



SPECIAL ARTICLE

Sonographic guide for botulinum toxin injections of the lower limb: EUROMUSCULUS/USPRM spasticity approach

Bayram KAYMAK ¹, Murat KARA ^{1*}, Fatih TOK ², Alper M. ULAŞLI ³, Gökhan T. ÖZTÜRK ³, Ke-Vin CHANG ^{4,5}, Ming-Yen HSIAO ⁴, Chen-Yu HUNG ⁵, Arzu YAĞIZ ON ⁶, Levent ÖZÇAKAR ¹

¹Department of Physical and Rehabilitation Medicine, Hacettepe University Medical School, Ankara, Turkey; ²Gaziler Physical Medicine and Rehabilitation, Training and Research Hospital, Ankara, Turkey; ³Ankara Physical Medicine and Rehabilitation, Training and Research Hospital, Ankara, Turkey; ⁴Department of Physical Medicine and Rehabilitation, National Taiwan University Hospital, College of Medicine, National Taiwan University, Taipei, Taiwan; ⁵Department of Physical Medicine and Rehabilitation, National Taiwan University Hospital and Community and Geriatric Research Center, Bei-Hu Branch, Taipei, Taiwan; ⁶Department of Physical and Rehabilitation Medicine, Ege University Medical School, İzmir, Turkey

*Corresponding author: Murat Kara, Hacettepe Üniversitesi Tıp Fakültesi Hastaneleri, Zemin Kat FTR AD, Sıhhiye, Ankara, Turkey.
E-mail: mkaraftr@yahoo.com

ABSTRACT

The pertinent literature lacks overt technical data for optimal lower limb muscle botulinum toxin injections using ultrasound (US) imaging. Therefore, this guide is prepared for the commonly injected muscles of the lower limb and the pelvic girdle mainly in spasticity. It includes clinical information, anatomical description and explanation regarding the US imaging of several muscles. The figures have been organized to orient the readers on the innervation zones, injection sites, probe positionings and the US images simultaneously.

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KEY WORDS: Lower extremity - Muscle spasticity - Innervation - Ultrasonography - Botulinum toxins.

Although it is well established that injections are performed with better precision under ultrasound (US) imaging, the pertinent literature lacks technical guides as to how US guided botulinum toxin injections for lower limb muscles can be performed. Further, there is still discussion as to which part of the muscle the injection needs to be directed for better effectivity (*i.e.* as regards the locations of innervation zones for botulinum toxin injections).

Accordingly, this guide is prepared for the commonly injected muscles of the lower limb and pelvic girdle mainly in spasticity (Table I). It entails short clinical information, anatomical description and brief explanation regarding the

US imaging of several muscles. Each figure comprises an anatomical drawing where the innervation zones (dotted lines/curves) and the suggested injection sites (white circles) are displayed. Innervation zones are determined according to the previous literature (Table II).¹⁻²¹ The appropriate probe positionings (black and empty rectangles) and the corresponding US images (pertaining to the black rectangles) are illustrated as well. All US images were acquired by a physiatrist with >15 years of experience in musculoskeletal US -using a 5.5-18 MHz linear array probe (Siemens Acuson S3000™, Siemens Medical Solutions, Mountain View, CA, USA).

TABLE I.—Commonly seen spasticity patterns and functions of the lower extremity muscles.

Region	Pattern	Function	Muscle
Hip	Flexion Adducted (scissoring) thigh	Flexion Adduction	Iliopsoas
			Adductor magnus (adductor part)
			Adductor longus
			Adductor brevis
			Gracilis
		Internal rotation	Semitendinosus
			Semimembranosus
			Pectineus
		Extension	Gluteus maximus
			Semitendinosus
Knee	Stiff knee	Extension	Semimembranosus
			Biceps femoris (long head)
			Adductor magnus (hamstring part)
			Rectus femoris
			Vastus intermedius
	Crouch gait	Flexion	Vastus medialis
			Vastus lateralis
			Semitendinosus
			Semimembranosus
			Biceps femoris
Ankle/foot	Equinus/equinovarus	Plantar flexion	Gracilis
			Soleus
			Gastrocnemius
			Tibialis posterior
			Tibialis posterior
		Inversion	Tibialis anterior
			FDL
			FHL
			Triceps surae
			Fibularis longus
Forefoot/toe(s)	Clawing toes	Flexion	Fibularis brevis
			FDB
			FDL
			FHL
			FHB
	Striatal/Hitchhiker's toe	Great toe extension	EHL

FDL: flexor digitorum longus; FHL: flexor hallucis longus; FDB: flexor digitorum brevis; FHB: flexor hallucis brevis; EHL: extensor hallucis longus.

Hip

Most common spasticity patterns of upper motor neuron syndrome in the lower limb are flexed hip, adducted thigh (scissoring), stiff knee, flexed knee (crouch gait), equinovarus foot and hyperextended great toe (Table I). Flexor and adductor spasticity in the hip joint can result in difficulties with walking, balance, transfer, posture, positioning, dressing, toileting and perineal hygiene. In addition, adductor spasticity in cerebral palsy is an important contributing factor to hip dyslocation/dysplasia.

Piriformis muscle can occasionally cause entrapment of the sciatic nerve in the buttock, giving rise to so-called “piriform-

mis syndrome”. Corticosteroid or botulinum injection of the piriformis muscle is usually performed in this syndrome.^{22, 23}

Iliopsoas (iliacus and psoas major)

Origin: Iliac fossa (iliacus); and transverse processes, intervertebral discs and adjacent bodies from T12 to L5 vertebrae (psoas major).

Insertion: Lesser trochanter of femur.

Innervation: Femoral nerve (iliacus); and anterior rami of L1-L3 spinal nerves (psoas major).

Function: Hip flexion and external rotation, and lateral flexion of lumbar spine (only psoas major).

TABLE II.—*Innervation zones and suggested injection sites of the lower extremity muscles.*

