

Ultrasound Applications in Aesthetic Practice

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Faculty

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Faculty Disclosure

Contributing faculty, Vincenzo Giuliano, MD, DABR, ARMDMS, has disclosed no relevant financial relationship with any product manufacturer or service provider mentioned.

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Division Planners/Director Disclosure

The division planners and director have disclosed no relevant financial relationship with any product manufacturer or service provider mentioned.

Audience

This course is designed for clinicians and healthcare professionals currently performing aesthetic medicine.

Accreditations & Approvals



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NetCE designates this continuing education activity for 4 ANCC contact hours.



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Course Objective

This course is designed to provide clinicians and healthcare professionals currently performing aesthetic medicine with a practical concise guide and overview to using aesthetic ultrasound as a safe diagnostic aid to minimally invasive aesthetic procedures and as a point-of-care modality for patients who have undergone these procedures.

Learning Objectives

Upon completion of this course, you should be able to:

1. Review the terminology and mechanics of diagnostic ultrasound technologies.
2. Define the important biologic effects of ultrasound for clinicians.
3. Review ultrasound techniques for pre-procedure planning, with understand basic tissue properties.
4. Compare and contrast the ultrasound appearance of common cosmetic fillers.
5. Discuss potential pitfalls to avoid when using ultrasound in aesthetic treatments.
6. Identify residual unwanted cosmetic filler and safe methods of dissolution.
7. Discuss ultrasound screening for RF-microneedling for nonsurgical blepharoplasty and evaluation of post-surgical blepharoplasty eye bag swelling.
8. Review use of ultrasound for treatment of vascular occlusion complications of cosmetic fillers.
9. Discuss key anatomic landmarks using ultrasound guidance.



Sections marked with this symbol include evidence-based practice recommendations. The level of evidence and/or strength of recommendation, as provided by the evidence-based source, are also included so you may determine the validity or relevance of the information. These sections may be used in conjunction with the course material for better application to your daily practice.

INTRODUCTION

Diagnostic ultrasound is well established as a point-of-care modality in clinical decision-making, particularly with regard to intervention across various medical and surgical disciplines. While diagnostic ultrasound has remained a staple in medical practice for decades, application-specific use of this modality for aesthetic practice is limited. This course outlines potential uses and techniques of diagnostic ultrasound technology for routine aesthetic practice, while also providing relevant details regarding technology selection, basic points regarding operation, safety considerations, and basic image interpretation.

Cosmetic fillers, a staple of aesthetic practice, are amenable to targeted aesthetic ultrasound. Cosmetic fillers are soft tissue filler injections widely acknowledged as safe and straightforward treatment for aesthetic purposes of volume restoration and rejuvenation. These fillers are derived from various materials, most common including hyaluronic acid, calcium hydroxyapatite, and poly-L-lactic acid. The U.S. Food and Drug Administration (FDA) has approved more than 30 dermal fillers. According to the American Society for Aesthetic Plastic Surgery, an estimated 3,410,730 soft tissue filler injections were performed in the United States in 2020, ranking it as the second most common minimally invasive cosmetic procedure [4]. However, the growing popularity of these procedures has resulted in an expected proportional increase in associated adverse events. Inadvertent filler placement is becoming a more frequent occurrence. Other complications, once considered rare, are now recognized with increasing frequency, most serious being local tissue necrosis and arterial embolism [5; 6]. Recent research and development of newer filler products have circumvented these concerns with enhanced efficacy and minimized complications through novel pharmaceutical design and techniques of administration but nevertheless remain highly user-dependent

based on the experience of the injector [7].

The dominance of aesthetic medicine in recent years, and resulting new variables and potential risks, has created the need for an effective and versatile technology to address these concerns. This course expands on the use of a new discipline of aesthetic ultrasound as a valuable tool for aesthetic practice, with many novel potential applications useful even to the experienced clinician. When properly implemented, aesthetic ultrasound techniques can be applied to any ultrasound system, irrespective of ultrasound vendor.

This activity also provides a salient summary of the types of commercially available ultrasound units (including detailed discussion of piezoelectric versus microchip transducer systems) that can be used in aesthetics practice. Aesthetic ultrasound units are designed for limited or targeted use, not for total body application, typically consisting of a single handheld device (the imaging transducer) in combination with a base system or software. Some clinicians refer to the imaging transducer as imaging probe, a term now generally considered archaic.

Nearly all commercially available ultrasound systems operate on piezoelectric crystal technology for operation [8; 9]. Pioneering research and development with the tech sector has produced newer engineering designs utilizing a vibrating membrane assembly with silicon microprocessor chip, replacing the conventional piezoelectric crystal systems [9; 10]. Aesthetic ultrasound has unique technical requirements of higher spatial resolution of up to 20 MHz at the expense of a larger device footprint, presenting some physical limitations in scanning curved structures, such as facial convexity. Another limitation of aesthetic ultrasound is the lack of certain Doppler vascular applications, mainly a power Doppler (a higher-level application) function only available on larger, more expensive ultrasound systems equipped with suitable technology to visualize smaller lower

flow vessels.

