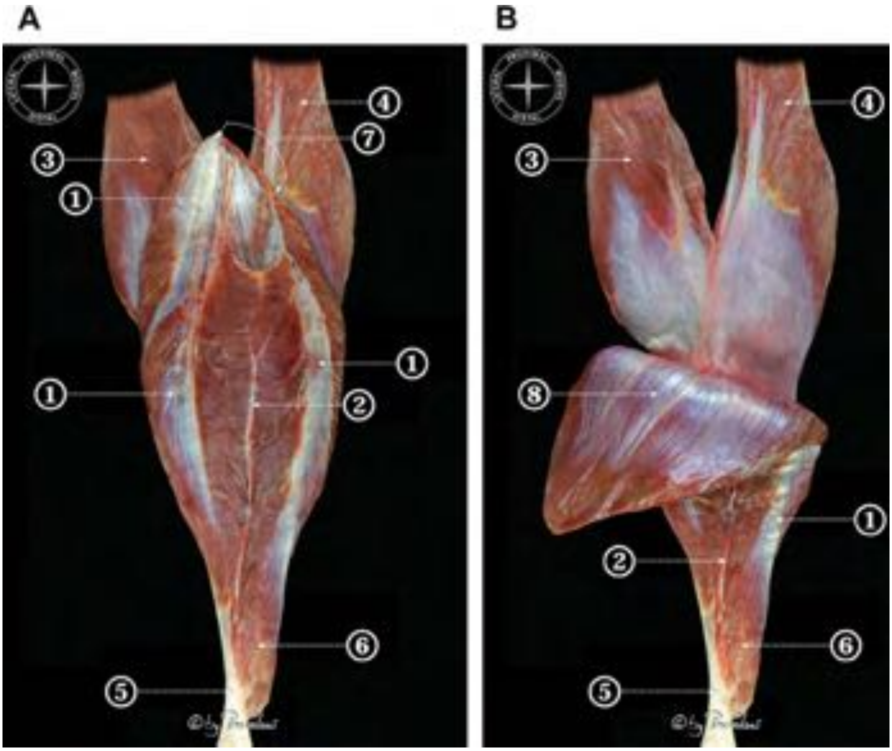

Fig. 13. Overview of the triceps surae components. Muscles have been disinserted. (*A*) Anterior view. (*B*) Anterior view with soleus muscle retracted. 1, intramuscular aponeurosis of the soleus muscle; 2, median septum; 3, lateral head of gastrocnemius muscle; 4, medial head of gastrocnemius muscle; 5, calcaneal tendon; 6, accessory soleus muscle; 7, tendinous arch of soleus muscle; 8, soleus posterior aponeurosis. (Figure Copyright © Pau Golanó 2014.)

aponeurosis.[59] A recent study ruled out a connection between the calcaneal tendon and the plantar aponeurosis, and showed that the only connection is between the paratenon and the plantar aponeurosis.[60]

Some studies associate an excess of tension in the posterior muscles of the thigh and leg with plantar fasciopathy.[61] Furthermore, it seems that proximal release of the medial head of the gastrocnemius is an effective approach to chronic plantar fasciopathy.[62] However, the investigators suggest that reduced dorsiflexion of the ankle is at least partly responsible for plantar fasciopathy, and not the existence of the Achilles-calcaneal-plantar system.

Therefore, despite an apparent functional connection between the structures, the authors believe that the lack of anatomic evidence and reports in the literature makes it possible to rule out the existence of the Achilles-calcaneal-plantar system.

Plantar Aponeurosis

The plantar aponeurosis (plantar fascia) is the fascial covering of the sole.[63] It lies deep to the skin and is separated therefrom by a thick layer of fatty tissue,[11] the plantar fat pad (**Fig. 20**). This fascia is organized into longitudinal, transversal, and vertical bands and tracts. Together with the encapsulated fat lying between the tracts, the fascia connects the skin to the skeleton and enables passage for vessels, nerves, and tendons,

