Chapter 6

Visualization of Ultrasound-Guided Intramuscular Injections in Muscles Relevant for Cervical Dystonia

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Why Use Ultrasound for Injections?

When carried out properly, botulinum toxin injection is a safe procedure (Truong and Jost,, 2006; Schramm et al., 2015; Castelao et al., 2017). However, for the best therapeutic effect, a precise and complete injection into the intended target is required (Castagna and Albanese, 2019). Individual differences in muscle location, muscle anatomy, patient body mass or even muscle size, which might be reduced due to prior botulinum toxin injections, lead to anatomical variations from the textbook; therefore, a standardized, landmark-based, blind approach is probably less effective. Other structures adjacent to the targeted muscles, such as blood vessels, nerves, the lung or the thyroid gland, may be injured when hit by the cannula. Furthermore, most muscles in the neck lie close to one another and in some instances have a thickness of only a few millimeters.

Image-based guidance is an important support in tricky interventional procedures – for example, for taking a biopsy from the non-necrotic part of a large tumor, for ablating a small tumor in a large organ, for diagnostically blocking a small nerve with a tiny amount (e.g., 0.1 ml) of local anesthetic or for the effective delivery of botulinum toxin into relevant neck muscles in patients with cervical dystonia (Schramm *et al.*, 2015).

Ultrasound is the preferred imaging modality if the specific body region is sonographically accessible, and if an adequate clinical ultrasound system and an experienced physician are available. Being superior in image quality and more flexible during the procedure compared to other imaging modalities (fluoroscopy, CT, and MRI), there are virtually no medical contraindications for this technique.

Based on the safety issues statements by the US Food and Drug Administration (FDA: www.fda.gov/radiation-emitting-products/medical-imaging/ultrasound-imaging) and the European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB: www.efsumb.org/blog/archives/885), we conclude that ultrasound is a very safe imaging modality for the patient and the physician. Finally, the costs of acquisition and maintenance of a clinical ultrasound system are moderate, compared to other imaging modalities.

This Chapter

In this chapter, we performed selective muscle injections using cadaver specimens to illustrate the muscles involved in the treatment of cervical dystonia.

The cadaver specimens were fresh, neither frozen nor embalmed. With ultrasound, we identified the muscle and performed a selective intramuscular injection with 2 ml of diluted India ink (1:10). Using a 22-gauge needle 5 cm in length, we advanced the needle with the in-plane technique to the center of the muscle. We documented an ultrasound still image with the needle tip in the center of the muscle. After injection, the specific muscle was exposed in a standard dissection. The extent of the staining was photo documented.

In order to preserve a familiar view of the anatomical site, we did not incise the specific muscle to uncover the entire extent of the ink inside the muscle body. Thus, the true extent of the injected ink may be slightly larger than in the figures presented.

As a black-and-white presentation of the figures makes the perception of the regional topography difficult, we added explanatory figures next to the original photos.

In the last section, we present panoramic still images of neck regions with a difficult muscle topology.

In-Plane Technique for Needle Guidance

There is a never-ending discussion of whether ultrasound-guided intervention should be performed using an in-plane or an out-of-plane technique.

In the in-plane technique, the long axis of the needle is aligned to the scanning plane of the ultrasound probe. So, the entire length of the needle is visualized at all times (Fig. 6.1a,b).

With an out-of-plane technique, the ultrasound probe is positioned perpendicular to the longitudinal needle axis. So, the needle is visualized on the screen as a hyperechoic dot. It can only be assumed whether we see the needle segment close to the tip or any other part of the needle. By tilting the probe, it is possible to move the scanning plane along the body of the needle right to the tip of the needle, where the above-mentioned hyperechoic dot suddenly disappears from the screen (Fig. 6.2b,c,d).

Both techniques have advantages and disadvantages: The main advantage of the in-plane technique is the visualization of the entire needle at all times. This is very helpful when we want to steer the needle tip into a very thin muscle and apply the injection fluid into the middle of the muscle body. A disadvantage is that one can easily lose sight of the needle when the probe is tilted slightly to the side. Then it takes some time to put the needle and probe back in alignment. High-end

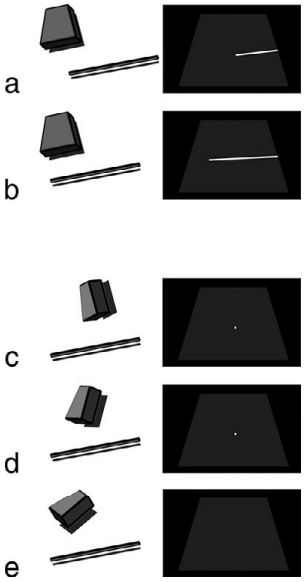

Fig. 6.1 In-plane versus out-of-plane-technique. (a, b) Using the in-plane technique, the entire length of the needle is constantly visualized during the advancement of the needle; especially, the needle tip can be seen at all times.
(c, d, e) In the out-of-plane technique, the needle is visualized as a hypoechoic dot. The disadvantage of this method is that the ultrasound probe must be tilted in order to find the tip of the needle. Thus, a constant visualization of the needle tip during needle movement is not possible.

Fig. 6.2 Injection site. Demonstration of the in-plane technique for an injection in the neck region. Note the sterile cover for the ultrasound probe and cable.

matrix ultrasound probes with several rows of crystals may make this even more difficult.

The advantage of the out-of-plane technique is the fast and easy visualization of the needle and the best image resolution regarding the area lateral to the needle. This makes inserting a cannula into a tubular structure (e.g., blood vessels) very easy. However, the lack of constant visualization of the needle tip – especially during needle movements – makes this technique useless for selective intramuscular injections.

As each technique has its own advantages and disadvantages, the choice depends on the task at hand. In the case of a selective intramuscular injection, we favor the in-plane technique.

Injection Site Preparation

As published extensively, we follow sterile conditions for the injection procedure (Lorentzen *et al.*, 2015). This includes not only skin disinfection but also a sterile cover for the ultrasound probe. As it is virtually impossible to avoid contact between the needle and the side of the probe, especially when using the in-plane technique, the probe also needs a sterile cover (Fig. 6.2). As presented in Fig. 6.3a, there are dedicated ultrasound probe cover kits including sterile ultrasound gel and mounting material. Alternatively, one can use a simple sterile glove as a probe cover (Fig. 6.3b).

After the interventional procedure, disinfection of the ultrasound probe and cable is mandatory (Nyhsen *et al.*, 2016).

Identification of Injections into Muscles Typically Affected in Patients with Cervical Dystonia

For each specific muscle, there is an image series showing the actual dissection site, an explanatory version of the dissection site and a figure highlighting the surroundings of the dissection site. Additionally, there is an ultrasound still image showing the actual injection for the very same cadaver specimen.

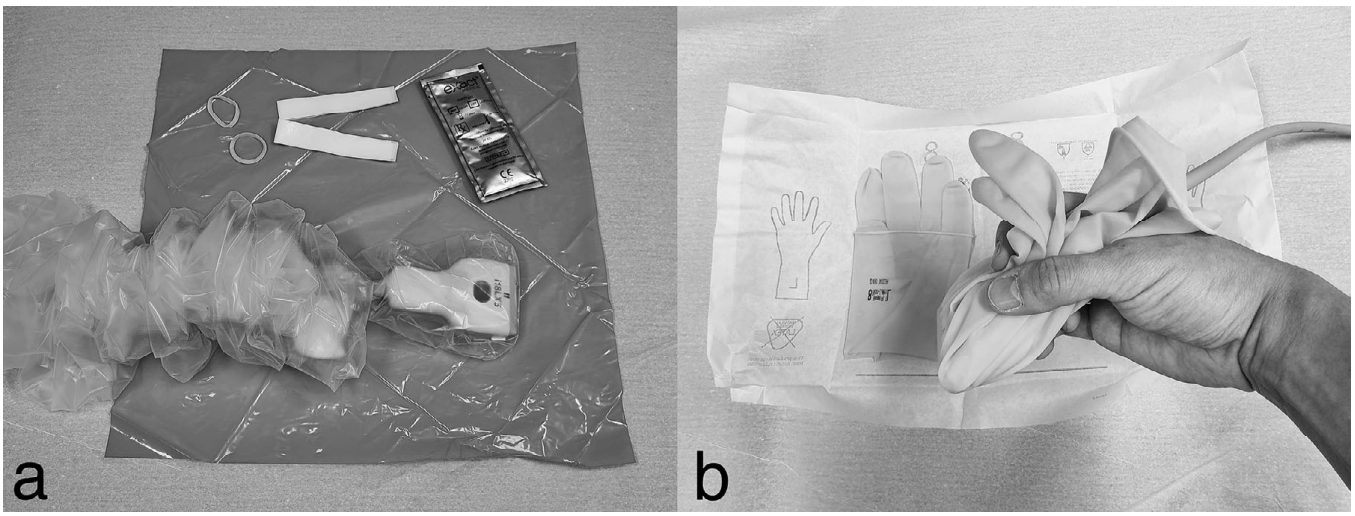

Fig. 6.3 Sterile ultrasound probe cover. (a) Commercially available cover sets include a long probe cover, which would ensure sterile handling at an operation table, fastening material (sterile rubber bands or tapes) and a sachet of sterile gel. (b) When the intervention setting is not as delicate as in an operating room, a simple sterile glove might suffice as a probe cover.

