A Guide to Doppler Ultrasound Analysis of the Face in Cosmetic Medicine. Part 1: Standard Positions

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Special Topic

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Abstract

Interest in Doppler ultrasound (DUS) analysis of the face has grown in cosmetic medicine, in particular for injectable fillers. When dealing with complications, DUS has the advantage of easily visualizing the filler and identifying the problem in relation to the patient's anatomy. When working with hyaluronic acid filler, ultrasound-guided injections with hyaluronidase can precisely target the problem. In addition, DUS can be used to study the anatomy of a patient, specifically to prevent intravascular injections. We predict that in a few years' time DUS will become standard equipment in the offices of cosmetic doctors. We discuss the basics of ultrasound imaging of different tissues with the concomitant terminology. With the use of 7 basic DUS probe positions, key anatomic reference points can be easily found. From these, all relevant anatomic structures in the face can be observed and analyzed. With some practice, physicians will ultimately be able to acquire a complete 3-dimensional mental image of a patient's face.

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Cosmetic medicine has recently shown interest in the use of Doppler ultrasound (DUS) analysis of the face because of the apparent advantage this technique offers in the prevention and treatment of complications. DUS is the easiest way to detect the presence of previously injected fillers and their complications. It can be used in office-based settings, producing real-time feedback from visual and palpable observations. Most types of fillers, either resorbable or nonresorbable, can be distinguished.[1-12] Threads can also be visualized.[13] The latest higher-frequency probes produce better-quality imaging, offering opportunities to acquire more detailed information about currently unobservable aspects of filler treatments, eg, detection of their in situ behavior.[14] A specific nomenclature to describe the in situ properties of fillers has been proposed.[15]

DUS offers the potential to detect arteries, which can then be avoided when injecting.[16] Individual variations are

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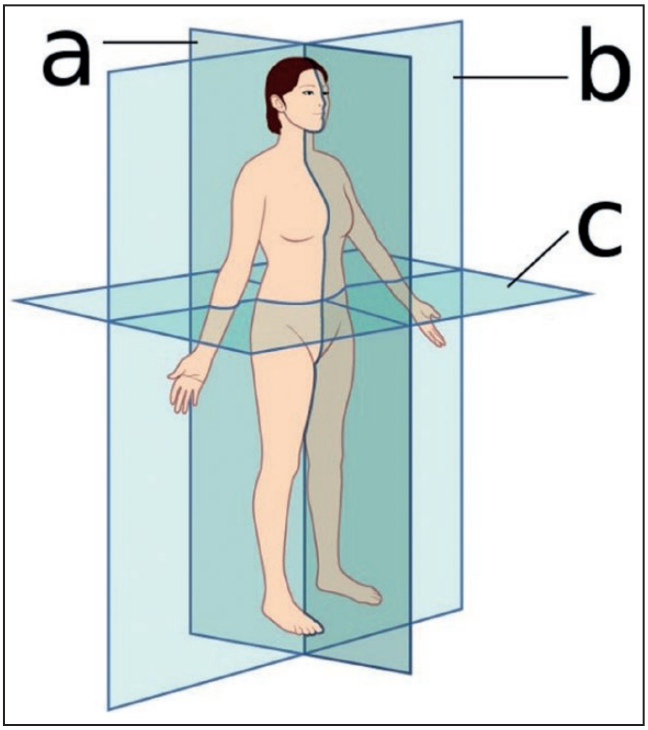

Figure 1. The 3 standard planes of the body: (A) Sagittal or vertical. (B) Frontal or coronal. (C) Axial, transverse, or horizontal.

known to exist and may also be acquired after trauma, surgery, or nonsurgical procedures of the face. In case of hyaluronic acid filler complications, DUS enables the practitioner to precisely deliver ultrasound-guided injections intralesionally.[9,17,18] In addition to treatment and prevention of complications, DUS can give the physician a 3-dimensional (3D) insight into subcutaneous anatomy, presenting an opportunity to aim for a specific injection plane. The increasing popularity of DUS has been assisted by the appearance of a number of low-priced portable devices that have become available during the past few years.

However, most practitioners in cosmetic medicine are not familiar with the use of ultrasound. There has been a call for standard ultrasound transducer positions in DUS examinations to make things easier when starting to use the equipment and to assist with interpretation of the images. This study attempts to realize this. Part 1 presents static anatomy with ultrasound images; part 2 discusses images of vascular structures obtained with color Doppler ultrasound (duplex mode).

Transducer Positioning

The 3 different standard planes of imaging are termed transversal, sagittal, and coronal (Figure 1). All transducers (also named probes) have a one-sided marking that should point to the patient's right ear in the cranial orientation. The right side of the patient then corresponds with the right side of the image on the screen. In the sagittal orientation the marking should point to the cranium, which then delivers the upper part of the face on the left side of the screen. Deviations from these nonstandard directions are named after the closest standard plane, eg, semisagittal or semicoronal. Handling of the transducer gives 3 degrees of freedom: tilt or angulation, rotation, and shifting or gliding (Figure 2).

Recognition of Different Structures

Ultrasound devices produce an image composed of various tones of gray. In-depth descriptions can be found in textbooks.[19,20] In short: absent reflection of sound waves is depicted as black (anechoic), and complete reflection as white (hyperechoic). In between are various shades of gray (hypoechoic). In some instances a structure has the same echogenicity as the surrounding structures (isoechoic), but can be recognized as a separate entity because of the distortion of the tissue architecture or of its internal structure. Internal structures may be either homogeneous or heterogeneous.

Vascular structures are most easily recognized in Doppler mode. With this modality the flow of blood is given in red (towards the probe) or blue (away from the probe). Care must be taken during examination not to impede blood flow by pressing too hard on the skin with the probe. This will hinder venous flow in particular. To avoid this, ample use of ultrasound gel is advocated.

Images of the most common tissue types in the face are given in Figure 3 (dermis, subdermis, fascia, muscle, bone). The dermis is a small hypoechoic band. The subdermal area contains different structures, being either fat (hypoechoic mass), blood vessel (anechoic round to oval; see Figure 4), or fibrous tissue (short hyperechoic streaks). Muscles contain a vast amount of water (blood) and are therefore hypoechoic structures. Larger muscles are interspersed with small tendon sheets. Bone and fascia are dense hyperechoic structures. Nerves are too small to visualize with the devices commonly available.

