Chapter 18

The Use of Botulinum Neurotoxin in Spasticity Using Ultrasound Guidance

Andrea Santamato, Alessio Baricih and Alessandro Picelli

Introduction

One important factor influencing the effectiveness of botulinum neurotoxin (BoNT) injection in the treatment of upper and lower limb spasticity is the accuracy of administration into the target muscle. Indeed, incorrect needle placement can result in complete failure of treatment. Neurotoxin diffusion outside of target muscles can cause weakness or paresis, particularly for small muscles of the hand and forearm. The use of various guidance techniques may improve both effectiveness and safety, decreasing the occurrence of side effects.

A wide range of injection techniques has been described, such as manual needle placement using surface anatomy landmarks or palpation, electromyographic guidance, electrical stimulation of the muscle and ultrasound guidance (Childers, 2003; Berweck *et al.*, 2004). Generally, manual needle placement is an acceptable technique for delivering the BoNT to large, superficial muscles, but not for small, slender, deep muscles. Therefore, guidance is recommended where the goal of treatment is the modulation of muscle hypertonicity to improve the dexterity of spastic muscles (particularly for hand spasticity), as well as for deep and small muscles of the limbs, whereas it is considered optional for larger, easily palpated muscles.

In recent years, the availability of portable ultrasound devices has facilitated the application of ultrasound technology for guidance in BoNT injection procedures. It is easy, quick, painless and available in most hospitals. Ultrasonography has been used to guide BoNT administration in the urinary system and salivary glands and is being assessed for skeletal muscles (Westhoff *et al.*, 2003; Berweck *et al.*, 2004).

Skeletal Muscle Ultrasound

First characterized in the early 1950s, ultrasound has become an innovative technique in medical practice to visualize several living tissues by combining noninvasive, high-frequency ultrasonic waves with real-time display (Wild and Neal, 1951). Currently, ultrasound is widely available, with muscle tissue resolutions up to 0.1 mm (Cosgrove, 1992). This resolution permits the identification of several muscles from near structures such as bone, nerves, blood vessels, fibrosis and fat (Fig. 18.1). Additionally, Heckmatt and colleagues (1980) discovered that muscles affected by certain disorders show a different appearance to healthy muscles when viewed on ultrasound.

Echogenicity may vary somewhat with different ultrasound probe frequencies and machine setup. Usually, the main ultrasound technique to observe skeletal muscles is the brightness mode (B-mode), which provides a two-dimensional image with different brightness points in a gray scale. Surrounding tissue also influences echogenicity through beam attenuation. Normal muscle is relatively black with hypoechoic intensity; between muscle fibers, some hyperechoic interfaces may be seen (reflections of perimysial connective tissue). Hyperechoic fascia surrounds each muscle belly, delineating the muscle groups. The boundaries of the muscle are clearly visible, as the epimysium surrounding the muscle is a highly reflective structure (Fig. 18.2).

The acoustical impedance is very different between muscles and bones, causing a strong reflection with hardly any sound passing through. In normal subjects, the echo from the bone and periosteum forms a highly reflective hyperechoic linear or curvilinear line with a characteristic anechoic bone shadow underneath (Fig. 18.1). The hyperechoic tendon consists of parallel fibers running in the long axis of the tendon. The tendon sheath is hyperechoic and separated from the tendon by a thin hypoechoic area (Bradley and O'Donnell, 2002). Nerves are relatively hyperechoic, linear nerve bundles being separated by hyperechoic interfaces, whereas blood vessels are hypo- or anechoic circles or lines depending on the direction of the ultrasound beam. To correctly identify blood vessels in muscle sections, power Doppler imaging is used as it shows blood flow (Fig. 18.3).

In neuromuscular disorders such as spasticity, when the muscle tissue is replaced by fat and by infiltration of intramuscular connective tissue (fibrosis), the ultrasound beam encounters tissues with different acoustic impedance and much reflection. This explains why the muscle ultrasound image appears white (Fig. 18.4).

Subcutaneous fat is hypoechoic, but the echogenicity varies in different anatomies and pathologies, and several echogenic septa of connective tissue may be visible within this tissue. Other fatty areas may vary in echogenicity depending on their structure and surrounding tissue.

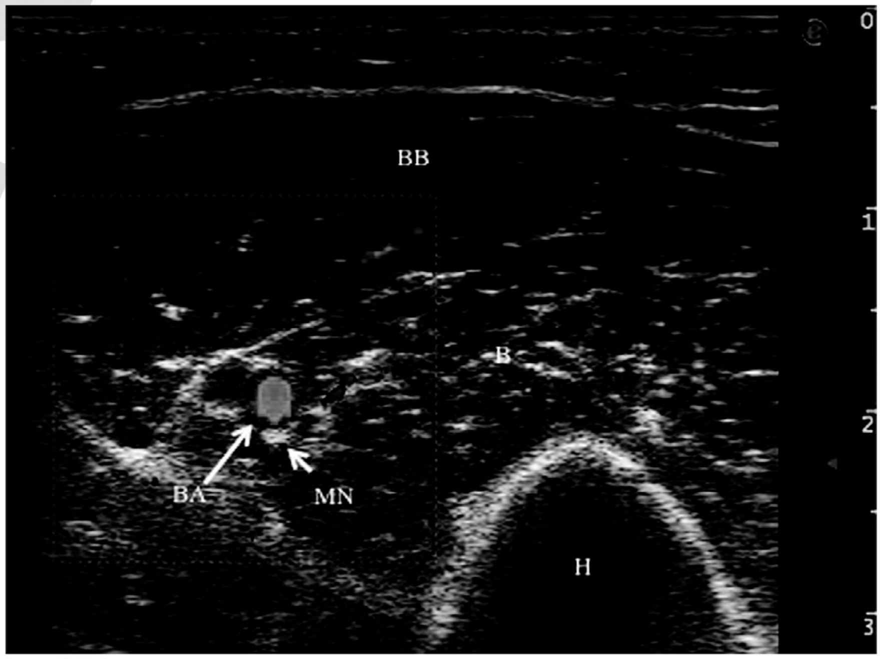

Fig. 18.1 Transverse ultrasound image of the arm. BB, biceps brachii muscle. B, brachial muscle; H, humerus; MN, median nerve; BA, brachial artery.

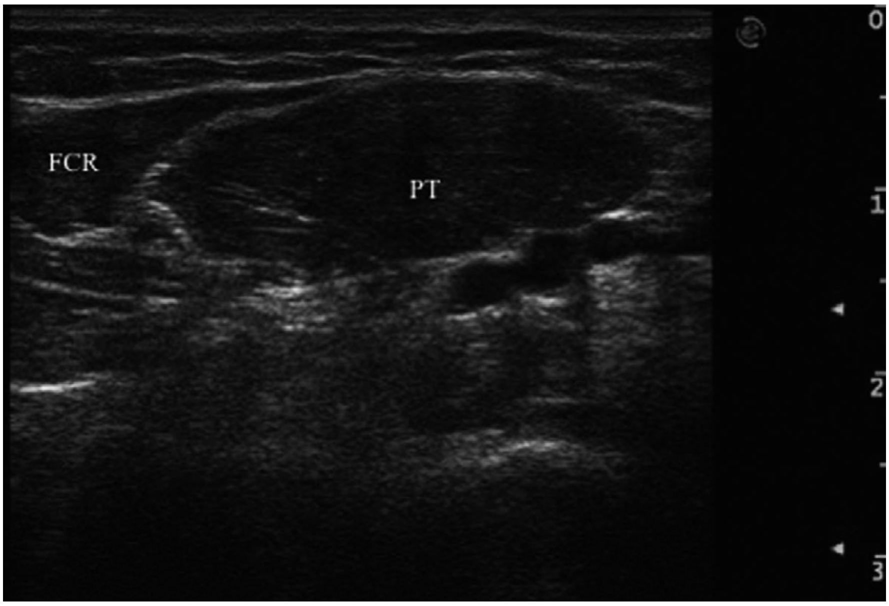

Fig. 18.2 Transverse ultrasound image of pronator teres (PT) and flexor carpi radialis (FCR) muscles in the left forearm.

Skeletal muscle ultrasound examination can be performed by a transverse or longitudinal evaluation. In the transverse plane, perpendicular to the long axis of the muscle, the muscle has a speckled appearance, whereas in the longitudinal plane (along the long axis of the muscle), the fascicular architecture of the muscle becomes visible (Pillen, 2010). Usually, a probe with a resolution of 7.5–12 MHz is adequate to observe all superficial muscles, but it is not useful for the identification of individual small muscles. For small muscles, a high frequency (18 MHz) with a corresponding higher resolution transducer must be used. In the case of deeper muscles, it is possible to use lower frequencies (5–7.5 MHz) or a convex transducer.

Ultrasound Guidance for Botulinum Neurotoxin Injection in Spastic Muscles

Why Use Ultrasound Guidance?

Ultrasonography is well established as a reliable and reproducible imaging method in muscle anatomy (Bradley and

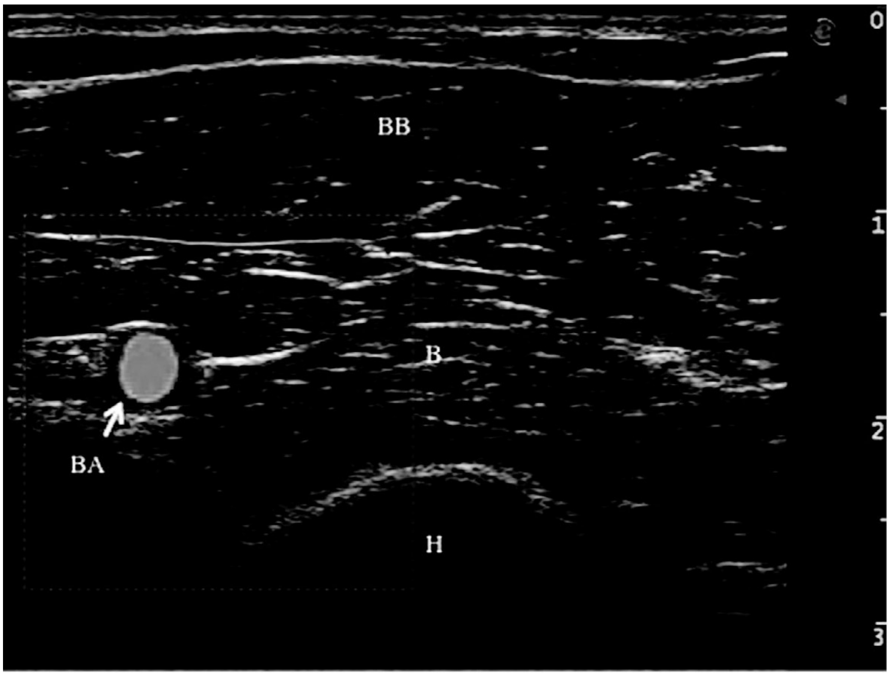

Fig. 18.3 Power-Doppler imaging of brachial artery (BA) with surrounding biceps brachii (BB) and brachialis (B) muscles in transverse ultrasound image of the left arm. H, humerus.

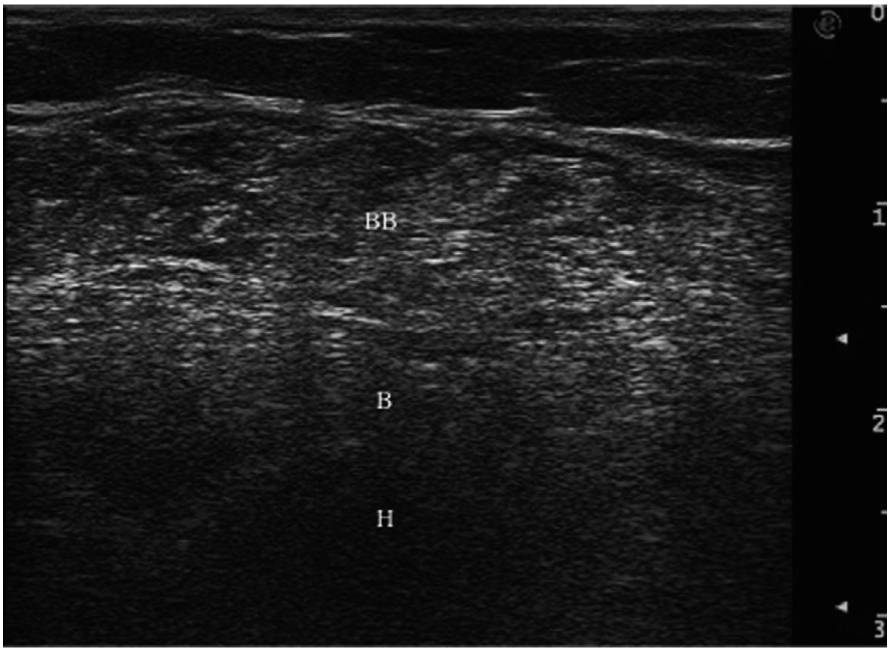

Fig. 18.4 Fibrotic area into transverse ultrasound image of biceps brachii (BB) muscle. Boundaries of the muscles are not clearly visible. B, brachialis muscle; H, humerus.

O'Donnell, 2002), and several studies have shown applicability of the procedure for visually controlled BoNT injections as an alternative to electrophysiological techniques (Willenborg et al., 2002; Westhoff *et al*., 2003; Berweck *et al*., 2004). Kwon and colleagues (2010) compared the clinical outcomes of two different BoNT injection guidance techniques, electric stimulation and ultrasound, into both gastrocnemius muscles in 30 children with cerebral palsy. Gait pattern and hindfoot position–maximum foot/floor contact during stance significantly improved in the ultrasound-guided group, while no statistical differences were noted in the Modified Ashworth Scale, Modified Tardieu Scale or Selective Motor Control. These authors concluded that visual feedback by ultrasonography could improve the accuracy of selective neuromuscular blocking of the gastrocnemius muscles.

Yang and colleagues (2009) investigated the accuracy of manual needle placement for BoNT injection into the gastrocnemius muscle in 39 children with spastic cerebral palsy. These authors showed that the needle was accurately inserted into gastrocnemius muscles in 78.7% of cases. Accuracy was 92.6% into gastrocnemius medialis and 64.7% into gastrocnemuis lateralis. Muscle thickness at the needle insertion site was significantly thinner in gastrocnemius lateralis than in gastrocnemius medialis, so injection of the BoNT into gastrocnemius muscles using an anatomical landmark was acceptable in gastrocnemius medialis but not in gastrocnemius lateralis. Finally, Py and colleagues (2009) showed that ultrasonically guided BoNT injections into the lower limbs of children with cerebral palsy led to greater functional improvement than seen in those performed with manual needle placement. Therefore, reasons to use ultrasound guidance for BoNT administration include the accuracy of muscle identification, correct needle placement into the muscle mass and reduced likelihood of inserting the needle into tissues surrounding the target muscle.