Muscle	Method	Reference line	Innervation zone *	Injection	
				Number	Site
Psoas major	Stereoscopic dissection ¹	T12 vertebra - mid-point of the inguinal ligament	30-70%	1	50% (just above the iliac crest)
Sartorius	Sihler's staining ²	Muscle	10-40% and 70-95%	2	25%
	Surface EMG/ChE staining ³⁻⁵		Scattered distribution		50% 75% (ASIS - MFE)
Adductor longus	Modified Sihler's staining ⁶	Pubic tubercle - MFE	15-25% (lateral), 20-40% (medial) §	2	20% (lateral) 35% (medial)
Adductor brevis	Anatomic dissection ^{7,8}	Pubic tubercle - MFE	NS (Motor points exist at 21% or 22%)	1	20%
Adductor magnus	Anatomic dissection ^{7,8}	Pubic tubercle - MFE	NS (Motor points exist at 30% or 38%)	2	(adductor part) 20% 40%
Gracilis	Modified Sihler's staining ⁶	Pubic tubercle - MFE	25-35%	2	30%
	Modified Sihler's staining ⁹	Muscle	Proximal 1/3 and distal 1/3		60%
	ChE staining ⁴		2 oblique bands		(Pubic tubercle - MFE)
	ChE staining ¹⁰		3-5 bands		
Semitendinosus	Modified Sihler's staining ¹¹	Ischial tuberosity - tibial intercondylar line	20-40% and 60-75%	2	30% (upper-lateral) 70% (lower-medial)
	Optical microscope ¹²	Ischial tuberosity - MFE	19-37% (lateral) and 57-79% (medial)		(Ischial tuberosity - MFE)
	ChE staining ^{4,10}	Muscle	2 oblique bands; upper-lateral, lower-medial More in the proximal part		
Semimembranosus	Surface EMG ³		60-80%	1	75% (Ischial tuberosity - MFE)
	Modified Sihler's staining ¹¹	Ischial tuberosity - tibial intercondylar line			
BF <i>short head</i>	Optical microscope ¹²	Ischial tuberosity - MFE	56-89%	1	80% (Ischial tuberosity - MFE)
	Modified Sihler's staining ¹¹	Ischial tuberosity - tibial intercondylar line	70-85%		
BF <i>long head</i>	Optical microscope ⁸	Ischial tuberosity - MFE	59-80%	1	50% (Ischial tuberosity - MFE)
	Modified Sihler's staining ¹¹	Ischial tuberosity - tibial intercondylar line	40-50%		
	Optical microscope ⁸	Ischial tuberosity - MFE	40-73%		
Rectus femoris	Surface EMG ⁷	Muscle	More in the proximal part	2	40%
	Surface EMG ³	ASIS - patella	Distributed at the middle third		60% (ASIS - patella)
	ChE staining ⁴	Muscle	An upwardly concave band		
	Anatomic dissection ¹³	ASIS - MFE	NS (Motor point exists at proximal 1/3)	2	50% and 65% Medial 1, lateral 1
Vastus medialis	Surface EMG ¹⁴	ASIS - patella	Middle of the muscle fascicles From proximal-lateral to distal-medial	2	75% (proximal-lateral) 85% (distal-medial)
Vastus lateralis	Anatomic dissection ¹³	ASIS - MFE	(Motor point exists at distal 1/3)	2	(ASIS - patella)
	Surface EMG ³	ASIS - patella	Middle of the muscle fascicles		50% (proximal-medial)
	Anatomic dissection ¹³	ASIS - MFE	(Motor points exist at proximal 1/3 and distal 1/3)		65% (distal-lateral) (ASIS - patella)
Gastrocnemius	Stereoscopic dissection ¹⁵	MTC - MM	14-35% (medial head) § 12-29% (lateral head)	4	20% and 30% (lateral), 25% and 35% (medial), 2
	Modified Sihler's staining ¹⁶	Popliteal fold - IML	20-30%		(Popliteal fold - IML)
	ChE staining ⁴	Muscle	An upwardly convex band		

(To be continued)

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TABLE II.—Innervation zones and suggested injection sites of the lower extremity muscles (continues).

Muscle	Method	Reference line	Innervation zone *	Injection	
				Number	Site
Soleus	Stereoscopic dissection ¹⁵	MTC - MM	24-44% (posterior) [§] 35-48% (anterior)	6	35%; medial and lateral, 2 (posterior part)
	Modified Sihler's staining ¹⁶	Popliteal fold - IML	40-50%		45%; medial and lateral, 2 (posterior part) 45%; medial and lateral, 2 (anterior part) (Popliteal fold - IML)
Tibialis posterior	Modified Sihler's staining ¹⁷	FH - LM	20-30%	2	25% 40%
FDL	Modified Sihler's staining ¹⁷	FH - LM	60-70%	1	65%
FHL	Modified Sihler's staining ¹⁷	FH - LM	50-80%	1	65%
Tibialis anterior	Surface EMG ³ ChE staining ^{4,5}	FH - LM Muscle	Distributed at the middle third An upwardly convex band (Motor point exists at 35%)	1	35% (FH - LM)
EHL	Anatomic dissection ¹⁸ ChE staining ¹⁹	FH - submalleolar point Muscle	Distributed at the middle part (Motor points exist at 20% and 40%)	1	65% (FH - submalleolar point)
Fibularis longus	Anatomic dissection ²⁰ Surface EMG ³	FH - LM	Distributed at the proximal half (Motor points exist at 40% and 60%)	1	35%
Fibularis brevis	Anatomic dissection ²⁰ Surface EMG ³	FH - LM	Distributed at the distal half	1	65%
FDB	Ultrasound	Posteroinferior midpoint of the sole - MTP of the great toe	NS	1	50%
FHB	Optical microscope ²¹	Posteroinferior midpoint of the sole - MTP of the great toe	NS (Motor points exist at 50-70% medial [§] and lateral parts)	2	70% Medial 1, lateral 1

*The percentage values are given from proximal to distal according to the pertinent reference line; §the part of the relevant muscle where the motor points/terminal nerve endings are denser than the other parts.

NS: not studied in the previous literature according to Sihler's/modified Sihler's staining, anatomic dissection, cholinesterase and/or surface electromyography methods; EMG: electromyography; ChE: cholinesterase; MFE: medial femoral epicondyle; BF: biceps femoris; ASIS: anterior superior iliac spine; MM: medial malleolus; IML: intermalleolar line; MTC: medial tibial condyle; FDL: flexor digitorum longus; FHL: flexor hallucis longus; FH: fibular head; LM: lateral malleolus; EHL: extensor hallucis longus; FDB: flexor digitorum brevis; FHB: flexor hallucis brevis; MTP: metatarsophalangeal joint.

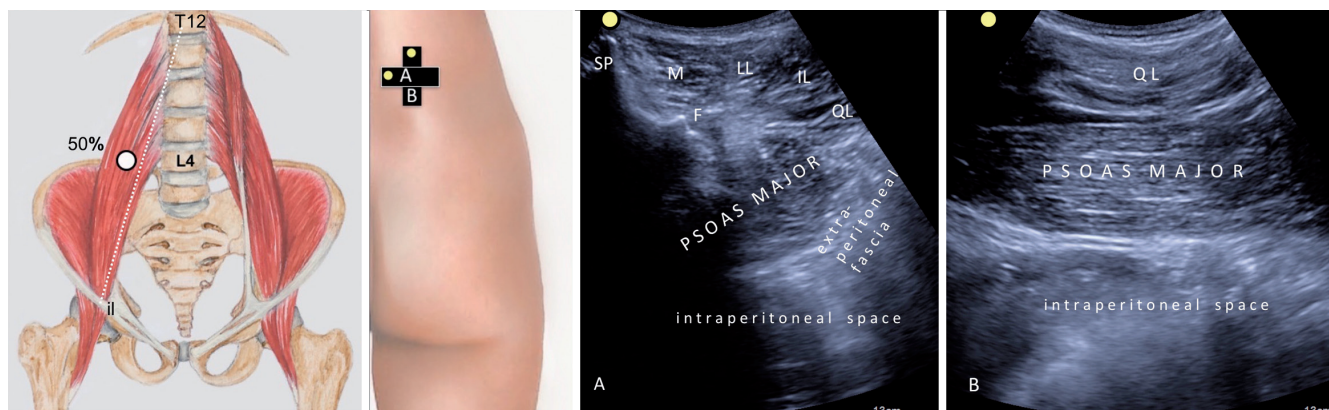


Figure 1.—Psoas major muscle.
F: facet joint; M: multifidus; LL: longissimus lumborum; IL: iliocostalis lumborum; il: inguinal ligament.

