



SPECIAL ARTICLE

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

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ABSTRACT

The pertinent literature lacks overt technical data for optimal upper limb muscle botulinum toxin injections using ultrasound (US) imaging. Therefore, this guide is prepared for the commonly injected muscles of the upper limb and the shoulder 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, injection sites, probe positioning and the US images simultaneously.

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KEY WORDS: Upper 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 upper 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 upper limb and the shoulder girdle 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).¹⁻¹⁷ 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).

Shoulder

Adducted and internally rotated shoulder is the most common pattern seen in spastic patients (Table I). Pectoralis major, latissimus dorsi, teres major and subscapularis are

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

Region	Pattern	Function	Muscle		
Shoulder	Adduction - internal rotation	Adduction	Pectoralis major		
			Latissimus dorsi		
		Internal rotation	Teres major		
			Subscapularis		
		Flexion	Pectoralis major		
			Latissimus dorsi		
Extension	Teres major				
	Pectoralis major (clavicular head)				
Elbow	Flexion - pronation	Flexion	Latissimus dorsi		
			Teres major		
			Biceps brachii		
		Pronation	Brachialis		
			Brachioradialis		
			Pronator teres		
Wrist	Flexion - ulnar deviation	Extension	Pronator quadratus		
			Triceps brachii		
		Flexion	FCR		
			FCU		
		Ulnar deviation	FDS		
			FDP		
			Palmaris longus		
			FCU		
			ECRL		
			ECRB		
		Hand	Clenched fist	Finger flexion	ECU
					FDS
Thumb-in-palm	Thumb flexion		FDP		
			FPL		
Intrinsic plus hand	Thumb adduction		FPB		
			Adductor pollicis		
	Thumb opposition		Opponens pollicis		
			Interossei		
	MCP flexion and IP extension		Lumbricals		
			Extensor indicis		
Finger extension	Extensor digitorum				
	EPL				
			EDM		

FCR: flexor carpi radialis; FCU: flexor carpi ulnaris; FDS: flexor digitorum superficialis; FDP: flexor digitorum profundus; MCP: metacarpophalangeal joints; IP: interphalangeal joints; ECU: extensor carpi ulnaris; ECRL: extensor carpi radialis longus; ECRB: extensor carpi radialis brevis; FPL: flexor pollicis longus; FPB: flexor pollicis brevis; EPL: extensor pollicis longus; EDM: extensor digiti minimi.

the most commonly involved muscles. Relevant clinical consequences include poor hygiene, skin breakdown, difficulties in positioning/dressing and shoulder pain.

Subscapularis

Origin: Medial two thirds of the subscapular fossa.

Insertion: Lesser tubercle of the humerus.

Innervation: Upper and lower subscapular nerves.

Function: Internal rotation of the arm, preventing anterior dislocation of the humeral head.

US imaging: In the posterior axillary fold approach, the shoulder is kept in a position of flexion, internal rotation and abduction (Figure 1). Subscapularis can be obtained at the lateral border of the scapula under the teres major and teres minor muscles. Injection should be performed cautiously to avoid pneumothorax during progression of the needle through inner parts of the muscle. Injection should follow just distal/medial to the reference line of the motor points (Table II).² On the other hand, the superior portion of the muscle can be injected by using medial/vertebral approach without US-guided technique.¹⁸

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

Muscle	Method	Reference line	Innervation zone*	Injection	
				Number	Site
Subscapularis	Dissection microscope ¹	Muscle	Superior, middle and inferior portions	3	Just distal to the reference line
	Anatomic dissection ²	From the middle of the line between the inferior angle of scapula and acromial tip to the middle of the line between the medial spine of the scapula and acromial tip	Motor points exist along the reference line		
Pectoralis major	Muscle architecture ^{3 §}	Fascicle ends	NS (Mid-points of the fascicles)	3	Mid-portions of the fascicles Clavicular head, 1 Sternal head, 2
Pectoralis minor	Muscle architecture ^{3 §} Sihler's staining ⁴	Fascicle ends Muscle	Mid-points of the fascicles Superior and inferior	2	Mid-portions of the superior and inferior parts
Latissimus dorsi	Sihler's staining ⁴	Muscle	Superolateral and mid-inferior	3	Mid-portions of the three reference lines
	Surface EMG ⁵	From axillary fossa to T12 and L4 vertebrae and to iliac crest	Scattered zones		
Biceps brachii	Modified Sihler's staining/ChE staining ⁶⁻⁸	Acromion - olecranon	A 1-cm-wide inverted-V-shaped band, located at 75% (lateral), 61% (midline) and 72% (medial)	2	65% (Coracoid process - ME) Short head, 1 Long head, 1
	Surface EMG ⁹	Coracoid process - distal insertion of the biceps tendon	75%		
Brachialis	Optical microscope ¹⁰	Coracoid process - ME	65-70%	2	75% Medial, 1 Lateral, 1
	Optical microscope ¹⁰	Coracoid process - ME	75%		
Brachioradialis	Surface EMG ¹¹	Muscle	A wide area from the middle forearm to elbow 2 close bands	1	20% of the line (Interepicondylar - interstyloid)
	ChE staining ⁷ Ultrasound ¶	Interepicondylar - interstyloid			
Triceps brachii	ChE staining ⁷ Surface EMG ¹¹	Muscle	Inverted U-shaped/oval bands around the triceps tendon	3	50% (lateral head) 60% (long head) 60% (medial head) (Tip of the acromion - olecranon)
	Muscle architecture ^{3 §}	Fascicle ends	Mid-points of the fascicles		
Pronator teres	Ultrasound ¶ Modified Sihler's staining ¹²	Tip of the acromion - olecranon Interepicondylar - interstyloid	20%	1	20%
Pronator quadratus FCR	Optical microscope ¹³	Interepicondylar - interstyloid	9-35%	1	90%
	Optical microscope ¹³ Modified Sihler's staining ¹²	Interepicondylar - interstyloid	26-45% 32%	1	35%
Palmaris longus	Modified Sihler's staining ¹²	Interepicondylar - interstyloid	24%	1	25%
FCU	Modified Sihler's staining ¹²	Interepicondylar - interstyloid	14%	2	30% (ventral part) 50% (dorsal part)
	Optical microscope ¹³		17-46% and 25-71%		
FDS	Optical microscope ¹³	Interepicondylar - interstyloid	27-72%	2	30% (humeroulnar part) 50% (radial part)
	Optical microscope ¹⁴		16-38% and 51-73%		
	Modified Sihler's staining ¹²		2-80%		

(To be continued)

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

Muscle	Method	Reference line	Innervation zone*	Injection	
				Number	Site
FDP	Modified Sihler's staining ¹² Optical microscope ¹³	Interepicondylar - interstyloid	13-75% and 35-91%	2	40% (medial part) 60% (lateral part)
FPL	Optical microscope ¹³ Muscle architecture ³ § Dissection microscope ¹⁵	Interepicondylar - interstyloid Fascicle ends Muscle	37-61% and 41-76% 46-80% Mid-points of the fascicles	2	50% and 65% of the line (Interepicondylar - interstyloid)
ECRL			NS (Motor points exist at proximal 1/3 and middle 1/3 of the muscle)	1	20% of the line (Interepicondylar - interstyloid)
ECRB	Ultrasound † Modified Sihler's staining ¹⁶ Ultrasound †	Interepicondylar - interstyloid Muscle	Obliquely from medial to lateral	1	40% of the line (Interepicondylar - interstyloid)
ECU	Ultrasound †	Interepicondylar - interstyloid	NS	1	40%
Extensor digitorum	Ultrasound †	Interepicondylar - interstyloid	NS	1	40%
EDM	Ultrasound †	Interepicondylar - interstyloid	NS	1	60%
APL	Ultrasound †	Interepicondylar - interstyloid	NS	1	60%
EPL	Ultrasound †	Interepicondylar - interstyloid	NS	1	70%
EPB	Ultrasound †	Interepicondylar - interstyloid	NS	1	75%
Extensor indicis	Ultrasound †	Interepicondylar - interstyloid	NS	1	85%
APB	Optical microscope ¹⁷	Hook of hamate - 1 st MC head	40-41%	1	40%
Opponens pollicis	ChE staining ⁷ Optical microscope ¹⁷	Muscle Hook of hamate - 1 st MC head	Distributed at the middle part 47-70%	1	60% of the line (Hook of hamate - 1 st MC head)
FPB	Optical microscope ¹⁷	Hook of hamate - 1 st MC head	50-70%	1	60%
Lumbricals	Ultrasound †	Radial styloid - MCP	NS	1	75%
Adductor pollicis	Optical microscope ¹⁷	Hook of hamate - 1 st MC head	41-66%	2	50% (1 oblique, 1 transverse)
Palmar & dorsal interossei	Ultrasound †	Radial styloid - MC heads	NS	7	75%
1 st dorsal interosseous	Surface EMG ¹¹	Muscle	A narrow band around the muscle belly	1	Mid-portion of the muscle