An additional advantage of ultrasound guidance may also be a reduction in the time required for muscle identification. Berweck and colleagues (2004) assessed more than 6000 ultrasound-guided BoNT injections and demonstrated that the average time to identify and inject the targeted muscle ranged from 5 seconds in superficial muscles such as the gastrocnemius muscle to 30 seconds in deep-seated muscles such as the tibialis posterior or the iliopsoas muscle.

Moreover, ultrasound guidance permits the identification of a muscle's depth and thickness. Depth is defined as the distance from the skin to the superficial aponeurosis of each muscle. Thickness is defined as the distance from the superficial to the deep aponeurosis of each muscle (Fig. 18.5).

It is known that immobilization and spasticity lead to changes in muscle morphology over time, represented by atrophy, fibrosis and fat replacing sarcomeres. Therefore, a risk of BoNT administration is the needle's insertion over the thickness of target muscle, particularly in cases of atrophy and for small and superficial muscles. The advanced ultrasound machines show the exact muscle depth measured in centimeters, allowing the choice of a specific sized needle for injection. For example, to inject gastrocnemius muscle, it is sufficient to use a 25-gauge (0.5 mm $\times$ 16 mm) needle. The injection of soleus muscle with the same needle may be difficult in adult patients considering its depth (Fig. 18.6).

In obese patients, the needle needs to pass through the fat between skin and superficial aponeurosis of each muscle. Immobilization and spasticity of the arm disrupt the normal muscle architecture through the infiltration of fat and the development of fibrosis. Ultrasound guidance avoids administration of BoNT into fibrotic or fatty areas and increases its accuracy.

Ultrasound guidance for BoNT administration can also facilitate the identification of nerves and vessels, thereby avoiding unwanted bleeding and enhancing the accuracy of BoNT placement (Fig. 18.1). It also allows estimation of muscle volumes so that the amount of BoNT needed for specific muscles can be calculated. However, ultrasound technology is unable to register muscular hyperactivity or to localize neuromuscular junctions. There is evidence from animal models and clinical studies that distance to neuromuscular junctions influences efficiency of BoNT treatment.

Technique for Ultrasound-Guided Botulinum Neurotoxin Injection

Transverse as opposed to longitudinal scans permit "panoramic" images, which make it possible to visualize several muscles in one plane. In this mode, the injector can move the probe laterally or medially along the target muscle's areas,

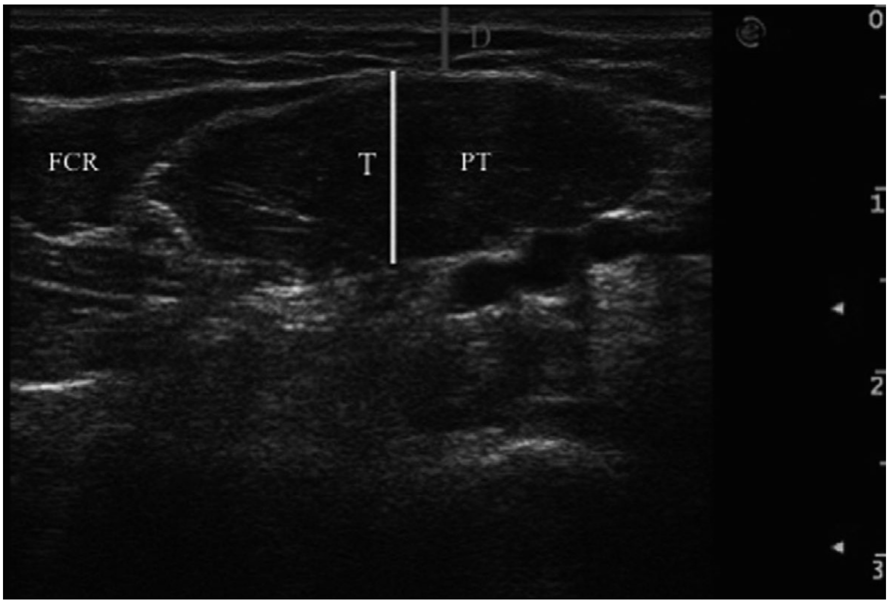

Fig. 18.5 Transverse ultrasound image of pronator teres (PT) muscle. Right-hand side scale indicates depth; FCR, flexor carpi radialis; T, thickness.

Fig. 18.6 Transverse ultrasound image of the left calf. Depth of single muscles is indicated by arrowheads in the right margin. GM, gastrocnemius medialis; GL, gastrocnemius lateralis; SOL, soleus.

facilitating the identification of muscles that are to be treated with BoNT. Moreover, the injector can activate the muscle identified, consider their motor function biomechanically and can observe this activation with the probe.

Before proceeding to the injection, it is best to prepare several needles of various sizes for the different muscle depths (Fig. 18.7). To observe the correct placement into target muscles, it is important to introduce the needle tip under ultrasound beam at an angle of 30 degrees with the axis of the probe. The needle is identified directly as an echogenic line or indirectly by imaging the movements of the surrounding soft tissues during real-time observation (Fig. 18.8).

After correct placement, BoNT is injected under real-time observation mode, and by changing the position of the needle, the BoNT can be well distributed in the muscle belly. The appropriate number of injection sites usually depends on the size of the muscle. Injecting a small volume at several sites is preferred over a large volume at a single site.

Ultrasound-Guided Botulinum Neurotoxin Injections for Common Patterns of Upper and Lower Limb Spasticity

In following paragraphs, the common muscles involved in spasticity are shown with their position in upper or lower limb and their transverse ultrasound image.

Upper Limb Spasticity

The most common patterns of spasticity in the upper limb involve flexion of the fingers, wrist and elbow; adduction with internal rotation at the shoulder; and clenched fist with thumb in palm (Mayer *et al.*, 2002). Wrist or elbow extension is less common.

Shoulder: Adduction and Internal Rotation

Inject pectoralis major and minor (Fig. 18.9); optional injection of latissimus dorsi and teres major (Fig. 18.10).

It is useful to identify the coracobrachialis muscle at the proximal and anterior surface of the arm. From there, moving the probe medially to the axillary fold, it is possible to palpate the pectoralis major muscle insertion fibers at the anterior axillary fold. The pectoralis major muscle is superficial (Fig. 18.9); advance through it to reach pectoralis minor muscle. Latissimus dorsi is approached at the posterior chest wall, looking for its origin, spinous processes of lower thoracic vertebrae, lumbodorsal fascia and posterior crest of ilium (Fig. 18.10).

Arm: Elbow Flexion

Inject biceps brachii, brachialis and/or brachioradialis muscles (Figs. 18.11 and 18.12).

Biceps brachii muscle is approached at the third medium of the anterior arm surface, superficially, with brachialis muscle separating it from humerus (Fig. 18.11). Brachioradialis

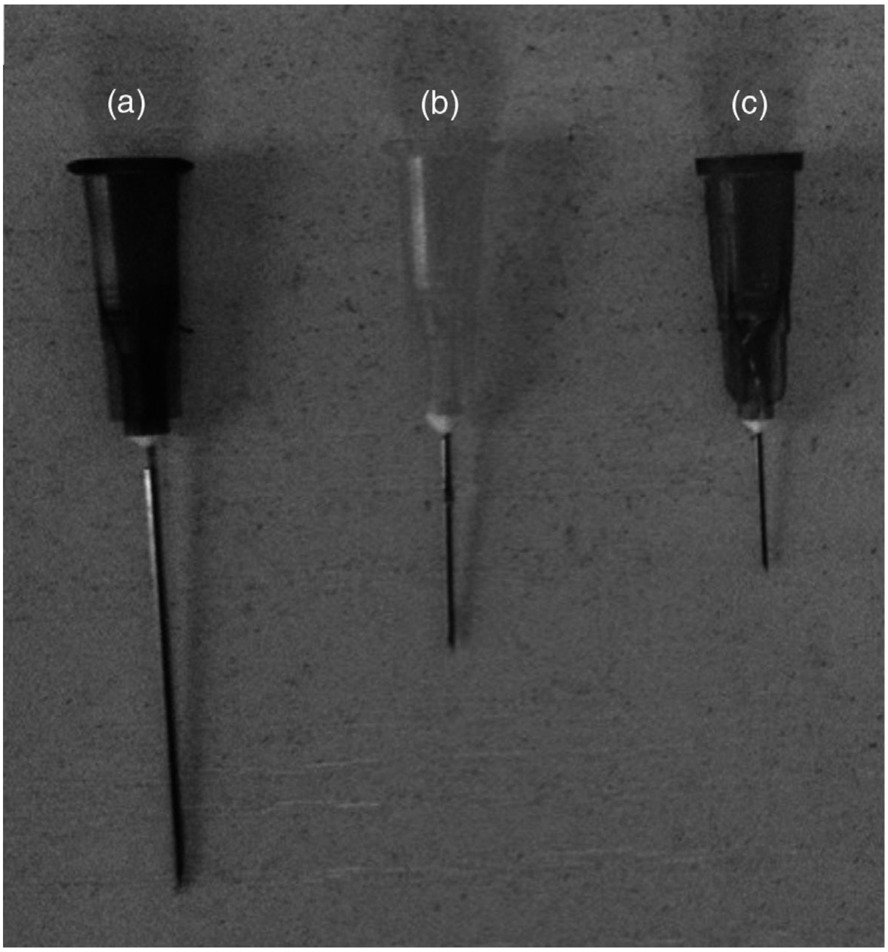

Fig. 18.7 Needles: (a) 0.7 mm × 30 mm; (b) 0.5 mm × 16 mm; (c) 0.45 mm × 10 mm.

muscle is approached at the third proximal of dorsal surface of the forearm (Fig. 18.12).

Forearm

For the forearm, ultrasound evaluation is carried out while the patient lies in supine position with a forceful fully supinated forearm. In this mode, transverse ultrasound image allows visualization of several flexor muscles in one plane. At the proximal third of the ventral surface of forearm, the pronator teres muscle can be easily observed because of its size and hypoechogenicity with respect to other surrounding muscles. By first identifying this muscle, it is possible to observe the other muscles from lateral to medial: pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum superficialis, flexor carpi ulnaris muscles, flexor digitorum profundus (Fig. 18.13).

Pronated Forearm

Inject pronator teres muscle (Fig. 18.14).

Inject pronator teres muscle at the proximal third of the ventral surface of forearm (Fig. 18.14).

Wrist Flexion

Inject flexor carpi radialis and/or flexor carpi ulnaris (Figs. 18.14 and 18.15).

Flexor carpi ulnaris is approached directly at the medial border of the forearm midway between the antecubital and distal wrist creases (evaluation can be facilitated with forearm flexion). Flexor carpi radialis lies along the ventral surface of the forearm just medial to the midline.

Hand: Clenched Fist

Inject flexor digitorum superficialis and flexor digitorum profundus (Fig. 18.16).

The flexor digitorum superficialis muscle is injected for flexion at the proximal interphalangeal joints and the flexor digitorum profundus muscle to reduce flexion at distal interphalangeal joints.

Flexor digitorum superficialis lies between flexor carpi radialis and flexor ulnaris carpi, while flexor digitorum profundus is approached between flexor digitorum superficialis and flexor ulnaris carpi (Fig. 18.16).

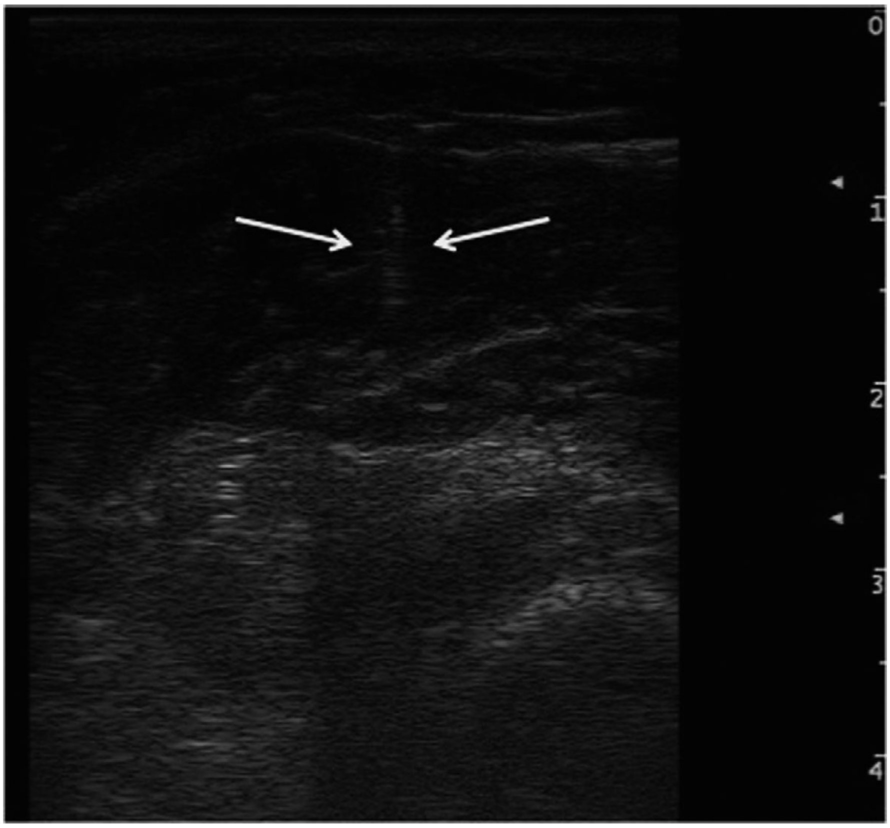

Fig. 18.8 Hyperechogenic appearance of the needle in the muscle, in the midline, indicated by the two arrows.

Hand: Thumb in Palm

Inject flexor pollicis longus, adductor pollicis and other thenar muscles (Figs. 18.17 and 18.18).

Flexor pollicis longus muscle is approached from the middle to the distal third of the ventral forearm, adjacent to the medial border of the brachioradialis muscle (Fig. 18.17). Adductor pollicis muscle may be approached from the dorsal surface by going through the overlying first dorsal interosseus muscle, or, more commonly, from the palmar side. Into the palmar side, flexor pollicis brevis muscle lies medial and adjacent to abductor pollicis brevis muscle (Fig. 18.18). The other thenar muscles that may be injected include opponens pollicis, flexor brevis pollicis and abductor pollicis brevis.

Other Upper Limb Muscles

Elbow Extension

Inject triceps brachii (Fig. 18.19).