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US imaging: The probe should be axially placed over the spinous process (SP) of L4 vertebra while the patient is lying prone. Moving the probe laterally, erector spinae (ES) and quadratus lumborum (QL) muscles and transverse process of the vertebrae can be visualized. Psoas major is located under the ES muscle (Figure 1A). For longitudinal view, probe should be placed over the QL muscle and be tilted medially (Figure 1B). Injection should be performed cautiously just above the iliac crest in order to avoid possible kidney injury. On the other hand, iliac muscle injections should be performed with transabdominal approach.

Piriformis

Origin: Anterior surface of S2-4 segments, sacrotuberous ligament.

Insertion: Superomedial border of the greater trochanter.

Innervation: S1, S2 branches.

Function: Hip external rotation (during hip extension), hip abduction (during hip flexion).

US imaging: As piriformis is located deeply at gluteal region, linear probe with lower frequencies or a convex probe (especially for obese subjects) is required. While the patient is lying prone, place the probe at the lateral border of the ischial tuberosity to locate the sciatic nerve (S), and then move the probe proximally. US image shows the obturatorius internus below the nerve. Keep moving the probe more proximally and obliquely until the middle of the lateral border of sacrum is reached. Then rotating the hip joint internally/externally (passively) while the knee

is in semiflexion would help distinguish piriformis under the gluteus maximus (GM) (Figure 2). Injections should be performed cautiously considering the sciatic nerve that lies (usually) under or inside the piriformis muscle.

Sartorius

Origin: Anterior superior iliac spine (ASIS).

Insertion: Anteromedial surface of the proximal tibia (pes anserinus region).

Innervation: Femoral nerve.

Function: Hip and knee joint flexion.

US imaging: While the patient is lying supine with the lower limb in neutral position, place the probe axially on the ASIS and locate the sartorius tendon medially. Then, move the probe downwards following the muscle belly — the only muscle superficial to rectus femoris (RF), adductor longus (AL) and adductor brevis (AB), coursing medially towards the medial thigh. Femoral artery (a), vein (v) and saphenous nerve (n) are located in close relationship with the sartorius muscle. At the distal thigh, sartorius, vastus medialis (VM), AL and adductor magnus (AM) muscles delimitate medial, anterolateral and posteromedial aspects of the Hunter's canal, respectively (Figure 3).

Hip adductors

Adductor longus

Origin: Pubic body inferior to pubic crest.

Insertion: Middle third of linea aspera.

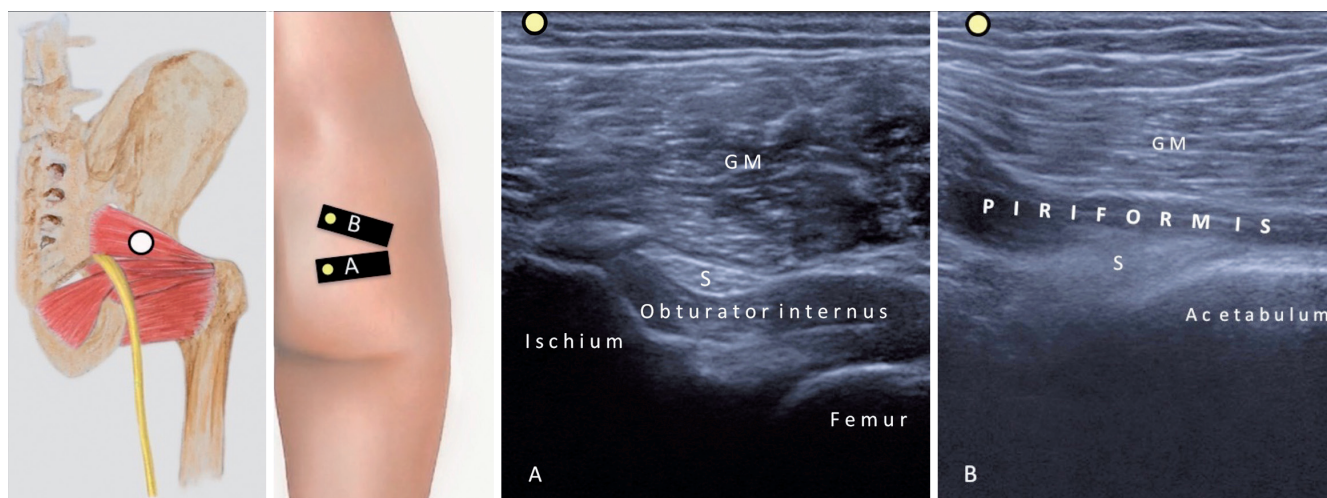


Figure 2.—Piriformis muscle.

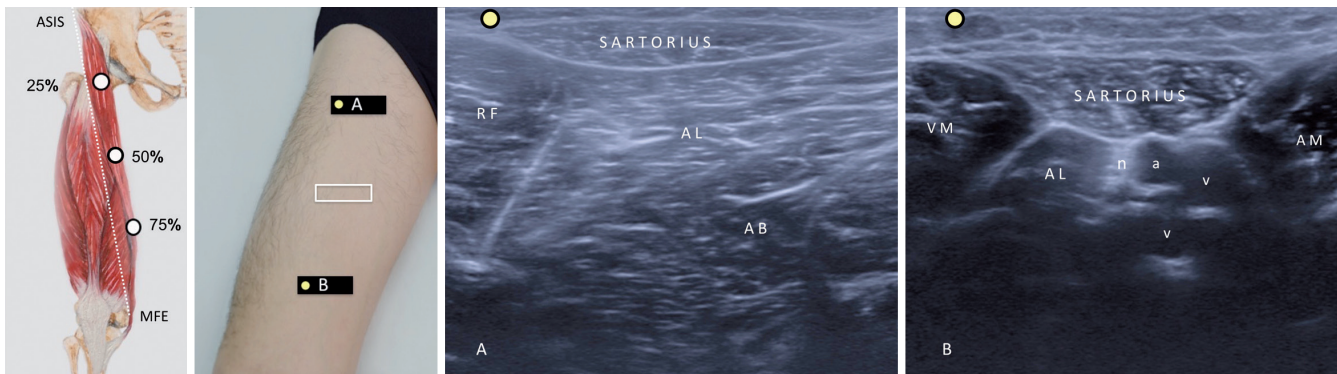


Figure 3.—Sartorius muscle.
ASIS: anterior superior iliac spine; MFE: medial femoral epicondyle.