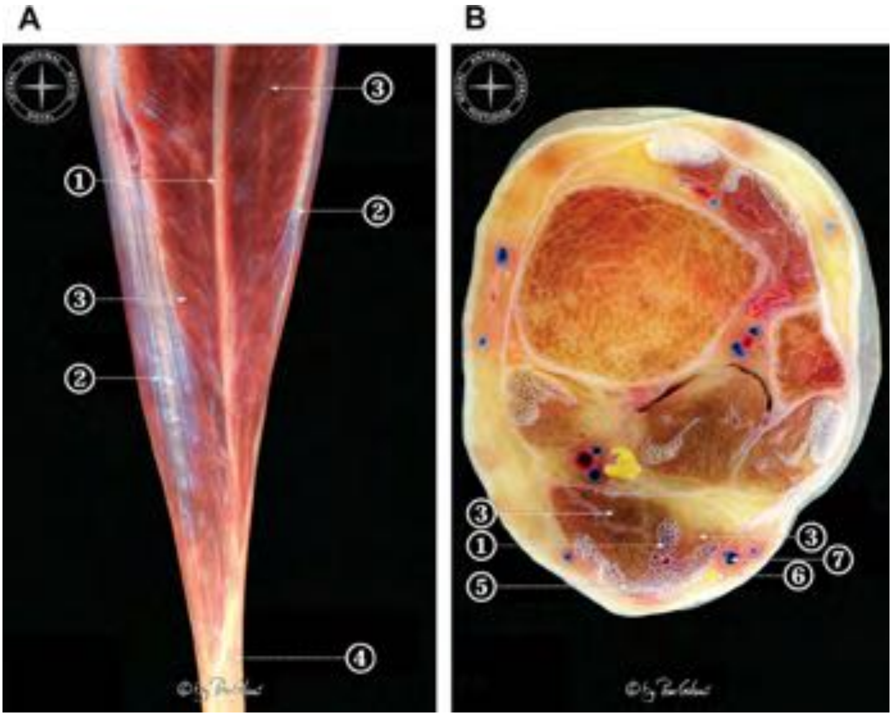

Fig. 14. The median septum of soleus muscle. (*A*) Photomacrography of an anterior view of the soleus muscle showing the median septum and the insertion lamina, finishing in the calcaneal tendon. (*B*) Transversal section at the distal third of the leg showing the sagittal orientation of the median septum. 1, median septum of soleus muscle; 2, intramuscular aponeurosis of the soleus; 3, muscle fibers of the bipennate anterior aspect of soleus muscle; 4, calcaneal tendon; 5, gastrocnemius aponeurosis; 6, sural nerve; 7, lesser saphenous vein. (Figure Copyright © Pau Golanó 2014.)

which it protects from the load of the metatarsal heads.[64] The plantar aponeurosis is also the main support structure of the medial longitudinal arch of the foot.[63]

The plantar aponeurosis is divided into 3 components; medial, central, and lateral. It is triangular in shape, with the apex posterior (calcaneal) and the base anterior (toes). It originates in both apophyses (medial and lateral) of the calcaneal tuberosity. Anteriorly, the fascia finishes at the metatarsophalangeal joints of the first to fifth toes, with some fibers reaching the skin and others contributing to the plantar plate and natatory ligament. The lateral and medial components adhere to the corresponding edge of the foot, in continuity with the dorsal fascia of the foot.[11]

Medial component

The medial component is the smallest of the 3 and forms the fascia of the abductor muscle of the great toe. It originates in the medial tuberosity of the calcaneus and continues medially with the dorsal fascia of the foot.[65]

Lateral component

The lateral component originates on the lateral calcaneal tuberosity[11] or on the lateral side of the medial tuberosity.[63] It then continues anteriorly before bifurcating medially and laterally at the cuboid. The medial component inserts on the base of the fifth metatarsal and the lateral tract on the fascia of the abductor of the fifth toe.[63]

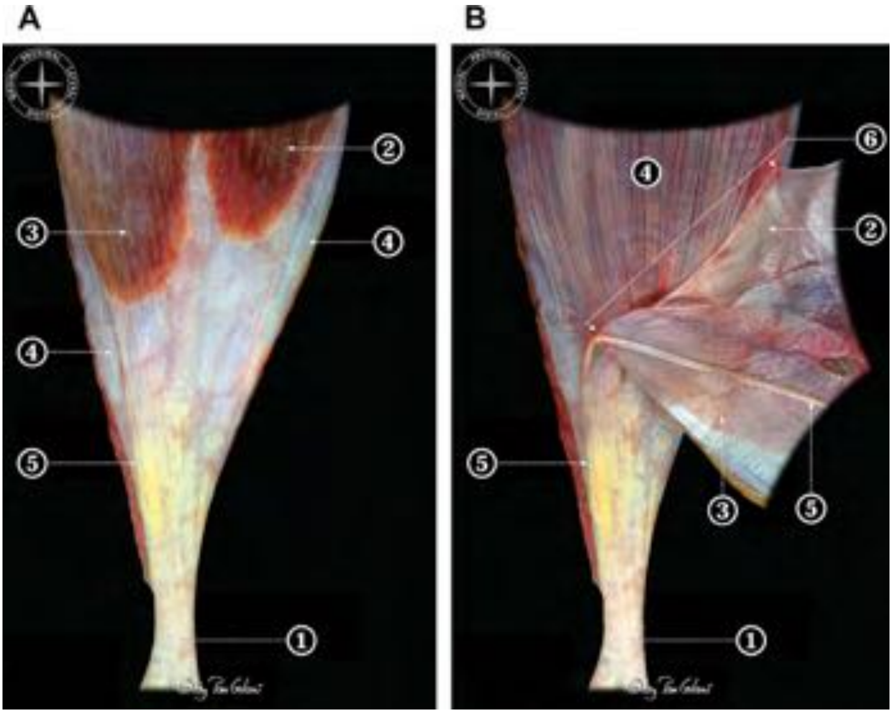

Fig. 15. Muscular dissection of the distal part of the triceps surae showing the aponeurosis of gastrocnemius and soleus muscles and its fusion to form the calcaneal tendon. There is a degenerative lesion (tendinosis) on the medial part of the calcaneal tendon (*yellow area*). (*A*) Posterior view. (*B*) Posterior view with gastrocnemius muscle retracted, showing the fusion of gastrocnemius aponeurosis with soleus posterior aponeurosis. 1, Calcaneal tendon; 2, lateral head of gastrocnemius muscle; 3, medial head of gastrocnemius muscle; 4, soleus posterior aponeurosis; 5, plantaris tendon; 6, area of insertion of gastrocnemius aponeurosis into soleus posterior aponeurosis. (Figure Copyright © Pau Golanó 2014.)