The triceps brachii muscle is injected in cases of elbow extension or to reduce co-contraction with biceps brachii and brachialis muscles. Triceps brachii is approached behind the posterior surface of humerus at the third medium (Fig. 18.19).

Wrist Extension

Inject extensor carpi radialis longus, extensor carpi radialis brevis or extensor carpi ulnaris (Figs. 18.20 and 18.21).

In case of upper limb spasticity, it's possible to inject extensor carpi radialis longus, brevis or extensor carpi ulnaris muscles. Extensor carpi radialis longus and extensor carpi ulnaris muscles are approached at the third proximal of dorsal surface of the forearm (Figs. 18.20 and 18.21).

Lower Limb Spasticity

The most common pattern of spasticity in the lower limb involves extension at the knee, plantarflexion at the ankle and inversion of the foot (Mayer *et al.*, 2002). Other patterns of spasticity in the lower limbs include "scissoring" adduction at the hip joints, along with flexion or extension at the knees and spastic extension of the large toe.

Ankle: Plantarflexion Spasm

Inject lateral gastrocnemius, medial gastrocnemius and soleus (Fig. 18.22); optional injection of the tibialis posterior.

The lateral and medial heads of the gastrocnemius muscle lie superficially, while the tibialis posterior muscle (injected in cases of foot inversion) lies deep in the calf. Because of the great depth of the tibialis posterior muscle, it is better to put the probe on the middle third of the anterior and medial surface of the leg to facilitate its identification (Fig. 18.23).

Foot: Extension of the Large Toe

Inject extensor hallucis longus (Fig. 18.24).

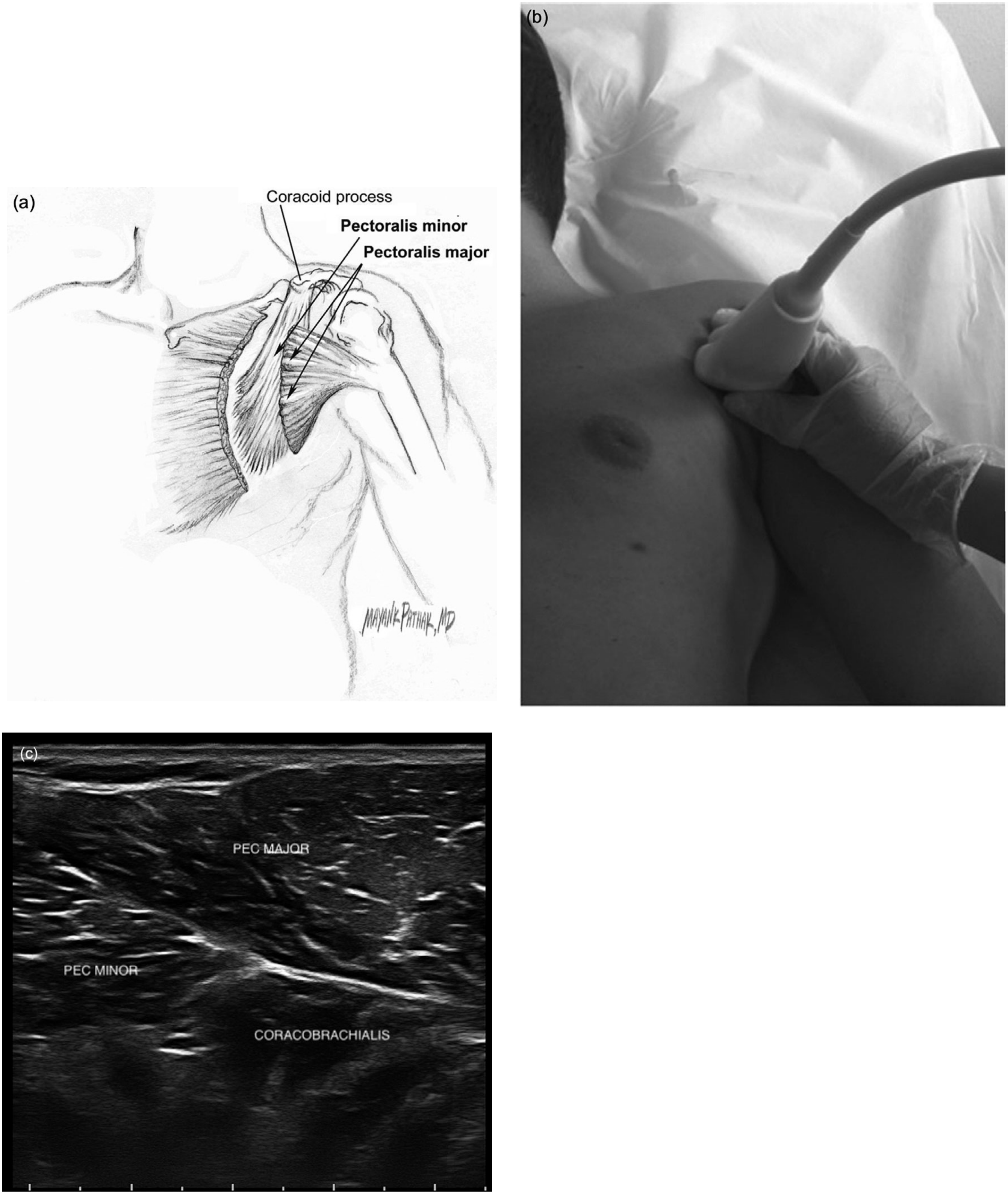

Fig. 18.9 Adduction and internal rotation of the shoulder. (a) The pectoralis major and minor muscles. (b) Position of probe for a transverse ultrasound image. (c) The left pectoralis major muscle, coracobrachialis muscle.

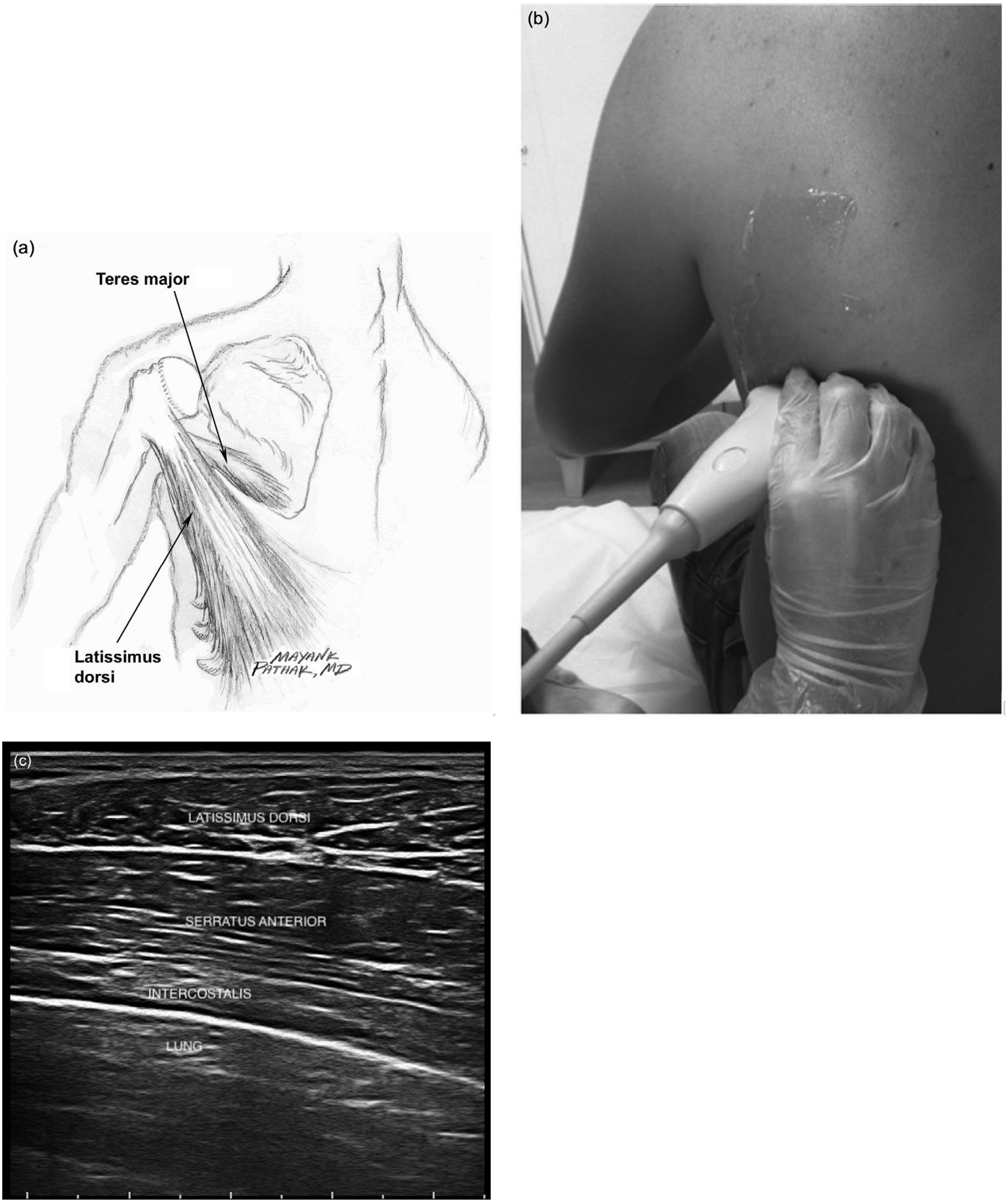

Fig. 18.10 Adduction and internal rotation. (a) Latissimus dorsi and teres major. (b) Position of probe for transverse ultrasound image. (c) Latissimus dorsi muscle; the underlying serratus anterior muscle, intercostalis muscle and the lung, are also shown.

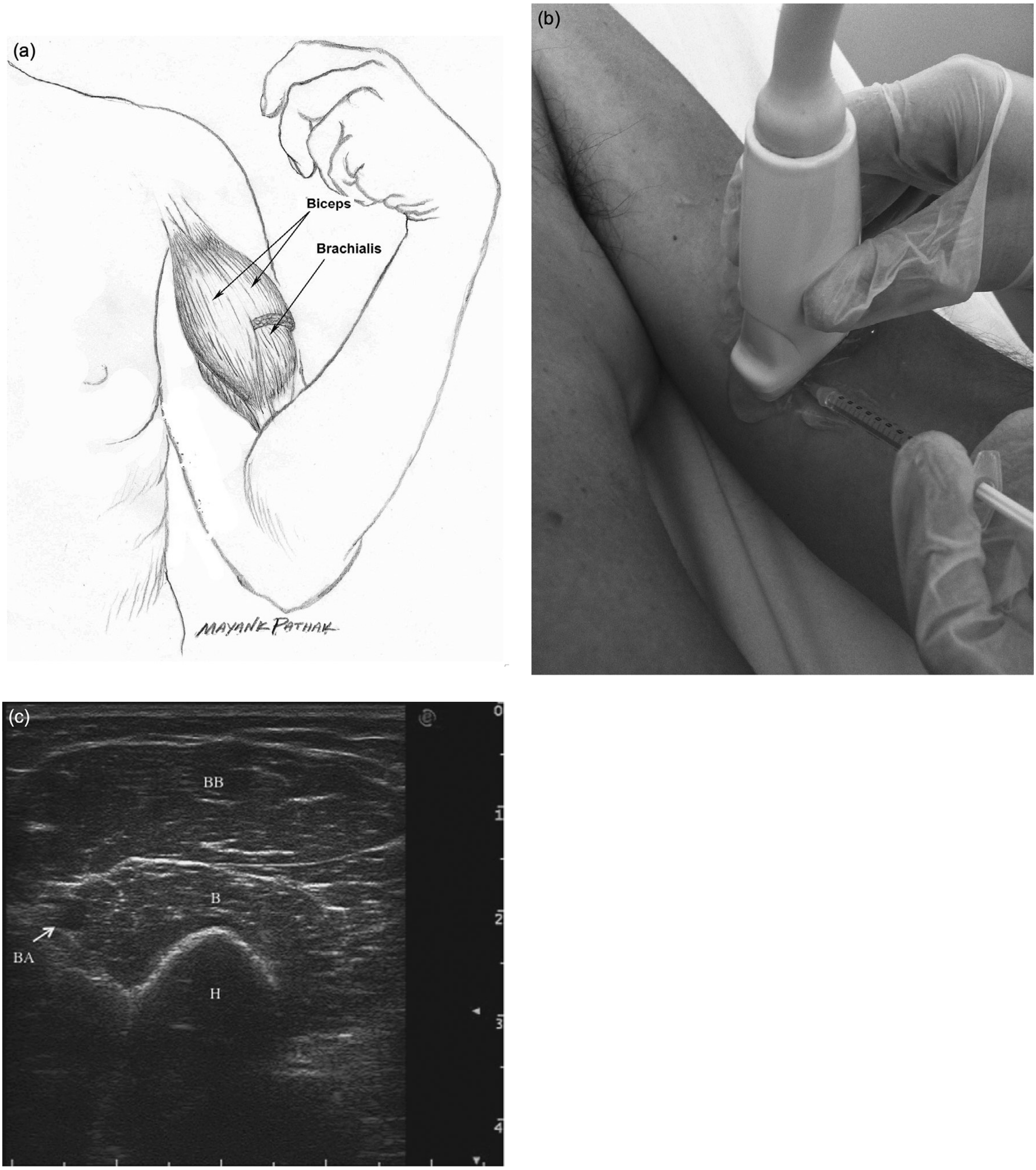

Fig. 18.11 Elbow flexion. (a) Biceps and brachialis. (b) Position of probe for a transverse ultrasound image. (c) The biceps brachii (BB) and brachialis (B) muscles and brachial artery (BA). H, humerus.