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; ME: medial epicondyle; FCR: flexor carpi radialis; FCU: flexor carpi ulnaris; FDS: flexor digitorum superficialis; FDP: flexor digitorum profundus; FPL: flexor pollicis longus; ECRL: extensor carpi radialis longus; ECRB: extensor carpi radialis brevis; ECU: extensor carpi ulnaris; EDM: extensor digiti minimi; EPL: extensor pollicis longus; EPB: extensor pollicis brevis; APB: abductor pollicis brevis; MCP: metacarpophalangeal joint; MC: metacarpal; FPB: flexor pollicis brevis.

*The percentage values are given from proximal to distal according to the pertinent reference lines; § fascicle mid-portions in a single muscle — where the fascicle lengths do not exceed 13 cm — may compose the innervation zones; † the bulkiest portion of the muscle detected by ultrasound imaging according to given reference line.

Pectoralis major

Origin: Medial half of the clavicle (clavicular head), sternum and costal cartilages of the first six ribs (sternocostal head) and aponeurosis of the external oblique muscle.

Insertion: Lateral lip of the bicipital groove.

Innervation: Lateral and medial pectoral nerves.

Function: Shoulder flexion (up to 60°, clavicular head), adduction and internal rotation.

US imaging: When the probe is placed on the anterior thoracic wall, the most superficial muscle can be visualized as the pectoralis major. Its close relationship with the

pectoralis minor and intercostal muscles, axillary artery (a) and vein (v), and cords of the brachial plexus (n) can also be observed (Figure 2).

Pectoralis minor

Origin: 3rd to 5th ribs.

Insertion: Coracoid process of the scapula.

Innervation: Medial pectoral nerve.

Function: Stabilization, protraction and rotation of the scapula.

US imaging: It can be detected between the pectoralis major and anterior thoracic wall. The axillary artery (a)

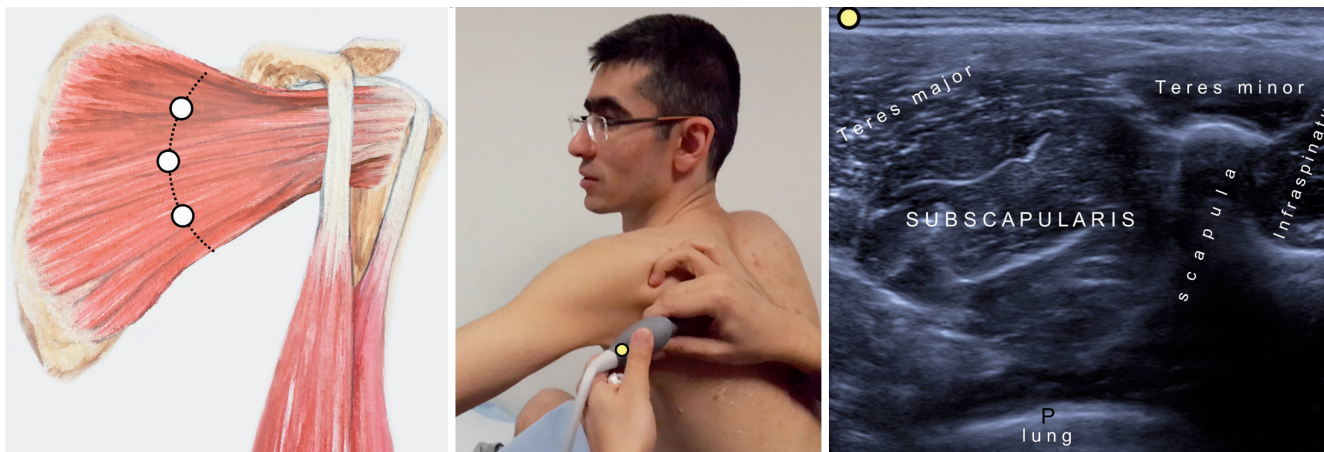


Figure 1.—Subscapularis muscle.
P: pleura.

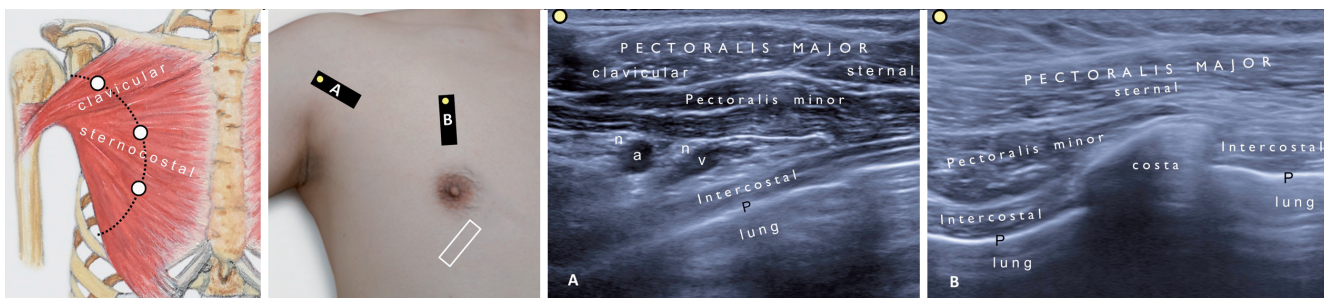


Figure 2.—Pectoralis major muscle.
P: pleura.

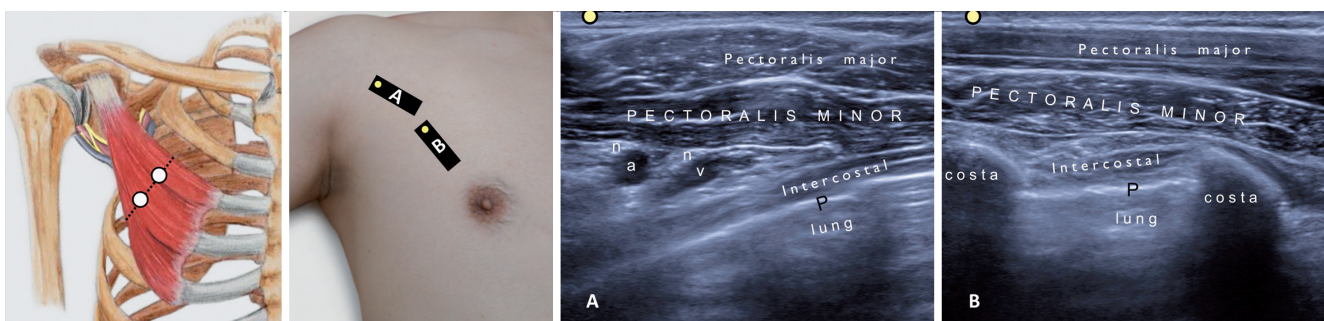


Figure 3.—Pectoralis minor muscle.
P: pleura.

and vein (v) together with the cords and distal branches of the brachial plexus (n) pass deep to the pectoralis minor muscle. The injection must be performed cautiously due to its close relationship with the aforementioned neurovascular structures, and lung (Figure 3).

Latissimus dorsi

Origin: Spinous processes of T5-L5 vertebrae, thoracolumbar fascia, 9th to 12th ribs, iliac crest.

Insertion: Floor of the bicipital groove.

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Innervation: Thoracodorsal nerve.

Function: Shoulder extension, adduction and internal rotation.