Central component

The central component is the largest of the 3 and is triangular, with the apex posterior and the base anterior. It originates on the medial apophysis of the calcaneal tuberosity.[63]

The fibers of the central component of the plantar aponeurosis become longitudinal in orientation and expand anteriorly. Proximally, at the head of the metatarsals, they divide into 5 divergent superficial bands,[64] each of which in turn divides into 3 parts, 1 superficial and 2 deep. The superficial fibers insert into the dermis distal to the metatarsophalangeal joints, thus contributing to the formation of the superficial transverse intermetatarsal ligament,[21] also known as the natatory ligament.[66,67]

The 2 deep components (sagittal septa), which arise from the longitudinal bands, are arranged as septa situated in the sagittal plane and surrounding the corresponding flexor tendons, thus contributing to the formation of its fibrous sheath.[65] These septa insert into the plantar plate and/or sesamoid bones (great toe) and into the deep transverse metatarsal ligament. Both septa continue with vertical fibers that insert into the skin. Moreover, these sagittal septa divide the plantar fat pad into compartments, thus

Fig. 16. The calcaneal tendon. (*A*) Dissection showing a posterior view of the calcaneal tendon. (*B*) Anterior view of the calcaneal tendon demonstrating the characteristic rotation of its fibers (specimen is the same in *A* and *B*). 1, calcaneal tendon; 2, insertional area of the calcaneal tendon; 3, lateral head of gastrocnemius muscle; 4, medial head of gastrocnemius muscle; 5, soleus muscle; 6, lateral intermuscular septum; 7, posterior deep fascia of the leg; 8, median septum; 9, plantaris tendon. (Figure Copyright © Pau Golanó 2014.)

creating bodies of adipose tissue between the flexor tendons that protect the neurovascular bundle and fibrous tunnels that enable passage of the lumbrical tendons (see Fig. 20).

SURGICAL ANATOMY

Several procedures have been described for the treatment of contracture of the gastrocnemius and soleus.[1–6,68–72] Over the years, the original techniques have undergone various modifications with the aim of preventing or reducing complications (especially those affecting the sural nerve), predicting potential anatomic variations, reducing postsurgical convalescence, and improving cosmetic outcome.

The main complications arising from surgical procedures in the area described here include neurologic lesions,[10,73,74] especially those affecting the sural nerve, and poor cosmetic outcome resulting from an excessively wide incision.[75] The intimate relationship between the sural nerve and the triceps surae and its components means that the nerve is at risk of injury during surgery (Fig. 21).

Irrespective of the technique applied, knowledge of the local anatomy is a prerequisite if complications, which occur in 0% to 22.2% of cases, are to be reduced or avoided.[10,76–84]

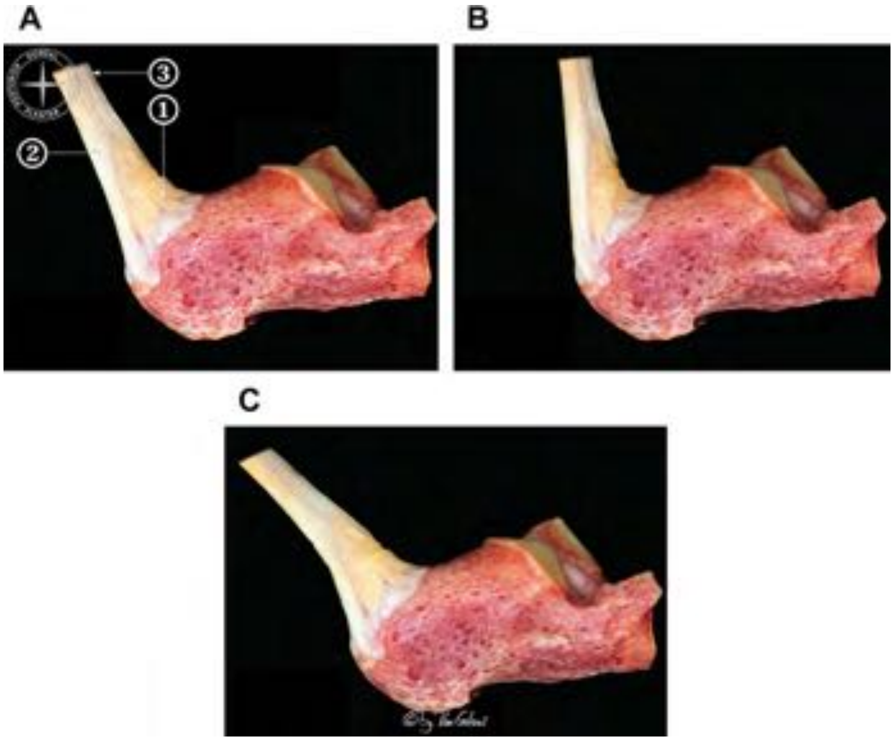

Fig. 17. Dissection of the calcaneal tendon and its insertion on the calcaneus showing the retrocalcaneal bursa through ankle's range of motion (calcaneus has been disarticulated from the foot skeleton). (*A*) Ankle in neutral position. (*B*) Ankle in dorsiflexion. (*C*) Ankle in plantar flexion. 1, retrocalcaneal bursa; 2, calcaneal tendon; 3, plantaris tendon. (Figure Copyright © Pau Golanó 2014.)