Most commercially available aesthetic ultrasound systems are equipped with conventional color and duplex Doppler capability that can be used to identify high-flow arteries amenable to imaging, such as in the case of facial aesthetic procedures, the superficial temporal artery (typically mapped prior to performing polydioxanone/PDO thread lifts) and the facial artery. The long course of the facial artery is routinely visible from its emergence from the mandible then oblique laterally to the lip commissure, terminating into the nasal ala; furthermore, it can be seen in profile (termed *en face*).

An important technique/application introduced in this course (not commonly used by aesthetic practitioners currently performing ultrasound) is the use of an acoustic standoff pad, which permits greater visibility of superficial soft tissues and vessels by placing the anatomy closer to the optimal focal zone of imaging, thereby optimizing near-field visibility [11; 12]. Without this application, the anatomy of interest is placed too far superficially and greatly limits visualization by crowding superficial soft tissues within a thin space. The acoustic standoff pad is somewhat limited by the large lateral footprint of the ultrasound imaging transducer; therefore, it is better suited for use in combination with transducers of narrow width. The standoff pad technique is particularly advantageous in the visualization of superficial cosmetic fillers and mapping of imaging guided dissolution treatments with hyaluronidase enzyme, when needed.

Finally, this course also discusses the use of aesthetic ultrasound technique as a useful application in the evaluation of lower lid eye bag evaluations, particularly in screenings for periorbital edema versus bulging fat and assessment of the integrity of the orbicularis oculi retaining ligament.

These applications are particularly advantageous during the planning stage. For instance, aesthetic ultrasound can be used to triage non-invasive methods (such as RF-microneedling) versus surgical blepharoplasty, recognizing that not all cases are amenable to treatment and should be referred for surgical blepharoplasty.

TERMINOLOGY

Both aesthetic medicine and radiologic imaging use terminology that are for a highly specialized professional audience. Aesthetic medicine is a combination of art and science involving procedures and techniques to improve and enhance the morphologic appearance, texture, and contour of skin, face, and body. This course references facial aesthetic techniques and technologies that are non-invasive or minimally invasive and be performed without or with local anesthesia.

The lexicon of minimally invasive procedures in aesthetic medicine denotes dermal or subcutaneous injections, punctures, or small incisions that do not require surgery. Therapeutic goals are not standardized and are generally subjective. Most methods and techniques are designed to minimize aging related to skin laxity, rhytids, and contour abnormalities. Desirable therapeutic goals include volumizing, rejuvenation, restoration, resurfacing, and correction, not specific to one standard or facial feature, and therefore variable from individual to individual. This course will not attempt to modify terminology used in the published literature. Several excellent resources are available to familiarize this audience. For the purposes of this course, the terms aesthetic medicine and cosmetic medicine referenced in the literature are interchangeable [1; 2; 3].

Similarly, diagnostic ultrasound uses a complex lexicon of terminology. For this course, the terms ultrasound and sonography commonly referenced in the literature can be regarded as interchangeable. Comprehensive discussion of diagnostic ultrasound as a discipline is beyond the scope of this course. However, new users of this technology are encouraged to refer to available literature, which reviews basic understanding and use of ultrasound-specific language/terminology. This course will not attempt to modify terminology currently used in the published literature. The term aesthetic ultrasound implies use of the same technology used in routine clinical diagnostic ultrasound; however, it is limited in scope and confined to specific anatomic references, procedures, and methods applicable to aesthetic medical practice.

TECHNOLOGY OVERVIEW

Ultrasound is a type of mechanical (not electrical) energy collectively known as sound energy. The normal human range of sound is between 16 Hz to 20,000 Hz (1 MHz = 1 million cycles per second), with higher end of the spectrum seen in children and young adults. Ultrasonic frequencies beyond 20,000 Hz and can be applied in both therapeutic and diagnostic applications. The frequencies generally used in therapy are typically between 1–3 MHz for deeper tissues and 2–20 MHz in diagnostic ultrasound studies. Ultrasound beams are emitted by handheld devices, called transducers, which are mechanized high-frequency sound generators [13; 14]. **Figure 1** illustrates a schematic of a basic ultrasound system.