Trapezius Muscle

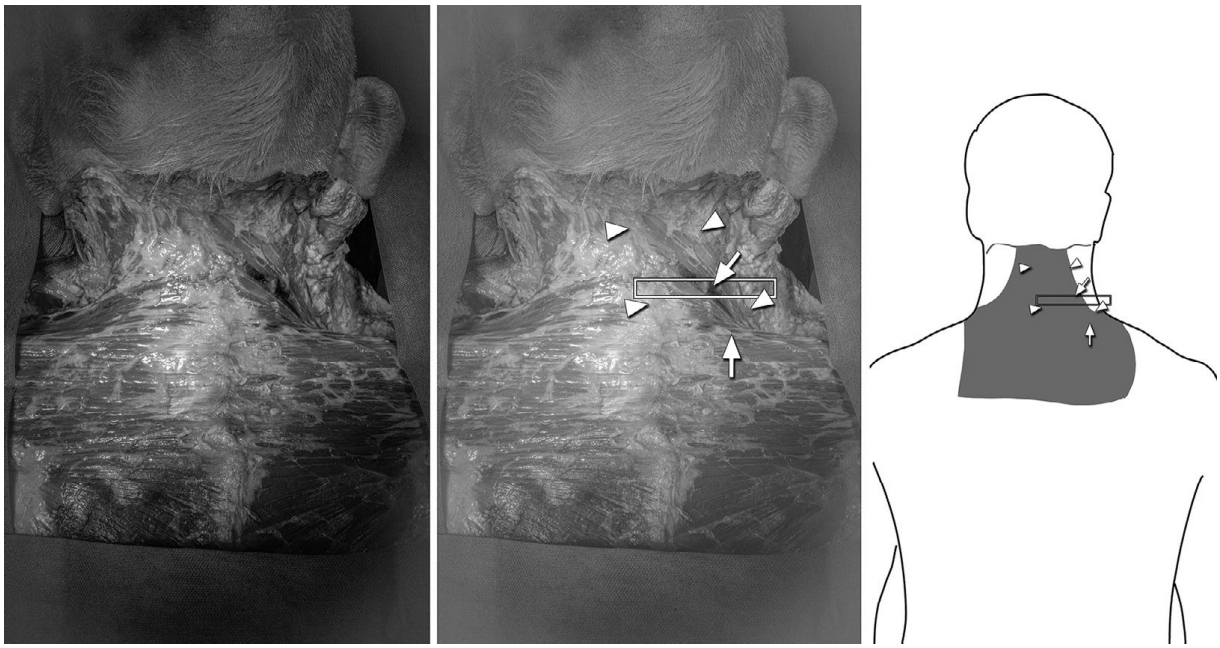

Fig. 6.4 Trapezius muscle injection – cadaver specimen. Dye (arrows) was injected into the descending and transversal part of the trapezius muscle of the right side (arrowheads). The ultrasound probe (box) is positioned in an axial plane at the descending part.

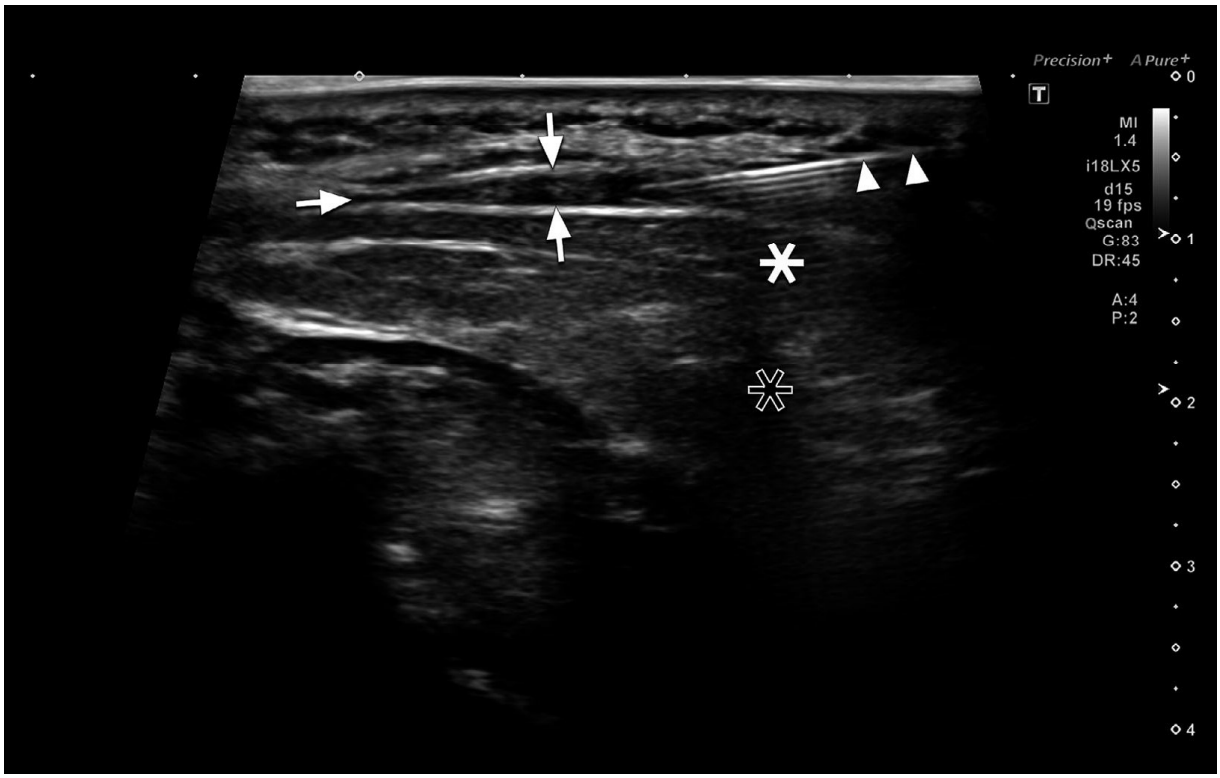

Fig. 6.5 Trapezius muscle injection – ultrasound procedure. The tip of the injection needle (arrowheads) is advanced to the middle of the descending part of the trapezius muscle (arrows). Beneath the trapezius muscle (arrows) are the splenius capitis muscle (white asterisk) and the semispinalis capitis muscle (black asterisk).

Spenius Capitis Muscle

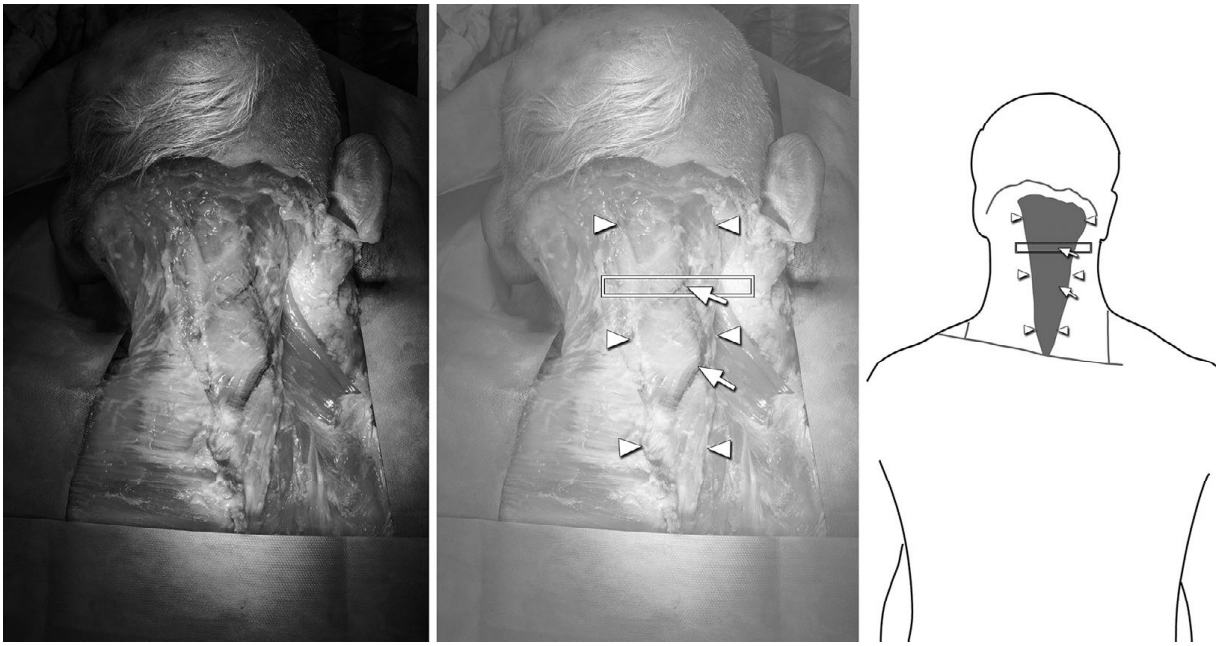

Fig. 6.6 Splenius capitis muscle injection – cadaver specimen. Dye (arrows) was injected into the splenius capitis muscle of the right side (arrowheads). The ultrasound probe (box) was positioned in an axial plane at the cranial part of the muscle.