Principles of Facial Orientation

It is important to realize that DUS is not like reading a series of pictures from standardized sections of the face, as is the case in computed tomography scans, magnetic resonance imaging, X-ray images, etc. DUS is a dynamic tool aimed at gaining insight into the spatial relation of the anatomic structures in a face. DUS allows us to visualize in our mind a 3D image of the patient's face. It

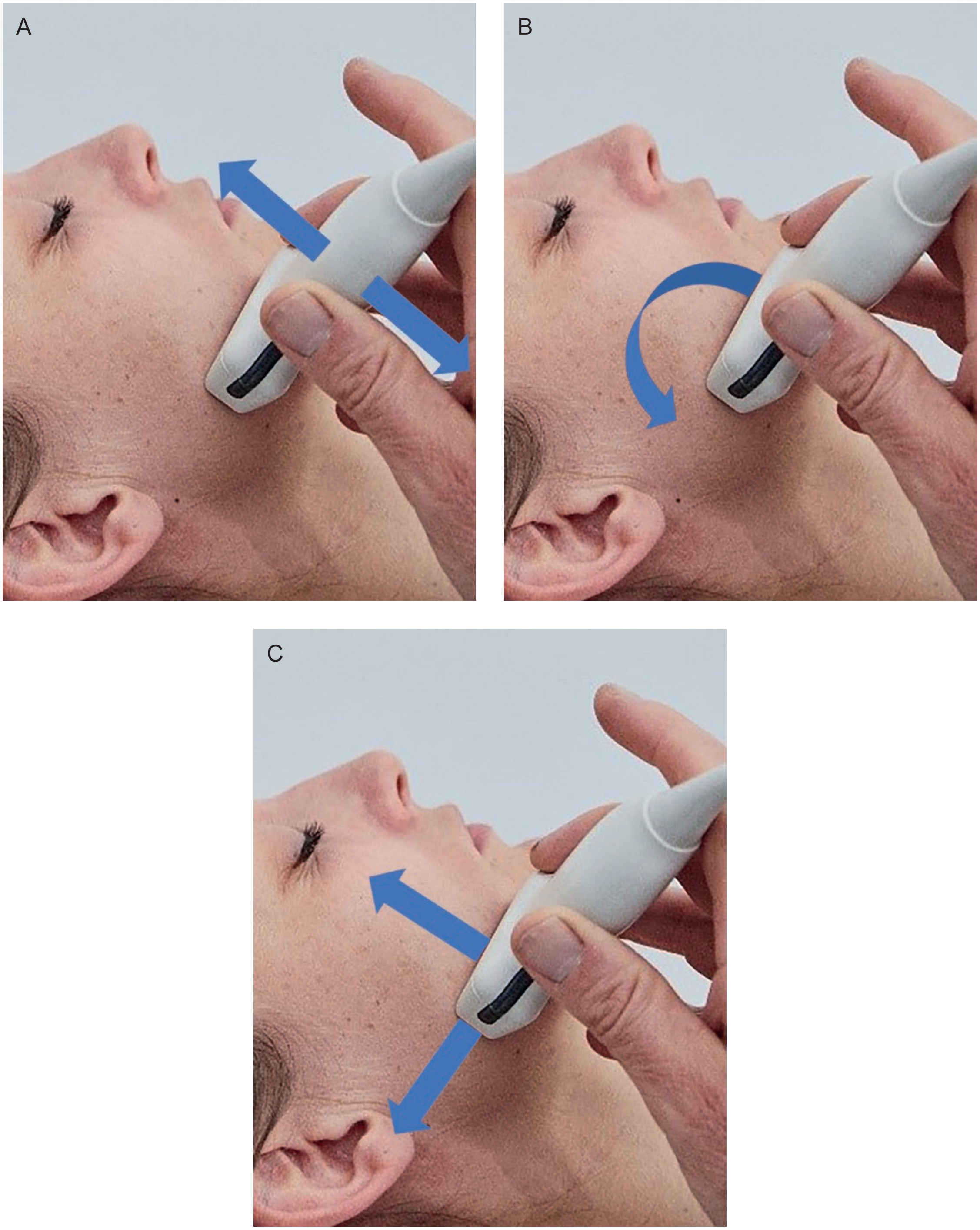

Figure 2. Probe movements. (A) Angulation or tilting: changing the angle between probe and skin surface while the point of contact with the skin remains fixed. (B) Rotation. (C) Shifting or gliding: moving the probe over the skin surface in a horizontal or vertical direction while the orientation of the probe remains fixed.

is, for instance, not only important to see how far away from the nasolabial fold the facial artery is in the lateral plane; it is just as important to know how deep under the skin surface the artery runs. In addition, the assessment of depth of the superficial musculoaponeurotic system (SMAS) on the cheeks, the inferior part of the orbicularis oculi muscle, or the location of the infraorbital foramen may be of importance for diverse reasons. With DUS it is all about the relation of variable anatomic structures to fixed ones. Therefore, at the start of any facial ultrasound

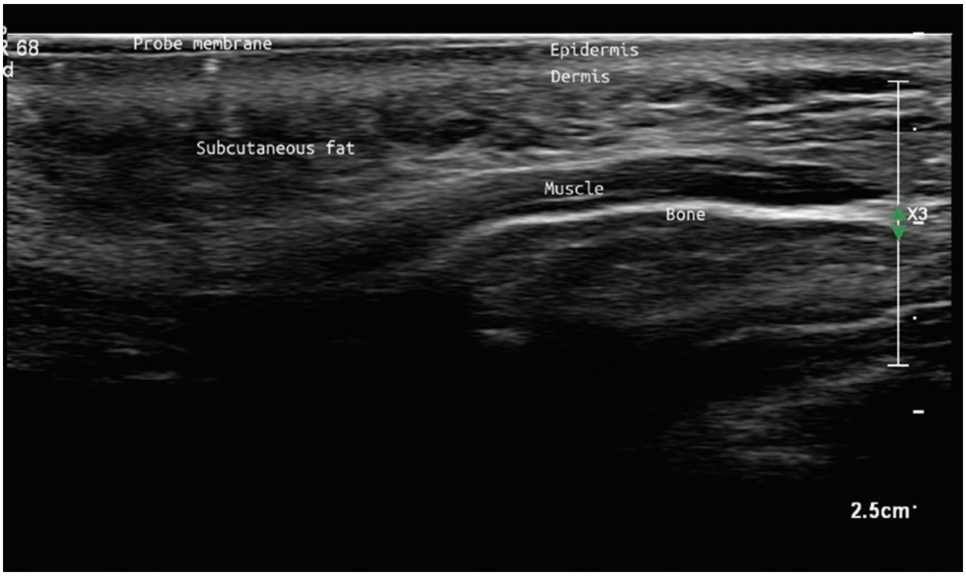

Figure 3. Basic ultrasound image of the face. From top to bottom: thin hyperechoic line (probe membrane), dense hyperechoic structure (epidermis + dermis), hypoechoic area with linear hyperechoic structures (subcutaneous fat pad), longitudinal hypoechoic structure (muscle), and a thick hyperechoic line (bone). Note: all imaging below the bone does not represent real anatomic structures but artifacts resulting from interaction of sound waves and tissue.