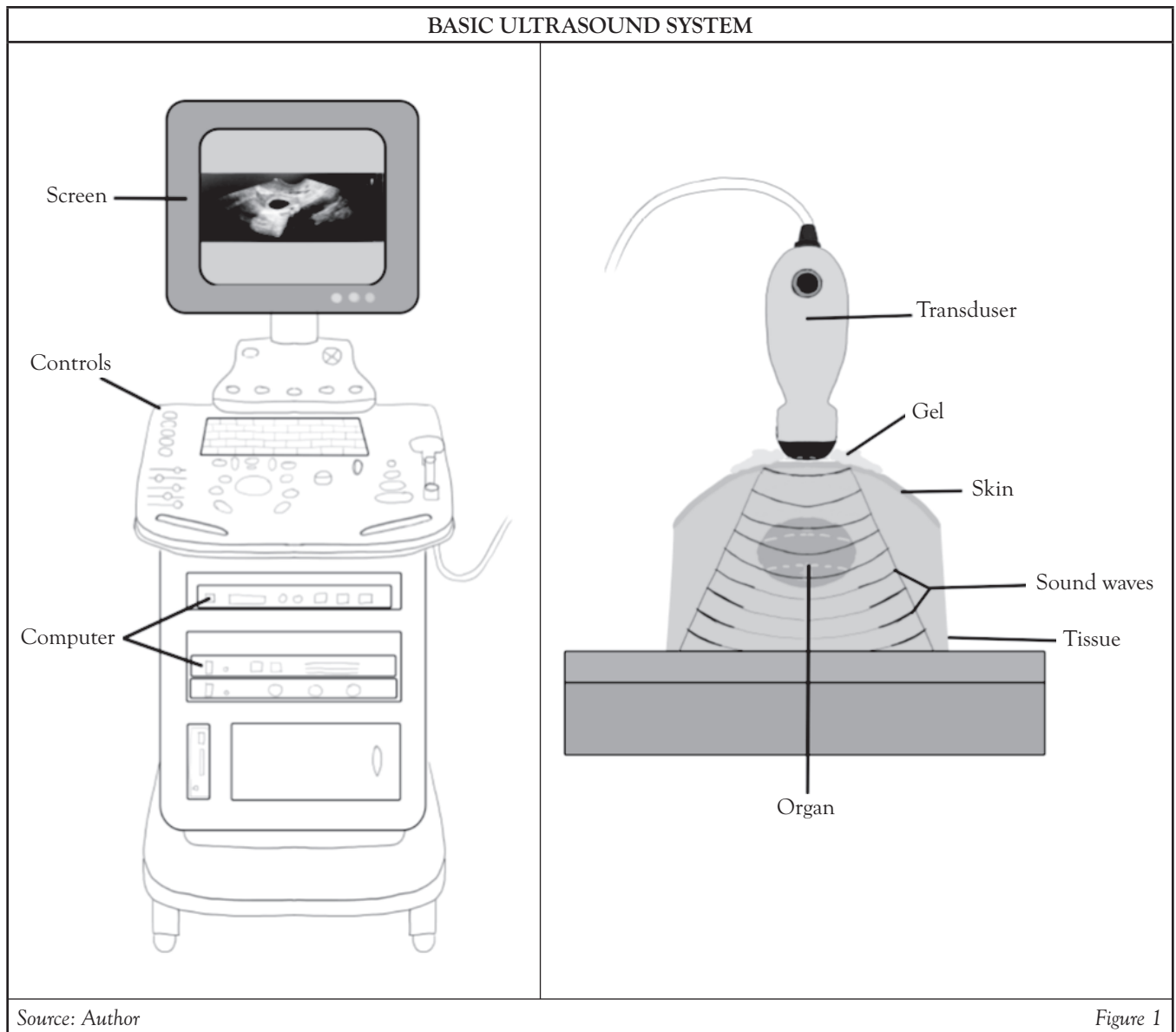
The mechanics of the ultrasound beam is complex. A simplified explanation is a sound wave of longitudinal energy that causes compression and rarefaction, meaning that it will cause oscillation of a fixed point of body tissue, rather than motion of that tissue within the wave itself [15]. Although ultrasound presents a theoretical concern for heat generation and tissue destruction by cavitation, the frequencies used in both therapeutic and diagnostic ultrasound are non-thermal in nature [16]. The energy absorption to body tissues is minimal, but different depending on depth and type of body tissue. In addition, the ultrasound energy is pulsed rather than continuous to further mitigate energy absorption by body tissues [17]. Another important property of ultrasound energy source is that it is non-ionizing, and therefore produces no teratogenic risks in pregnancy and developing fetuses [18].

All body tissues will impede the passage of ultrasound waves, with variability based on tissue density and elasticity. The presence of air and metal will effectively impede nearly 100% of the beam resulting in no effective transmission. For this reason, a coupling gel (typically water-based) is used to maximize contact between the imaging transducer and body tissues for optimal ultrasound wave transmission [19].