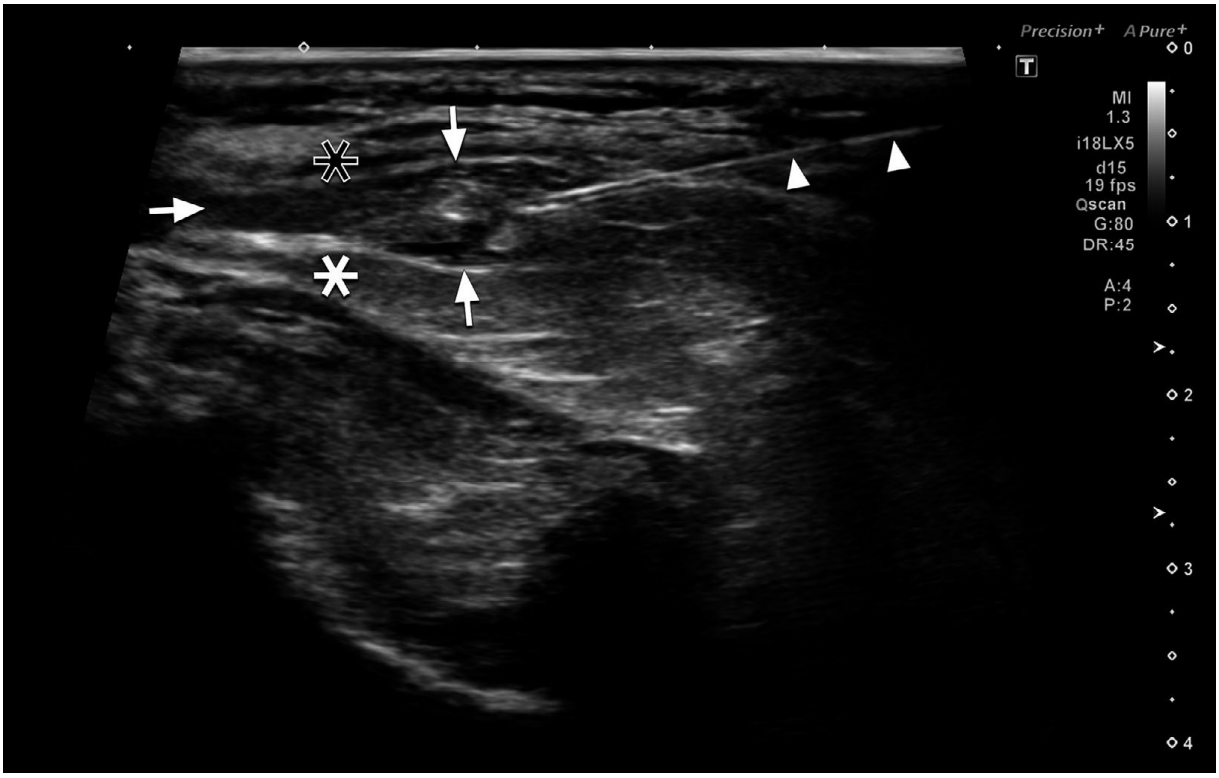

Fig. 6.7 Splenius capitis muscle injection – ultrasound procedure. The tip of the injection needle (arrowheads) is advanced to the middle of the splenius capitis muscle (arrows). Superficially covering the splenius capitis is the trapezius muscle (black asterisk), and lying beneath the splenius capitis muscle is the semispinalis capitis muscle (white asterisk).

Semispinalis Muscle

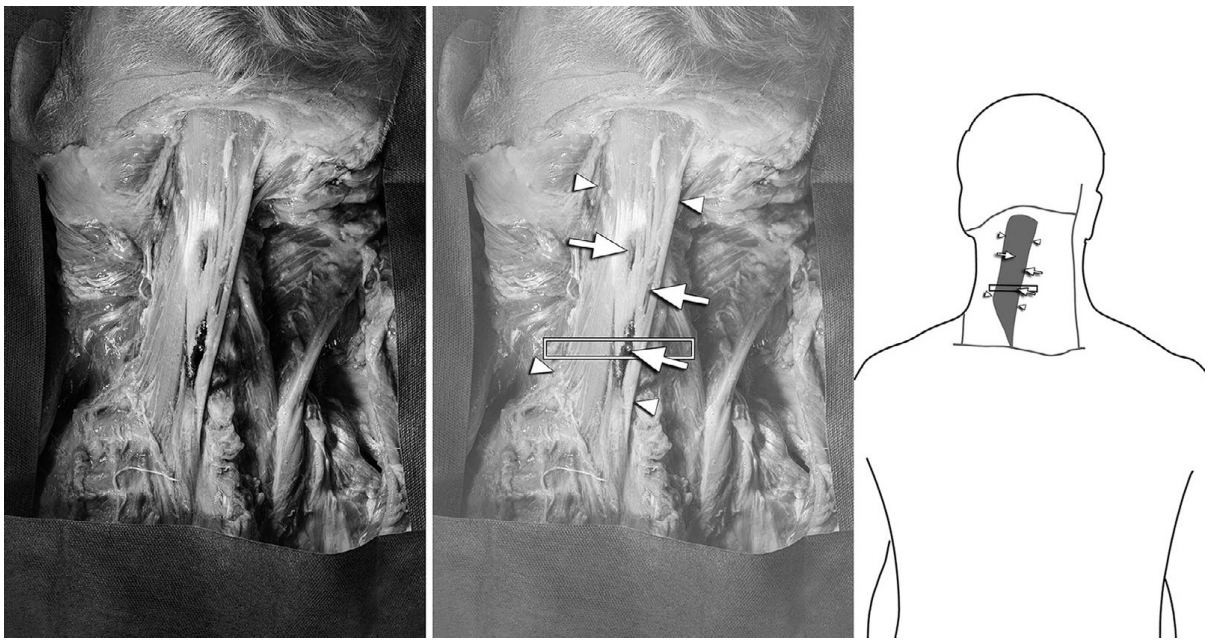

Fig. 6.8 Semispinalis capitis muscle injection – cadaver specimen. Dye (arrows) was injected into the left semispinalis capitis muscle of the left side (arrowheads). The ultrasound probe (box) was positioned in an axial plane at the caudal part of the muscle.

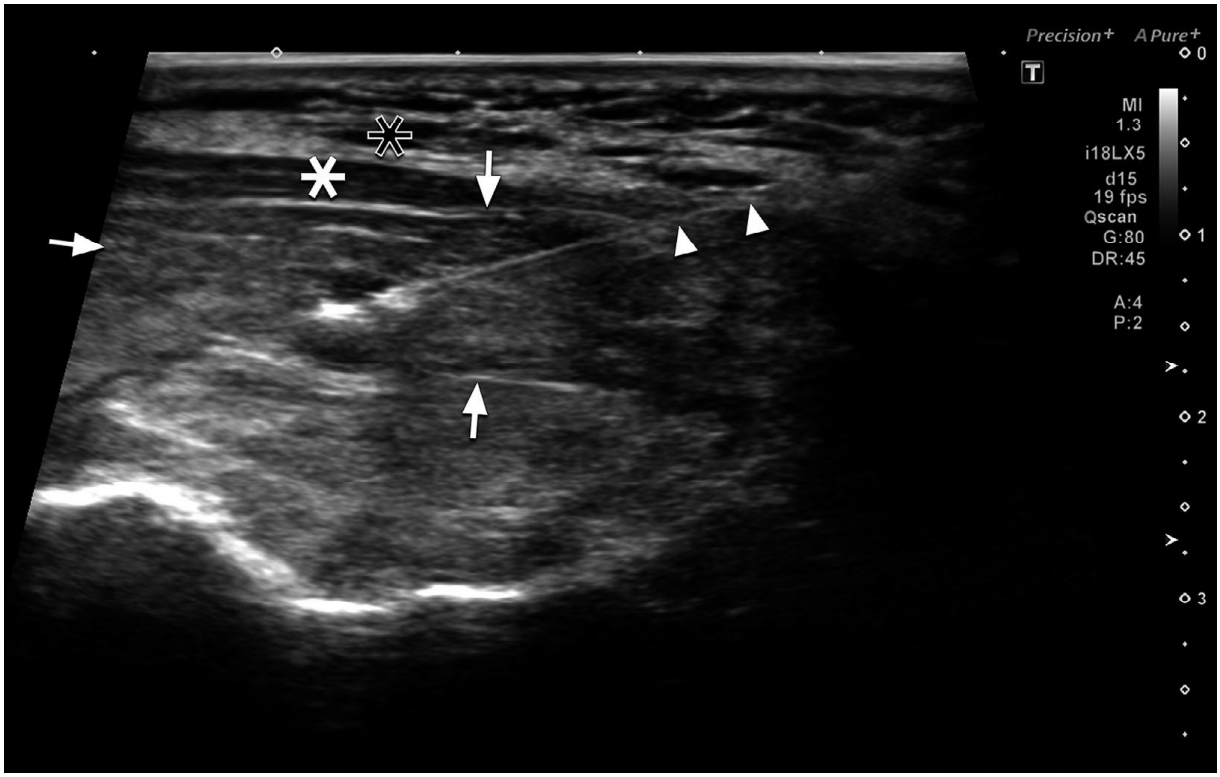

Fig. 6.9 Semispinalis capitis muscle injection – ultrasound procedure. The tip of the injection needle (arrowheads) is advanced to the middle of the semispinalis capitis muscle (arrows). Superficially covering the muscle is the trapezius muscle (black asterisk) and the splenius capitis muscle (white asterisk). Note the small hyperechoic air bubbles at the needle tip after incomplete venting of the syringe prior to the injection.