The type of technique is also important. The current trend is to propose minimally invasive open procedures in addition to endoscopic procedures. Fewer complications have been reported with these techniques.[10,76–84]

The anatomic site chosen to divide the triceps surae or any of its components is important. The surgeon should be fully acquainted with the various anatomic structures, because the difficulty of the technique and the number of complications will depend on this knowledge. Therefore, and following the schedule proposed by Lamm and colleagues,[85] the authors have divided surgical anatomy into 5 levels, of which level 5 is the most proximal and 1 the most distal (**Fig. 22**).

Level 5 comprises the proximal insertions and tendons of the medial and lateral heads of the gastrocnemius.

Level 4 comprises the medial and lateral bellies of the gastrocnemius.

Level 3 starts where the muscle bellies of the gastrocnemius merge to form the calcaneal tendon and finishes where the aponeuroses of the soleus and gastrocnemius merge.

Level 2 starts in the common aponeurotic tendon of the soleus and gastrocnemius and finishes at the distal end of the soleus muscle.

Level 1 consists of the calcaneal tendon.

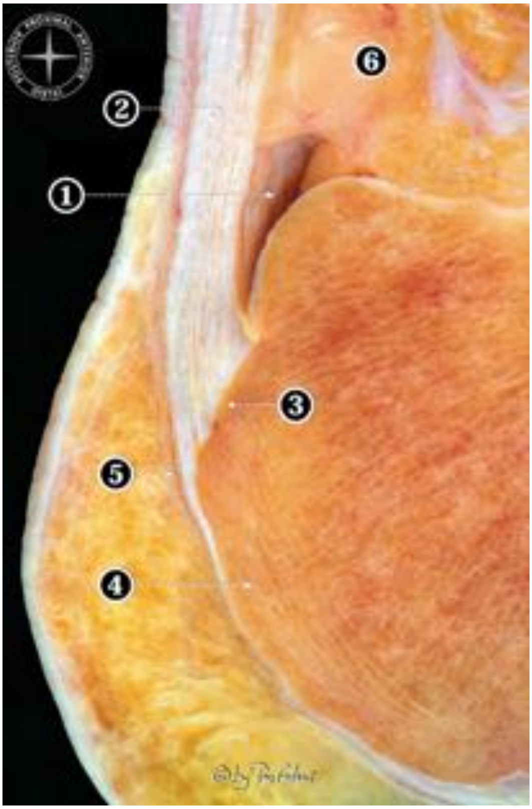

Fig. 18. Sagittal section showing the insertion of the calcaneal tendon and the adjacent bursae. 1, bursa of the calcaneal tendon; 2, calcaneal tendon; 3, insertional area of the calcaneal tendon; 4, calcaneal tuberosity; 5, subcutaneous calcaneal bursa; 6, precalcaneal fat tissue (Kager fat pad). (Figure Copyright © Pau Golanó 2014.)

A 3-level classification of the gastrocnemius-soleus complex based on the surgical procedures used at each level has been proposed.[20] However, the authors use the classification proposed by Lamm and colleagues,[85] considering that it is more anatomic.

The division into levels serves a didactic need and not an anatomic one, because levels 3 and 2 are not always easy to define owing to the anatomic variability of the way the aponeurosis of the gastrocnemius joins the soleus.[30] Nevertheless, the division enables the surgeon to identify the neurovascular structures at risk, depending on the level at which the surgical procedure is performed, thus enabling a safer and more complication-free procedure.

Level 5

Proximal gastrocnemius tenotomy can be performed at this level.

The original procedure for proximal release of the gastrocnemius was described by Silfverskiöld.[2] This procedure consisted of transferring the proximal insertions of the gastrocnemius from the femur to the tibia, thus converting the gastrocnemius into a second soleus muscle. The original technique described section of both the medial and lateral head; today, however, only section of the medial head is performed.[68–72]

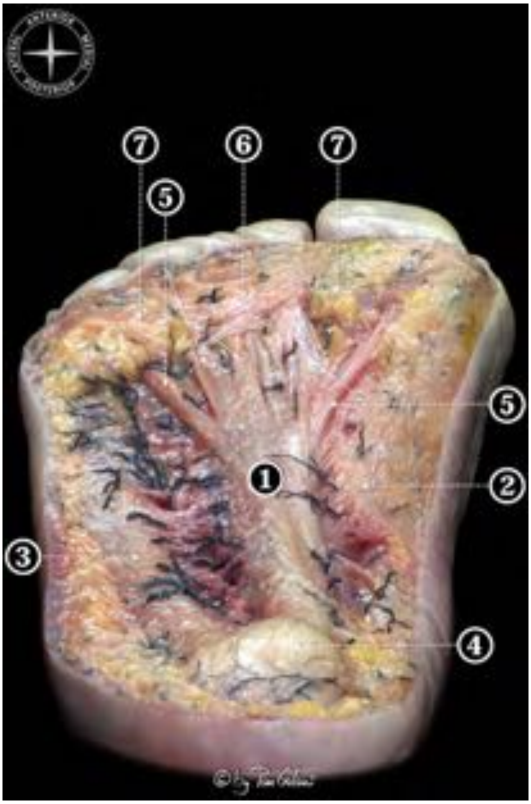

Fig. 19. Posteroplantar view of a dissection of the ball of the foot showing the plantar aponeurosis (arterial network was filled with *black latex*). 1, central component of the plantar aponeurosis; 2, medial component of the plantar aponeurosis; 3, lateral component of the plantar aponeurosis; 4, medial apophysis of the calcaneal tuberosity; 5, superficial bands; 6, transversal bands of the plantar aponeurosis; 7, bodies of adipose tissue. (Figure Copyright © Pau Golanó 2014.)