Innervation: Obturator nerve.
Function: Hip adduction and flexion.

Adductor brevis

Origin: Pubic body, inferior pubic ramus.
Insertion: Pectineal line, proximal linea aspera.
Innervation: Obturator nerve.
Function: Hip adduction, flexion and internal rotation.

Adductor magnus

Origin: Ischiopubic ramus (adductor part), ischial tuberosity (hamstring part).
Insertion: Posterior surface of proximal femur, linea aspera and medial supracondylar line (adductor part), adductor tubercle and supracondylar line (hamstring part).

Innervation: Obturator nerve (adductor part), tibial portion of sciatic nerve (hamstring part).

Function: Hip extension (hamstring part) and adduction (adductor part).

Gracilis

Origin: Pubic body, inferior pubic ramus.
Insertion: Anteromedial surface of proximal tibia (pes anserine region).
Innervation: Obturator nerve.
Function: Hip adduction, knee flexion.

US imaging: While the patient is lying in supine position with the hip abducted, semiflexed and externally rotated, and the knee semiflexed (frog leg position); place the probe axially on the proximal/medial thigh. The ad-

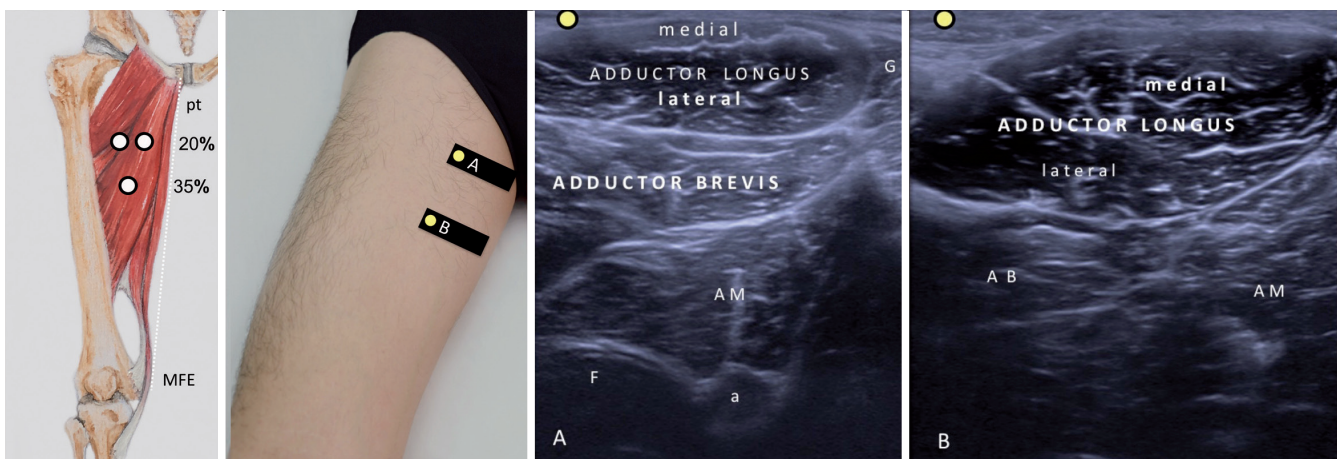


Figure 4.—Adductor longus and adductor brevis muscles.
F: femur; a: artery; pt: pubic tubercle; MFE: medial femoral epicondyle.

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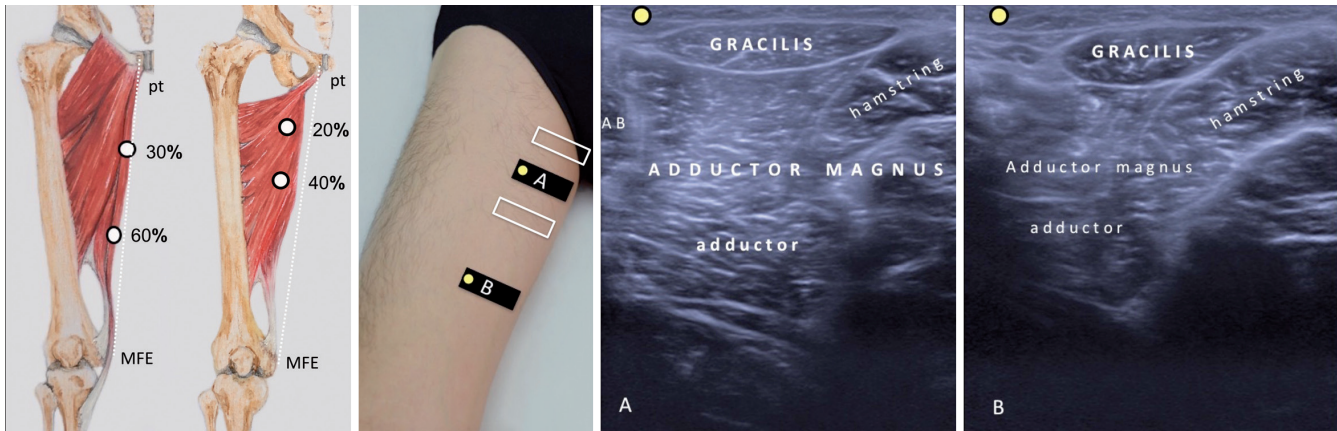


Figure 5.—Gracilis and adductor magnus muscles. pt: pubic tubercle; MFE: medial femoral epicondyle.

ductor muscles *i.e.* gracilis (G), AL, AB and AM can be scanned throughout their courses from proximal to distal (Figures 4, 5).

Knee

Knee extensor spasticity is the main reason of stiff knee gait resulting in reduced toe clearance, tendency to fall and increased energy expenditure during walking. Whereas, spasticity of the hamstring muscles results in excessive knee flexion during the gait cycles.

Medial hamstring muscles (semitendinosus [ST], semi-membranosus [SM])

Origin: Ischial tuberosity.

Insertion: Anteromedial proximal tibia (ST), and posteromedial tibial condyle (SM).

Innervation: Sciatic nerve (tibial division).

Function: Knee flexion (and internal rotation in knee semiflexion), hip extension (and internal rotation in hip extension).

Lateral hamstring muscle (biceps femoris [BF] long and short heads)

Origin: Ischial tuberosity (long head), lateral lip of linea aspera and proximal half of lateral supracondylar line (short head).

Insertion: Fibular head and lateral tibial condyle.

Innervation: Tibial (long head) and common fibular (short head) divisions of the sciatic nerve.

Function: Knee flexion (and external rotation in knee semiflexion), and hip extension (and external rotation in hip extension).

US imaging: Once the probe is placed axially above the popliteal fossa, medial (ST and SM) and lateral (BF) hamstring muscles can be imaged (Figure 6-8). Moving the probe cranially; SM and BF (short head) will become smaller whereas ST (with two compartments) and BF (long head) will get bigger. Sciatic nerve (S) lies between the medial and lateral hamstrings.