US imaging: The probe is placed caudal to the inferior angle of the scapula, either parallel or perpendicular to the intercostal muscles. The superolateral portion of the latissimus dorsi can be demonstrated over the serratus anterior muscle (Figure 4).

Teres major

Origin: Posteroinferior angle of the scapula.

Insertion: Medial lip of the bicipital groove.

Innervation: Subscapular nerve.

Function: Shoulder extension, adduction and internal rotation.

US imaging: The probe is placed over the posterior axil-

lary fold. Teres major muscle is seen lateral to the scapula, adjacent to the latissimus dorsi, teres minor and subscapularis muscles (Figure 5).

Rhomboids

Origin: Spinous processes of T2-T5 and supraspinous ligaments (rhomboid major), inferior border of the nuchal ligament and spinous processes of C7-T1 and supraspinous ligaments (rhomboid minor).

Insertion: Posteromedial border of scapula at the root of the spine of the scapula (rhomboid minor), and from the root of the spine of scapula to the inferior angle (rhomboid major).

Innervation: Dorsal scapular nerve.

Function: Elevation, retraction and downward rotation of the scapula.



Figure 4.—Latissimus dorsi muscle.
P: pleura; af: axillary fold; ic: iliac crest.

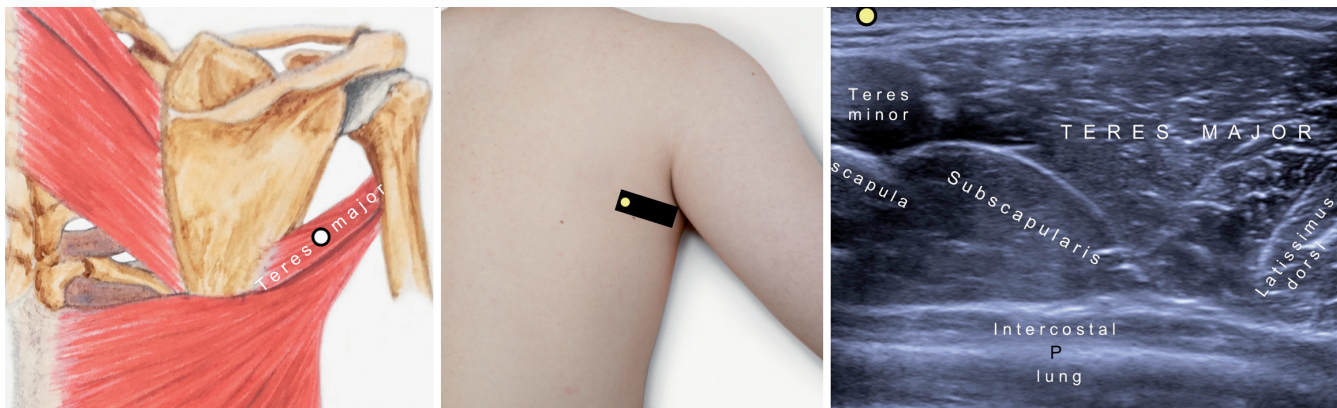


Figure 5.—Teres major muscle.
P: pleura.

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US imaging: Place the probe sagittally between the spinous processes and the medial scapula. The rhomboid major and minor muscles can be observed between the trapezius muscle and posterior thoracic wall (Figure 6).

Elbow

Elbow flexion and forearm pronation is the most common pattern seen in spastic patients (Table I). Pain, poor hygiene, skin maceration/breakdown, and difficulties in dressing and hand-to-mouth activities can develop. Extension is a less common pattern whereby spasticity of the triceps limits flexion of the forearm. Co-contraction of the elbow flexors and extensors can also be seen particularly in cerebral palsy patients.

Biceps brachii

Origin: Coracoid process (short head) and supraglenoid tuberosity (long head) of the scapula.

Insertion: Radial tuberosity.

Innervation: Musculocutaneous nerve.

Function: Elbow flexion (stronger in supination), forearm supination.

US imaging: The probe is placed axially over the distal third of the anterior arm. The median nerve (m) and brachial artery lie medially between the brachialis and triceps muscles (Figure 7).

Brachialis

Origin: Distal half of the anterior aspect of the humerus.

Insertion: Coronoid process and tuberosity of ulna.

Innervation: Musculocutaneous nerve.

Function: Elbow flexion (main elbow flexor, stronger in pronation).

US imaging: The probe is placed on the distal half of the anterior arm. Brachialis muscle can be seen deep to the biceps muscle. Considering the close proximity of neurovascular structures (median nerve and brachial artery), injection should be performed cautiously when the needle is accessed from the medial side (Figure 8).

Brachioradialis

Origin: Lateral supracondylar ridge of the humerus.

Insertion: Just proximal to the radial styloid process.

Innervation: Radial nerve.

Function: Weak elbow flexion during mid-pronation.

US imaging: Place the probe axially over the anterolateral aspect of the proximal forearm. Brachioradialis muscle (Brd) can be observed lying medial to the extensor carpi radialis longus (ECRL) and brevis (ECRB) muscles. Attention should be paid for the adjacent branches of the radial nerve (n) and artery (a) during the injection (Figure 9).

Triceps brachii

Origin: Infraglenoid tuberosity of the scapula (long head), proximal-lateral (lateral head) and distal-medial (medial head) to the radial groove of the posterior humerus.

Insertion: Olecranon process.

Innervation: Radial nerve.

Function: Elbow extension.

US imaging: Place the probe axially on the middle of

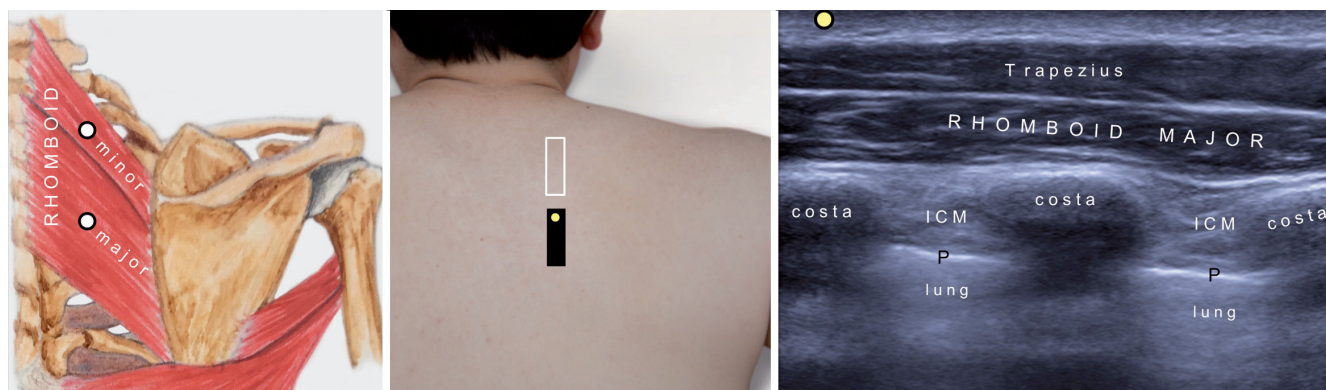


Figure 6.—Rhomboid muscles.
ICM: intercostal muscle; P: pleura.

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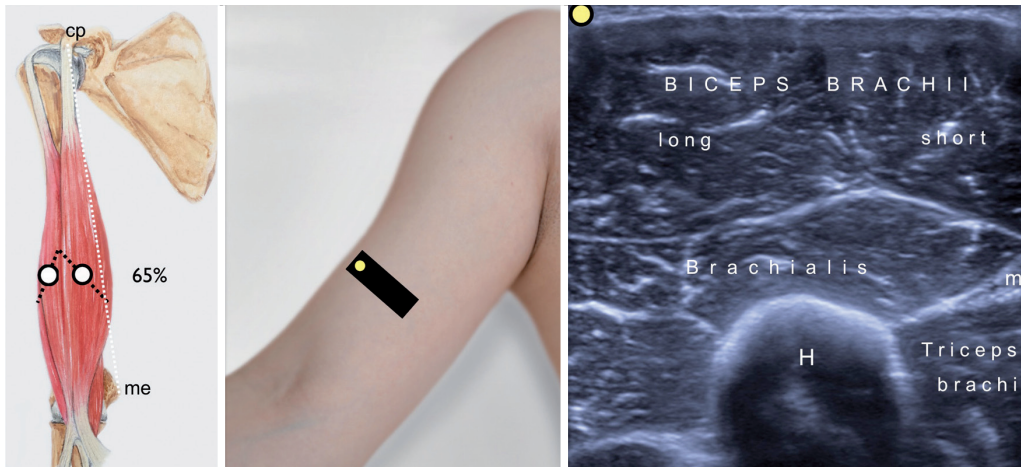


Figure 7.—Biceps brachii muscle.
H: humerus; cp: coracoid process; me: medial epicondyle.