examination, it is reasonable to begin with identifying a number of fixed structures as points of reference and from there explore the regions.

Standard Ultrasound Transducer Positions in the Face

For every area in the face we define a set of standard positions with a predefined orientation of the ultrasound transducer. In these positions fixed anatomic structures (reference points) can be found easily. With small movements of the ultrasound transducer other important structures can be identified and ultimately a 3D image of the area can be composed. The patient provided written consent for the facial examination. The examinations and study were conducted in accordance with guidelines of the Declaration of Helsinki as they are included in our standard of patient care.

Position 1: Jawline (Figure 4A-C)

- Transducer position: axial halfway along the edge of the mandibula along the mandibular ramus inferior border. Slide anteriorly and cranially
- Reference point: masseter muscle (the facial vein and artery can be identified at the medial border of the masseter muscle)

The masseter muscle is an hypoechoic structure interspersed with hyperechoic fibrous sheets. The muscle delineates the lateral boundary of the face. Its medial edge marks the crossing of the facial vein over the mandible. Directly anterior to the vein lies the facial artery. More cranially, the facial artery lies on top of the buccinator muscle, visible as a deeper dark band running to the modiolus of the mouth, which being fibrous is therefore hyperechoic. On top of the masseter muscle the parotid gland extends cranially as a homogeneous, slightly hypoechoic structure. The distance of the parotic gland and the skin can be appreciated; in some patients this distance is less than 1 mm and precautions should be taken with filler injections. The SMAS can be visualized as a hyperechoic fibrous sheet on top of the masseter and may be followed all the way up.

Position 2: Chin and Lower Lip (Figure 5A-C)

- Transducer position: axial from midchin laterally. Slide and rotate to identify structures
- Reference point: depressor anguli oris (DAO) muscle

The DAO can be seen as an hypoechoic oval structure, emerging from the modiolus and running to the inferior part of the mandibula. Underneath, the depressor labii inferior muscle and the inferior labial artery can be seen. The mental muscle can be seen more medially on both sides of the midline on the mandibula. From the modiolus the inferior part of the orbicularis oris muscle can be identified. The mental foramen presents as a small gap in the chin bone about 1.5 cm above