Quadriceps femoris (Rectus femoris [RF], vastus medialis [VM], vastus lateralis [VL], vastus intermedius [VI])

Origin: RF; anterior inferior iliac spine and ilium just superior to the acetabulum. VM; medial part of the intertrochanteric line, medial lip of the linea aspera, and medial supracondylar line. VL; intertrochanteric line, margin of the greater trochanter and lateral lip of the linea aspera. VI; proximal 2/3 of the anterolateral femoral shaft.

Insertion: Patella.

Innervation: Femoral nerve.

Function: Hip flexion (only RF) and knee extension.

US imaging: Following the quadriceps tendon proximally with US, RF and VI can be visualized at the midline (Figure 9), VM medially and VL laterally (Figure 10).

Ankle and foot

Equinovarus foot deformity is the most commonly seen pattern among spastic patients. Improper limb clearance and lack of appropriate foot posture result in tendency to

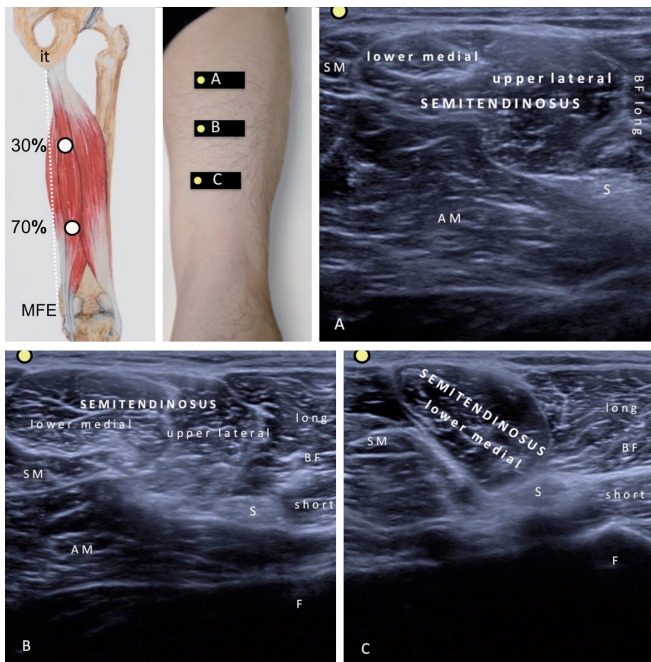


Figure 6.—Semitendinosus muscle.
S: sciatic nerve; it: ischial tuberosity; F: femur, MFE: medial femoral epicondyle.

totter/fall. Hitchhiker’s great toe and clawing toes lead to difficulties while using ankle/foot orthosis and wearing shoes.

Gastrocnemius

Origin: Posterior surface of the distal femur just superior to the medial condyle (medial head), and proximal posterolateral surface of the lateral femoral condyle (lateral head).



Figure 7.—Semimembranosus muscle.
VM: vastus medialis; v: vein; a: artery; F: femur; it: ischial tuberosity; MFE: medial femoral epicondyle; S: sciatic nerve.

Insertion: Posterior surface of calcaneus.
Innervation: Tibial nerve.

Function: Ankle plantar flexion, knee flexion and assists in foot inversion.

US imaging: Scanning the Achilles tendon proximally, medial and lateral heads of the gastrocnemius muscle will be obtained over the soleus muscle (Figure 11).

Soleus

Origin: Posterior fibular head, neck and proximal shaft, and soleal line and medial border of tibia.

Insertion: Posterior surface of calcaneus.
Innervation: Tibial nerve.

Function: Ankle plantar flexion, assists in foot inversion.

US imaging: Following the Achilles tendon proximally, posterior compartment of the soleus muscle is seen under the gastrocnemius muscle. Anterior compartment of the soleus muscle resides between the tibialis posterior (TP)

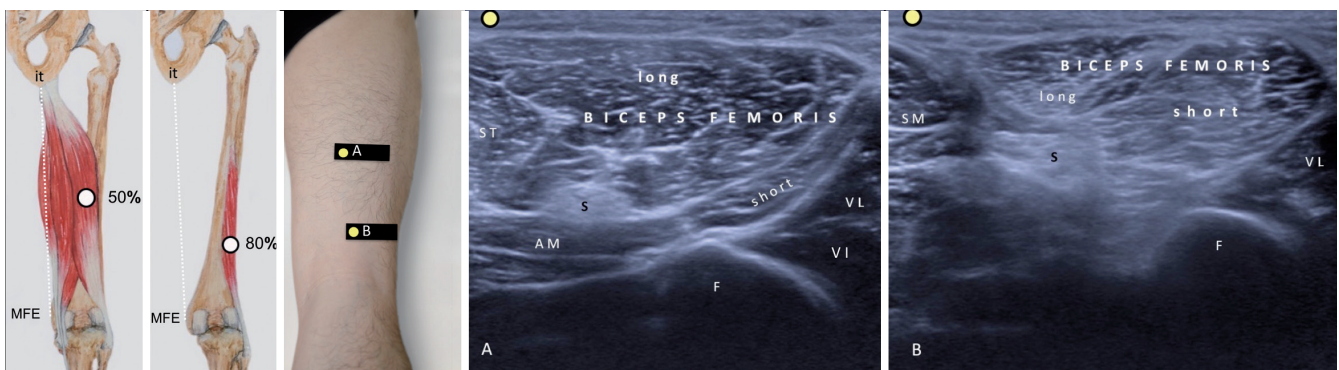


Figure 8.—Biceps femoris (long and short heads).
VI: vastus intermedius; F: femur; S: sciatic nerve; VL: vastus lateralis; it: ischial tuberosity; MFE: medial femoral epicondyle.

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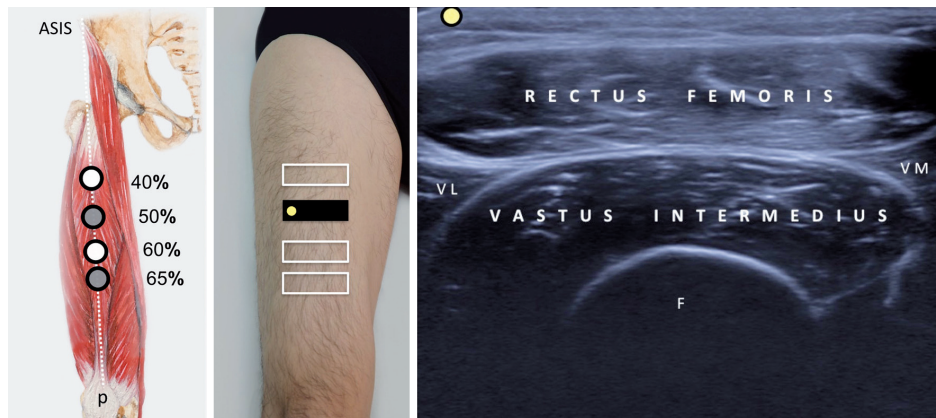


Figure 9.—Rectus femoris and vastus intermedius muscles. F: femur; ASIS: anterior superior iliac spine; p: patella. White and gray circles show the injection points for rectus femoris and vastus intermedius muscles; respectively.