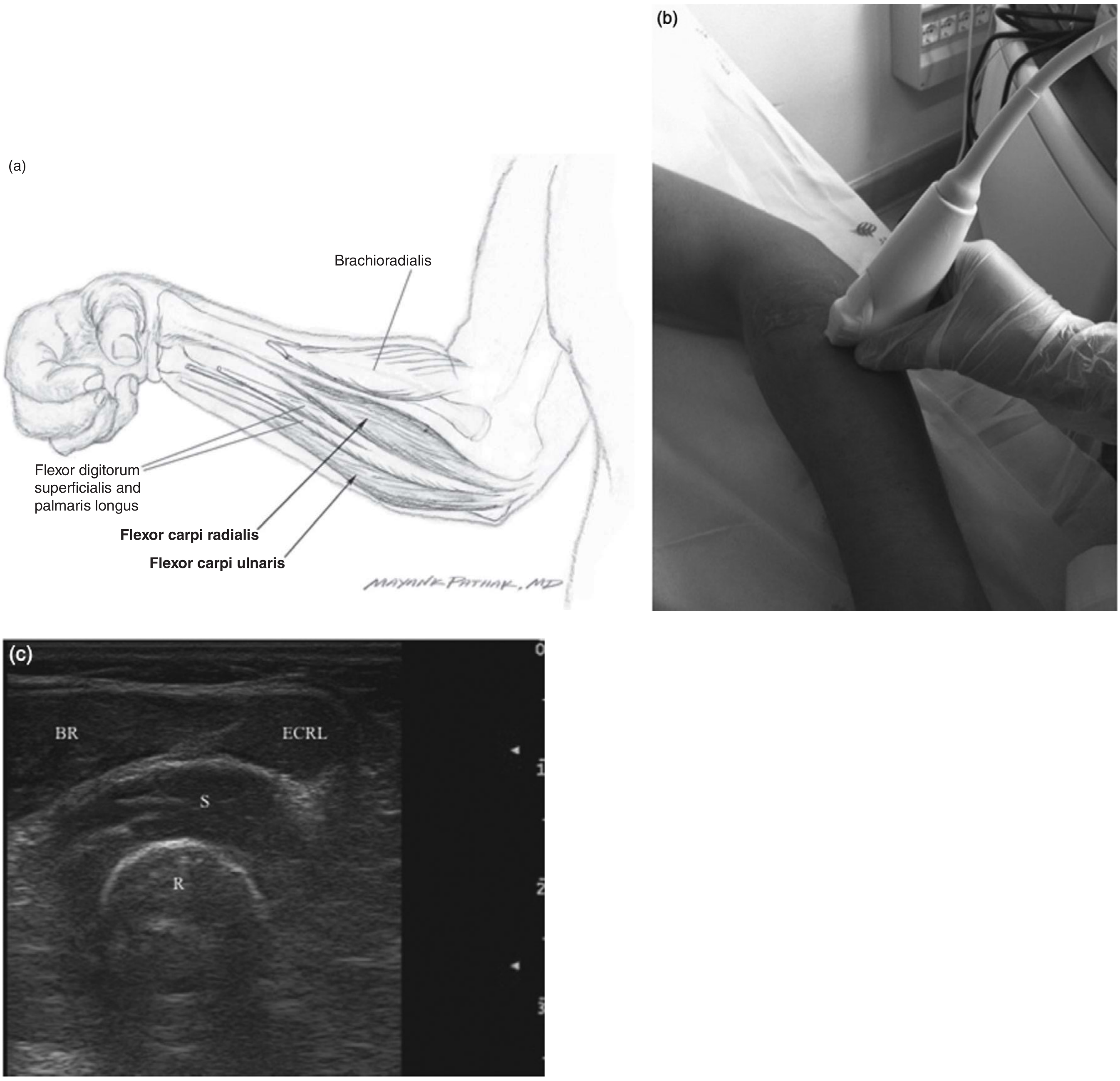

Fig. 18.12 Elbow flexion. (a) The brachioradialis muscle. (b) The probe approaches the muscle at the third proximal dorsal surface of the forearm. (c) Transverse ultrasound image of left brachioradialis (BR), extensor carpi radialis longus (ECRL) and supinator (S) muscles in the left forearm. R, radius.

The extensor hallucis longus is located by palpating its tendon just lateral to the tendon of the tibialis anterior and following it to about the proximal third of the tibia. At this level, its muscular belly lies one fingerbreadth lateral to the tibia (Fig. 18.24).

Flexion of the Large Toe and Other Toes

Inject flexor hallucis longus and flexor digitorum longus (Fig. 18.25).

Both flexor hallucis longus and flexor digitorum longus are below the soleus muscle in the calf, between the tibia and fibula. Flexor hallicus longus is approached adjacent to the posterior distal fibula, while flexor digitorum longus is adjacent to the medial posterior tibia (Fig. 18.25).

Other Lower Limb Muscles Sometimes Injected

Thigh: Hip Adduction Spasm

Inject adductor muscles: longus, brevis and magnus (Fig. 18.26).

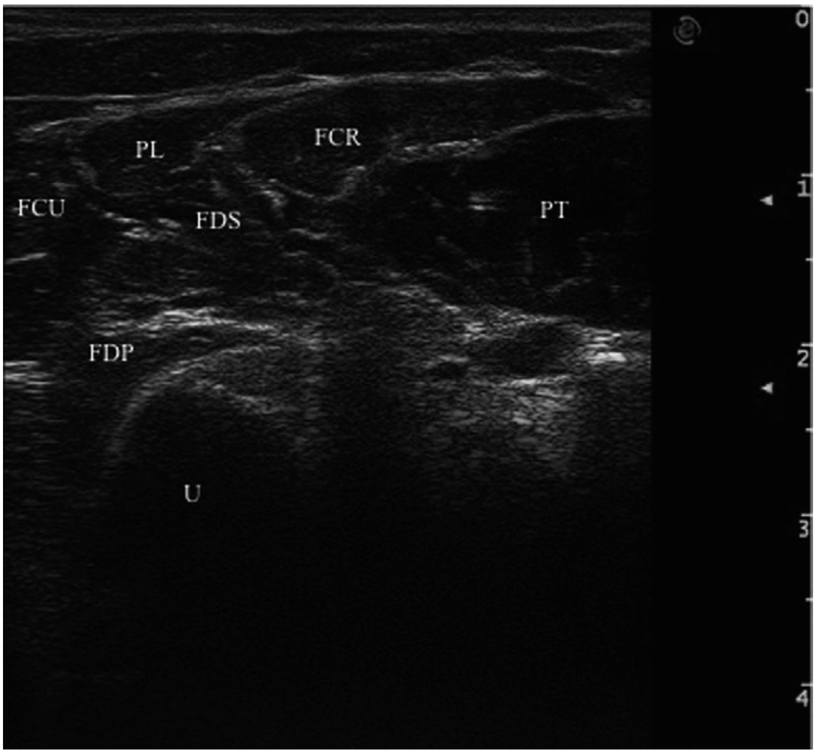

Fig. 18.13 Transverse ultrasound image of left forearm. PT, pronator teres; FCR, flexor carpi radialis; PL, palmaris longus; FDS, flexor digitorum superficialis; FCU, flexor carpi ulnaris; FDP, flexor digitorum profundus; U, ulna.

We prefer that the patient lie in the supine position with thighs flexed, abducted at the hips and the knees flexed. The adductor muscles (longus, brevis and magnus) are found proximally in the anteromedial thigh approximately a handbreadth distal to the groin fold, where they are superficial and the separation (in anterior to medial progression) of the adductor longus and gracilis muscles is palpable. The magnus adductor muscle lies deep in the medial part of the thigh; the longus adductor muscle is approached superficially while the brevis adductor muscle is between magnus and longus adductor muscles (Fig. 18.26). In this mode, it is possible to treat all adductor muscles with only one BoNT administration by varying the depth of needle insertion into the muscle tissue.

Leg: Flexion Spasm

Inject hamstring muscles (Fig. 18.27).

The hamstring muscles are biceps femoris, semimembranosus and semitendinosus muscles. The semitendinosus and semimembranosus muscles are medial in the posterior surface of the thigh, while the long and short heads if biceps femoris are lateral.

Leg: Extension Spasm

Inject extensor muscles (Fig. 18.28).

It is sometimes useful to inject the extensor muscles of the leg to improve gait and balance. The rectus femoris, vastus lateralis and vastus medialis muscles are readily approached in the anterior thigh. The vastus medialis is best found more distally (Fig. 18.28).

Foot: Eversion Spasm

Inject peroneus muscles (Fig. 18.29).

Peroneus longus and brevis are approached from the proximal one-third of the fibula. The peroneus tertius is approached at the distal one-third of the fibula.

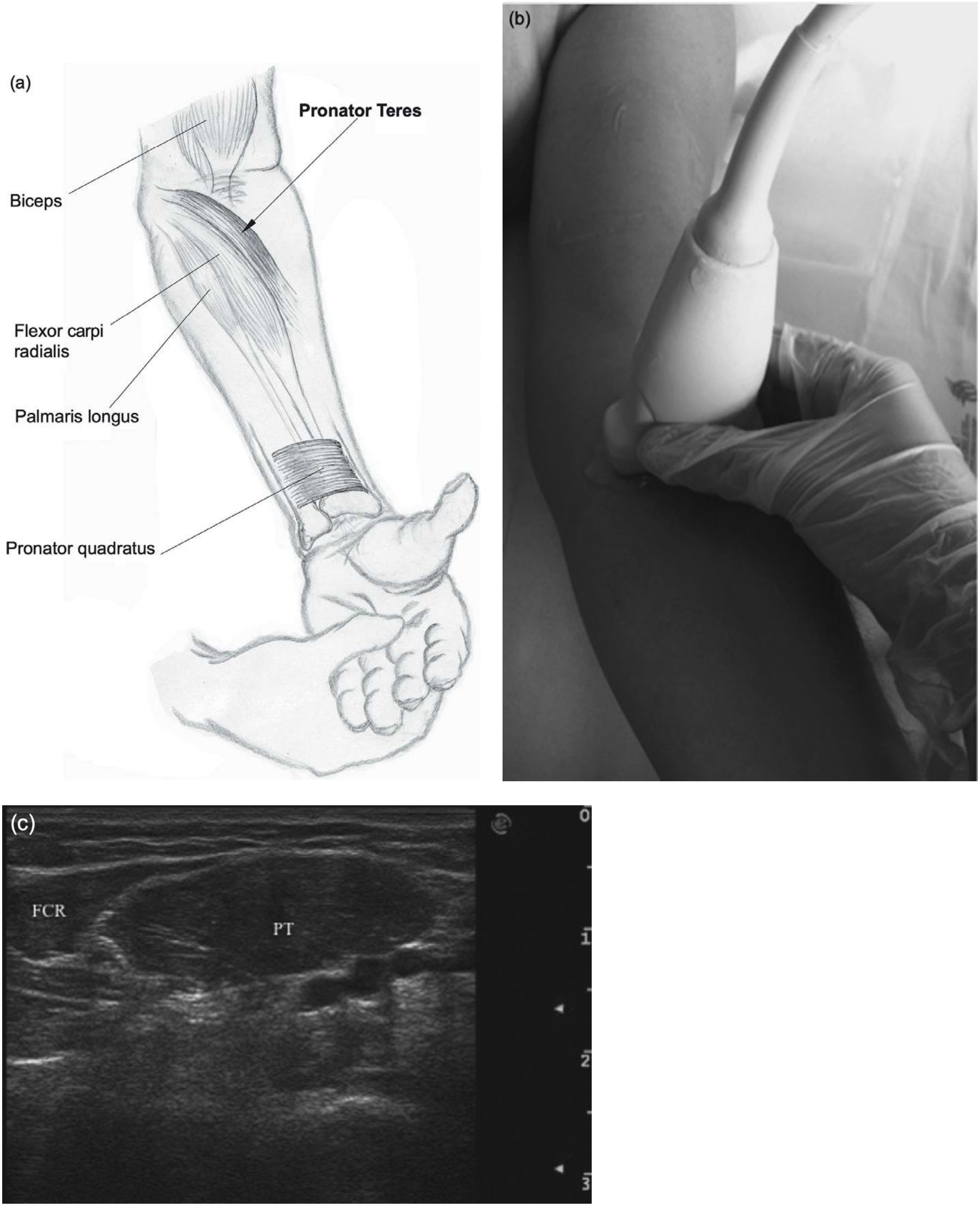

Fig. 18.14 Pronated forearm. (a) The muscles of the forearm. (b) Position of probe for a transverse ultrasound image. (c) Ultrasound image of left pronator teres (PT) and flexor carpi radialis (FCR) muscles in the left forearm.

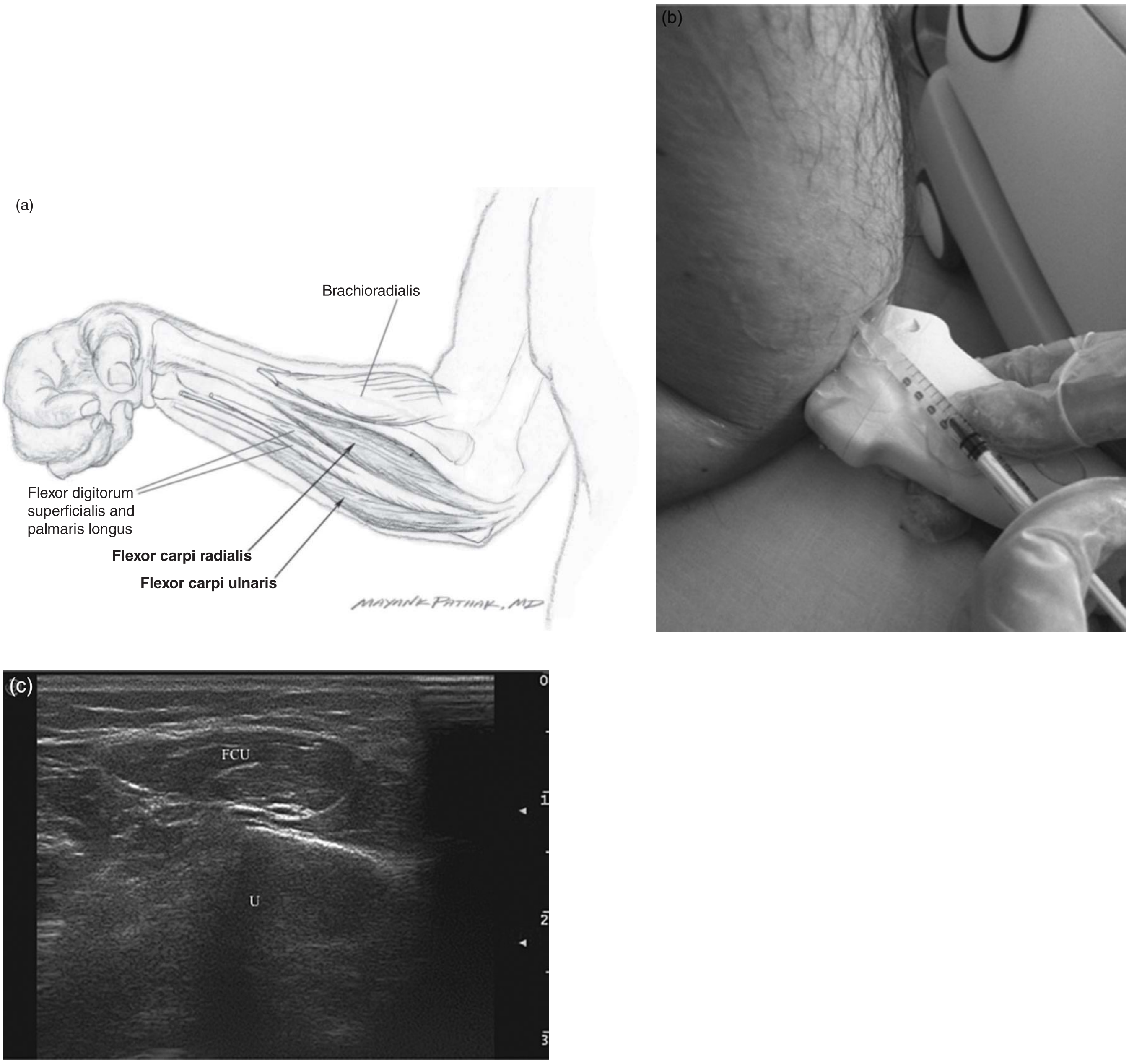

Fig. 18.15 Wrist flexion. (a) Muscles of flexion. (b) Position of probe for a transverse ultrasound image. (c) Ultrasound image of left flexor carpi ulnaris (FCU) and ulna (U) in the left forearm.