Longissimus Capitis Muscle

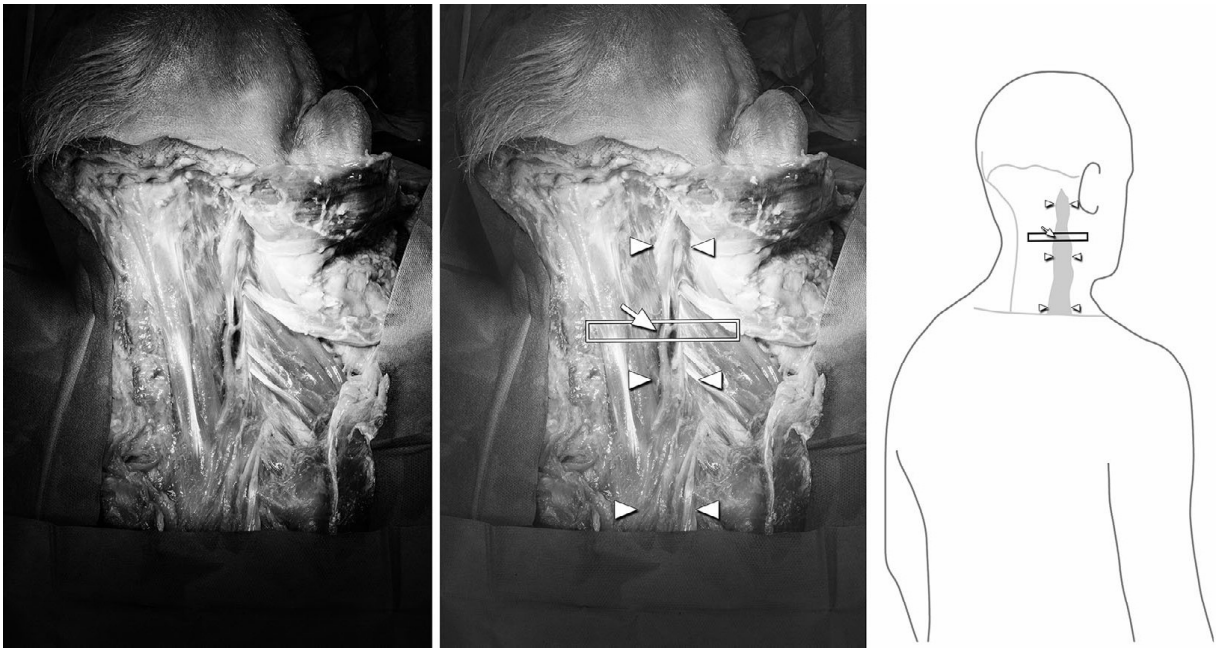

Fig. 6.10 Longissimus capitis muscle injection –- cadaver specimen. Dye (arrows) was injected into the right longissimus capitis muscle of the right side (arrowheads). The ultrasound probe (box) was positioned in an axial plane at the middle part of the muscle.

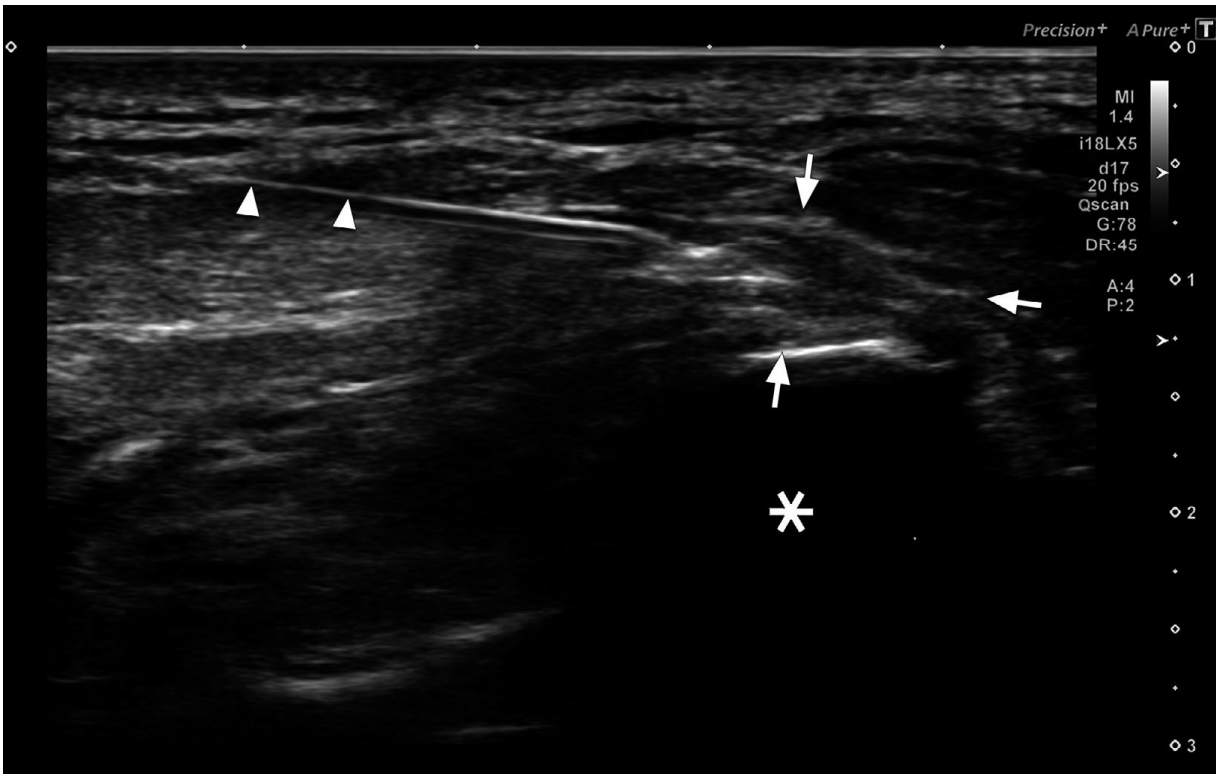

Fig. 6.11 Longissimus capitis muscle injection – ultrasound procedure. The tip of the injection needle (arrowheads) is advanced to the middle of longissimus capitis muscle (arrows). Below the muscle the surface of the posterior vertebral arch (white asterisk) can be seen.

Obliquus Capitis Inferior Muscle

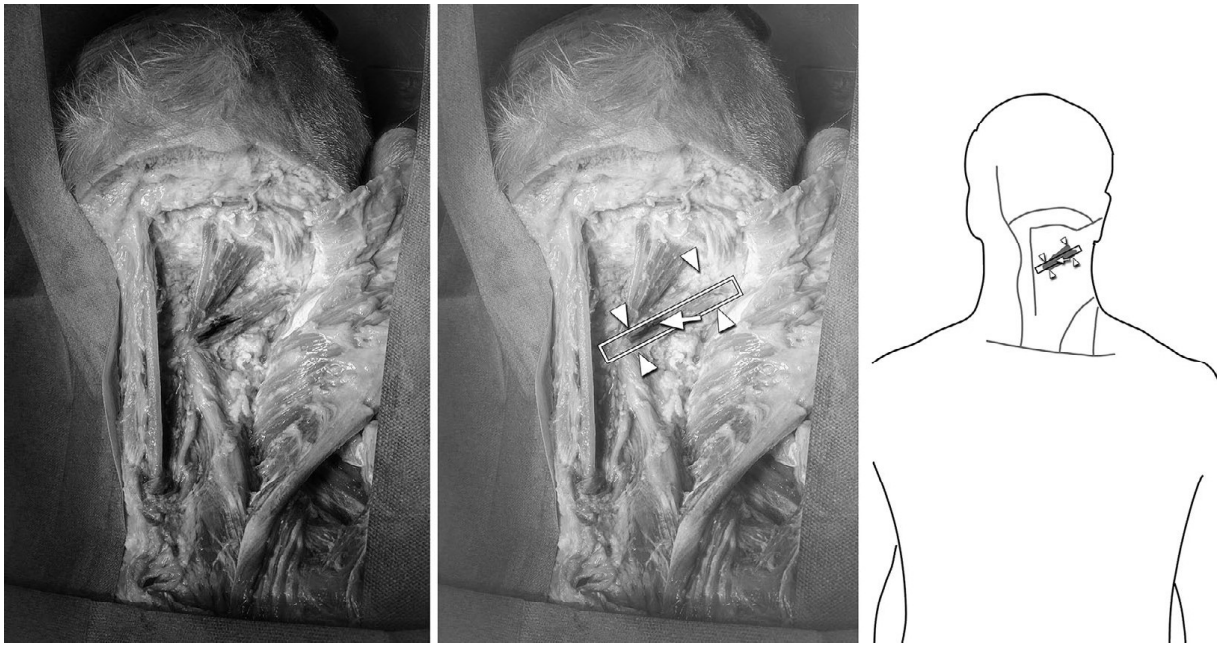

Fig. 6.12 Obliquus capitis inferior muscle injection – cadaver specimen. Dye (arrows) was injected into the obliquus inferior capitis muscle of the right side (arrowheads). The ultrasound probe (box) position was aligned parallel to the longitudinal axis of the muscle.