Nearly all commercial ultrasound systems are based on piezoelectric (quartz crystal) transducer technology, in which the crystal produces ultrasound waves when an electric current is passed through it. The ultrasound transducer is fabricated from a single piece of piezoelectric quartz material engineered into individual (generally less than 1,000 elements, called an array) attached to shielded electric cables, in three basic transducer configurations: linear, curvilinear, and sector/phased array [8; 9]. The main advantages of piezoelectric systems is superior image quality and ease of use [22; 23]. Disadvantages include limited application of the transducer to single body part, durability, higher cost, inherently lower frame rate (slower image acquisition), and susceptibility to damage when dropped [24; 25].

Newer commercially available non-piezoelectric technologies use a novel engineering of silicon microchip transducers, which can produce targeted ultrasound sound waves for virtually any body imaging application using simulated linear, curved, and phased-array capabilities, with additional platforms for artificial intelligence tools [26; 27]. This pioneering new engineering is still in development and has not replaced conventional piezoelectric systems.

Butterfly was the original portable hand-held silicon microchip unit. Engineering consists of 8,960 membrane (MEMS) elements on a single transducer-on-CMOS microchip, each with individual control and processing circuitry for sending and receiving ultrasound signals through the acoustic lens of a handheld transducer [28]. The MEMS membrane assembly produces an ultrasound sound wave when stimulated by electrical current [29]. Disadvantages include some reduction of image quality related to smaller footprints, limiting lateral resolution [30]. Advantages include lower cost, durability, higher frame rates (sharp images, faster processing), long battery life, total body applications, and military-grade durability, sustaining drops up to 4 feet and forces up to 100 G [10].



Source: Author

Figure 1

Mindray is a state-of-the-art proprietary system on chip (SOC) technology in a compact laptop style workstation, providing ultra-high resolution imaging capability of 20 MHz, and incredibly long battery life of eight hours [32]. Principle differences between Butterfly and Mindray units is that Butterfly is a single probe with multiple array configurations (for multiple body applications), while Mindray is limited to attachable single array probes (not regarded as a limitation for aesthetic application when using a single transducer setup).

BASIC ULTRASOUND OPERATION

This section summarizes basic parameter setting considerations intended as a general guide that can be applied to any ultrasound system, irrespective as to whether a fixed or portable ultrasound system. For facial aesthetics, a transducers generally consist of linear transducer configuration designed for visualization of superficial structures. These imaging transducers will typically have a higher frequency of 7–20 MHz [33]. Low frequency transducers below 7 MHz are not suitable for aesthetic ultrasound and should be avoided [34]. Higher frequency transduc-

ers are not designed to penetrate deep tissue depths of greater than 6 cm; deeper structures or thicker tissues generally require a curved array transducer in a lower frequency range in the range of 3 MHz, designed for increased depth penetration [35; 36].

Detailed diagnostic ultrasound user settings are beyond the scope of this course. However, rudimentary knowledge of a few important basic user settings can be sufficient for routine aesthetic application. These include depth, gain, and Doppler settings.

Depth

Depth is a modifiable setting set by the user, on the imaging parameter screen. As a general rule, set the depth to 1 cm deeper than the intended target to place the anatomy of interest in the center of the focal zone, where the detail will be seen with the highest spatial resolution [37].

Gain

Gain is a modifiable setting set by the user, on the imaging parameter screen. The gain function allows the user to darken or brighten the image to optimize visualization of tissues at various depths [38].

Color Doppler

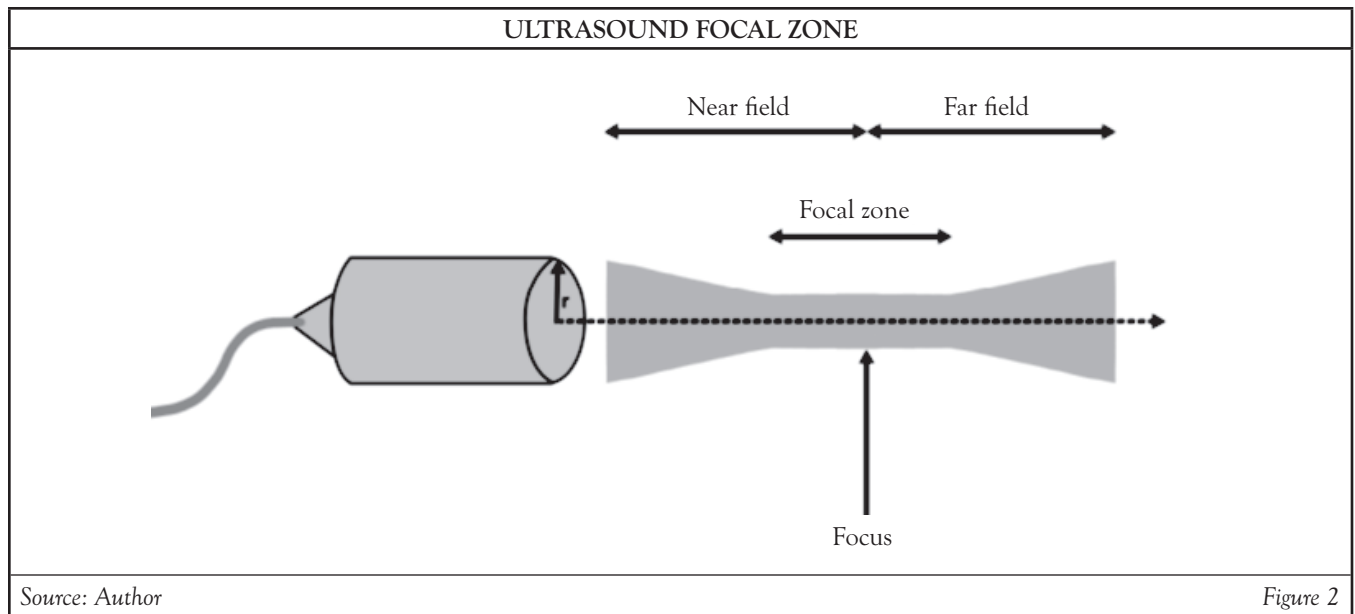
Color Doppler is a modifiable more advanced setting that is beyond the scope of most basic aesthetic practices. However, when mastered, it is a very useful tool in assessing variations in anatomical course of larger arteries, such as branches of the facial artery near the nasal ala, corners of the lip and mouth, and angle of the mandible. The rectangular color Doppler window should be centered over the artery of interest [39]. Color Doppler is most suitable for visualization of the superficial temporal and facial arteries, which are easily detectable high-flow vessels.