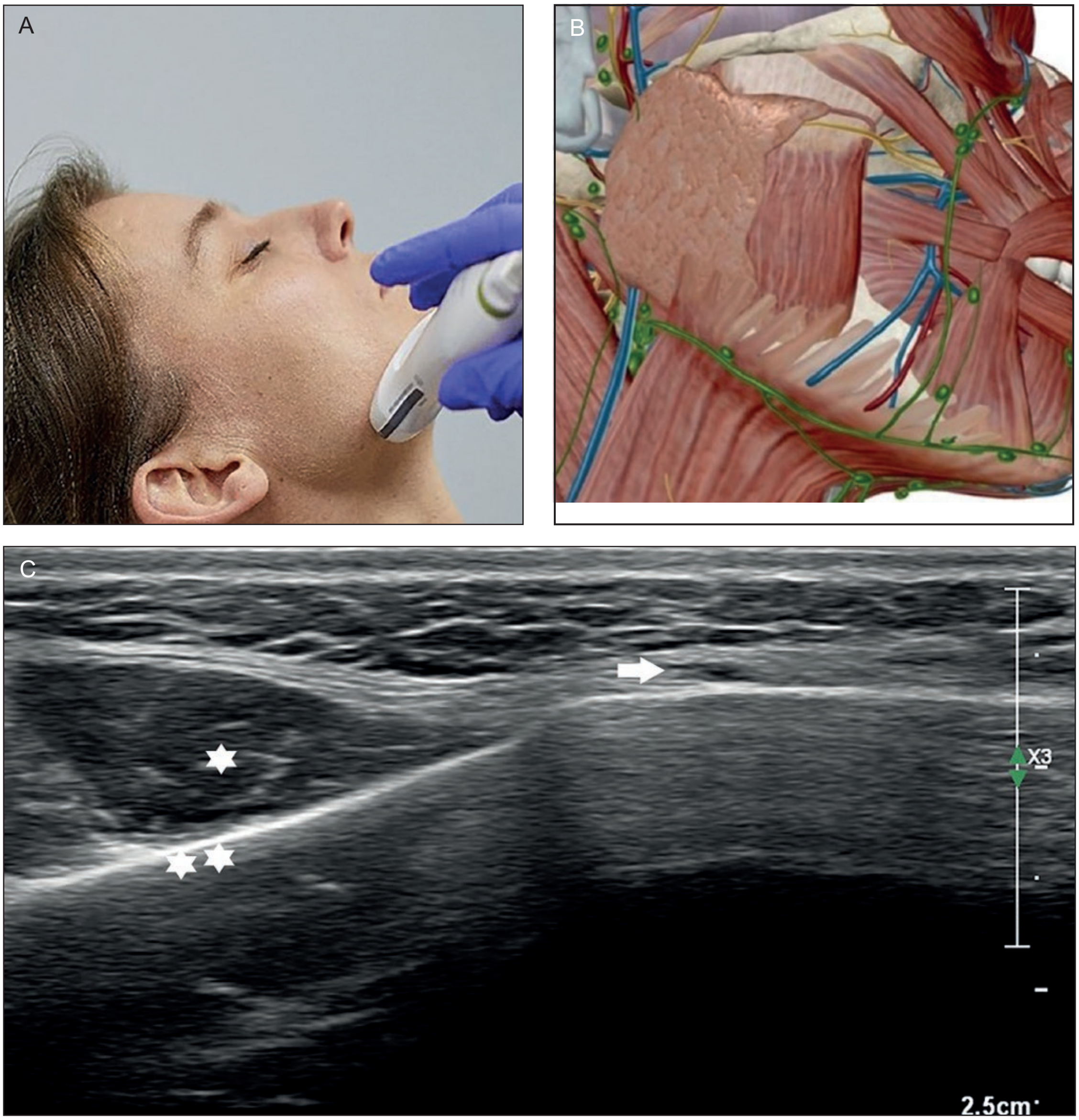

Figure 4. Position 1: jawline. (A) Probe position: axial (horizontal) halfway on the mandible. (B) Anatomy: parotid gland, m. masseter, m. buccinator, facial vein and artery. (C) Ultrasound image: m. masseter (asterisk), mandible bone (double asterisk), vascular structure (facial vein or artery) (arrow).

the jawline and should be avoided when administering filler injections.

Position 3: Upper Lip (Figure 6A-C)

- Transducer position: axial on the vermillion part of the upper lip with cranial sliding movement towards the nose
- Reference point: orbicularis oris muscle and teeth

The orbicularis oris muscle presents as a hypoechoic band. Beneath this, teeth are seen as individual hyperechoic elements. The superior labial artery, and in the midline the columellar artery, can be found. In this area the subdermis is much less fibrous and more homogeneous hypoechoic with only small hyperechoic elements.

Position 4: Midface (Figure 7A-C)

- Transducer position: semisagittal from zygoma to the corner of the mouth, sliding to the nose
- Reference point: zygomaticus major muscle

This position delineates the lateral border of the midface area, the medial border being the nose. The zygomatic

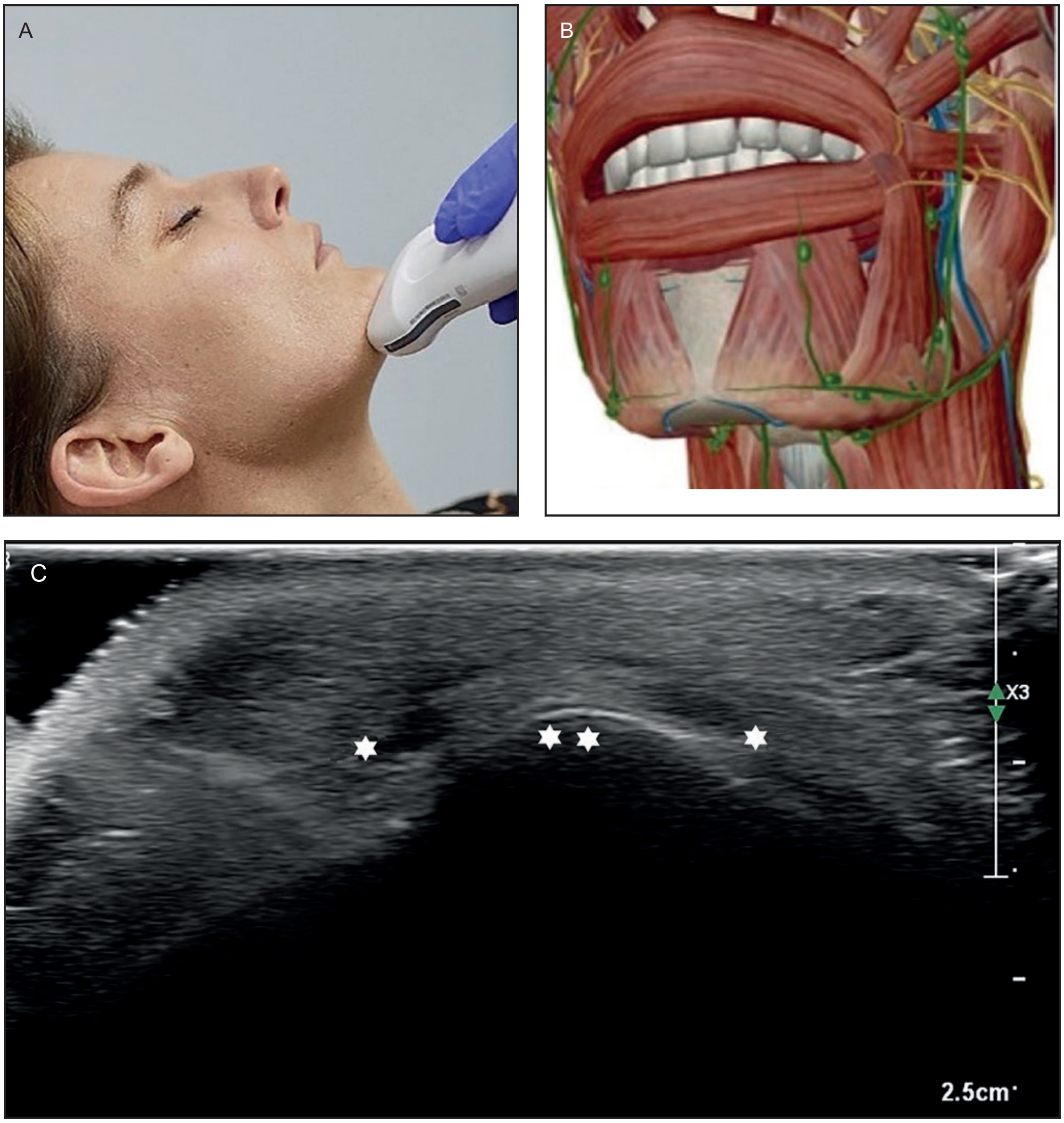

Figure 5. Position 2: chin and lower lip. (A) Probe position: axial (horizontal) lateral from midchin. (B) Anatomy: modiolus, m. depressor anguli oris, m. depressor labii inferioris, m. orbicularis oris, m. mentalis, mental foramen, inferior labial vein and artery. (C) Ultrasound image: mentalis muscles (asterisk), chin bone (double asterisk).

muscle can be seen as a hypoechoic (linear) band running from the zygomatic arc to the modiolus of the mouth. It lies underneath the superficial medial cheek fat compartment and delineates the deep malar medial fat compartment and the buccal fat compartment. Medial to the zygomatic muscle the levator labii muscles and the infraorbital notch (a small gap in the maxillary bone) are found. From here, the infraorbital artery emerges. Close to the nose (Figure 8) is the angular artery, giving off the lateral nasal artery to the alar nasi. These structures should be taken into account and avoided during injections.