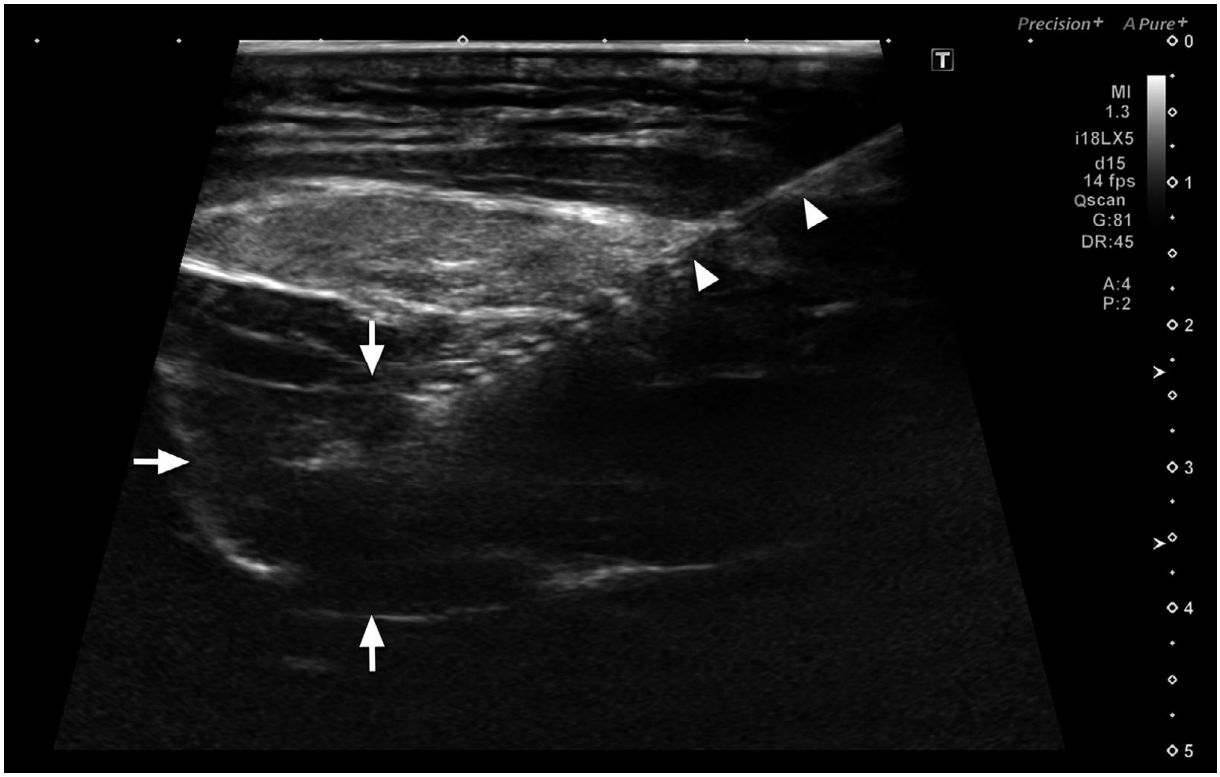

Fig. 6.13 Obliquus capitis inferior muscle injection – ultrasound procedure. The tip of the injection needle (arrowheads) is advanced to the middle of obliquus capitis inferior muscle (arrows). Superficial to the obliquus capitis inferior muscle (arrows) is the semispinalis capitis muscle (white asterisk) and the splenius capitis muscle (black asterisk).

Levator Scapulae Muscle

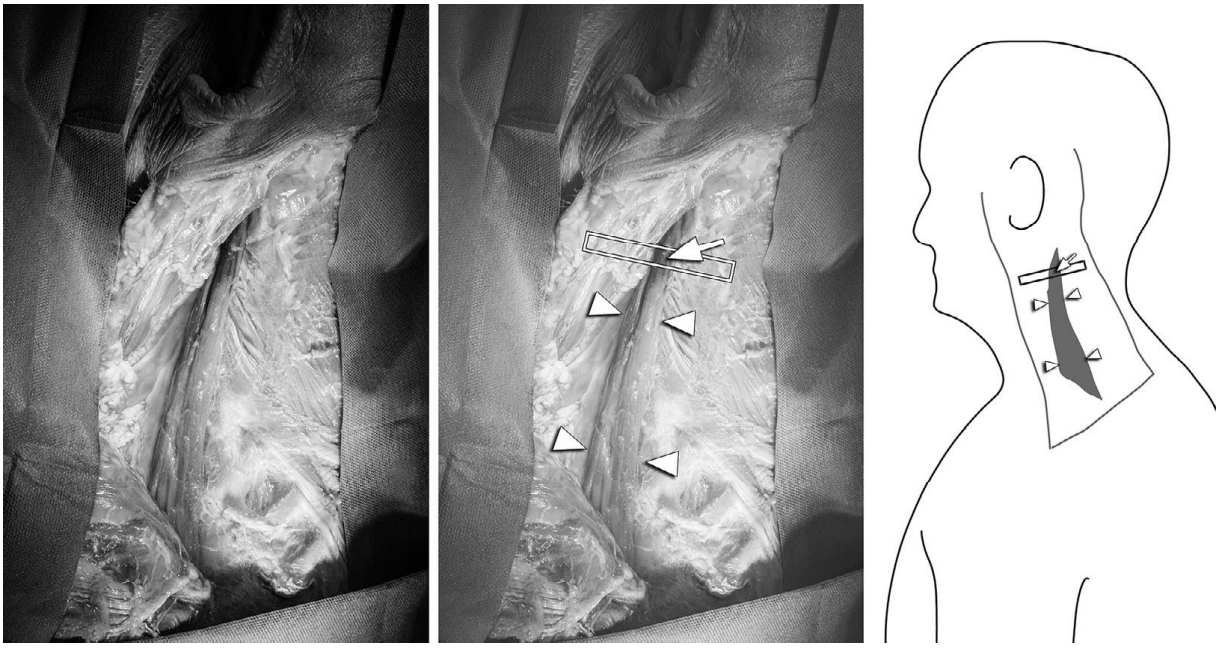

Fig 6.14 Levator scapulae muscle injection – cadaver specimen. Dye (arrows) was injected into the left levator scapulae capitis of the left side (arrowheads). The ultrasound probe (box) position was cranial and aligned transversal to the longitudinal axis of the muscle.

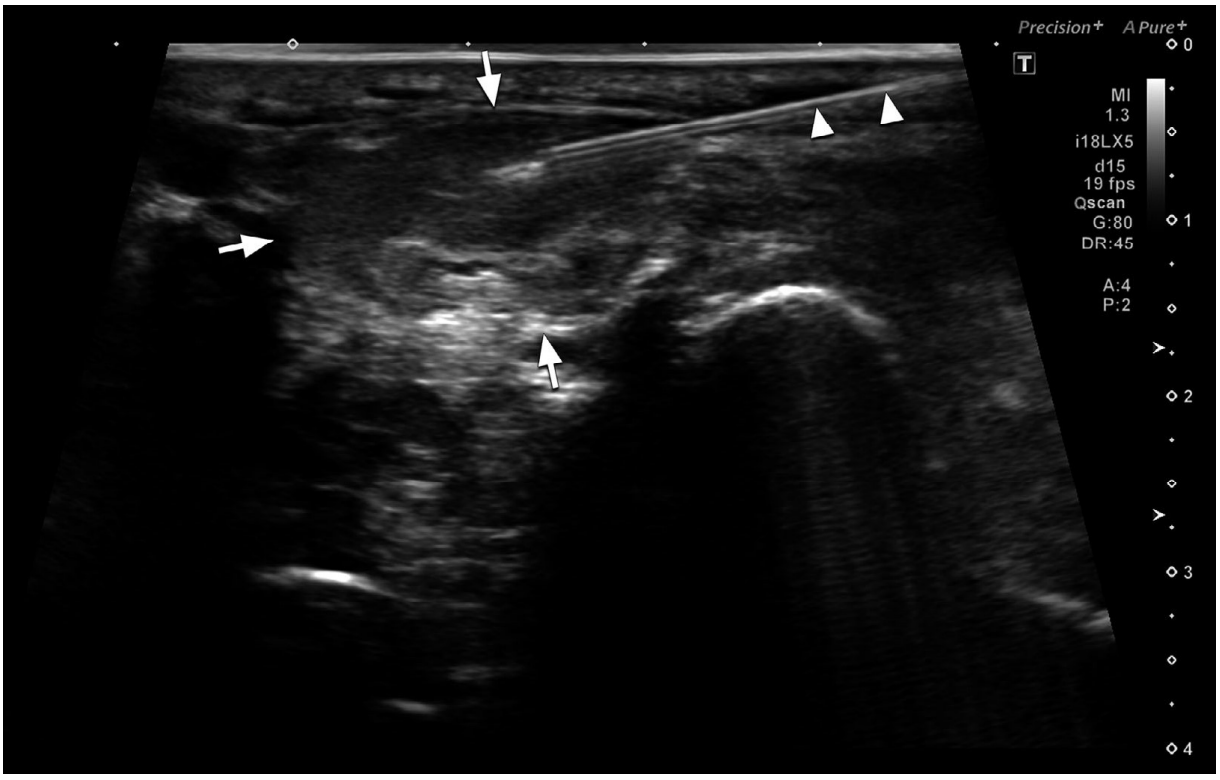

Fig. 6.15 Levator scapulae muscle injection – ultrasound procedure. The tip of the injection needle (arrowheads) is advanced to the middle of the left levator scapulae capitis muscle of the left side (arrows). Injected ink is marked as a hypoechoic zone around the needle tip. The transverse process (white asterisk) and the posterior part of the vertebral arch (black asterisk) can be seen deep to the muscle.

Sternothyroid Muscle

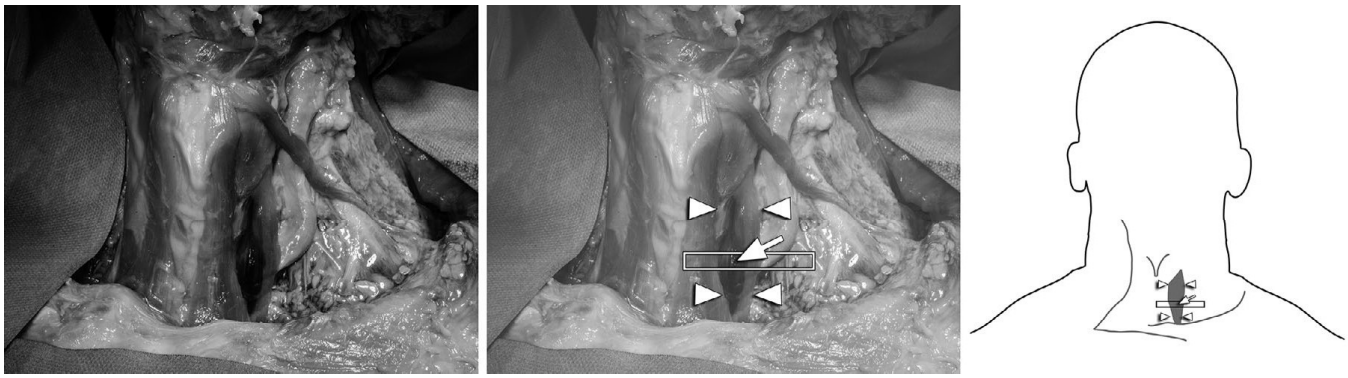

Fig. 6.16 Sternothyroid muscle injection – cadaver specimen. Dye (arrows) was injected into the left sternothyroid muscle of the left side (arrowheads). The ultrasound probe (box) position was axial at the anterior neck region.