BIOLOGICAL EFFECTS OF ULTRASOUND SIMPLIFIED

Ultrasound does not produce ionizing radiation, as in the case of x-ray or computed tomography scans. However, ultrasound does produce acoustic energy that does interact with human tissues, and is therefore considered relevant [40; 41]. Bioeffects, both thermal and non-thermal in nature, need to be considered. Commercially available diagnostic ultrasound units are designed for safe application; no latent harmful biologic effects have been shown in humans [42]. However, scans should be performed setting the amount of acoustic exposure as low as reasonably achievable (known as the ALARA principle) [43]. These biological effects are reported by the manufacturer as two main FDA-required standard preset values that appear on the image display as thermal index and mechanical index.

Thermal index (TI) is an indicator of the potential temperature increase resulting from the friction of tissues interfaces caused by acoustic energy [44]. Mechanical index (MI) is an indicator of non-thermal effects of cavitation from rarefaction of the ultrasound beam [45].

Standard good practices should include making sure factory default settings are integrated into the diagnostic ultrasound image display and performing periodic monitoring of the mechanical index and thermal index values. Minimize scan times to obtain required diagnostic information in the shortest time possible. Whenever possible, keep the transducer moving except when recording diagnostic images. Also apply special care to minimizing acoustic exposure to sensitive tissues (such as the eyes, most applicable when doing facial aesthetic ultrasounds) [46; 47].



PRE-PROCEDURE PLANNING

In pre-procedure planning, the use of an ultrasound gel standoff pad is optimal. The device allows optimized detection and specificity of superficial lesions and peripheral vessels that may be otherwise too superficial to visualize. The device places the anatomy of interest deeper into the focal zone (**Figure 2**), optimizing visualization of the lesion of interest. The technique is particularly useful when using lower resolution ultrasound systems. Currently available aesthetic ultrasound units do not provide power Doppler feature needed to visualize ultra-fine vascular structures, a technology only available on conventional larger complex, expensive state-of-the-art ultrasound imaging systems used in medical clinics and hospital settings.

Ultrasound images involve of spectrum of echogenicity, a medical term for the tissue property of the ability of the sound wave to reflect or transmit in surrounding tissues, each with a visible difference in contrast (from dark to bright) on the imaging screen [48].

Fluid, as can be seen with cystic lesions, are completely devoid of signal (decreased echogenicity) and appears uniformly black (termed anechoic) due to decreased acoustic impedance of the ultrasound wave [49].

Soft tissue encompasses a gray-scale spectrum of possible acoustic properties (heterogeneous echogenicity), ranging from tendons and ligaments on the lower end of acoustic impedance, and appear darker (hypoechoic) to muscle and dermal layers. Subcutaneous fat has the highest acoustic impedance and appears the brightest (hyperechoic) [36].

Calcium and air, with almost complete ultrasound wave impedance, results in a shadowing and scattering of sound waves (devoid of echogenicity), as can be commonly seen with bone and hollow air-containing structures [51].

Cosmetic filler shows a variable appearance (from anechoic to hypoechoic), depending on composition and age [52].