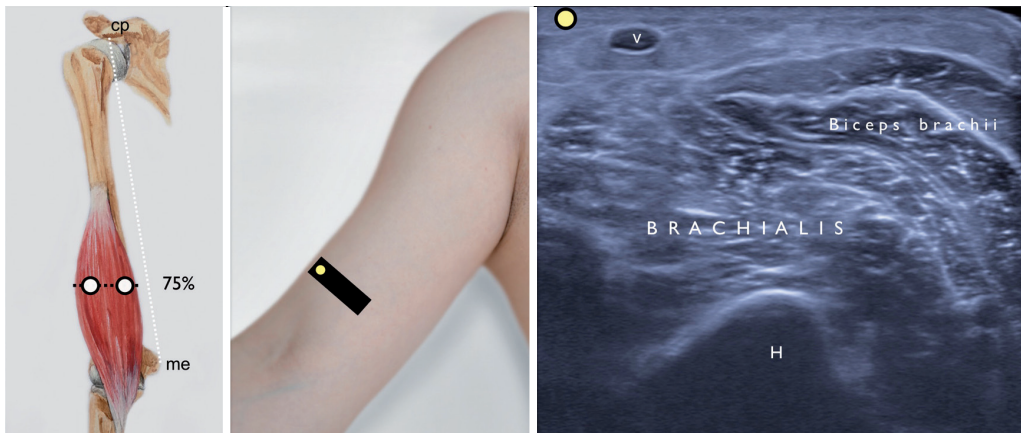


Figure 8.—Brachialis muscle.
H: humerus; cp: coracoid process; me: medial epicondyle.

the posterior arm. Each head of the triceps muscle can be seen separately (Figure 10). Long head lies medially and superficially, medial head lies medially and deeply, and lateral head lies laterally. The close proximity of this muscle to median (m), ulnar (u) and radial (r) nerves; and brachial vein (v) and artery (and its branches [a]) should be taken into consideration during injection.

Pronator teres

Origin: Medial epicondyle and supraepicondylar ridge (humeral head), and medial side of the coronoid process (ulnar head).

Insertion: Lateral aspect of the middle radius.

Innervation: Median nerve.

Function: Forearm pronation, weak elbow flexion.

US imaging: The probe is placed axially on the proximal forearm. Pronator teres lies lateral to the flexor carpi radialis (FCR) and flexor digitorum superficialis (FDS). Median nerve (m) can be seen between the two heads of the pronator teres muscle (Figure 11). The muscle has an oblique alignment between the medial epicondyle and the middle portion of the radius (R). Moving the probe distally towards its insertion could be helpful to delineate the muscle and distinguish it from FCR.

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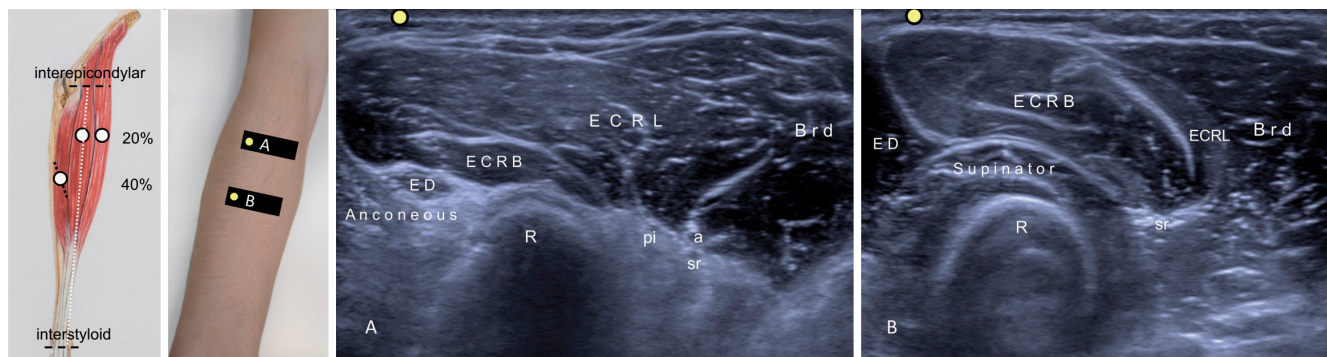


Figure 9.—Brachioradialis, extensor carpi radialis longus and brevis muscles. ED: extensor digitorum; R: radius; pi: posterior interosseous nerve; sr: superficial radial nerve.

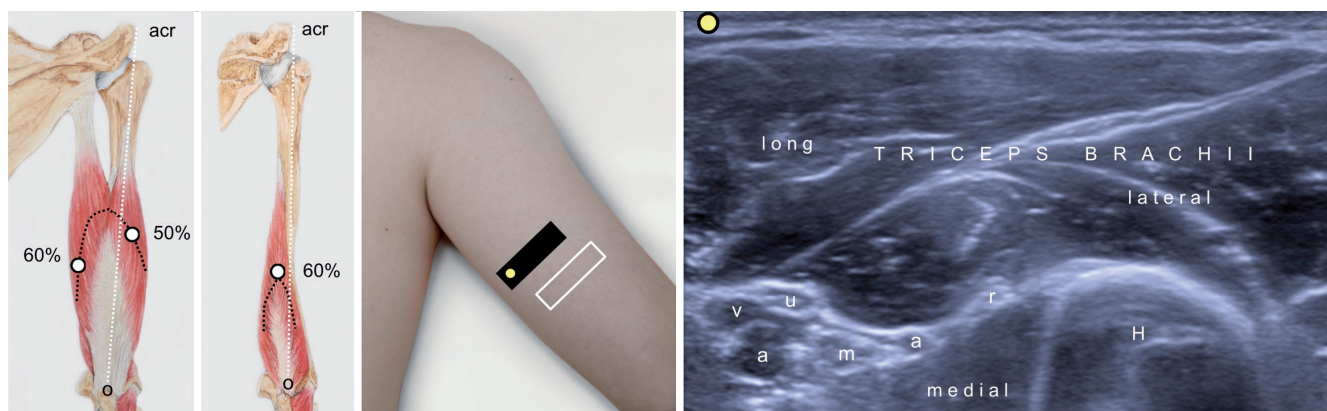


Figure 10.—Triceps brachii muscle. H: humerus; acr: acromion; o: olecranon.

Pronator quadratus

Origin: Distal fourth of the anterior surface of the ulna.
Insertion: Distal fourth of the anterior surface of the radius.
Innervation: Anterior interosseous nerve.
Function: Forearm pronation.

US imaging: The probe is placed axially on the palmar side of the distal forearm (Figure 12). Pronator quadratus has a mild oblique alignment between the flexor muscles/tendons and anterior interosseous membrane (asterisk). US can also demonstrate the neurovascular structures both on the lateral (radial artery (a), median nerve (m)) and medial (ulnar artery (a) and nerve (u)) sides. The injection must be performed cautiously in order to avoid potential injuries to these structures.

Wrist

Wrist flexion with ulnar deviation is the most common pattern seen in spastic patients (Table I). Pain, skin maceration/breakdown, difficulties in dressing and hand dysfunction can develop. Extension deformity of the wrist may also be seen.

Flexor carpi radialis

Origin: Medial epicondyle.
Insertion: Base of the 2nd and 3rd metacarpal bones.
Innervation: Median nerve.
Function: Wrist flexion and radial deviation.