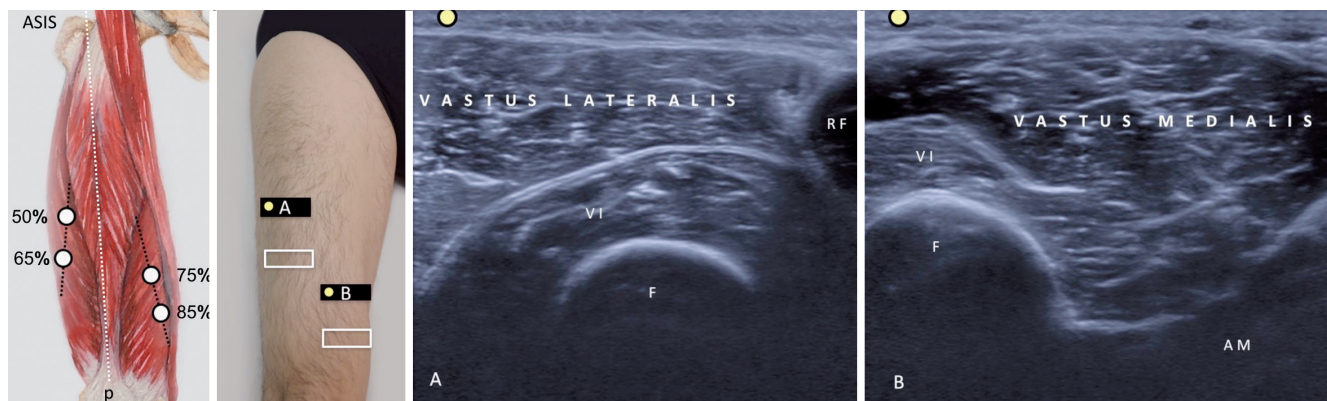


Figure 10.—Vastus lateralis and vastus medialis muscles. F: femur; ASIS: anterior superior iliac spine; p: patella.

and posterior compartment of the soleus muscles. Aponeurosis between the muscles and the compartments can easily be detected while imaging with US (Figure 12).

Tibialis posterior

Origin: Proximal half of posterior tibia and fibula, interosseous membrane.

Insertion: Navicular tuberosity, plantar surface of medial cuneiform.

Innervation: Tibial nerve.

Function: Foot inversion, ankle plantar flexion, supports medial longitudinal arch.

US imaging: Tibialis posterior muscle can easily be demonstrated under the tibialis anterior (TA) muscle and the interosseous membrane (asterisks) (Figure 13). Injection should be performed cautiously with anterior approach in order to avoid injury to the nerve (n) or artery (a).

Flexor digitorum longus

Origin: Posteromedial surface of tibia below the soleal line.

Insertion: Plantar bases of the distal phalanges of the lateral four toes.

Innervation: Tibial nerve.

Function: Flexion of lateral four toes, assists in foot inversion and ankle plantar flexion.

Flexor hallucis longus

Origin: Distal third of the posterior surface of fibula, interosseous membrane.

Insertion: Plantar base of the distal phalanx of the great toe.

Innervation: Tibial nerve.

Function: Hallux flexion, assists in foot inversion and ankle plantar flexion.

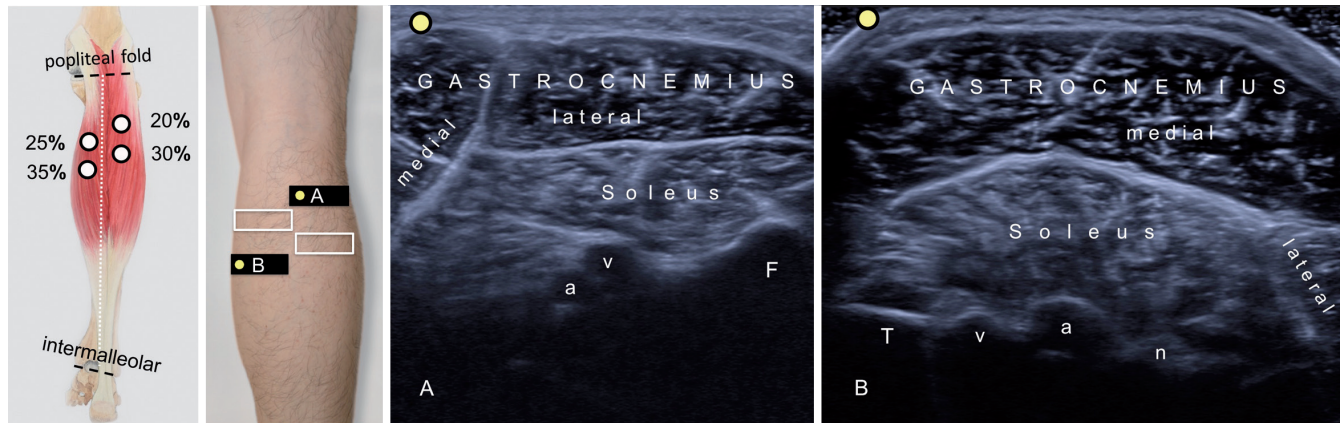


Figure 11.—Gastrocnemius muscle.
T: tibia; F: fibula; a: artery; v: vein; n: tibial nerve.

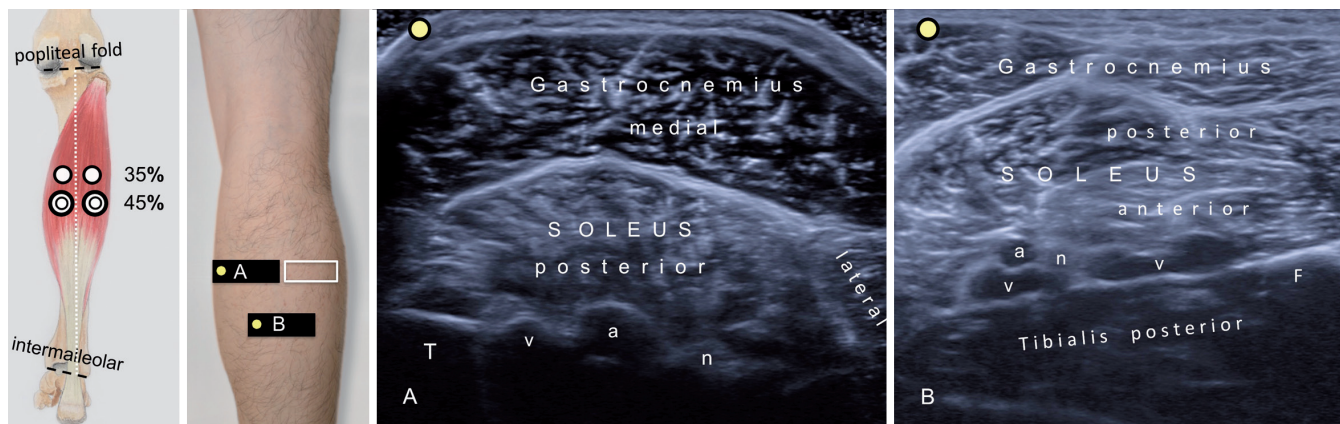


Figure 12.—Soleus muscle. Circles at 45% level show the injection points for anterior and posterior parts of the soleus muscle.
F: fibula; v: vein; a: artery.