At this level, certain anatomic details are worthy of mention.

Adequate localization of skin reference points in the medial zone of the popliteal region is essential. In nonobese patients, a small cutaneous fossa can be easily observed in the medial popliteal area; this area results from the proximal-distal course of the semitendinosus and semimembranosus tendons (**Fig. 23**). It is worth remembering that this reference can disappear or be reduced in patients who have undergone anterior cruciate ligament reconstruction using a hamstring graft. The skin incision (3–5 cm) should be made at this level, coinciding with the fold of the flexed knee.[68] Although this medial incision respects neurovascular structures, possible variations in the lesser saphenous vein should be taken into consideration.[86] Of note, an excessively lateral incision could place neurovascular structures at risk (eg, common fibular nerve, lateral and medial sural cutaneous nerve, tibial nerve, and lesser saphenous vein).[86]

In addition to anatomic reasons, there are clinical reasons for isolated tenotomy of the medial head of the gastrocnemius, which plays a much more important role than the lateral head.[68] Cohen[57] found greater tension in the medial head than in the lateral

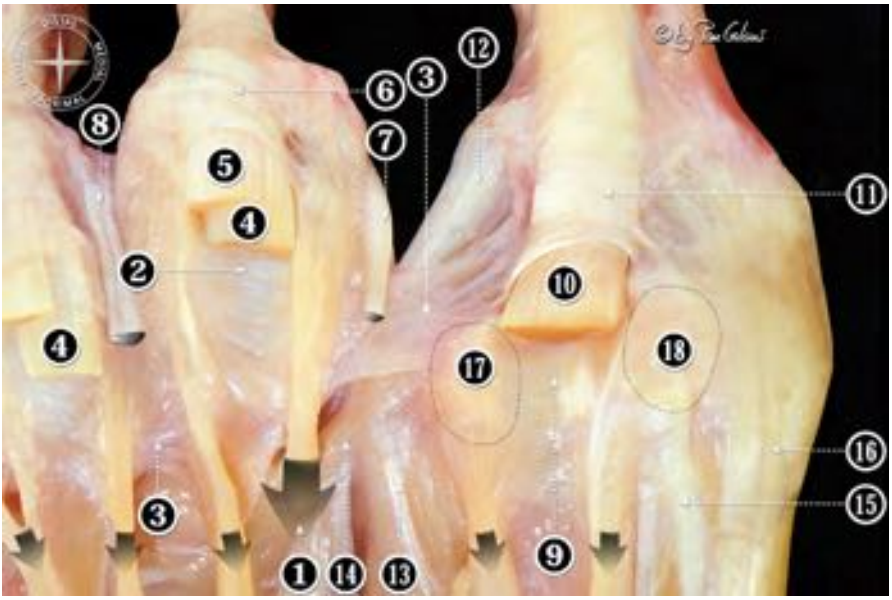

Fig. 20. Dissection of the plantar aspect of the metatarsophalangeal joints of a right foot showing the insertion of the sagittal septa into the plantar plate. 1, sagittal septa (and *black arrows*); 2, plantar surface of the plantar plate of the second toe; 3, deep transverse intermetatarsal ligament; 4, tendons of flexor digitorum longus muscle; 5, tendons of flexor digitorum brevis muscle; 6, fibrous tendinous sheet for the flexor tendons of the second toe; 7, first lumbrical muscle; 8, second lumbrical muscle; 9, plantar surface of the plantar plate of the great toe; 10, tendon of flexor hallucis longus muscle; 11, fibrous tendinous sheet for the flexor hallucis longus tendon; 12, tendon of the adductor hallucis muscle; 13, oblique head of the adductor hallucis muscle; 14, transverse head of the adductor hallucis muscle; 15, flexor hallucis brevis muscle; 16, tendon of the abductor hallucis muscle; 17, lateral sesamoid (*outlined area*); 18, medial sesamoid (*outlined area*). (Figure Copyright © Pau Golanó 2014.)

head. Hamilton and colleagues,[86] on the other hand, found that the aponeurosis of the medial head was 2.4-fold larger than the lateral head (transversal section). Probably for these reasons, Barouk and colleagues[68] and later, Colombier[87] abandoned tenotomy of both heads in favor of isolated tenotomy of the medial head of the gastrocnemius.

Level 4

The only technique performed at this level is deep gastrocnemius or soleus recession.

The technique is known as the Baumann procedure[6] and involves division of the deep fascia of the gastrocnemius muscle using 1 or 2 parallel transverse incisions.[86,88]

The incision is made on the medial side at mid-calf and runs posteriorly, after blunt dissection, to the interval between the gastrocnemius and soleus muscles. The deep fascia of the gastrocnemius muscle is divided using 1 or more transverse incisions. The posterior aponeurosis of the soleus muscle can also be divided, bearing in mind that the transverse incision must be more distal than the others to avoid overlap.[6]

From an anatomic perspective, the incision endangers the greater saphenous vein and saphenous nerve[6]; therefore, these structures must be identified and retracted during surgery.