US imaging: Place the probe axially on the anterior proximal forearm. The triangular shaped muscle can easily be seen (Figure 13). US can also show Brd and prona-

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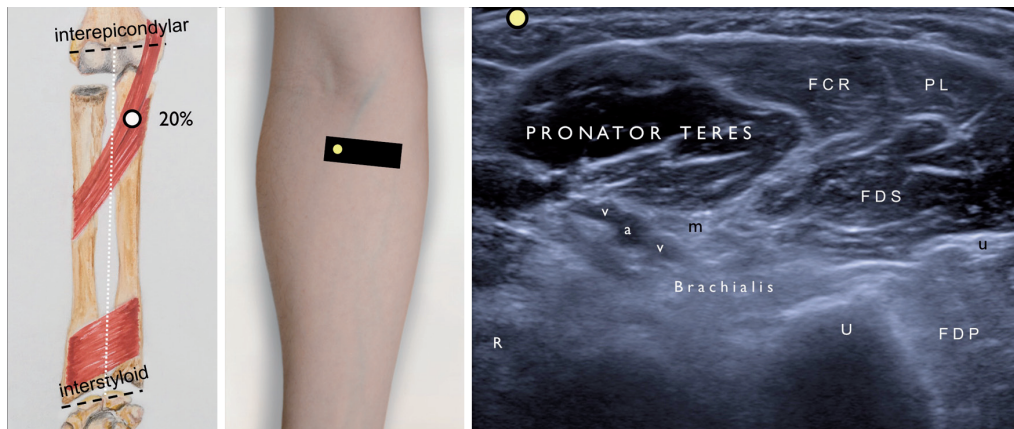


Figure 11.—Pronator teres muscle.
U: ulna; u: ulnar nerve; PL: palmaris longus.

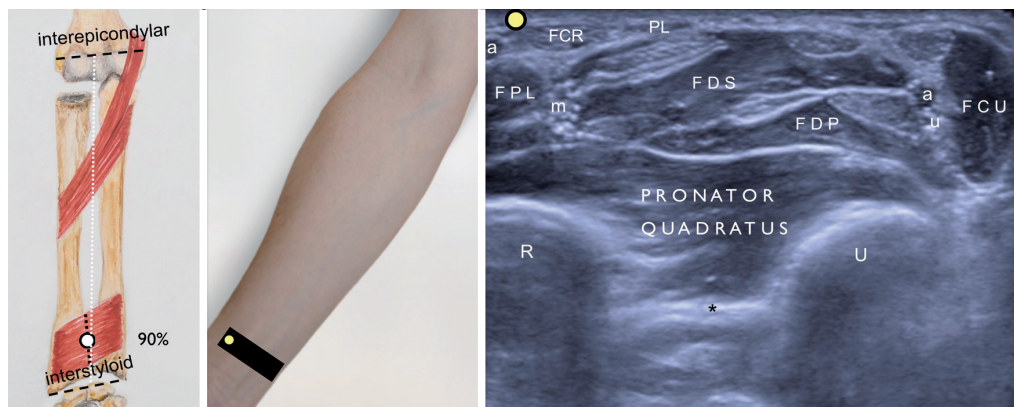


Figure 12.—Pronator quadratus muscle.
R: radius; U: ulna; PL: palmaris longus tendon; FCR: flexor carpi radialis tendon; FPL: flexor pollicis longus muscle.

tor teres (PT) lying medially, and median nerve (m) lying under the FCR.

Palmaris longus

Origin: Medial epicondyle.

Insertion: Flexor retinaculum and palmar aponeurosis.

Innervation: Median nerve.

Function: Wrist flexion.

US imaging: Place the probe axially on the anterior proximal forearm. US demonstrates palmaris longus (if present) between FCR, flexor carpi ulnaris (FCU) and FDS (Figure 14). PT, median (m) and ulnar (u) nerves and flexor digitorum profundus (FDP) are also seen. Palmaris longus tendon can be visualized close to the FCR muscle and tendon in the midline of the anterior wrist.

Flexor carpi ulnaris

Origin: Medial epicondyle (humeral head), and olecranon and posterior border of the ulna (ulnar head).

Insertion: Pisiform, hook of hamate, base of the 5th metacarpal.

Innervation: Ulnar nerve.

Function: Wrist flexion and ulnar deviation.

US imaging: Place the probe on the most medial proximal part of the anterior forearm. The oval shaped muscle lying superficially over FDP medial to FDS can be seen (Figure 15). FCU has two muscular parts (ventral and dorsal), which have distinct innervation zones and require separate injections. As the ulnar nerve (u) and artery (a) pass deep to this muscle, attention must be paid during injection.

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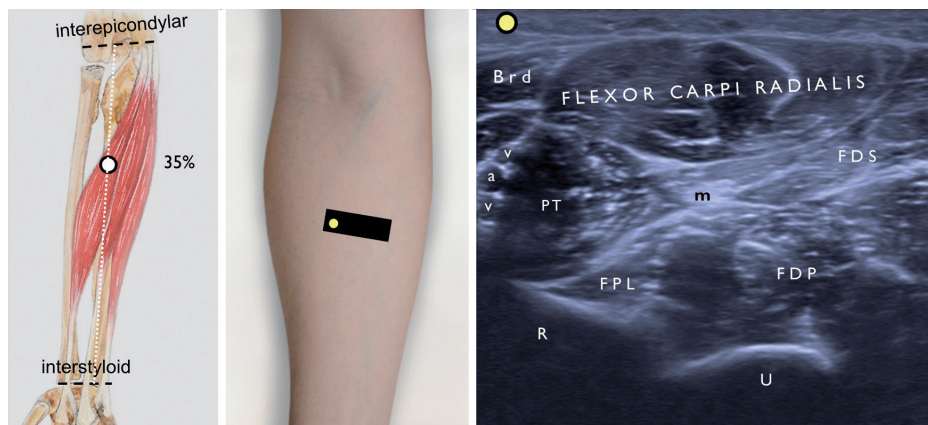


Figure 13.—Flexor carpi radialis muscle.
R: radius; U: ulna; a: radial artery; v: vein.

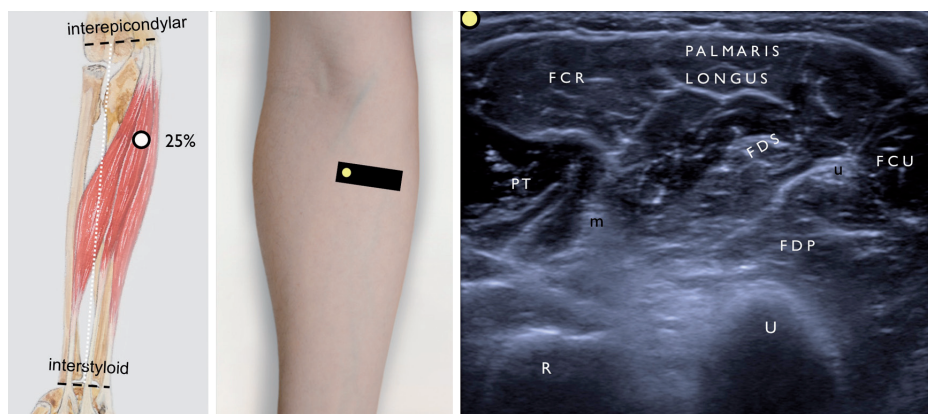


Figure 14.—Palmaris longus.
R: radius; U: ulna.

Flexor digitorum superficialis

Origin: Medial epicondyle and coronoid process (humeroulnar head), and oblique line of the radius (radial head).

Insertion: Palmar surfaces of the middle phalanges of the medial four fingers.

Innervation: Median nerve.

Function: Flexion of the proximal interphalangeal (PIP) and metacarpophalangeal (MCP) joints of the medial four fingers, and wrist flexion.

US imaging: Place the probe axially over the anterior forearm. FDS lies between FCU, and FCR and PL muscles above the FDP (Figure 16). The humeroulnar head has fascicles for the 3rd and 4th fingers, and the radial head for the 2nd and 5th fingers.¹³ Injection may be performed using

either the selective (for specific neuromuscular compartments in the muscle) or non-selective technique. As regards the former, flexion and extension of the respective finger may help locate the target neuromuscular compartment in the muscle. During injections, caution is necessary to avoid injury to the adjacent median (m) and ulnar (u) nerves.