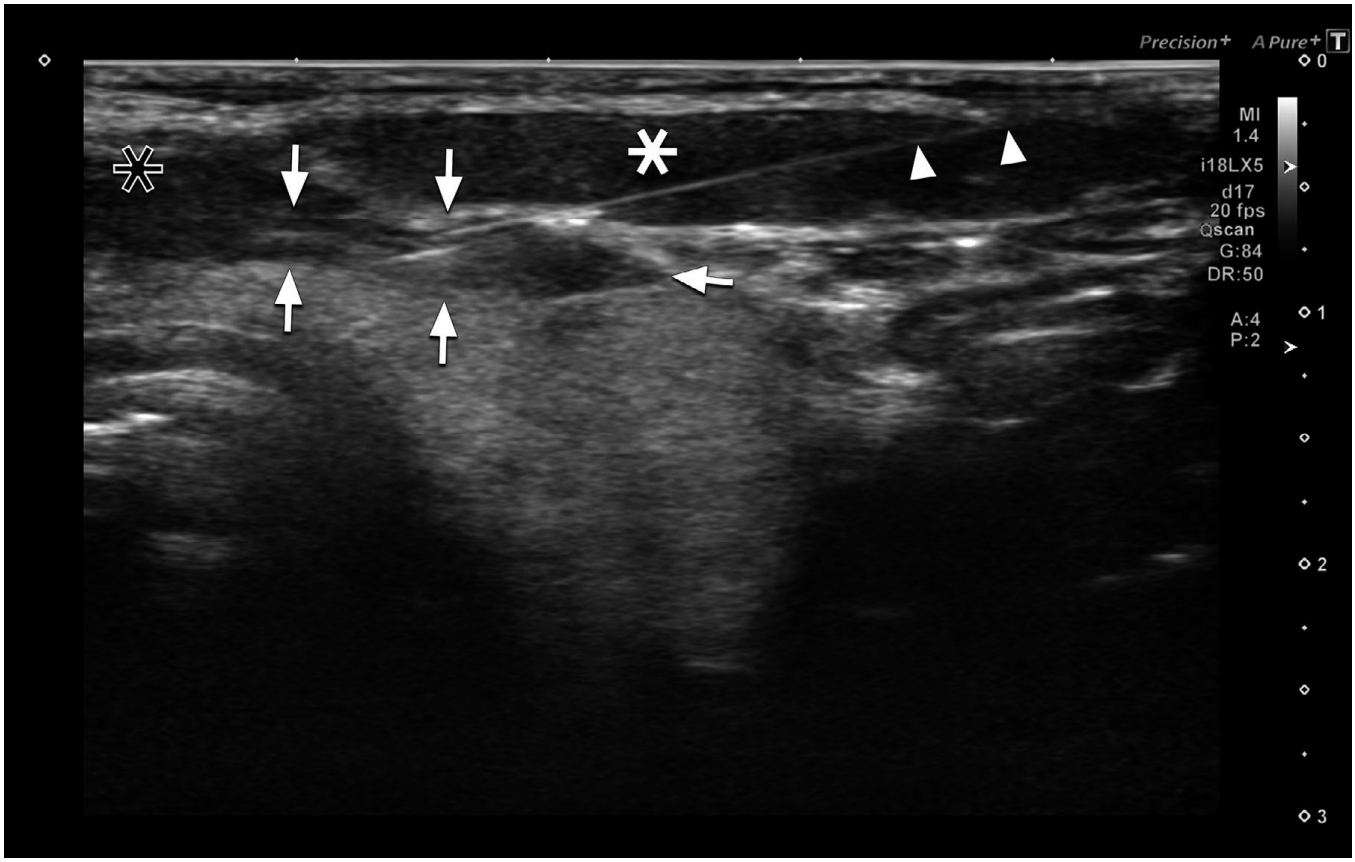

Fig. 6.17 Sternothyroid muscle injection – ultrasound procedure. The tip of the injection needle (arrowheads) is advanced to the middle of the left sternothyroid muscle of the left side (arrows). The needle track passes through the sternocleidomastoid muscle (white asterisk). Superficial to the sternothyroid is the sternohyoid muscle (black asterisk).

Longus Colli Muscle

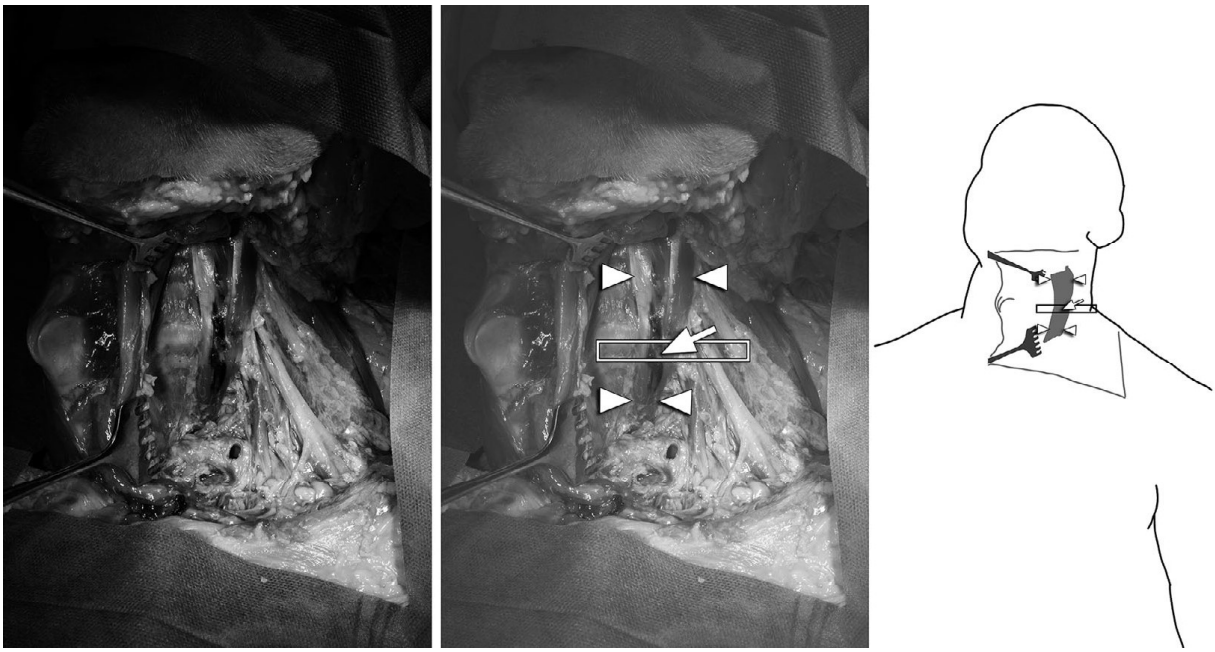

Fig. 6.18 Longus colli muscle injection –- cadaver specimen. Dye (arrows) was injected into the left longus colli muscle of the left side (arrowheads). The ultrasound probe (box) position was transversal to the longitudinal axis of the muscle. The infrahyoidal muscle group and the larynx are drawn medially by two hooks. Medial to the longus colli muscle the vertebral bodies and lateral to the muscle the anterior scalene muscle with the brachial plexus have been exposed.

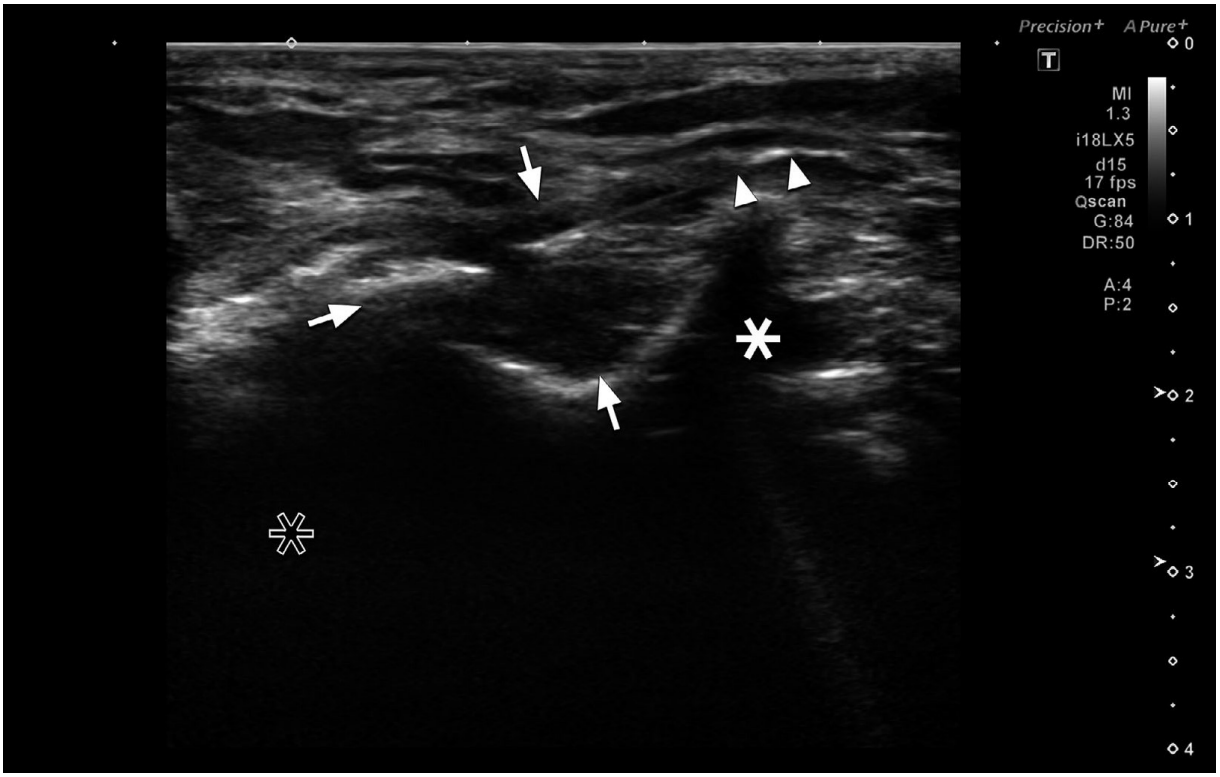

Fig. 6.19 Longus colli muscle injection – ultrasound procedure. The tip of the injection needle (arrowheads) is advanced to the middle of left longus colli (arrows) from lateral to medial. The needle track passes through the sternocleidomastoid muscle. Deep to the muscle, the vertebral body (white asterisk) and, laterally, the transverse process (black asterisk) can be seen.