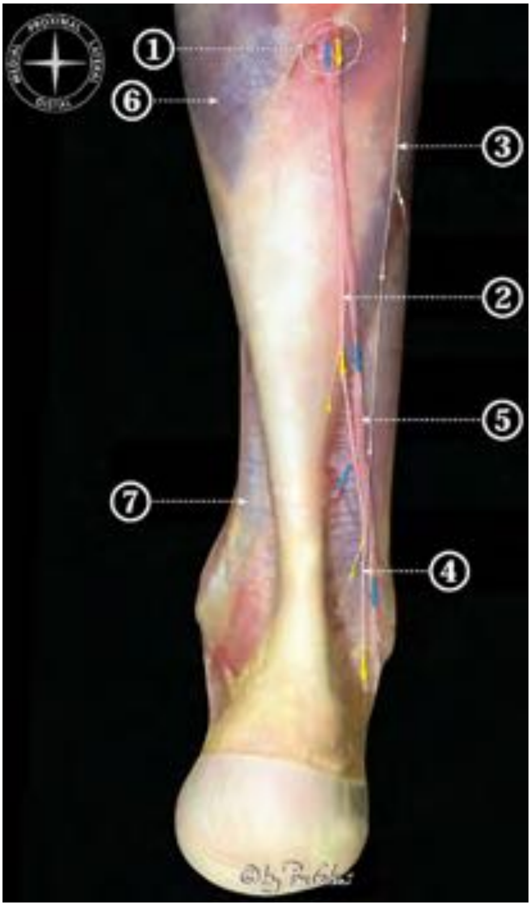

Fig. 21. Posterior view of a superficial dissection of the leg demonstrating the relationship between the sural nerve and the calcaneal tendon. 1, perforation point of the superficial fascia of the leg for the sural nerve (and in this case for the lesser saphenous vein too); 2, medial sural cutaneous nerve (branch of tibial nerve); 3, lateral sural cutaneous nerve (branch of common peroneal nerve); 4, sural nerve; 5, lesser saphenous vein; 6, posterior superficial fascia of the leg; 7, posterior deep fascia of the leg. (Figure Copyright © Pau Golanó 2014.)

Some investigators advise that to avoid injury to these structures, the incision should be made 2 fingerbreadths' distance posterior to the posteromedial aspect of the tibia[88] or 1 fingerbreadth's distance posterior to the palpable area between the bellies of the soleus and gastrocnemius.[6]

Level 3

The procedures that can be performed at level 3 include open gastrocnemius recession (Strayer procedure),[4] endoscopic gastrocnemius recession,[69,70] and gastrocnemius intramuscular aponeurotic recession.[89]

Today, most approaches at this level are endoscopic. In 2002, Trevino and Panchbhavi[69] first described endoscopic gastrocnemius recession. In a cadaver study, Saxena[70] described use of the endoscopic approach in 5 patients.

Fig. 22. Surgical anatomy of the triceps surae. The triceps surae is divided into 5 levels for a better understanding of the structures resected during surgery at each level, following the division proposed by Lamm and colleagues.[85] 1, Level 1: calcaneal tendon; 2, Level 2: starts in the common aponeurotic tendon of the soleus and gastrocnemius and finishes at the distal end of the soleus muscle; 3, Level 3: starts where the muscle bellies of the gastrocnemius merge to form the calcaneal tendon and finishes where the aponeuroses of the soleus and gastrocnemius merge; 4, Level 4: comprises the medial and lateral bellies of the gastrocnemius; 5, Level 5: comprises the proximal insertion and tendons of the medial and lateral heads of the gastrocnemius. (Figure Copyright © Pau Golanó 2014.)

The gastrocnemius aponeurosis is defined anatomically as the aponeurotic fascia. This fascia arises below the distal point of the medial head and finishes when it merges with the deep aponeurotic fibers of the soleus to form the calcaneal tendon.[31] This junction, known as the conjoint junction, is the area where the entry points for endoscopic gastrocnemius recession are made (**Fig. 24**). Elson and colleagues[30] and Tashjian and colleagues[90] based their measurements to locate this area on the length of the fibula. The authors believe that this approach is more suitable than that proposed

Fig. 23. Cutaneous references at the popliteal region. 1, cutaneous fossa; 2, flexion crease of the knee. (Figure Copyright © Pau Golanó 2014.)

elsewhere,[31] because it provides a value based on the relative length of the leg. However, most surgeons use the distance in centimeters from the calcaneal tuberosity as their reference point. Carl and Barrett[31] suggested that the ideal placement of surgical instruments is a reference point 16.4 cm proximal to the calcaneal tuberosity, because this area is considered safe for endoscopy. Furthermore, this safe area extends 1.79 cm distal and proximal to the reference point.[31] Endoscopy, which can be performed using 1 or 2 entry points, should ensure that the cannula is placed between the sural fascia and the aponeurosis of the insertion of the gastrocnemius to enable recession of the fascia. However, the authors' experience, based on 10 cadaveric dissections to study the anatomy of the triceps surae, is not consistent with the belief that recession at this level (the "safe endoscopic zone" described by Carl and