Position 5: Nose (Figure 8A-C)

- Transducer position: sagittal from glabella to tip of the nose, sliding movements up and down and to either side of the nose
- Reference point: nasal bone and cartilages

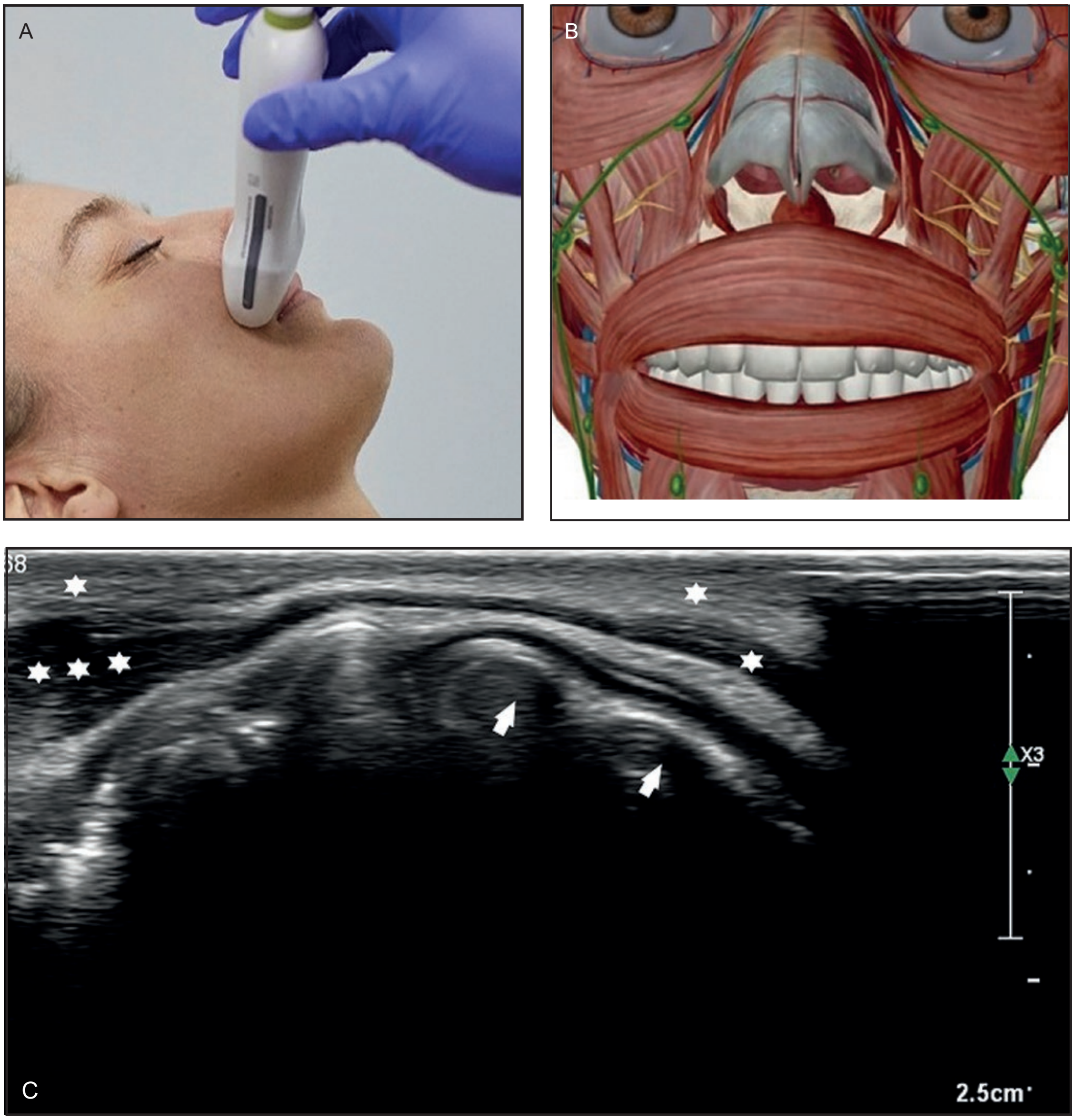

Figure 6. Position 3: upper lip. (A) Probe position: axial (horizontal) on the vermillion part of the lip. (B) Anatomy: modiolus, m. orbicularis oris, teeth, superior labial vein and artery, columellar artery. (C) Ultrasound image: subcutaneous tissue (asterisk), modiolus (triple asterisk) extending into the orbicularis oris muscle, and teeth (arrows).

In the midline the deepest plane of the ultrasound image shows the hyperechoic nasal bone, with thin anechoic muscular structures directly on top. Above that is hypoechoic subcutaneous tissue extending caudally the slightly more hypoechoic nasal cartilage. Procerus and nasal muscles are thin hypoechoic ovals or lines. The lateral nasal arteries, dorsal nasal arteries, and intercanthal veins can be found. Lateral injections of the nose are at an increased risk for intra-arterial product application due to the presence of the terminal branch of the anterior ethmoidal artery.