Flexor digitorum profundus

Origin: Anteromedial surface of the proximal 3/4 of ulna, and interosseous membrane.

Insertion: Distal phalanges of the last four fingers.

Innervation: Anterior interosseous nerve (lateral part) and ulnar nerve (medial part).

Function: Flexion of the PIP, distal interphalangeal (DIP) and MCP joints of the last four fingers, and wrist flexion.

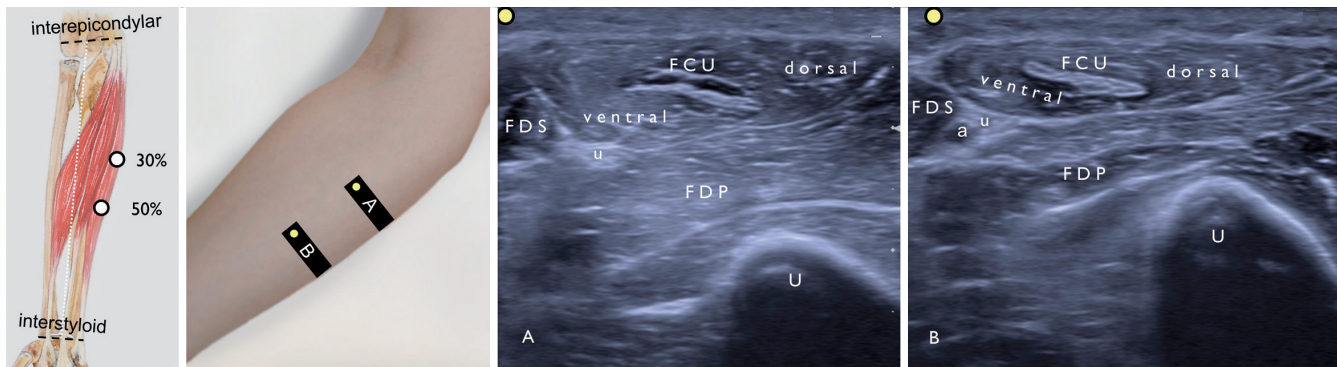


Figure 15.—Flexor carpi ulnaris muscle.
U: ulna.

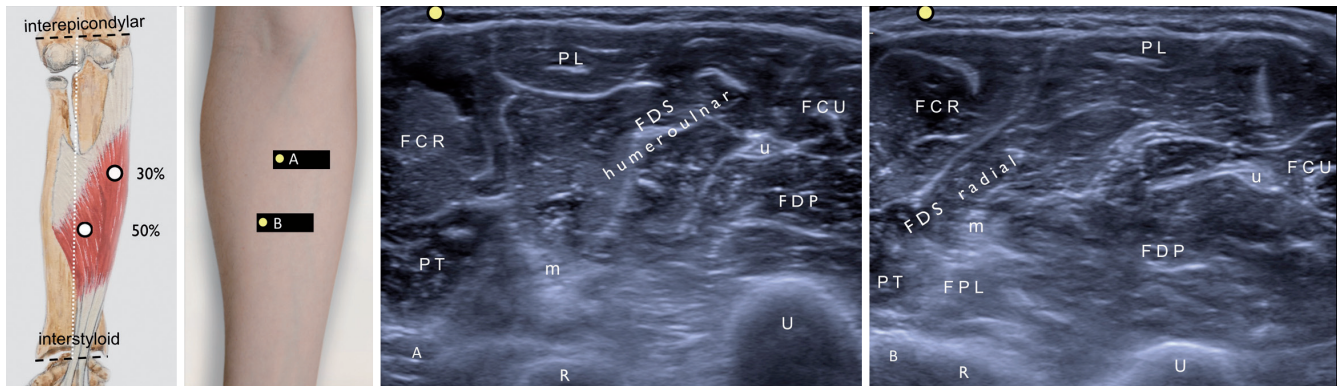


Figure 16.—Flexor digitorum superficialis muscle.
R: radius; U: ulna.

US imaging: The probe is placed axially over the anteromedial aspect of the forearm (Figure 17). Lying over ulna and the interosseous membrane, FDP is seen deep to FDS, FCU and PL, and medial to FPL muscles. FDP has medial and lateral parts, and divides into 4 heads extended by 4 tendons for the last four fingers.¹³ Injection may be performed using either the selective or non-selective technique. Concerning the former, flexion and extension movements of the respective finger may help locate the target neuromuscular compartment in the muscle. During injection, attention is prerequisite to avoid the ulnar artery (a), ulnar (u) and median (m) nerves.

Flexor pollicis longus

Origin: Anterior surface of the radius and adjacent interosseous membrane from the radial tuberosity to the attachment of pronator quadratus.

Insertion: Distal phalanx of the thumb.
Innervation: Anterior interosseous nerve.
Function: Thumb flexion.

US imaging: The probe is placed axially on the distal third of the anterolateral forearm (Figure 18). FPL is deeply located between FDP and radius under FDS. Flexion of the interphalangeal joint of the thumb may help confirm its location. As FPL has close relationship with the radial artery (a) and superficial radial nerve (sr) superficially, and anterior interosseous nerve (ai) and artery (a) deeply, the injections must be performed cautiously.

Extensor carpi radialis longus and brevis

Origin: Distal part of the supracondylar ridge of the humerus (ECRL), and lateral epicondyle (ECRB).

Insertion: Dorsal base of the 2nd (ECRL) and 3rd (ECRB) metacarpal bones.

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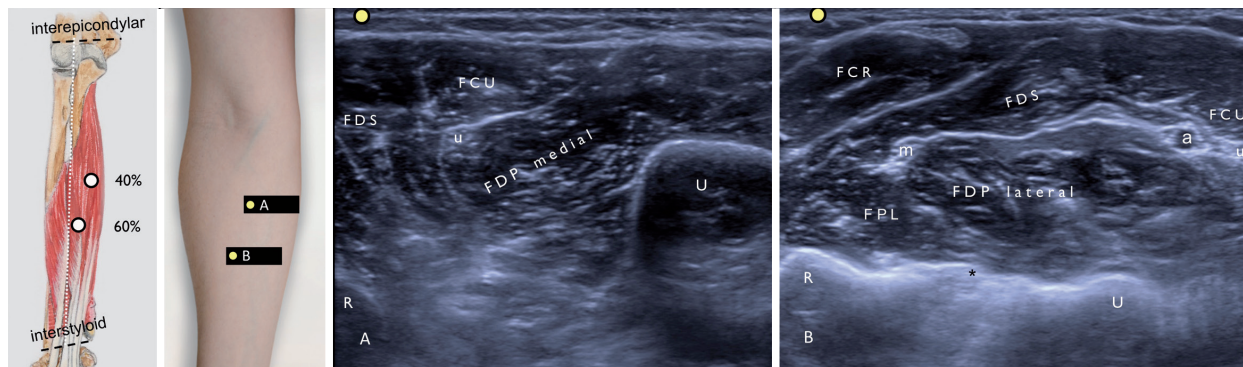


Figure 17.—Flexor digitorum profundus muscle. Asterisk shows the interosseous membrane. R: radius; U: ulna.

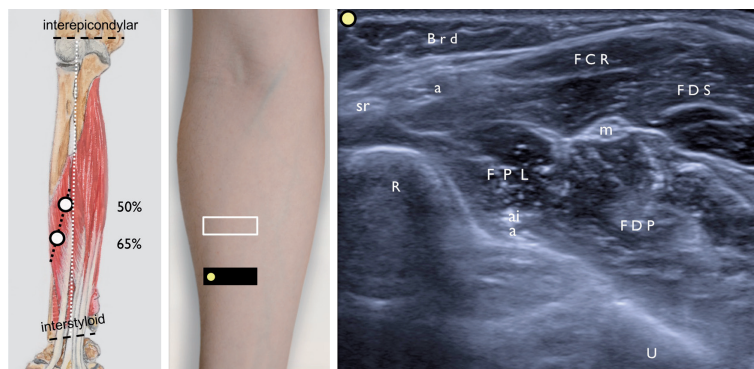


Figure 18.—Flexor pollicis longus muscle. R: radius; U: ulna.