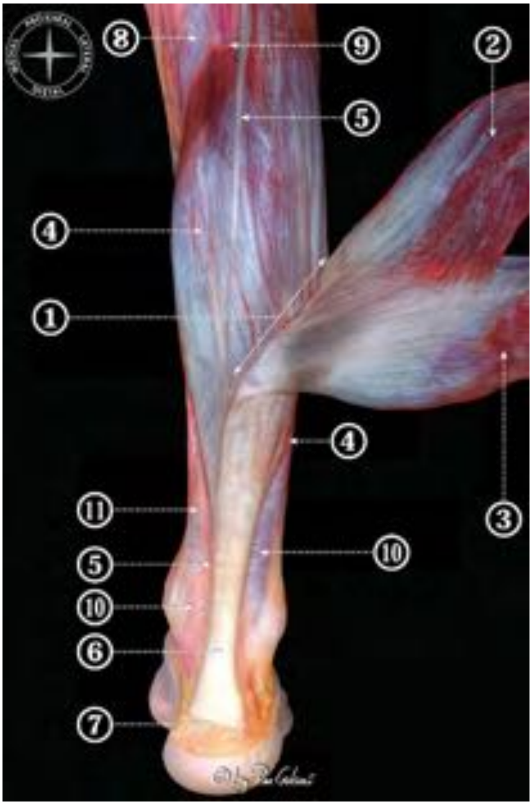

Fig. 24. Muscular dissection of the leg to show the components of the triceps surae (gastrocnemius muscle is rejected to reveal soleus posterior aponeurosis). 1, area of insertion of the gastrocnemius aponeurosis into the soleus posterior aponeurosis (conjoint junction); 2, lateral head of gastrocnemius muscle; 3, medial head of gastrocnemius muscle; 4, soleus posterior aponeurosis; 5, plantaris tendon; 6, calcaneal tendon; 7, insertional area of the calcaneal tendon; 8, popliteus muscle; 9, tendinous arch of the soleus muscle; 10, posterior deep fascia of the leg; 11, medial intermuscular septum. (Figure Copyright © Pau Golanó 2014.)

Barrett[31]) only affects the aponeurosis of the gastrocnemius; it also affects the posterior aponeurosis of the soleus. Therefore, sensu stricto, the term “endoscopic gastrocnemius recession” is not appropriate. In the authors’ opinion, a more appropriate term is “endoscopic triceps surae recession.”

Endoscopy provides a better cosmetic outcome, although it carries a considerable risk of sural nerve injury. The complication rate can reach 22.2%.[76] The importance of the association between the sural nerve and the endoscopic entry point led to the study by Tashjian and colleagues,[74] who found the distance between the sural nerve and the lateral border of the gastrocnemius and soleus to be 12 mm (range, 7–17 mm). This short distance justifies the use of a medial entry point in this type of endoscopic procedure.

Another procedure performed at this level is the technique originally described by Strayer,[4] which involves recession of the gastrocnemius aponeurosis using open surgery. This approach has the disadvantage of a poor cosmetic outcome, namely, excessively large scars. Consequently, several investigators have improved this

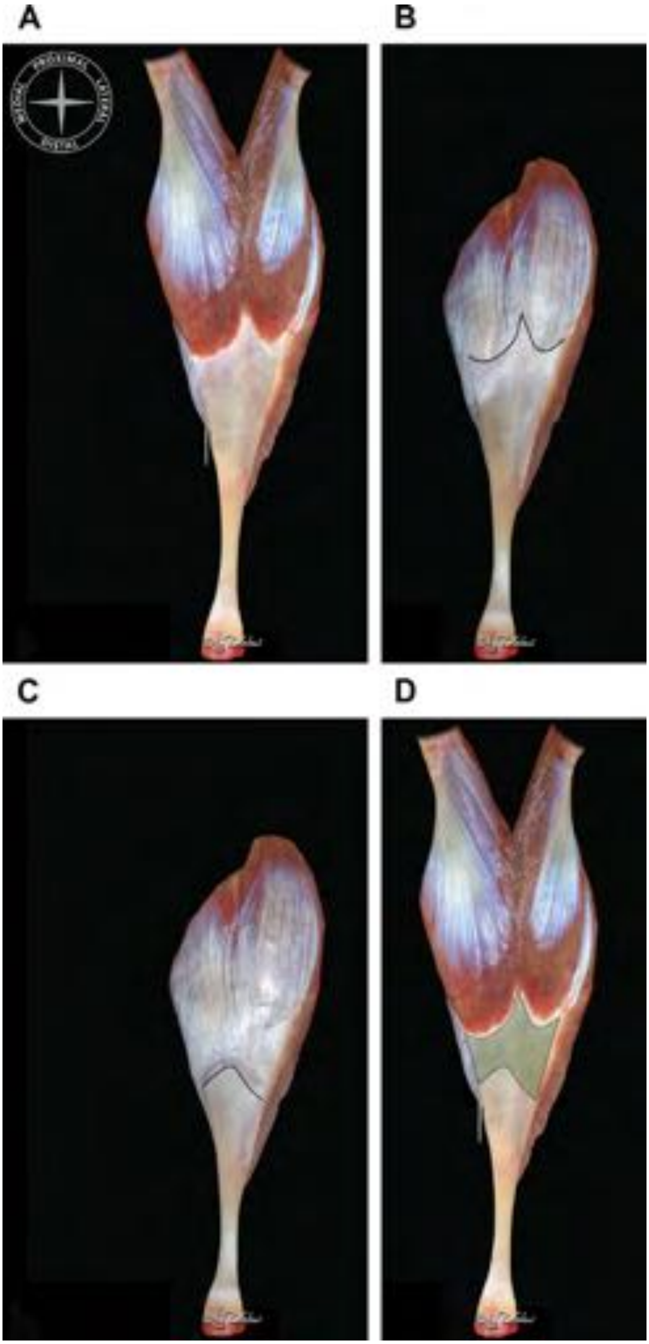

Fig. 25. Dissection of the triceps surae showing the area where gastrocnemius aponeurosis is not fused with soleus posterior aponeurosis. (*A*) Posterior view of the triceps surae. (*B*) Posterior view of the triceps surae (muscular bellies of medial and lateral head of gastrocnemius muscle have been resected). (*C*) Posterior view of the triceps surae (gastrocnemius aponeurosis has been resected until the level of fusion of gastrocnemius and soleus aponeuroses). (*D*) Posterior view of the triceps surae, showing the area where gastrocnemius aponeurosis can be transected in isolation before fusion with soleus posterior aponeurosis (area has been marked using Adobe Photoshop). (Figure Copyright © Pau Golanó 2014.)