ULTRASOUND APPEARANCE OF COSMETIC FILLERS

Cosmetic fillers have continued to take center stage as safe and effective restoration of facial volume, recontouring, and additional collagen biostimulatory effect, leading to improved skin quality, as validated by their long-term safety, stability, and efficacy. The most commonly used temporary fillers are conjugated hyaluronic acid (HA) fillers and calcium hydroxylapatite (CaHa) [53]. Permanent injectable fillers, such as polymethylmethacrylate (PMMA), are less desirable because they do not break down (termed biodegradable) [54]. HA filler is a preferred agent because it is similar to naturally occurring HA in the body, which forms an integral part of the extracellular matrix for mechanical structure of various body tissues, including skin, muscle, and bone [55].

The FDA designates fillers based on the biodegradability of the filler. Main criteria include absorbable, temporary, semi-permanent, and non-absorbable or permanent [56]. Examples of absorbable/temporary fillers are HA and CaHa; semi-permanent fillers are poly-L-lactic acid (PLLA); and an example of non-absorbable/permanent fillers is PMMA [57]. Criteria for biodegradability are based on how these agents break down. Temporary fillers absorb within 18 months. Temporary fillers use FDA-approved biodegradable materials absorbed by the body over time [58]. Permanent fillers do not absorb within 24 months. For practical purposes, permanent fillers persist indefinitely in tissue [59]. Semi-permanent fillers, such as PLLA combine absorbable material for immediate effect and carrier until a nonabsorbable material induces fibroblast stimulatory effects (in more than 18 months) [60].

Cosmetic fillers can induce minimal tissue response (termed volumizers) or strong tissue reaction (termed stimulators) [61]. The most commonly used cosmetic fillers demonstrate considerable variability with regard to soft tissue contrast dependent on chemical composition and ability to integrate within normal tissues.

Hyaluronic Acid

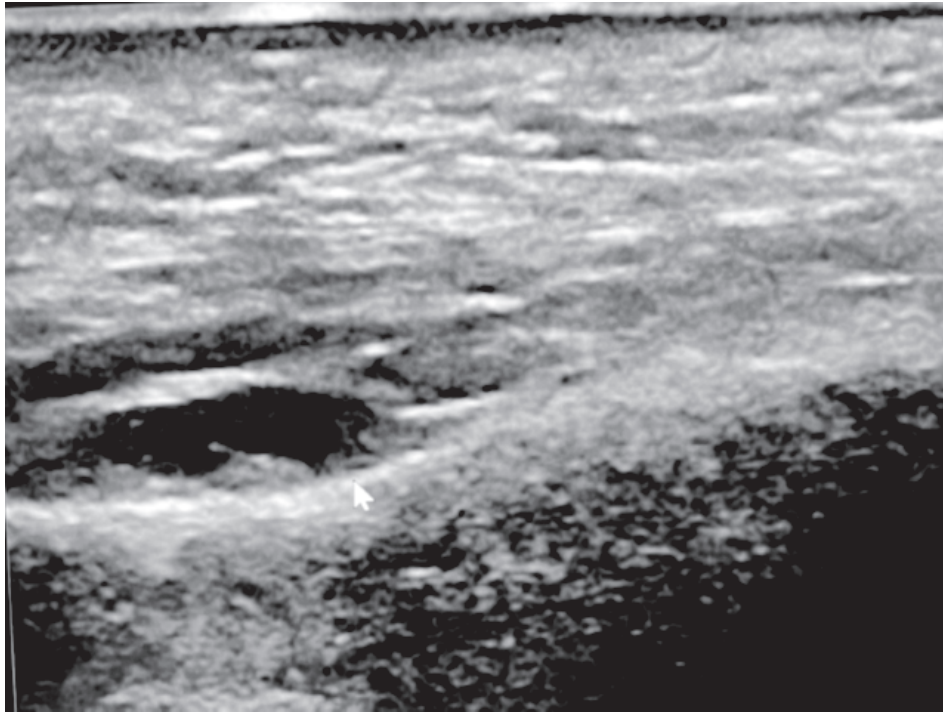
HA is the most commonly used filler in clinical practice. HA is a glycosaminoglycan disaccharide and natural constituent of the dermal extracellular matrix, cartilage, and connective tissue. HA is highly hydrophilic, enabling dermal hyaluronic acid to hydrate and cushion the skin and fill empty spaces within the extracellular matrix [62]. Dermal HA content declines with skin aging, which reduces water-binding capacity and elasticity, inducing volume loss and eventual development of rhytids and other aging features [63].

Unmodified HA readily dissolves in water to form a viscous gel. When injected into the dermis, unmodified HA is quickly degraded by natural tissue hyaluronidase and free radicals in the skin [64]. Most FDA-approved HA fillers are commercially prepared from non-animal stabilized HA synthesized from *Streptococci* bacteria [65].