Innervation: Radial nerve.

Function: Wrist extension and radial deviation.

US imaging: The probe is placed axially on the proximal dorsolateral forearm (Figure 9). ECRL is located under the Brd on the posterior forearm, and ECRB is posteromedial to ECRL.

Extensor carpi ulnaris

Origin: Lateral epicondyle, posterior border of the ulna.

Insertion: Base of the medial side of the 5th metacarpal.

Innervation: Posterior interosseous nerve.

Function: Wrist extension and ulnar deviation.

Extensor digitorum and extensor digiti minimi

Origin: Lateral epicondyle and intermuscular septum.

Insertion: Bases of the dorsal surfaces of the middle and distal phalanges of the last four fingers (ED) and the 5th finger (EDM) via extensor hood.

Innervation: Posterior interosseous nerve.

Function: Extension of the MCP, PIP and DIP joints of the last four fingers.

US imaging: The probe is placed axially over the dorsal aspect of the forearm. When the probe is placed axially on the proximal third of the posterolateral forearm; extensor carpi ulnaris (ECU) is the most medially located extensor muscle lying over the ulna (U), medial to the extensor digiti minimi (EDM) and abductor pollicis longus (APL) muscles (Figure 19A). At this level, extensor digitorum (ED) lies between ECRB and EDM over the supinator muscle. Moving the probe distally to the half of the forearm, ED becomes smaller, while EDM becomes larger (Figure 19B). In addition, flexion and extension of the corresponding finger(s) may help locate the target muscle neuromuscular compartment in the muscle.

Abductor pollicis longus

Origin: Dorsum of the ulna and radius (distal to the supinator and anconeus muscles), and the interosseous membrane.

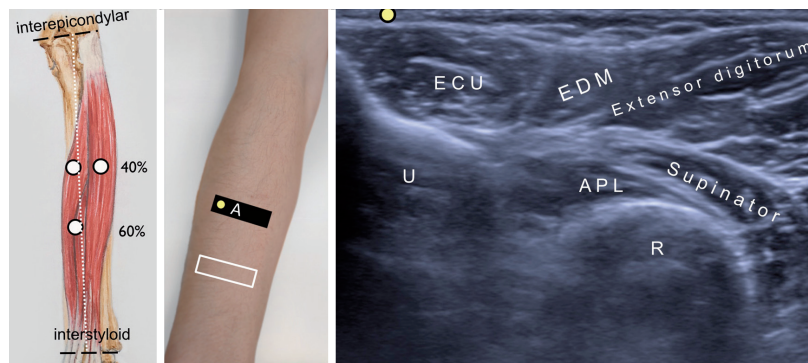


Figure 19.—Extensor carpi ulnaris, extensor digitorum, extensor digiti minimi muscles. R: radius.

Insertion: Lateral side of the base of the 1st metacarpal bone.

Innervation: Posterior interosseous nerve.

Function: Extension (radial abduction) of the carpo-metacarpal joint of the thumb.

Extensor pollicis longus

Origin: Dorsum of the ulna distal to the APL and interosseous membrane.

Insertion: Dorsum of the base of the distal phalanx of the thumb.

Innervation: Posterior interosseous nerve.

Function: Extension of the thumb.

Extensor pollicis brevis

Origin: Dorsum of the radius distal to the APL and the interosseous membrane.

Insertion: Base of the proximal phalanx of the thumb.

Innervation: Posterior interosseous nerve.

Function: Extension of the thumb.

Extensor indicis

Origin: Dorsum of the ulna distal to the EPL and the interosseous membrane.

Insertion: Extensor hood of the index finger.

Innervation: Posterior interosseous nerve.

Function: Extension of the index finger.

US imaging: The probe is placed over the distal third of the dorsal forearm (Figure 20A). Proximally, APL lies adjacent to radius (R), and EPL lies adjacent to ulna (U). Posterior interosseous nerve (n) is located between ED superficially and EPL and APL deeply. When the probe is moved to distal fifth of the forearm, US can also demonstrate EPB and extensor indicis (EI) (Figure 20B). Abduction/adduction, and flexion/extension of the thumb or index finger can help locate the target muscle.

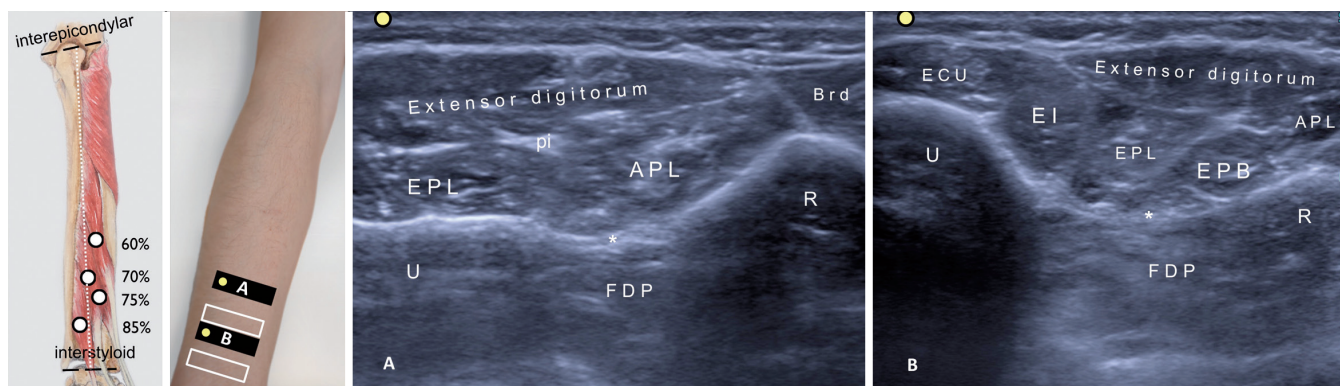


Figure 20.—Abductor pollicis longus, extensor pollicis longus, extensor pollicis brevis, extensor indicis muscles. Asterisks show the interosseous membrane.

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Hand

Clenched fist along with curled thumb (thumb-in-palm deformity) is the most common pattern in spastic patients. Clenched fist deformity may limit functional use of hand, impairs hand hygiene and leads to maceration or ulceration of the palm due to inability to access fingernails. Whereas, intrinsic plus hand deformity is a less common pattern.

Abductor pollicis brevis

Origin: Tubercle of the scaphoid, trapezium and flexor retinaculum.

Insertion: Radial side of the proximal phalanx and extensor hood of the thumb.

Innervation: Median nerve.

Function: Palmar abduction and opposition of the carpometacarpal joint and extension of the interphalangeal joint of the thumb.

Opponens pollicis

Origin: Tubercle of the trapezium and flexor retinaculum.

Insertion: Lateral side of the 1st metacarpal bone.

Innervation: Median nerve.

Function: Opposition of the thumb.

Flexor pollicis brevis

Origin: Flexor retinaculum, tubercle of the trapezium.

Insertion: Proximal phalanx of the thumb.

Innervation: Median (superficial head) and ulnar (deep head) nerves.

Function: Flexion of the proximal phalanx of the thumb.

US imaging of the thenar muscles: The probe is placed transversely on the thenar region (Figure 21). US can illustrate superficial (supf) and deep heads of the flexor pollicis brevis (FPB), abductor pollicis brevis (APB) and opponens pollicis (OP) muscles. OP lies deep to APB and radial to FPB muscles. Thin fasciae can be seen between the muscles.