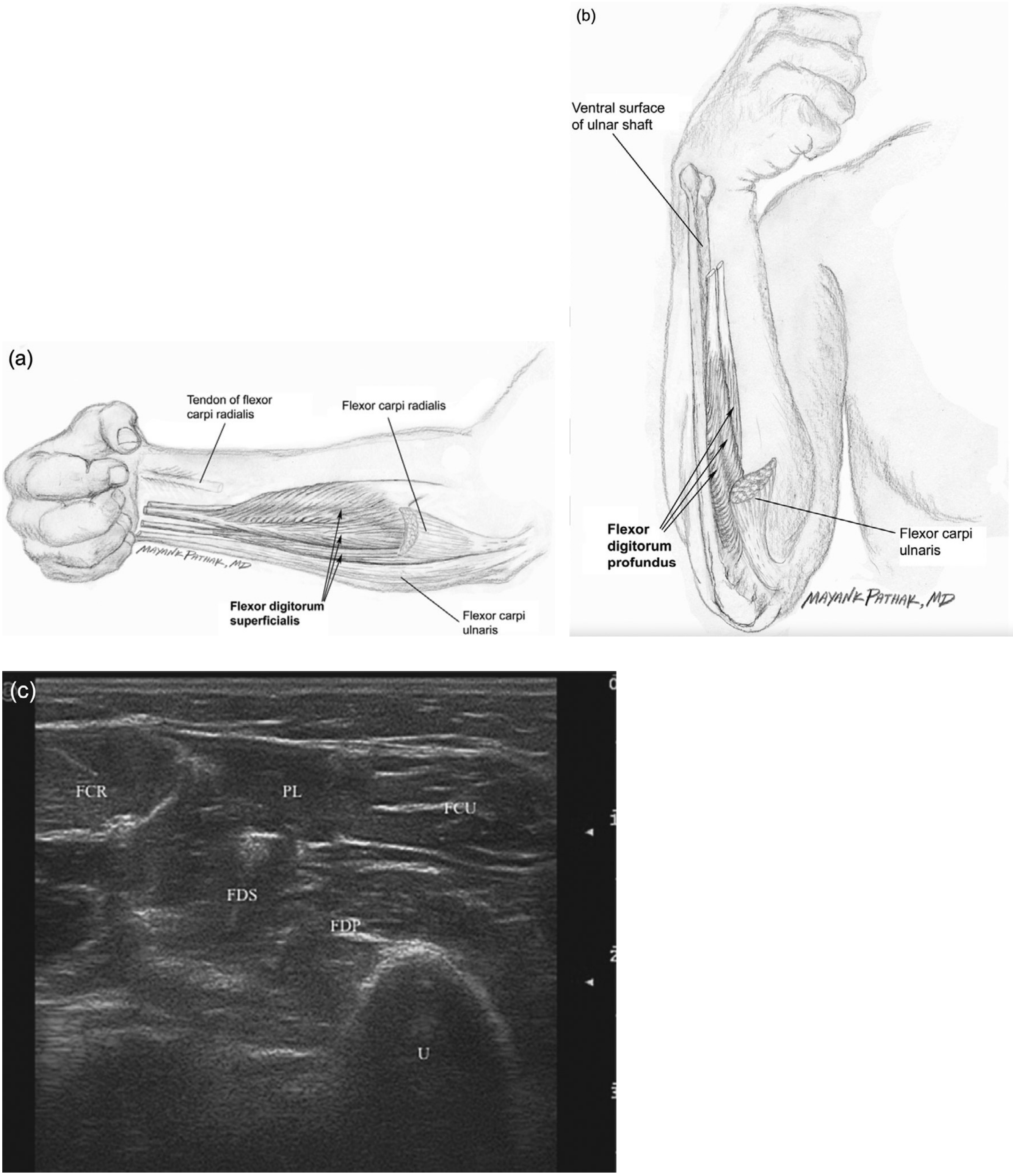

Fig. 18.16 Clenching the fist. (a,b) Muscles utilized in clenching the fist. (c) Transverse ultrasound image of flexor muscles in the left forearm. FCR, flexor carpi radialis; PL, palmaris longus; FDS, flexor digitorum superficialis; FCU, flexor carpi ulnaris; FDP, flexor digitorum profundus; U, ulna.

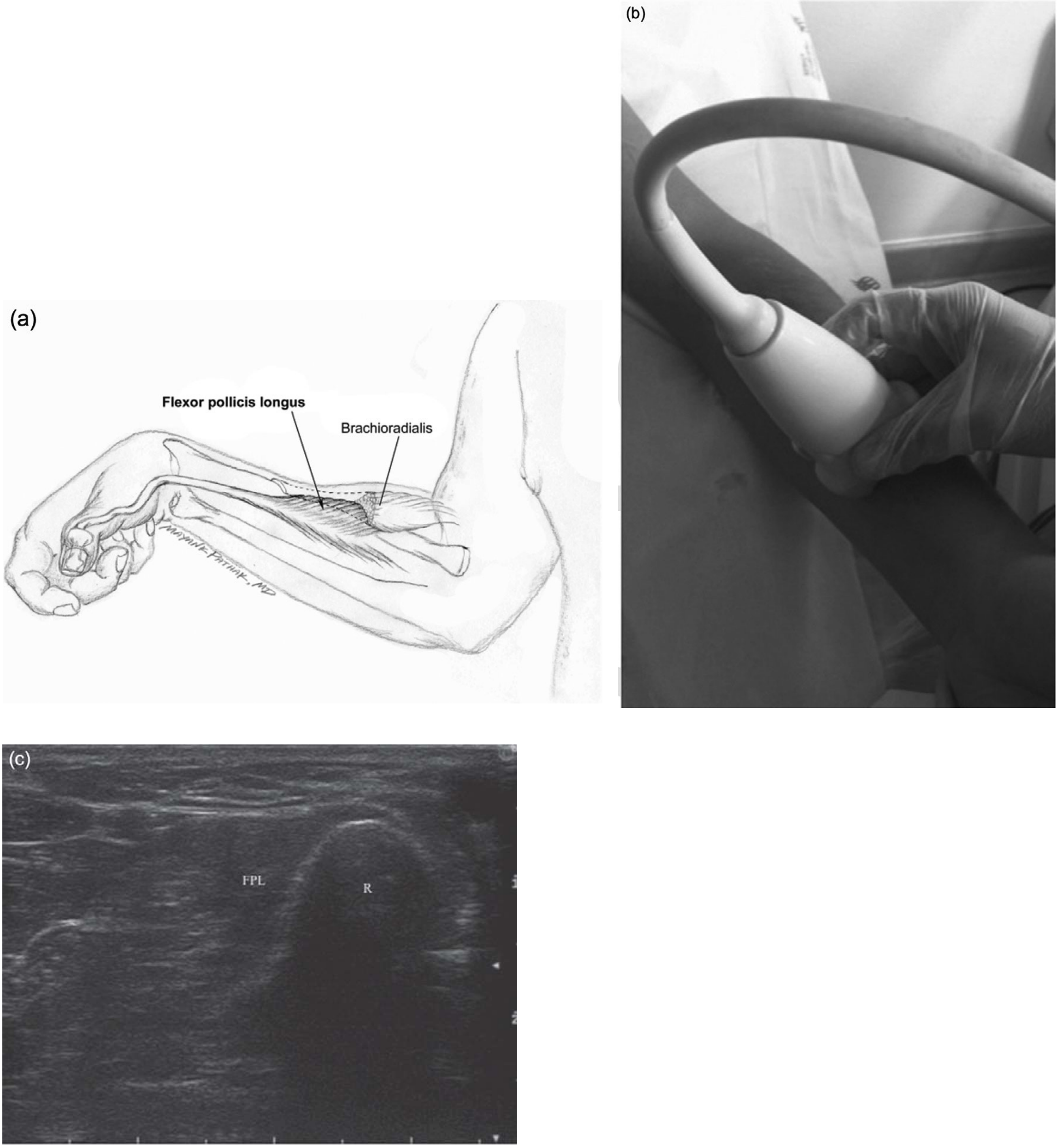

Fig. 18.17 Movement of the thumb into the palm. (a) Flexor pollicis longus muscle. (b) Position of probe for a transverse ultrasound image. (c) The flexor pollicis longus (FPL) muscle in the left forearm. R, radius

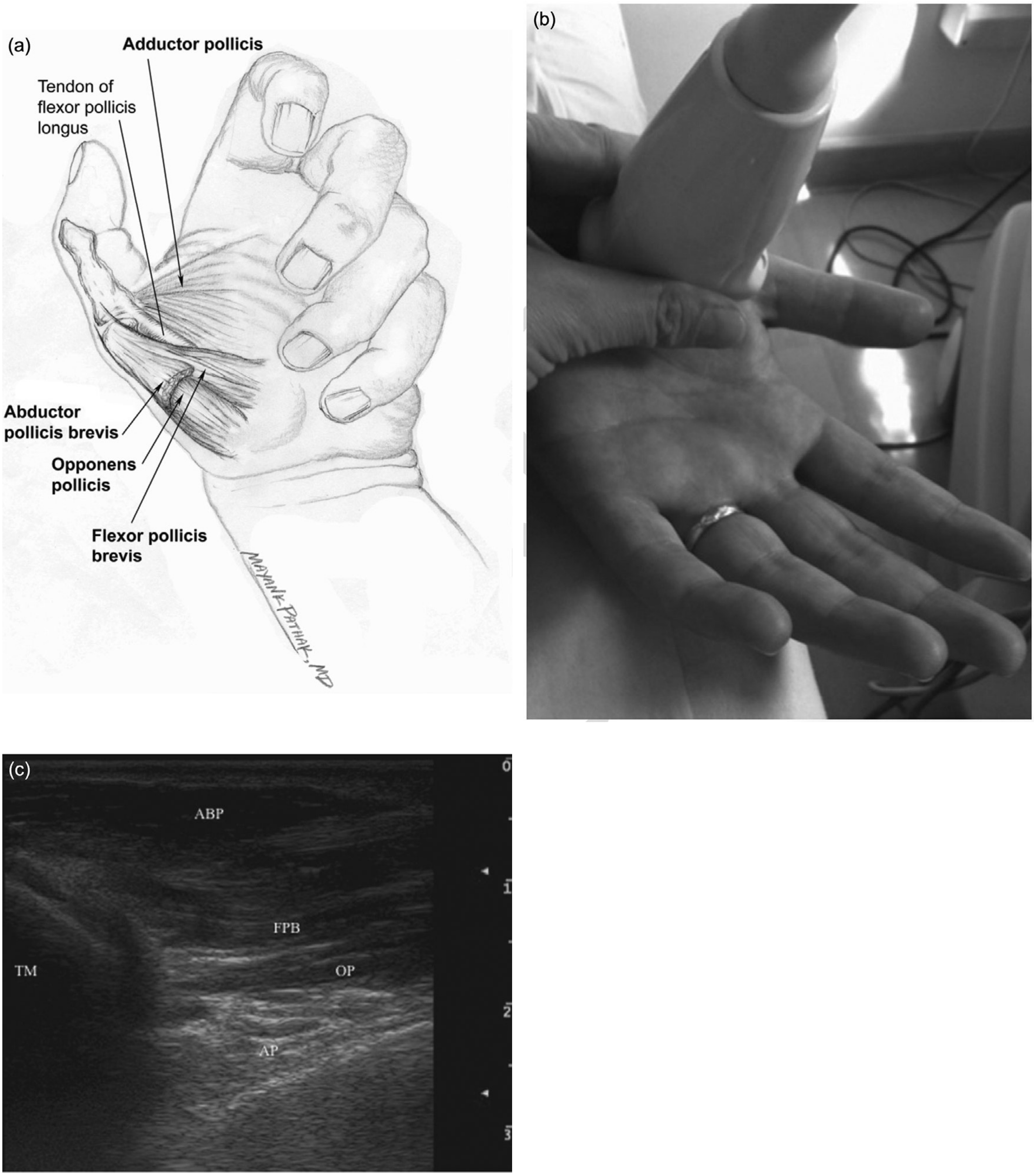

Fig. 18.18 Movement of the thumb. (a) The thenar muscles. (b) Position of probe for a transverse image. (c) Ultrasound image showing the abductor brevis pollicis (ABP), flexor pollicis brevis (FPB), opponens pollicis (OP) and adductor pollicis (AP) muscles. TM, thumb metacarpal.

Fig. 18.19 Elbow extension. (a) Probe position for the triceps brachii muscle. (b) Transverse ultrasound image of triceps brachii (TB) muscle in the left arm. H, humerus.