Liquid stabilized HA, similar to native hyaluronic acid, is rapidly degraded in vivo. To increase stability and longevity, manufacturers use crosslinking agents to bind HA polymer chains to each other, resulting in a gel resistant to enzymatic and free radical breakdown. Most fillers use 1,4-butanediol diglycidyl ether (BDDE) as a cross-linker. The HA acid manufacturing modification process, proprietary to each manufacturer, facilitates a wide spectrum of HA properties with variable gel hardness, lifting ability, tissue bio-integration properties that directly affect long-term gel viability. HA can bind 1,000 times its volume in water. This water-binding and space-filling effect underlies the principal volumizing efficacy of hyaluronic acid fillers [55; 67].

The highly hydrophilic nature of commercial HA gels provides an ideal acoustic appearance on ultrasound. HA acts like fluid, when properly hydrated, appearing anechoic to hypoechoic, with good acoustic transmission. HA does have a variable appearance dependent on filler viscosity, age, and degree of tissue biointegration [68]. Freshly injected HA may not have a significant acoustic footprint and can be imperceptible to normal tissue; it is

SUPRAPERIOSTEAL PLACEMENT OF HYALURONIC ACID FILLER



Source: Author

Figure 3

only when hydrated/fluid-bound and hydrophilic that it appears anechoic to hypoechoic, particularly with highly viscous HA preparations [69]. Acoustic enhancement posteriorly is a property of HA and hydrophilic preparations. An example of suprapariosteal placement of hyaluronic acid filler is illustrated in **Figure 3**.

Calcium Hydroxylapatite

CaHA is a mineral commonly found in human teeth and bones that functions as a scaffold for collagen ingrowth. CaHA filler contains CaHA microspheres as biodegradable particles suspended in an aqueous carboxymethylcellulose gel carrier. Once injected, the carrier gel gradually resorbs; the microspheres stimulate a fibroblastic response resulting in active

physiologic remodeling of the extracellular matrix and long-term collagen deposition around the implant that promotes volumizing [70; 71]. The microspheres eventually degrade into calcium and phosphate ions and are then excreted. Filler duration is around 18 months [72]. Radiesse (formerly Radiance) is the only FDA-approved CaHA filler [73]. This viscoelastic filler is ideal for suprapariosteal and deep fat placement, clinically indicated for correcting moderate-to-severe soft-tissue defects, facial folds, and rhytids, including nasolabial folds [74].

Calcium provides a characteristic acoustic signature on ultrasound. In contradistinction to HA filler, CaHA shows typical shadowing and reverberation artifact from calcium composition.

Poly-L-Lactic Acid

PLLA (Sculptra) is a biodegradable, biocompatible, synthetic polymer, historically used as resorbable sutures, orthopedic plates, urologic stents, and, later, for cosmetic use [75]. PLLA induces a subclinical inflammatory response that stimulates fibroblast proliferation, neocollagenesis, and type I collagen formation, leading to a progressive increase in dermal volume. PLLA provides global volume restoration in lean patients lacking sufficient dermal volume and thickness for space occupying fillers, an alternative to deep volumizing hyaluronic acid fillers that could be too expensive and difficult to use as suitable dermal scaffolding [76]. PLLA injection is recommended for the supraperiosteal injection in the temples, lateral brow, zygomatic area, maxillary area, mandibular area, mental area, and also in the subcutaneous fat in the mid-cheek regions and preauricular area [77].

PLLA presents with mixed or heterogeneous echogenicity, sometimes with acoustic shadowing. For practical purposes, the PLLA ultrasound appearance cannot be reliably distinguished from other cosmetic fillers.

Other Fillers

Free-based silicone, collagen gels, and bio-polymer cosmetic fillers are less commonly used. Silicone has a prominent hypoechoic footprint and can be similar in appearance to mature HA filler.

POTENTIAL PITFALLS

The most important landmarks for aesthetic imaging involve the facial and submental regions, which supply the complex vascular structures and neurovascular bundles. These structures must be avoided in facial aesthetic injections commonly used in clinical practice, such as the reduction of facial wrinkles and contouring. Injectables include botulinum toxin, cosmetic fillers (such as hyaluronic acid and hydroxyapatite) [78].

Botulinum toxin temporarily blocks the neuromuscular junction of underlying muscles, thereby causing relaxation and effectively eliminating wrinkles [79].

Cosmetic fillers are used primarily for volume augmentation and contouring of facial concavities and hollows caused by atrophy and age-related collagen loss. Accidental injury to neurovascular bundles from inadvertent or misplaced injection can result in adverse clinical outcomes, such as vascular occlusion leading to tissue necrosis, and temporary or permanent sensory deficits [80; 81].

More serious complications include rare peripheral nerve transection, with permanent anesthesia due to sensory nerve deficit, and compressive ischemic effects resulting in vasospasm with subsequent embolic phenomenon, blindness, and cerebral infarction [82; 83].