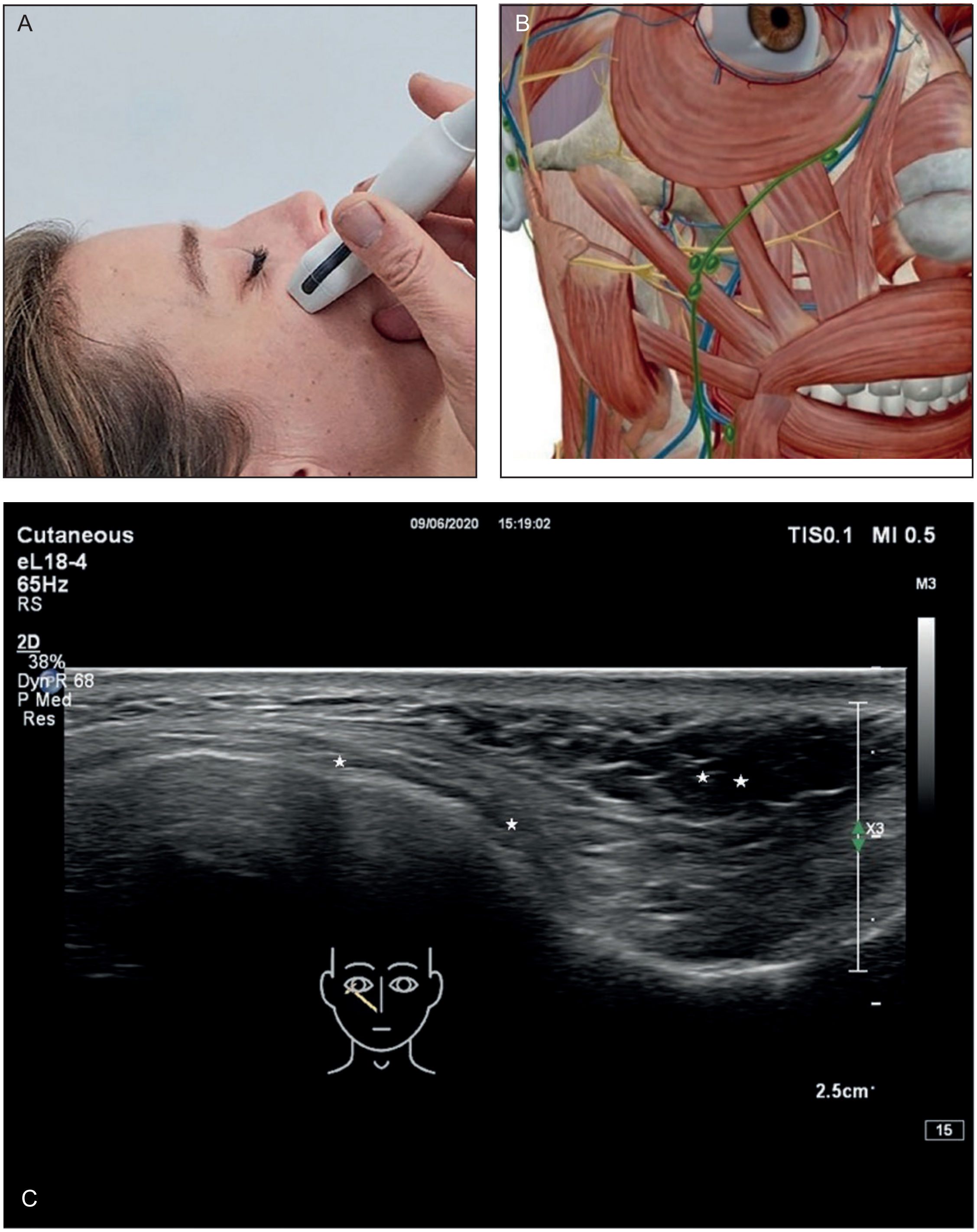

Figure 7. Position 4: midface. (A) Probe position: semisagittal from zygoma to corner of the mouth. (B) Anatomy: m. zygomaticus major, levator labii superior muscles, superficial and deep fat compartments, facial vein, angular artery. (C) Ultrasound image: zygomatic major muscle (asterisk) and deep medial cheek fat pad (double asterisk)

Position 6: Temporal Area (Figure 9A-C)

- Transducer position: sagittal at the hairline, sliding upwards and medial to the eyebrow
- Reference: temporal muscle

The temporal region (Figure 9) is built up from different layers of hypoechoic temporal muscle and multiple hyperechoic fascia sheets. From superficial to deep we can identify (1) epidermis, (2) dermis and (3) subcutaneous fat, (4) the hyperechoic SMAS or temporoparietal fascia, which is a continuation of the galea aponeurotica positioned on top of the (6) deep temporal fascia with (5) loose areolar tissue in between. The deep temporal fascia splits to harbor the deep temporal fat