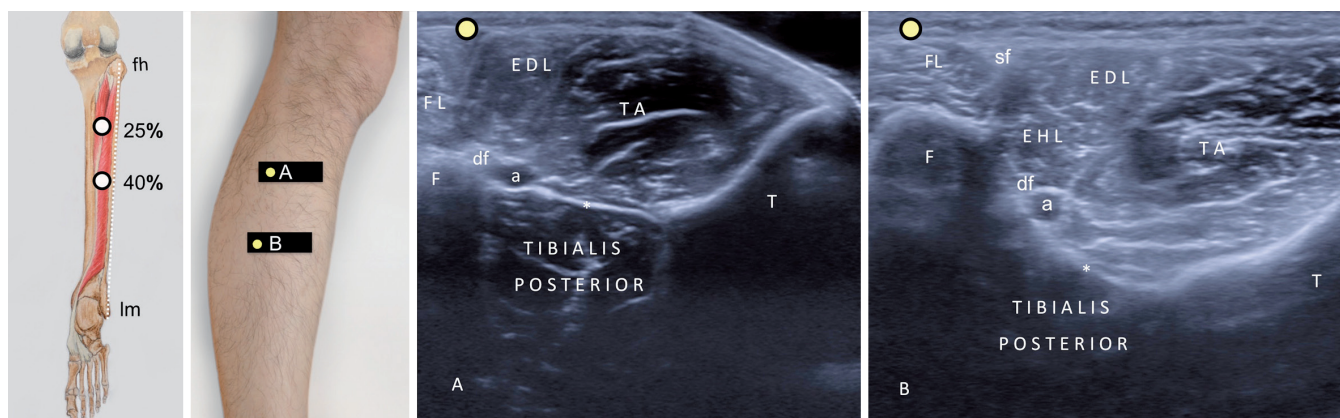


Figure 13.—Tibialis posterior muscle.
FL: fibularis longus; EDL: extensor digitorum longus; EHL: extensor hallucis longus; T: tibia; F: fibula, fh: fibular head; lm: lateral malleolus; df: deep fibular nerve; sf: superficial fibular nerve.

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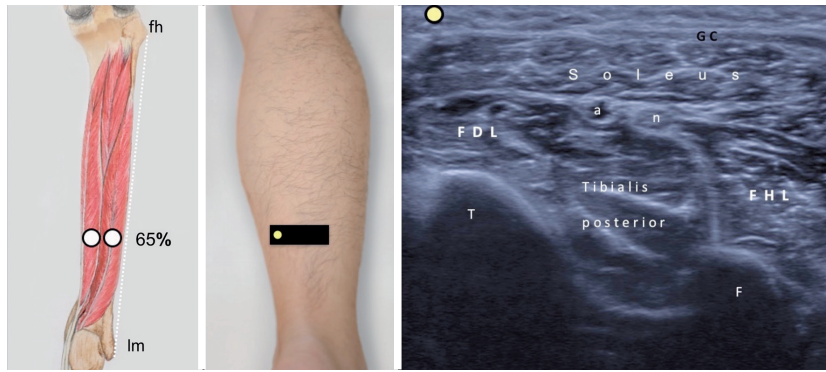


Figure 14.—Flexor digitorum longus and flexor hallucis longus muscles.
GC: gastrocnemius tendon; a: posterior tibial artery; n: tibial nerve; T: tibia; F: fibula; fh: fibular head; lm: lateral malleolus.

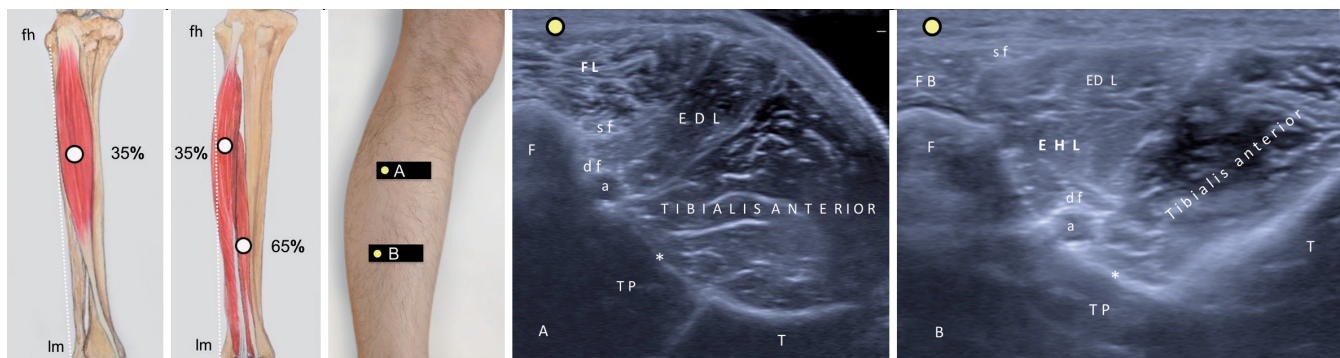


Figure 15.—Tibialis anterior, extensor digitorum longus and extensor hallucis longus muscles.
FL: fibularis longus; FB: fibularis brevis; T: tibia; F: fibula; a: artery; v: vein; df: deep fibular nerve; sf: superficial fibular nerve; fh: fibular head; lm: lateral malleolus.

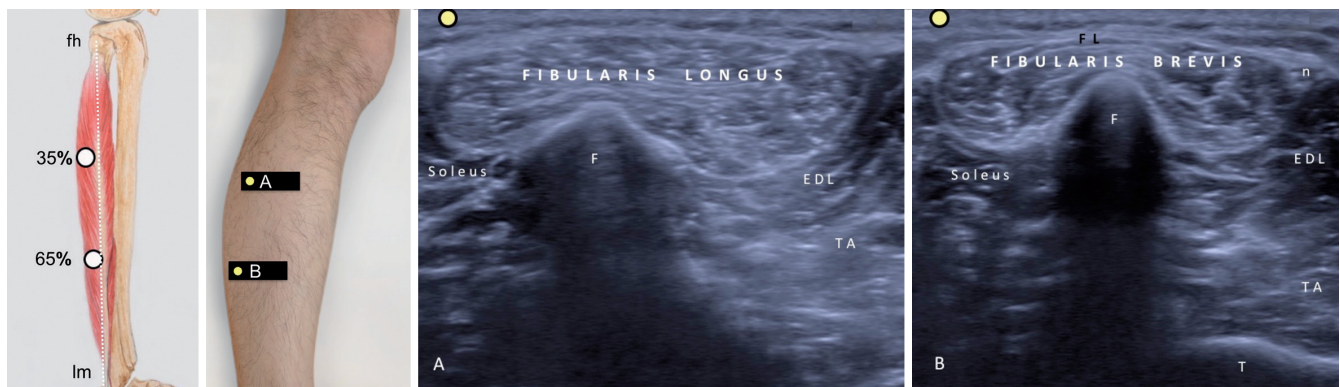


Figure 16.—Fibularis longus and brevis muscles.
T: tibia; n: superficial fibular nerve; fh: fibular head; lm: lateral malleolus.