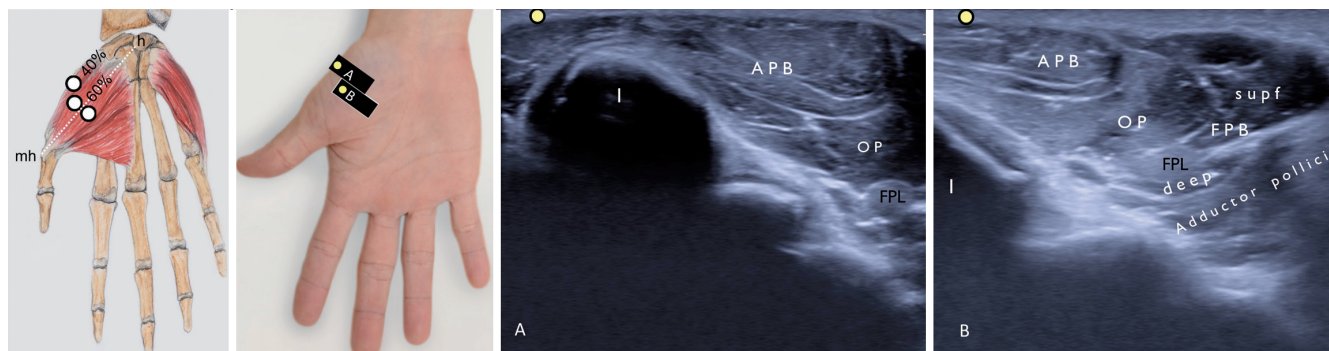


Figure 21.—Abductor pollicis brevis, flexor pollicis brevis, opponens pollicis muscles. FPL: flexor pollicis longus tendon; I: 1st metacarpal bone; mh: metacarpal head; h: hook of the hamate.

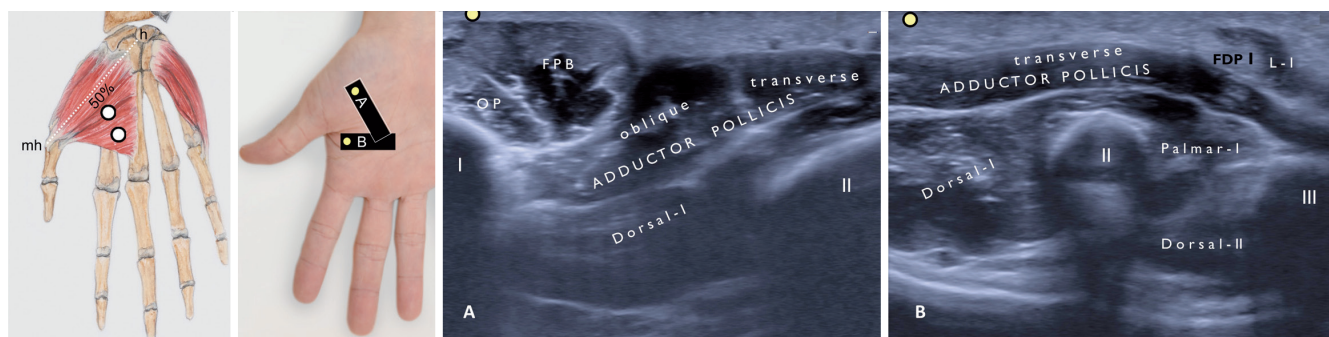


Figure 22.—Adductor pollicis muscle. mh: metacarpal head; h: hook of the hamate.

Adductor pollicis

Origin: Palmar side of the 3rd metacarpal (transverse head), capitate and bases of the 2nd and 3rd metacarpal bones (oblique head).

Insertion: Base of the proximal phalanx and extensor hood of the thumb.

Innervation: Ulnar nerve.

Function: Thumb adduction.

US imaging: It is a flat, triangular, and fan-shaped muscle deep in the thenar eminence. Oblique head can be seen with placing the probe more cranially, between FPB and the transverse head (Figure 22A). Transverse head can be depicted by placing the probe axially between the palmar sides of the 1st and 3rd metacarpal bones (I-III) in the longitudinal view (Figure 22B). Adduction and abduction of the thumb may again be contributory.

Lumbricals

Origin: Tendons of FDP.

Insertion: Extensor hood of last four fingers.

Innervation: Deep branch of the ulnar nerve (medial two) and digital branches of the median nerve (lateral two).

Function: Flexion of the MCP while extending the PIP and DIP joints.

US imaging: Lumbrical muscles lie radial and posterior to the FDP tendons (Figure 23). The first two muscles are unipennate, while the others are bipennate. Injection can be performed using palmar approach while the probe is in axial position. Each muscle (L-I to IV) can be recognized adjacent to the FDP tendons, moreover, flexion of the MCP joint while the interphalangeal joints are in extension position may help delineate the muscles.

Palmar and dorsal interossei

Origin: Sides of the 2nd (II), 4th (IV) and 5th (V) metacarpal bones (palmar interossei), and adjacent sides of metacarpal bones (dorsal interossei).

Insertion: Extensor hood and bases of proximal phalanges of the 2nd, 4th and 5th fingers.

Innervation: Ulnar nerve.

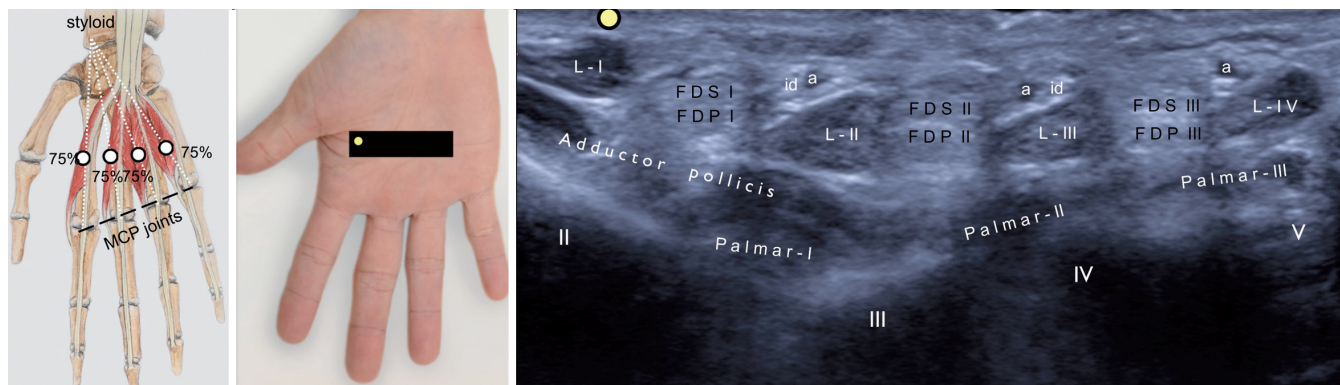


Figure 23.—Lumbrical muscles. a: artery; id: interdigital nerve.

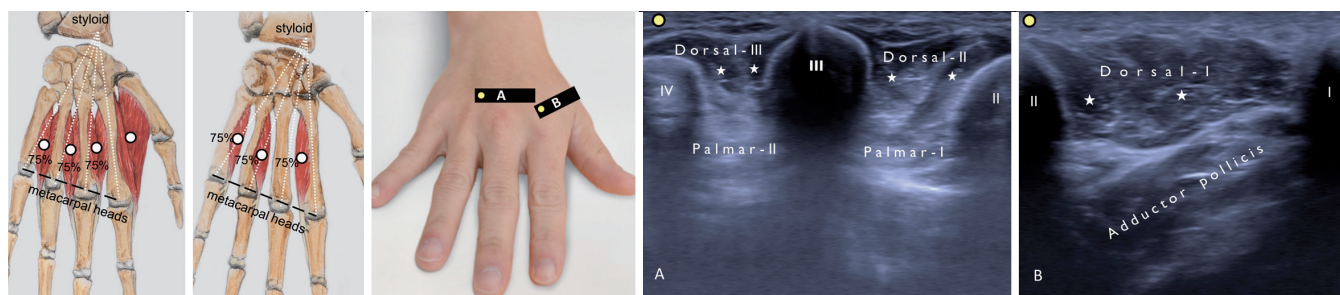


Figure 24.—Palmar and dorsal interossei muscles.

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Function: Adduction (palmar interossei), abduction (dorsal interossei) and flexion of the MCP joints while extending the PIP and DIP joints.

US imaging: The probe is placed axially on the dorsum of the hand (Figure 24A). Palmar interossei (palmar-I to III) are unipennate while dorsal interossei (dorsal-I to IV) are bipennate muscles (stars). Abduction and adduction of the fingers may help confirm the muscle locations. The 1st dorsal interosseous (dorsal-I) is larger than the others (Figure 24B).

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