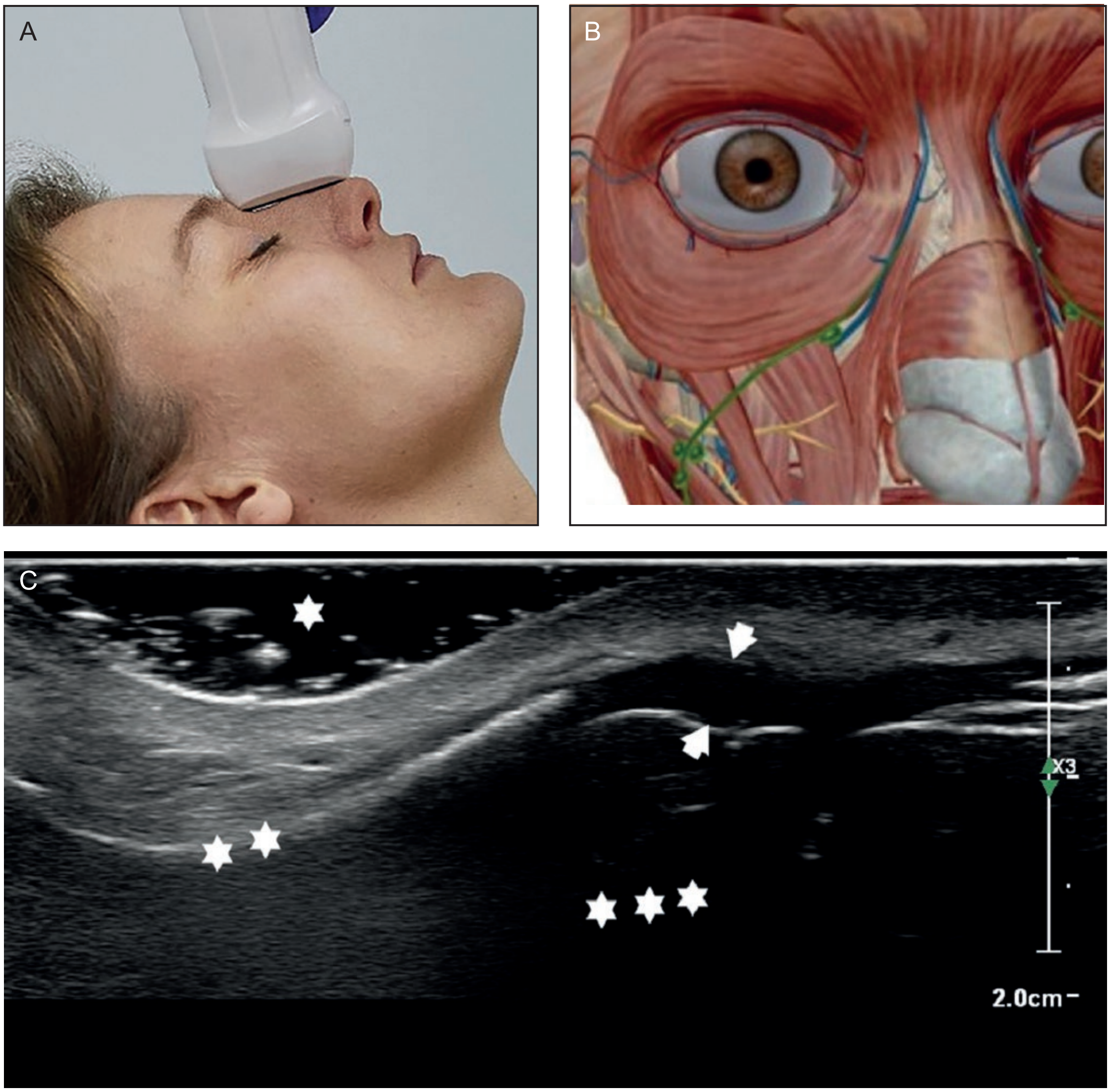

Figure 8. Position 5: nose. (A) Probe position: sagittal (vertical) from glabella to the tip of the nose. (B) Anatomy: m. procerus and nasal muscles, nasal bones (cranial) and nasal cartilages (caudal), dorsal nasal artery, lateral nasal artery and veins. (C) Ultrasound image: a thick layer of ultrasound gel (asterisk), nasal bone (double asterisk), nasal cavity (triple asterisk), nasal cartilage (between arrows).

pad positioned superficially to (7) the hypoechoic temporal muscle.

Arteries in this region are the transverse facial artery at the caudal side of the zygoma bone as well as, more cranially, the superficial temporal artery, which gives off a frontal branch to the forehead.

Position 7: Forehead (Figure 10A-C)

- Transducer position: axial on glabella and the superior orbital rim, sliding medial/lateral and cranial
- Reference: frontal bone and muscle

Anatomic structures to be visualized are the hypoechoic frontal, corrugator, and procerus muscles, as well as the supraorbital and supratrochlear arteries; the latter should be marked and avoided during filler injections.

DISCUSSION

There is growing interest in ultrasound use in medical education, exemplified by the integration of point-of-care ultrasound courses in some undergraduate medical school curricula.[21,22] Ultrasound use has grown in many medical specialties. Nevertheless, medical students still

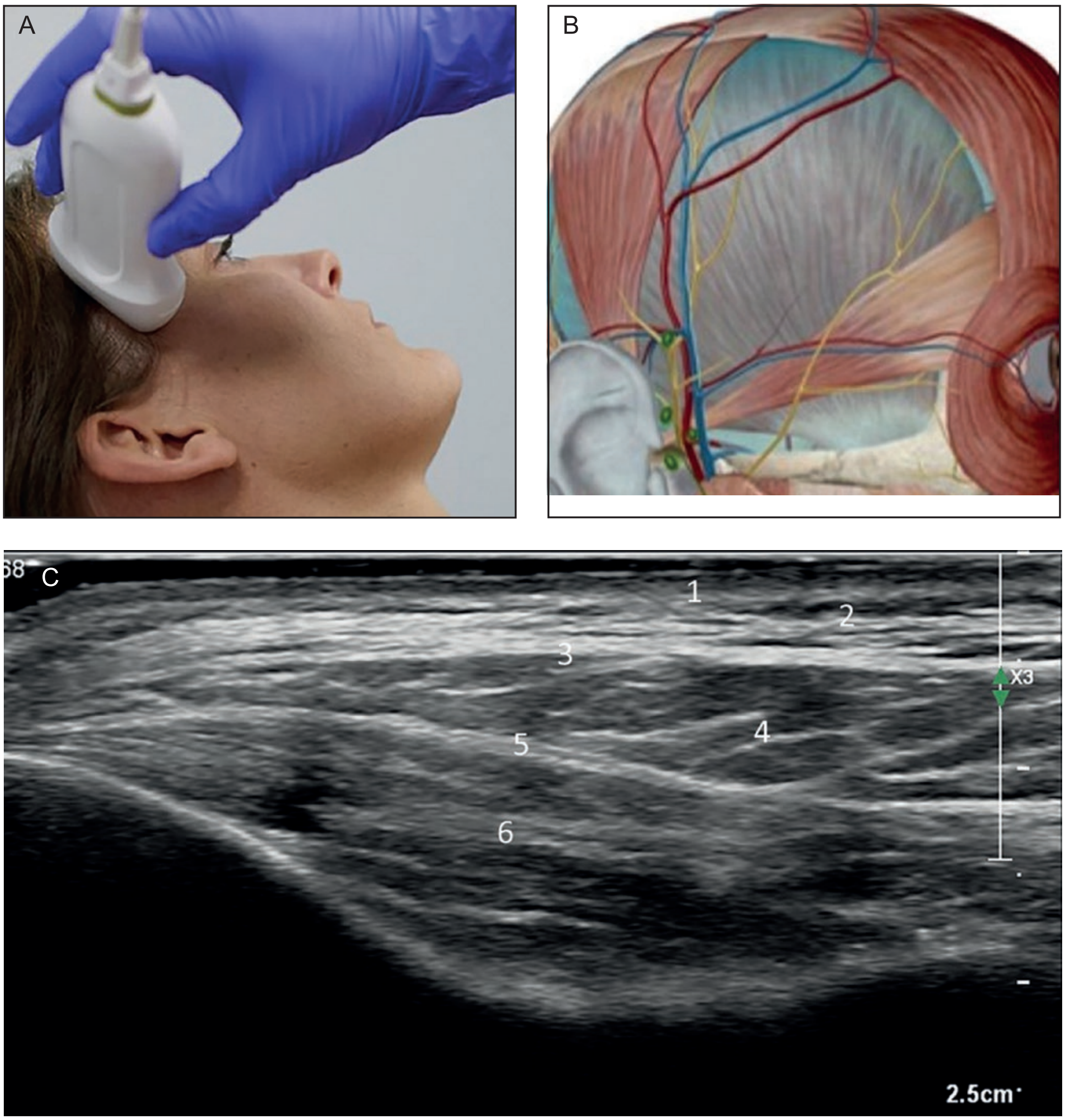

Figure 9. Position 6: temple. (A) Probe position: sagittal (vertical) in hairline. (B) Anatomy: temporal muscle fills the temporal fossa. On top of the muscle are 2 fat pads and several fibrous sheets, and frontal branches of the superfical temporal artery and the vein. (C) Ultrasound image from top to bottom: epidermis/dermis (1), superfical fat pad (between 1 and 2), superficial temporal fascia (2), loose areolar tissue (between 2 and 3), deep temporal fascia (superficial layer) (3), superfical temporal fat pad (4), deep temporal fascia (deep layer) (5), temporal muscle (6), bone (under 6)