US imaging: When the probe is placed axially on the posteromedial side of the distal third of the calf; underlying the soleus, flexor digitorum longus (FDL) can be seen over tibia (T) and flexor hallucis longus (FHL) over fibula (F). Passive movements of the toes would definitely help better distinguish these muscles (Figure 14).

Tibialis anterior

Origin: Proximal half of lateral tibia, interosseous membrane.

Insertion: Medial plantar surface of the medial cuneiform, base of the 1st metatarsal bone.

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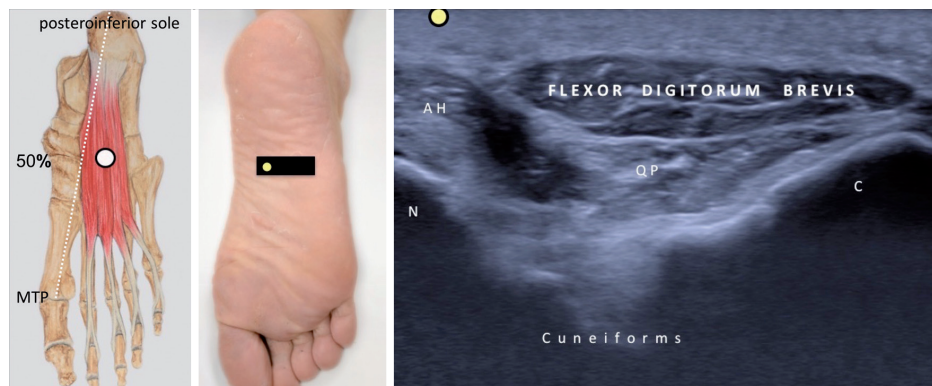


Figure 17.—Flexor digitorum brevis muscle.
N: navicular bone; C: cuboid bone; MTP: metatarsophalangeal joint.

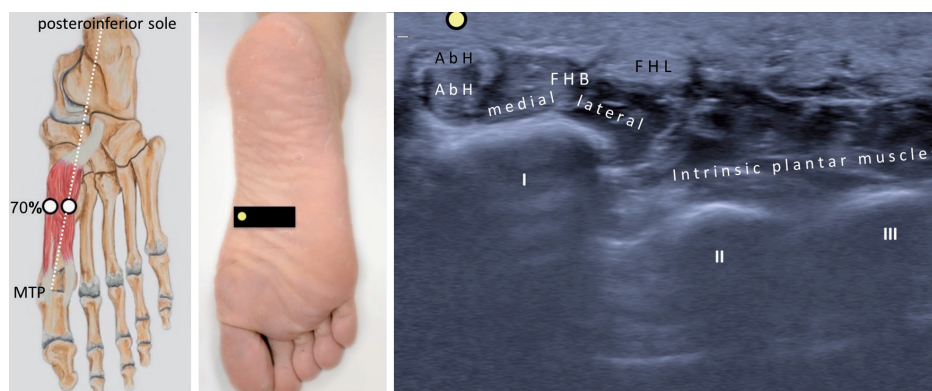


Figure 18.—Flexor hallucis brevis muscle.
FHL: flexor hallucis longus tendon; I-III: metatarsal bones; AbH: abductor hallucis muscle and tendon; MTP: metatarsophalangeal joint.

Innervation: Deep fibular nerve.

Function: Foot inversion, ankle dorsiflexion.

US imaging: Place the probe axially on the lateral side of tibial tuberosity. Moving the probe caudally, tibialis anterior (TA) muscle is identified alongside the lateral surface of tibia (T) above the interosseous membrane (Figure 15).

Extensor digitorum longus

Origin: Proximal half of the medial surface of fibula and lateral tibial condyle.

Insertion: Via dorsal digital expansion into bases of distal and middle phalanges of the lateral four toes.

Innervation: Deep fibular nerve.

Function: Extension of lateral four toes, assists in ankle dorsiflexion.

Extensor hallucis longus

Origin: Middle half of the medial surface of fibula, interosseous membrane.

Insertion: Dorsal surface of the base of the distal phalanx of the 1st toe.

Innervation: Deep fibular nerve.

Function: Hallux extension, assists in ankle dorsiflexion.

US imaging: Place the probe on the anterolateral side at the proximal third of the tibia in order to identify extensor digitorum longus (EDL) muscle lateral to the tibialis anterior (TA) muscle. Then move the probe distally to the distal third to depict the extensor hallucis longus (EHL) muscle medial to the EDL. If the EHL and EDL muscles are not well distinguished, active or passive movements of the great toe can be helpful (Figure 15).

Fibularis longus and brevis

Origin: Head and proximal 2/3 of the lateral surface of fibula (longus), distal 2/3 of the lateral surface of fibula (brevis).

Insertion: Medial cuneiform, plantar base of the 1st metatarsal bone (longus), lateral tubercle of the 5th metatarsal bone (brevis).

Innervation: Superficial fibular nerve.

Function: Foot eversion, assists in plantar flexion.

US imaging: As the probe is placed axially over the distal

third of the fibula (F), fibularis longus tendon (FL) and fibularis brevis muscle can be seen. Moving the probe upwards to the proximal third of the fibula would make fibularis brevis disappear and fibularis longus become apparent (Figure 16).

Flexor digitorum brevis

Origin: Medial process of calcaneal tuberosity and plantar aponeurosis.

Insertion: Both sides of the middle phalanges of the lateral four toes.

Innervation: Medial plantar nerve.

Function: Flexion of the lateral four toes at PIP joints.

US imaging: Place the probe axially over the plantar surface of the calcaneus and move towards the metatarsal bones to image flexor digitorum brevis lateral to abductor hallucis (AH), between the subcutaneous tissue and the quadratus plantae (QP) muscle (Figure 17).

Flexor hallucis brevis

Origin: Plantar surface of cuboid and the lateral cuneiform, tendon of the tibialis posterior.

Insertion: Lateral and medial sides of the base of the proximal phalanx of the great toe.

Innervation: Medial plantar nerve.

Function: Flexion of the metatarsophalangeal joint of the great toe.

US imaging: On the plantar surface, place the probe axially between the calcaneus and the great toe. The tendon and the two heads of flexor hallucis brevis (FHB) can be observed above the 1st metatarsal bone (Figure 18).

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