technique using minimally invasive entry points. An example of these improvements is gastrocnemius intramuscular aponeurotic recession, as described by Blitz and Rush,[89] who used the minimally invasive technique and also defined the term gastroc run-out to illustrate the zone of gastrocnemius aponeurosis free of both gastrocnemius muscular belly and of soleus aponeurosis. Within this area the gastrocnemius aponeurosis can be transected in isolation (**Fig. 25**). The authors consider this anatomic detail to be of high importance, because a recession of both the soleus and gastrocnemius muscle will produce a more debilitating effect in the leg of the patient, using either the Strayer or the endoscopic gastrocnemius recession procedures.

Based on anatomic studies,[91,92] it has been demonstrated that the aponeurosis of the lateral head of the gastrocnemius is longer than that of the medial head. It has also been observed that the insertion of the aponeurosis of the gastrocnemius into the soleus can be by direct, long, or short insertion (conjoint junction) (**Fig. 26**), thus leading to variations in the difficulty of the surgical procedure. In a long insertion, it is easier to perform an isolated recession of the aponeurosis of the gastrocnemius. On the other hand, in a short or direct insertion, the difficulty in separating the aponeuroses

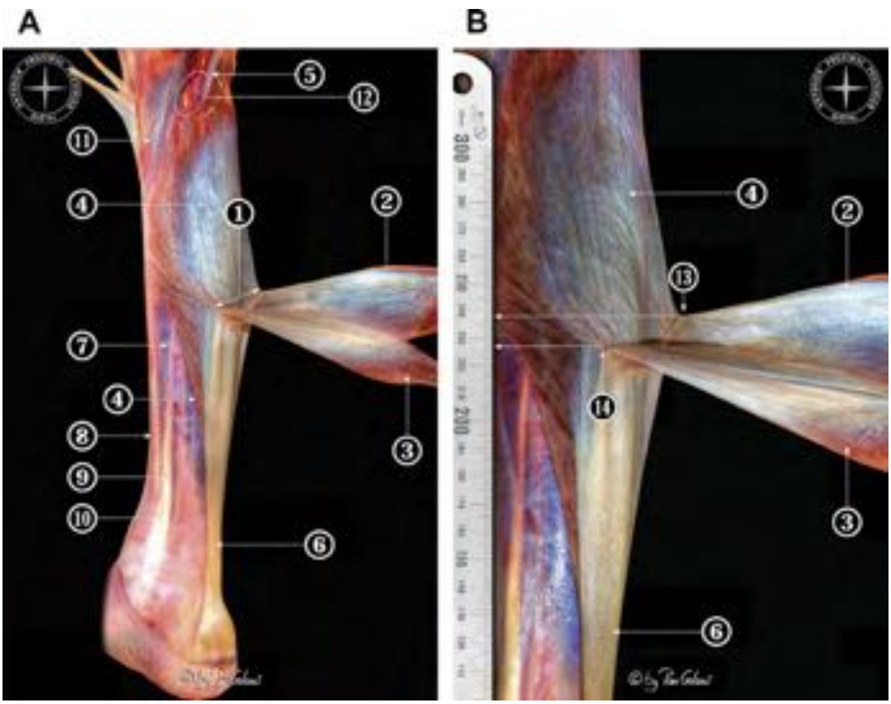

Fig. 26. Dissection of the superficial muscular layer of the leg showing the insertion of gastrocnemius aponeurosis into the soleus (conjoint junction). (*A*) Posteromedial view. (*B*) Photomacrography showing the conjoint junction in detail. 1, conjoint junction; 2, lateral head of gastrocnemius muscle; 3, medial head of gastrocnemius muscle; 4, posterior aponeurosis of soleus muscle; 5, tendinous arch of soleus muscle; 6, calcaneal tendon; 7, posterior deep fascia of the leg; 8, medial surface of the tibia; 9, flexor digitorum longus muscle; 10, tibialis posterior tendon; 11, popliteus muscle; 12, neurovascular bundle passing through the tendinous arch of the soleus muscle (posterior tibial vein, posterior tibial artery, tibial nerve); 13, level of insertion of the lateral head of gastrocnemius muscle; 14, level of insertion of the medial head of gastrocnemius muscle. (Figure Copyright © Pau Golanó 2014.)

of the gastrocnemius and soleus can lead to an iatrogenic recession of the soleus aponeurosis (see earlier discussion).

Levels 2 and 1

Given that this article is about the surgical anatomy of gastrocnemius, the surgical anatomy of more distal levels is not discussed, as they involve recession of the whole triceps surae.[1,3]

SUMMARY

A broad knowledge of the anatomy and biomechanics of the triceps surae is essential for an understanding of the etiology of the shortening or contracture of the gastrocnemius and its treatment.

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