learn their anatomy from cadaver dissections. That will probably never change. In fact, in order to understand the images ultrasound offers, a good knowledge of facial anatomy is required. But ultrasound may offer another way to understand the interrelation of anatomic structures. It can help to gain a 3D insight with the patient sitting right beside the doctor, making it easy to image the relevant anatomy when performing filler treatment. However, one has to invest time and money when introducing DUS into daily practice.

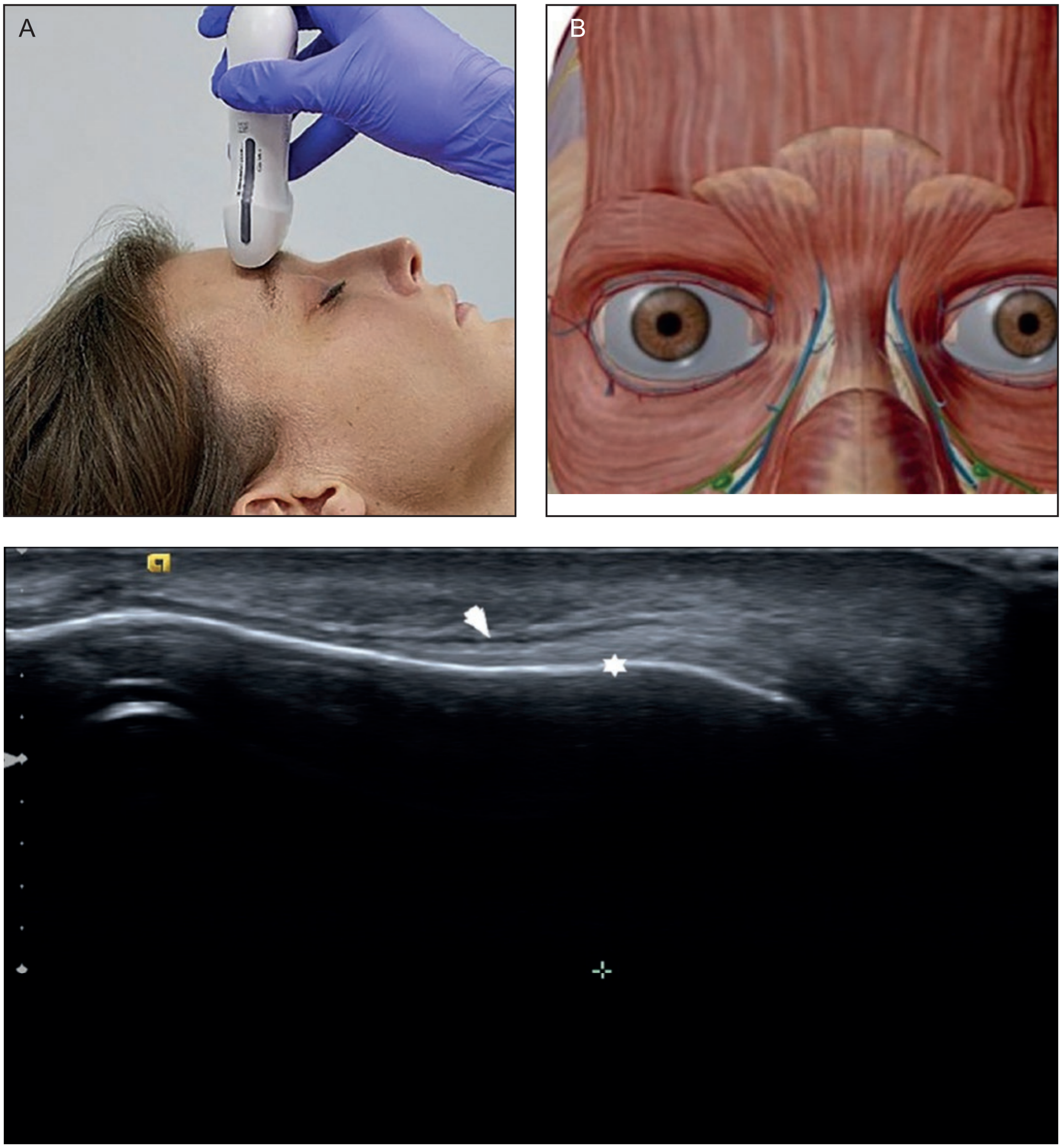

Figure 10. Position 7: forehead. (A) Probe position: axial (horizontal) on glabella and the superior orbital rim. (B) Anatomy: m. frontalis, m. corrugator, m. procerus, supratrochlear and supraorbital arteries. (C) Ultrasound image: frontalis muscle (arrow), frontal bone (asterisk)

CONCLUSIONS

The increased interest in DUS examination of the skin has been boosted by both affordable handheld devices and the emergence of high-frequency devices (18 MHz and higher). These machines will give increasing levels details in superficial imaging. In the future, this may change the way in which cosmetic filler treatments are performed. In addition to cosmetic medicine, DUS imaging holds great promise for anatomy, dermatology, and plastic surgery in a broader sense. With this technology a new area of research may unfold in these specialties.

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Disclosures

Dr Kadouch is consultant for Merz Pharma (Frankfurt, Germany). Dr Schelke, Dr Velthuis, and Dr Jansen are trainers for Cutaneous, facial ultrasound (Noord, Holland). Dr Cotofana is consultant for Merz, Allergan (Noord, Holland), and Galderma (Lausanne, Switzerland). Dr Ascher is Scientific Director of the IMCAS.

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