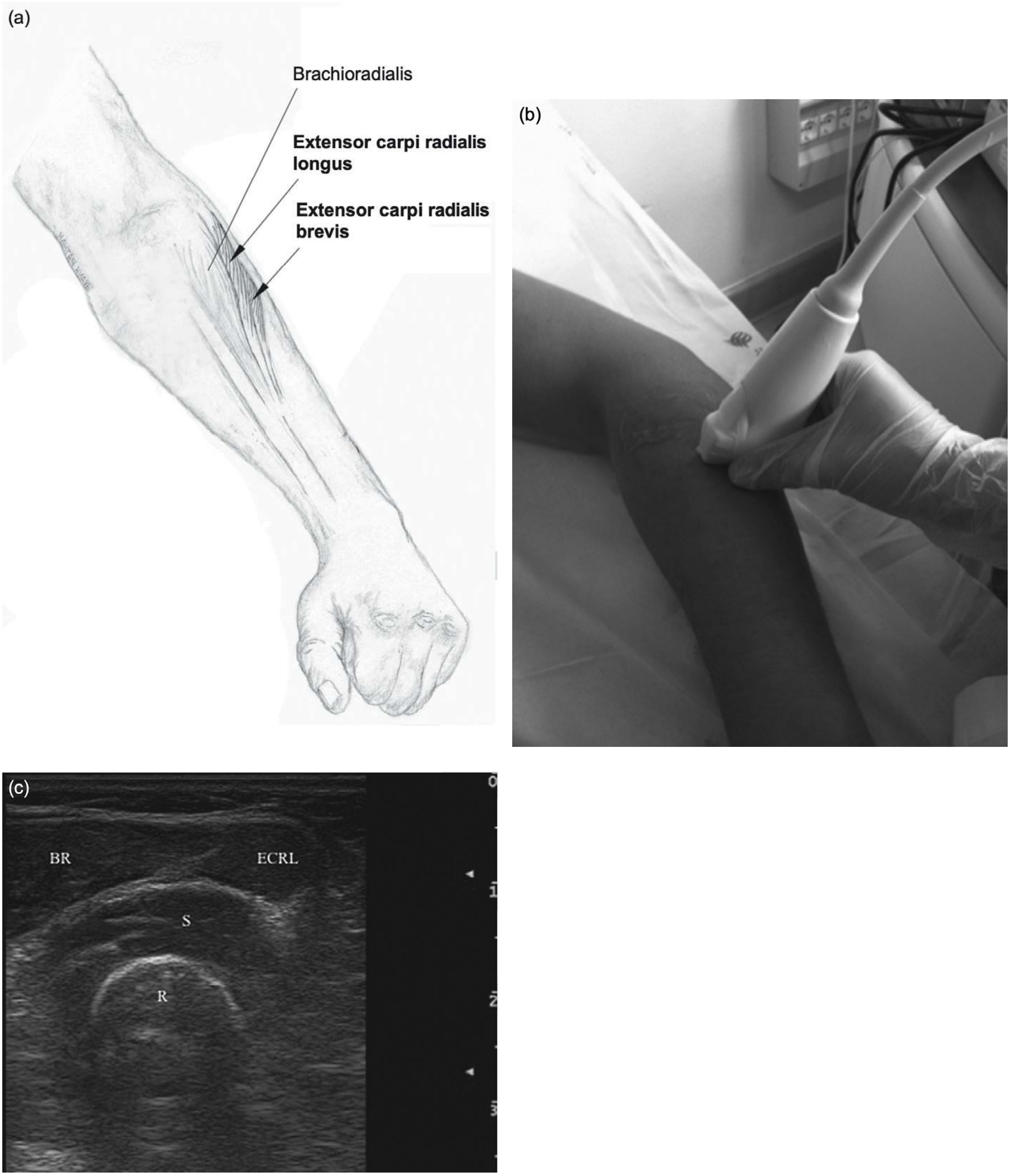

Fig. 18.20 Wrist extension. (a) Muscles of the forearm. (b) Probe position for a transverse ultrasound image. (c) The extensor carpi radialis longus (ECRL), brachioradialis (BR) and supinator (S) muscles in the left forearm. R, radius.

Fig. 18.21 Wrist extension. (a) The extensor carpi ulnaris. (b) Probe position for a transverse ultrasound image. (c) The extensor carpi ulnaris (ECU) and supinator (S) muscles in the left forearm. R, radius, U, ulna.

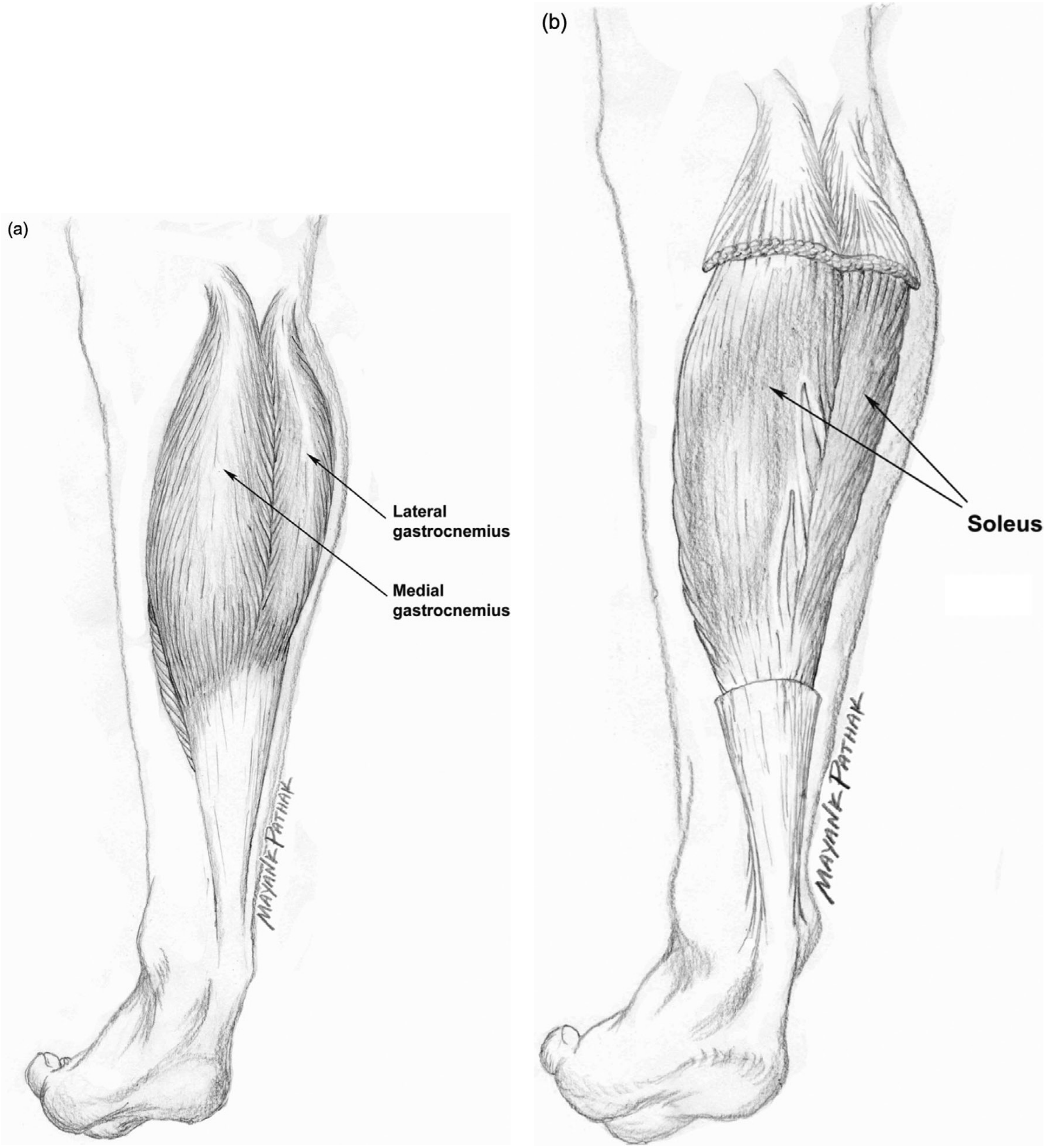

Fig. 18.22 Plantarflexion spasm of the ankle. (a,b) The plantar flexor muscles of the left calf. (c) Transverse ultrasound image of the gastrocnemius medialis (GM), gastrocnemius lateralis (GL) and soleus (SOL) muscles. (d) Probe and injection for the gastrocnemius medialis muscle. Probe and injection for gastrocnemius medialis muscle. (e) Probe and injection for soleus muscle.

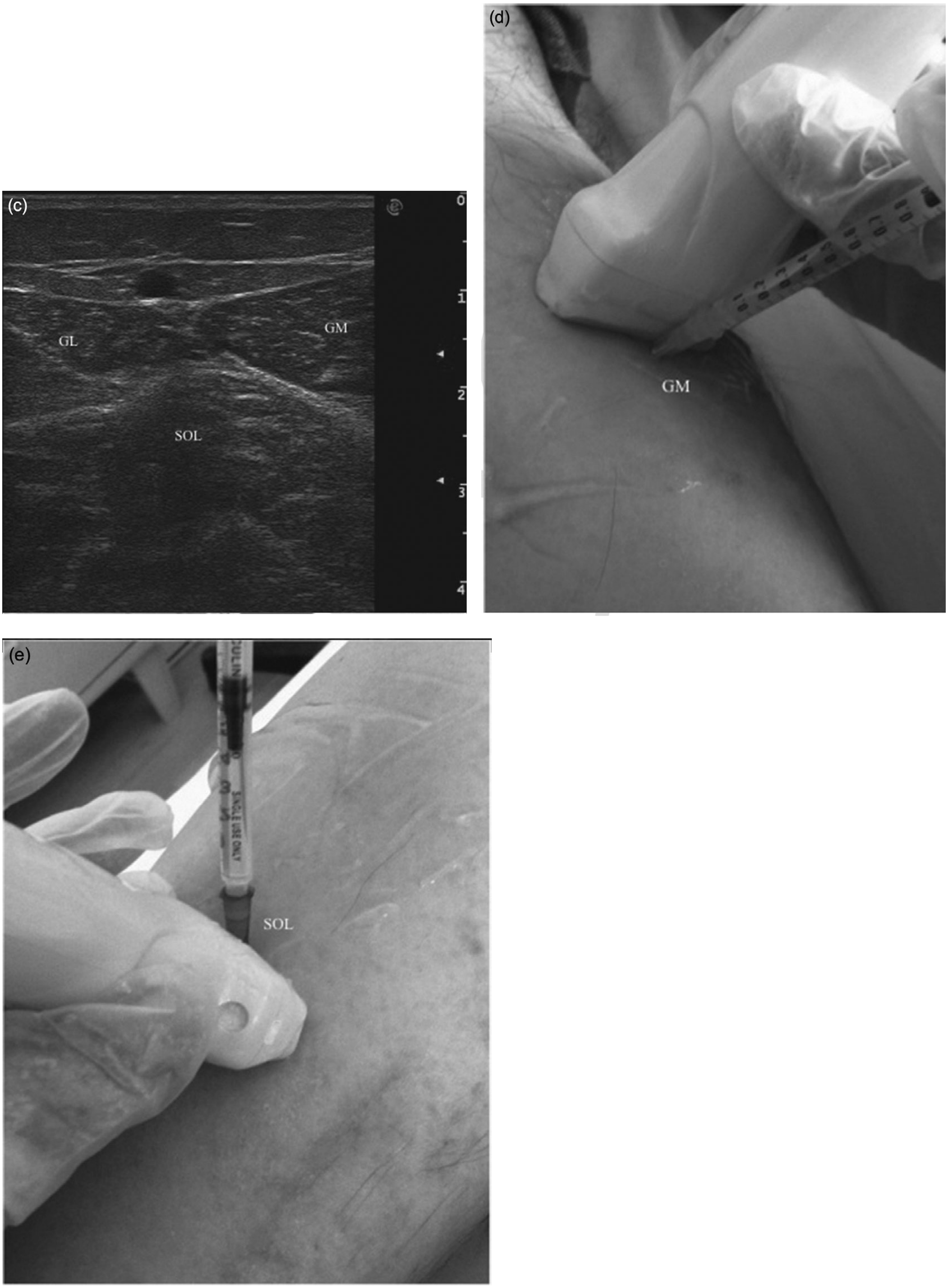

Fig. 18.22 (*cont.*)

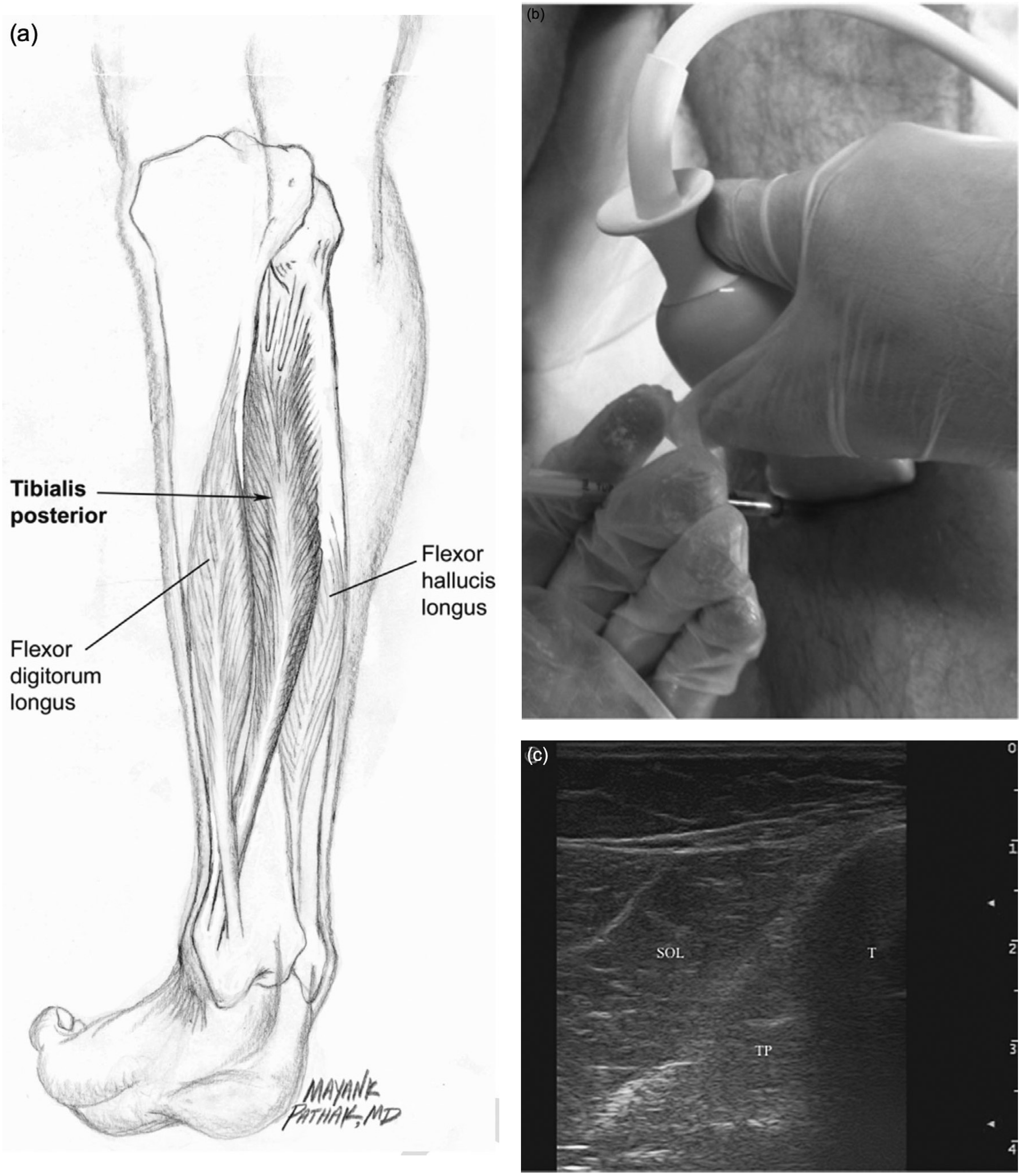

Fig. 18.23 The anterior and medial surface of the left leg. (a) The tibialis posterior muscle. (b) Probe on the middle third of the anterior and medial surface of the leg. (c) Ultrasound image of the soleus (SOL) and tibialis posterior (TP) muscles. T, tibia.