Scalene Muscles

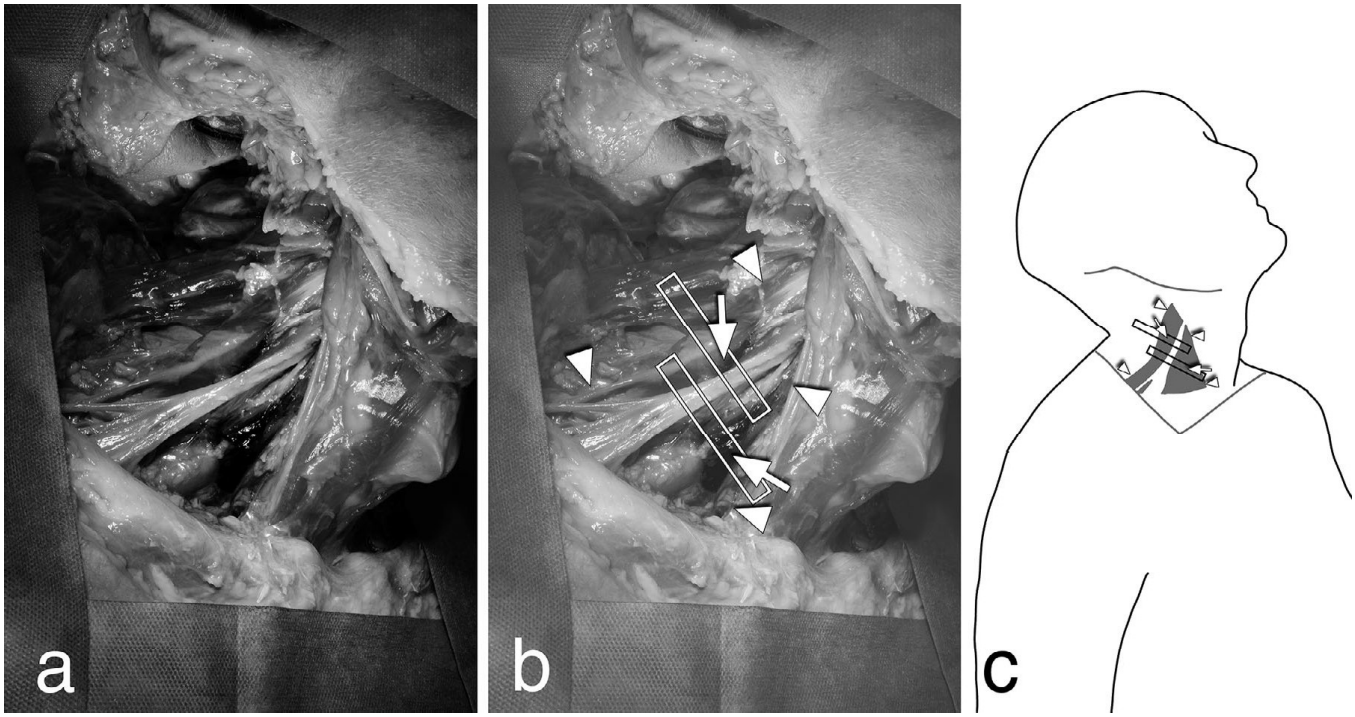

Fig. 6.20 Scalene muscles injection – cadaver specimen. Dye (arrows) was injected into the right scalenus anterior and medial muscles of the right-side (arrowheads). The ultrasound probe (box) positions were transversal to the longitudinal axis of each muscle.

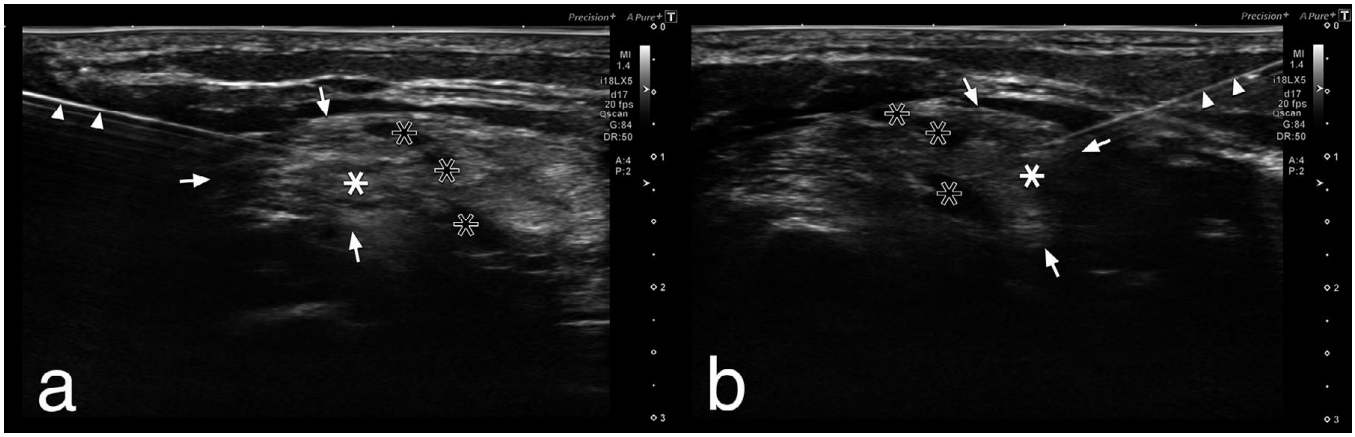

Fig. 6.21 Scalene muscles injection – ultrasound procedure. The tip of the injection needle (arrowheads) is advanced to the middle of each right scalene muscle.
(a) Middle scalene muscle (white asterisk), Brachial plexus (black asterisks).
(b) Anterior scalene muscle (white asterisk), Brachial plexus (black asterisks).

Panoramic Images of the Neck

These panoramic ultrasound still images show anatomically complex regions. The images were generated using the standard built-in panoramic software.

In all of the following figures (6.22–6.25) the panoramic ultrasound image is shown on the left, and the silhouette on the right indicates the position of the ultrasound probe.

Topology of the Upper Neck

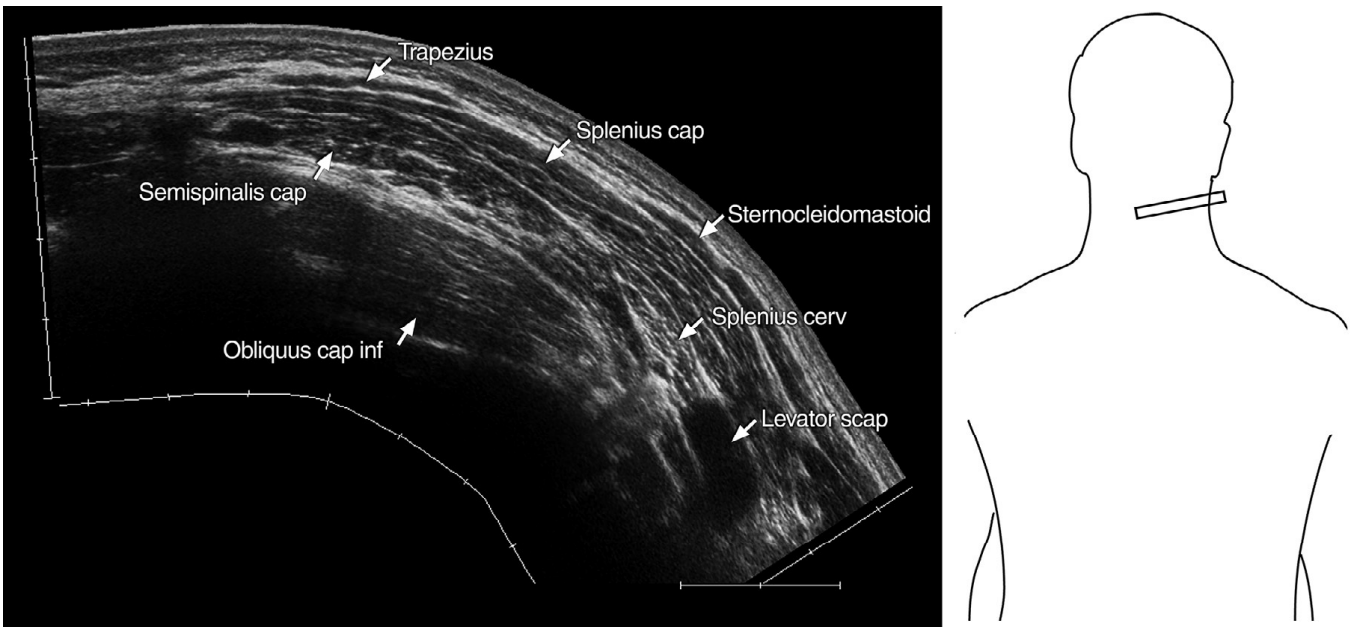

Fig. 6.22 Topology of the upper neck. Para-axial panoramic image of the upper neck region. Focusing on the anterior–posterior muscle sequence starting with the superficial trapezius muscle is most useful in identifying the target muscle. Note that in this cranial region the trapezius muscle is very thin. For correct identification of the trapezius muscle, it may be helpful to track the muscle from a caudal region, where it has a larger size, upward.

Topology of the Middle Neck

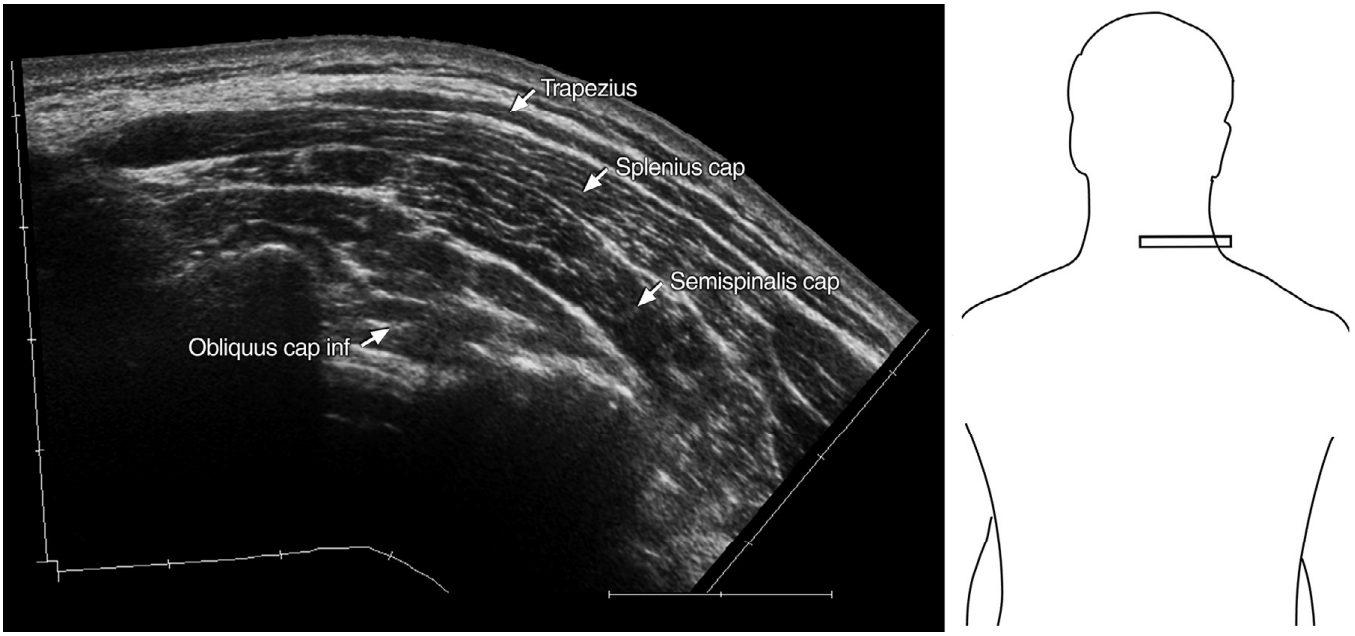

Fig. 6.23 Topology of the middle neck. Axial panoramic image of the middle neck region. The above-mentioned anterior–posterior sequence can be seen very clearly in this region of the neck.

Topology of the Lower Neck / Upper Dorsum

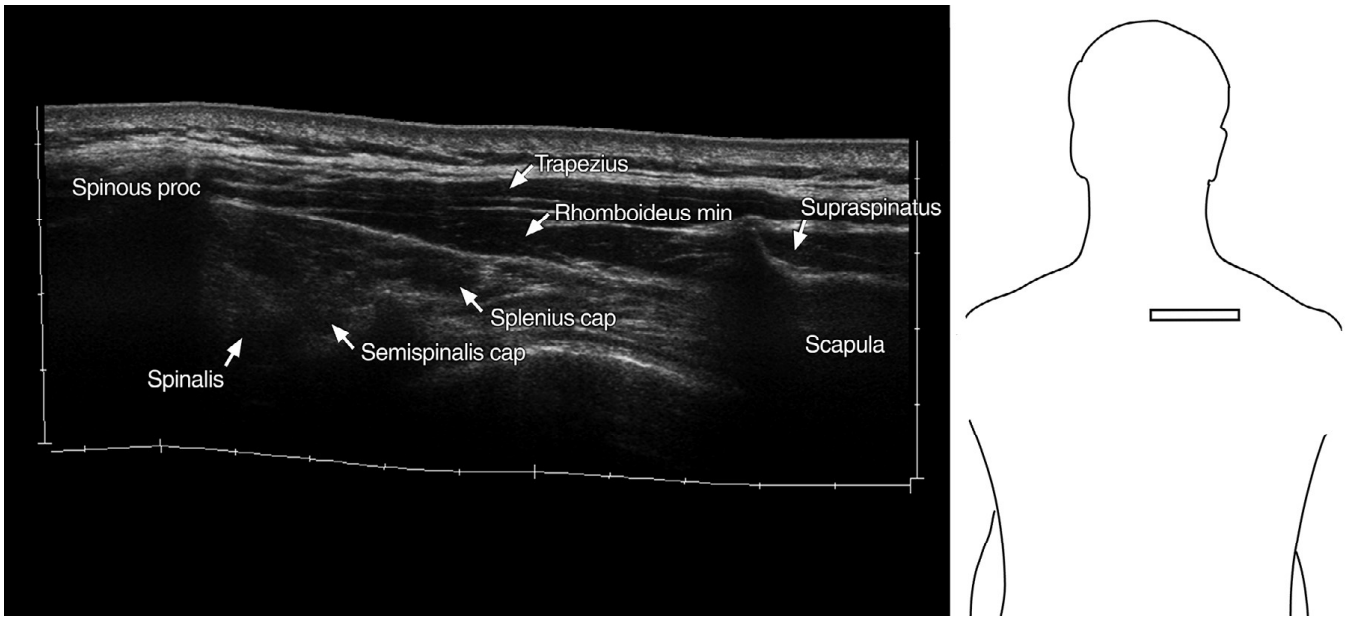

Fig. 6.24 Topology of the lower neck / upper dorsum. Axial panoramic image of the lower neck / upper dorsum region. In the transition zone between the lower neck and the upper back region, many smaller muscles from the autochthonous back muscle can be seen in the deeper layers. Note the layer of the rhomboideus maior and minor, and the levator scapulae muscle.

Topology of the Anterior Neck Region

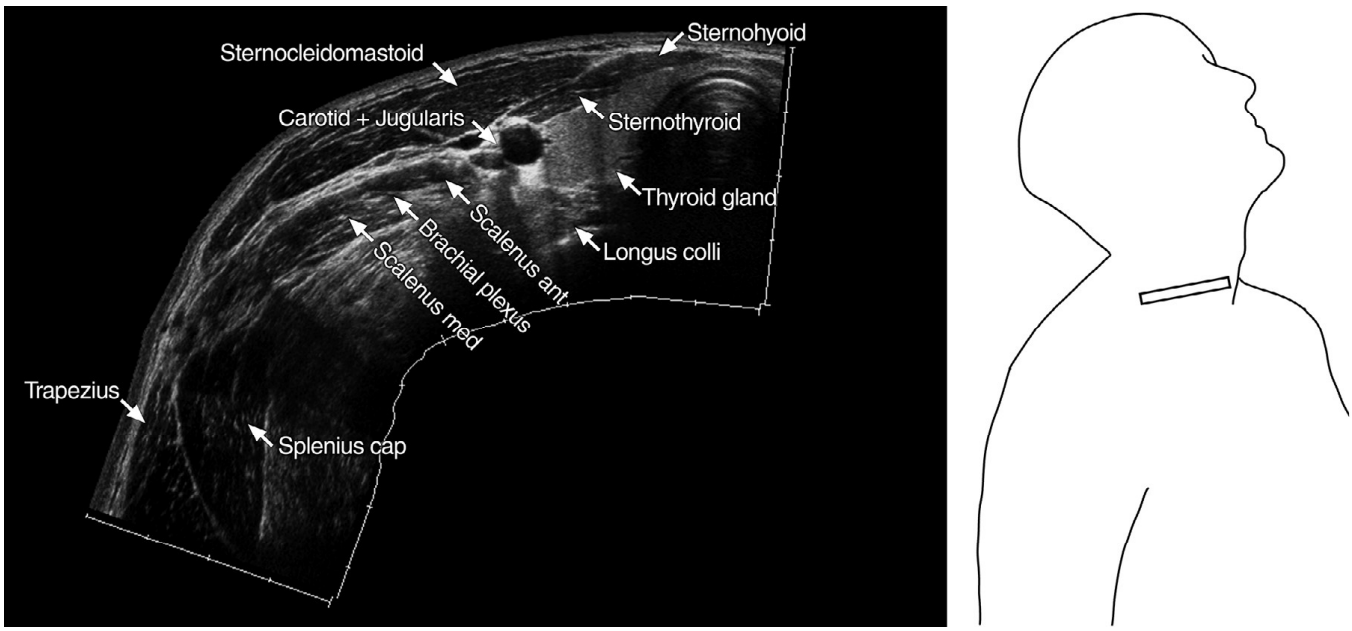

Fig. 6.25 Topology of the anterior neck region. Axial panoramic image of the anterior neck region. Be aware that there are many more structures than indicated in this image. The anterolateral neck regions harbor a plethora of arteries, veins, nerves and lymphatic vessels, of which the majority can be visualized with ultrasound.

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