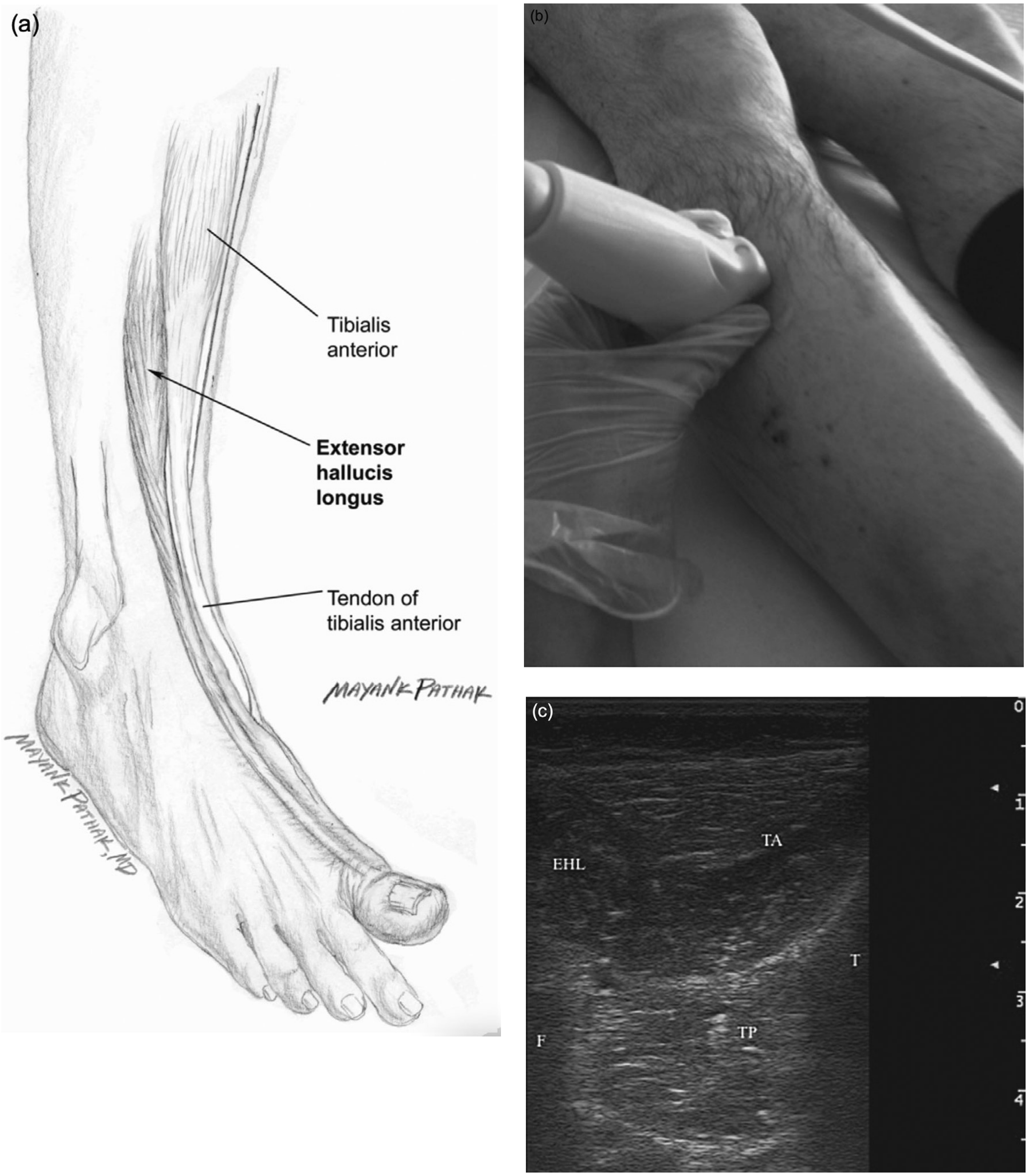

Fig. 18.24 Extension of the large toe. (a) Muscles involved in the movement of the large toe. (b) Position of probe for transverse ultrasound image of right shin and toe extensor. (c) Transverse ultrasound image of the anterior surface of the right leg. EHL, extensor hallucis longus muscle; TP, tibialis posterior muscle; TA, tibialis anterior muscle; T, tibia; F, fibula.

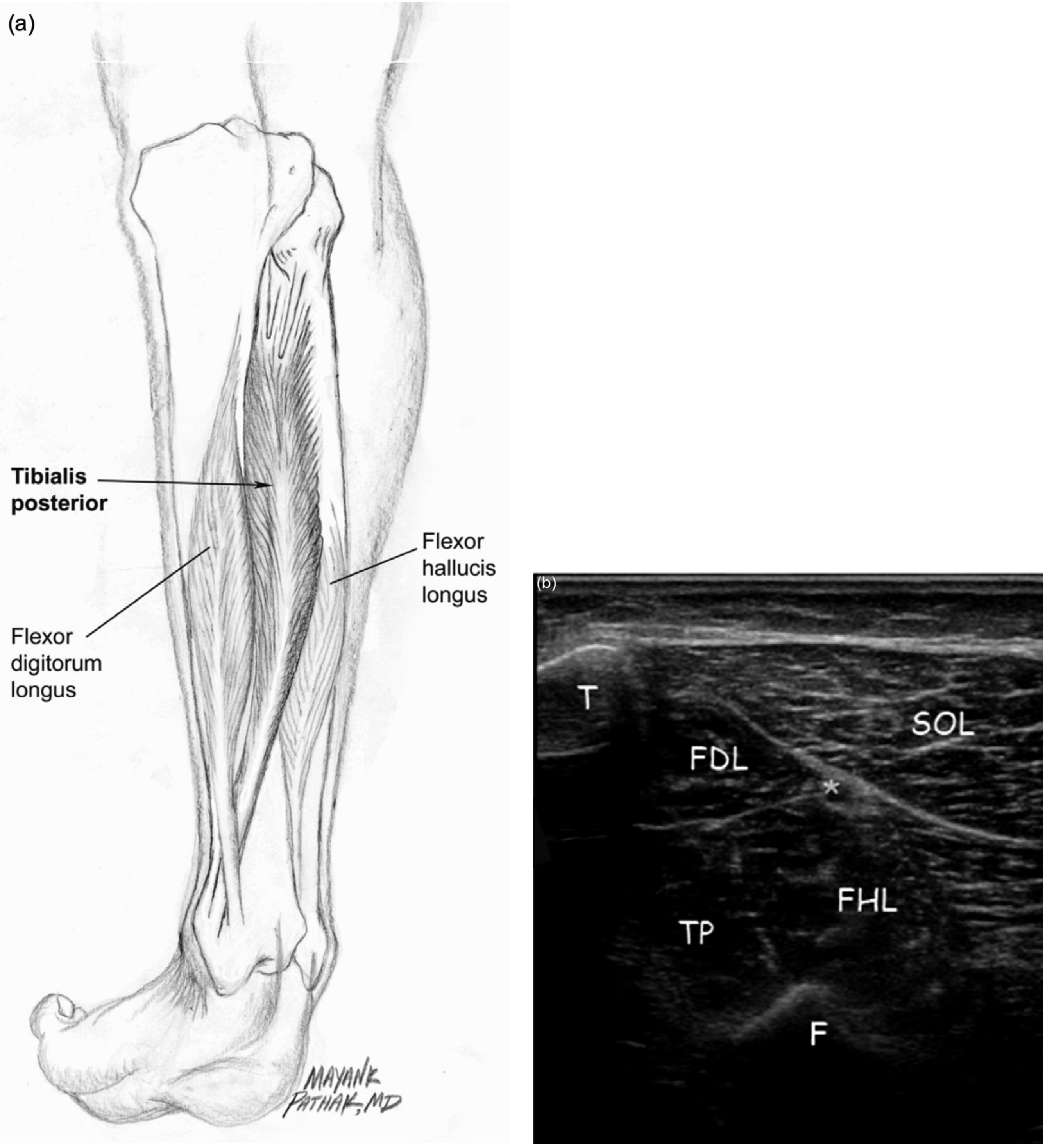

Fig. 18.25 Flexion of the toes. (a) The flexor hallucis longus and flexor digitorum longus muscles. (b) Transverse ultrasound image of the left calf showing the flexor digitorum longus (FDL) and flexor hallucis longus (FHL) muscles and the tibialis posterior (TP); T near tibia; F near fibula; SOL, soleus; asterisk, neurovascular bundle. (c) Probe and injection for the flexor digitorum longus muscle. (d) Probe and injection for the flexor hallucis longus muscle.

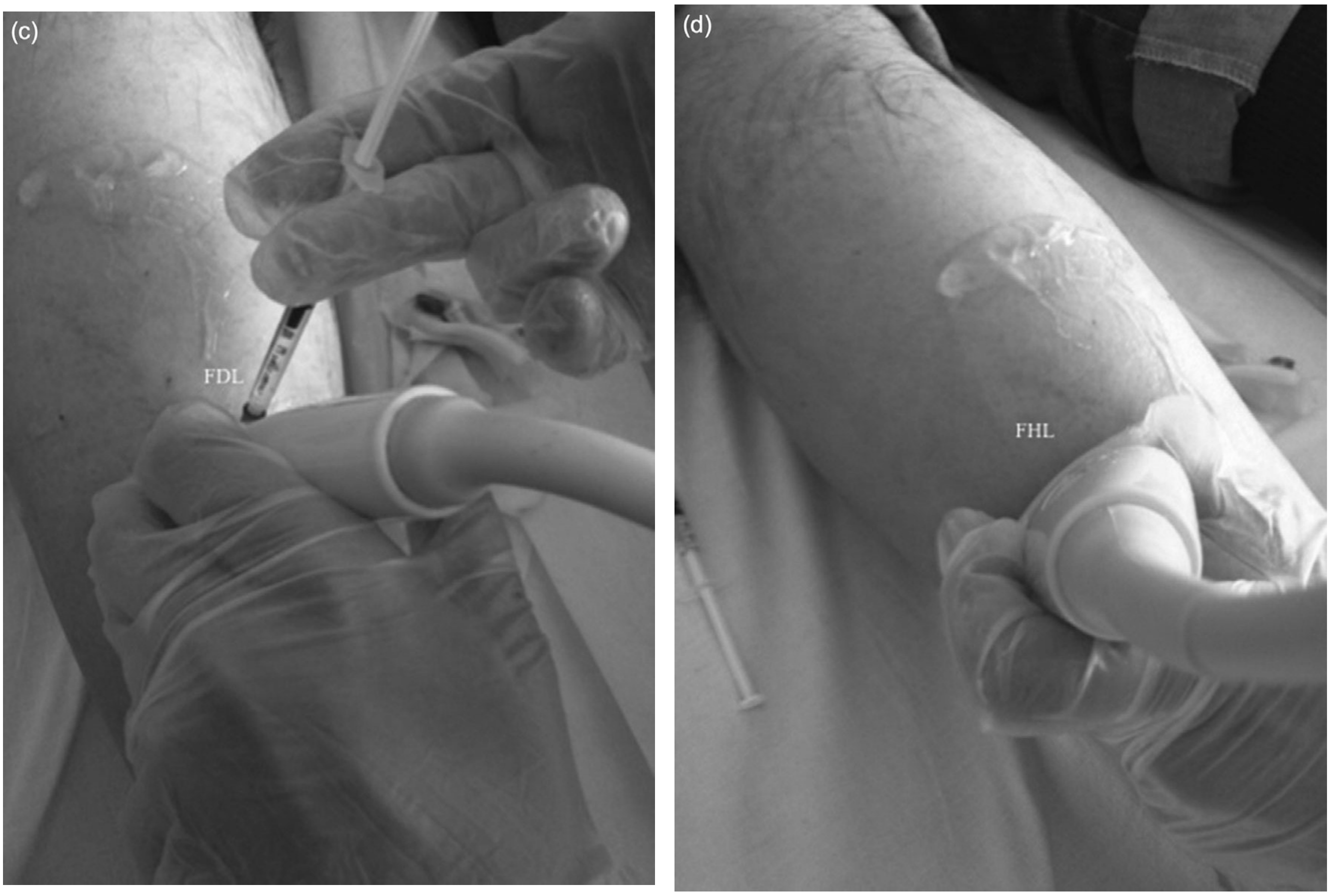

Fig. 18.25 (*cont.*)

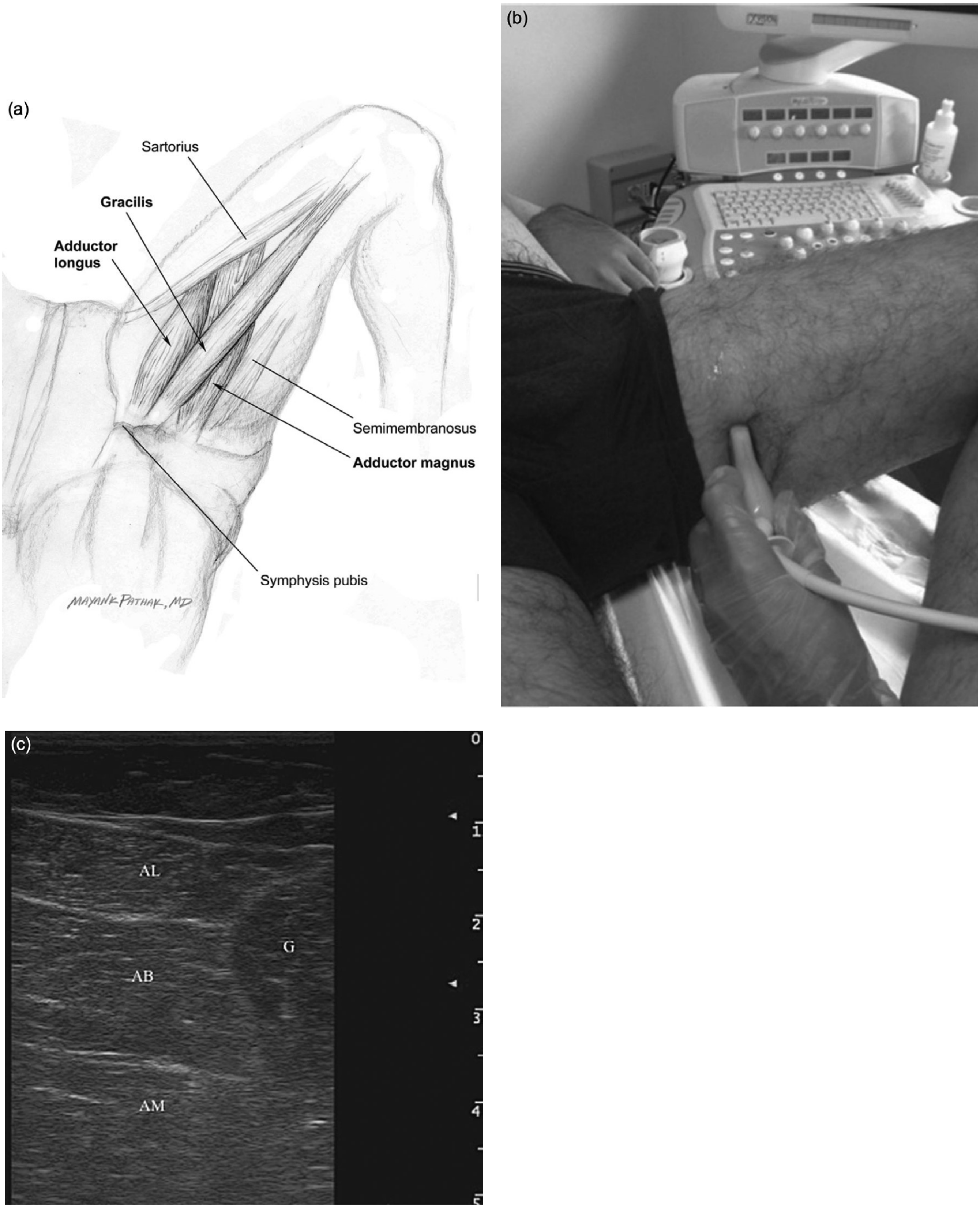

Fig. 18.26 Hip adduction spasm. (a) The adductor muscles. (b) Position of probe for transverse ultrasound image of the anterior and medial surface of the left thigh. (c) Ultrasound image showing the adductor longus (AL), adductor brevis (AB), adductor magnus (AM) and gracilis (G) muscles.

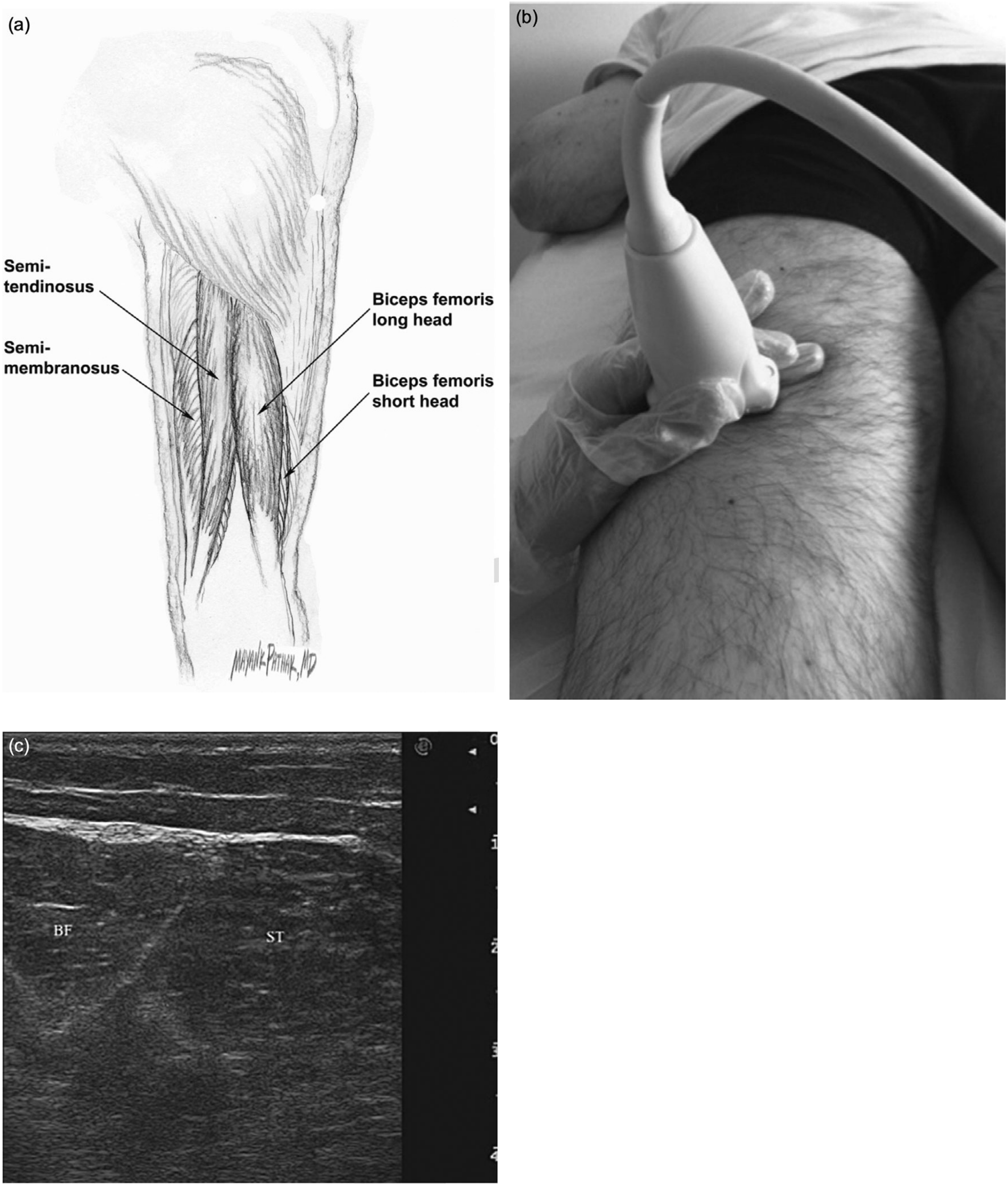

Fig. 18.27 Leg flexion spasm. (a) The hamstring muscles. (b) Position of probe for transverse image of posterior surface of the left thigh. (c) Ultrasound image showing biceps femoris (BF) and semitendinosus (ST) muscles.

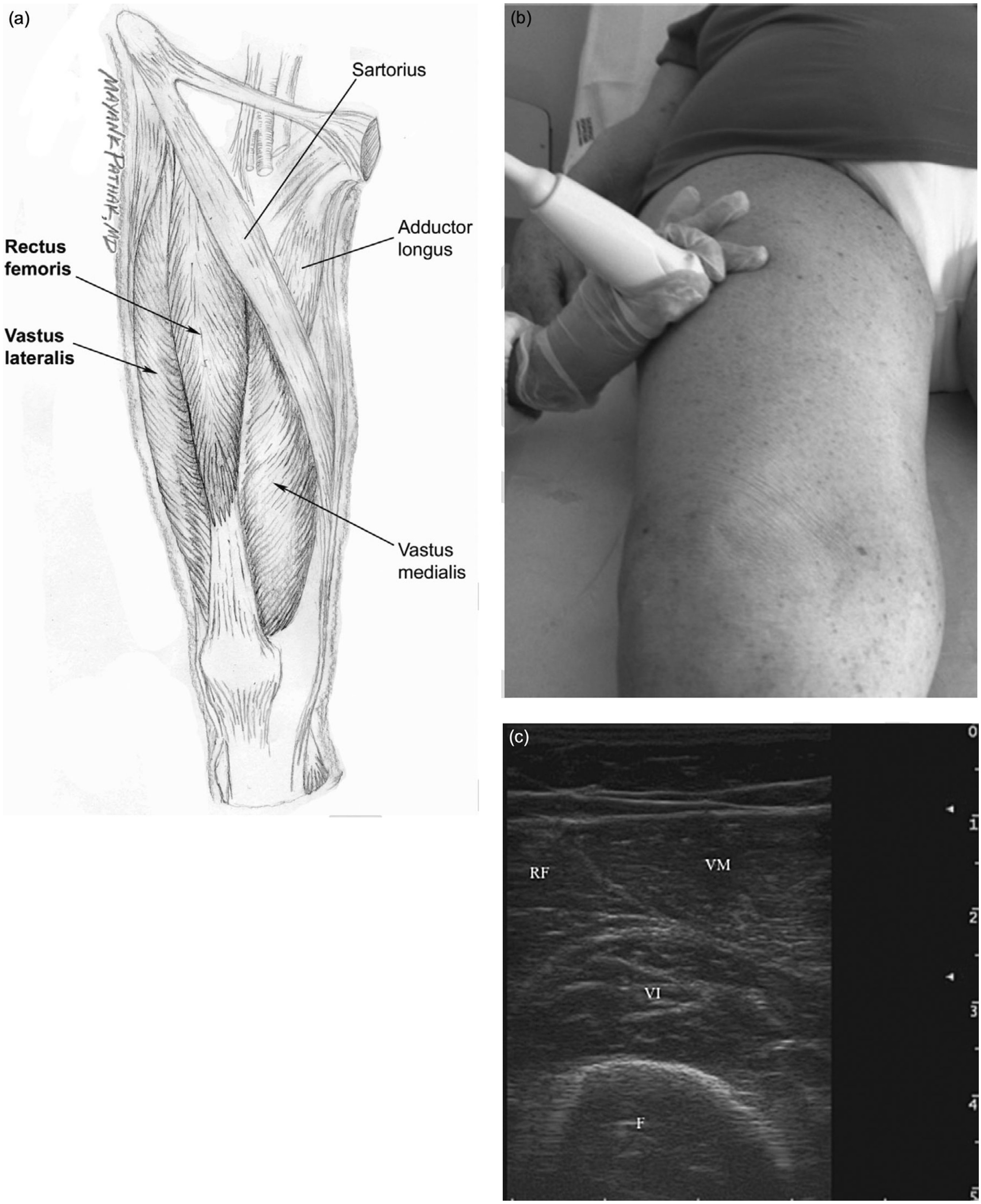

Fig. 18.28 Leg extension spasm. (a) The extensor muscles. (b) Position of probe for transverse image of the anterior surface of the right thigh. (c) Ultrasound image showing the vastus medialis (VM), rectus femoris (RF) and vastus intermedius (VI) muscles. F, femur.

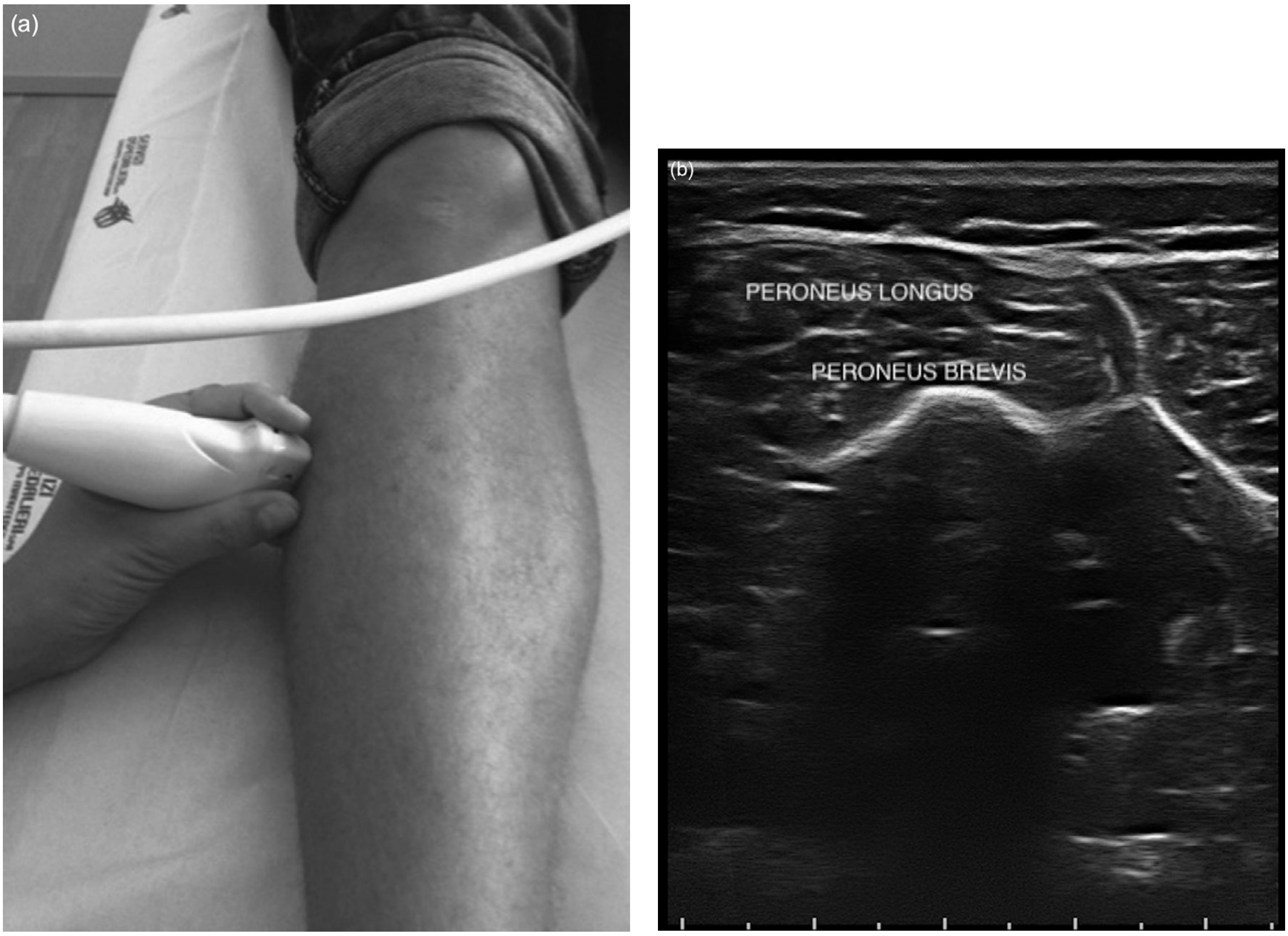

Fig. 18.29 Foot eversion spasm. (a) Probe position on the proximal one-third of the fibula of the right leg. (b) Transverse ultrasound image showing the peroneus longus and peroneus brevis muscles.

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