Neurovascular bundles typically consist of nerves, arteries, and veins [84]. In an ideal clinical setting, an ultra-high frequency ultrasound transducer of 20 MHz equipped with power Doppler would provide the best possible visualization of these structures (only available in large complex state-of-the-art ultrasound systems) [85]. However currently available aesthetic ultrasound units designed for aesthetic practice are generally less than 20 MHz and are not equipped with power Doppler capability to detect these very small vessels.

Another practical point is that standard total body ultrasound units equipped with 15–20 MHz transducers and power Doppler have relatively larger footprints, making them unsuitable for highly contoured facial structures. Phillips Lumify, GE V-Scan Air, and Butterfly iQ all use small footprints suitable for facial aesthetics. Clarius and Mindray provide the highest possible resolution (with Clarius having a larger footprint and heavier transducer weight, which could be limiting factors).

The preferred protocol involves the use of smallest possible footprint transducer (for simple ergonomic reasons) in combination with a gel standoff pad, which partially mitigates the problem of decreased near field resolution, particularly with color Doppler vessel signal.

ULTRASOUND-GUIDED AESTHETIC PROCEDURES

IDENTIFICATION OF RESIDUAL COSMETIC FILLER AND DISSOLUTION TREATMENTS

Anecdotal experience has suggested that HA fillers have a much longer lifespan than initially assumed. Prospective MRI studies have shown that HA fillers designed to dissolve within 6 to 12 months, surprisingly, can persist for up to 10 years post injection [86]. To date, there are no detailed clinical studies documenting a timeline of how long the dissolution process occurs in vivo, in human subjects [87]. Researchers have proposed a mechanism that the majority of dissolution occurs in the first initial weeks post-injection following a brief inflammatory response where hyaluronidase is produced by leukocytes causing a partial reduction in HA filler volume, a process that is dependent on the vascularity of the tissue. Once this inflammatory process has dissipated, the endogenous production of naturally occurring hyaluronidase is minimal [88]. Another consideration is a comparison between naturally occurring HA produced in the body, in vivo, compared to commercially prepared HA. Typical half-life of naturally occurring HA is one day or less in skin and dermis, compared with three weeks or less in cartilage. Commercial preparations of HA are typically cross-linked, making them more resistant to chemical breakdown, often lasting for months and years [89].

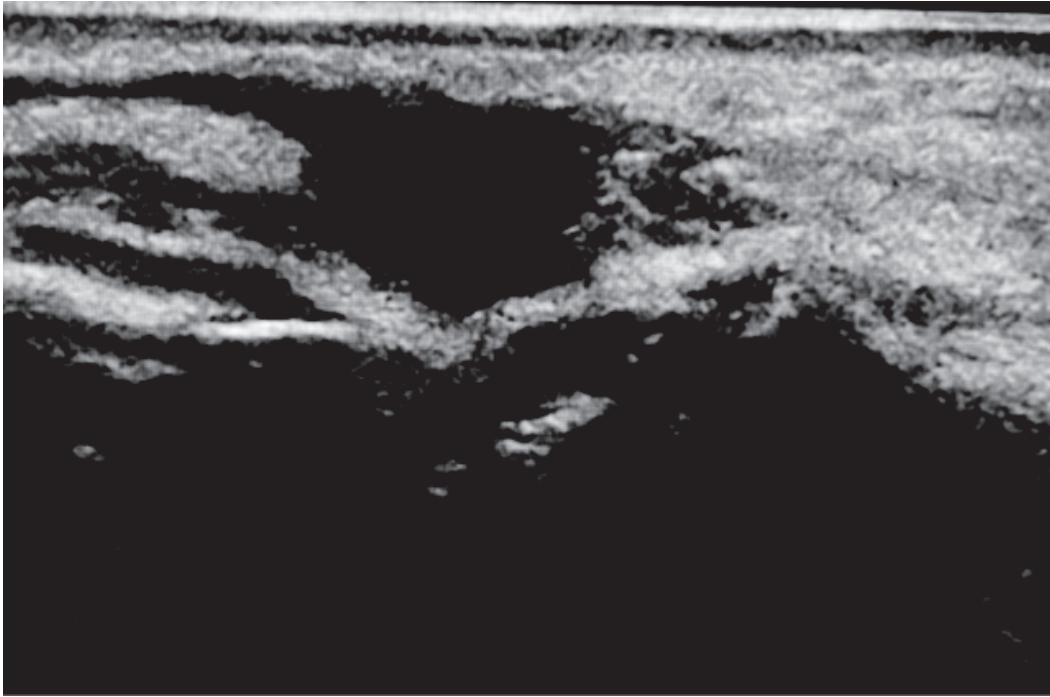
Ultrasound is a useful diagnostic tool in determining volume of residual “old” filler present and can assist in planning of volume and placement of “new”

filler. Specific issues to consider with regard to undesirable “old” filler, is inappropriate filler depth placement, such as superficial placement resulting in Tyndall effect. Tyndall effect is used to describe the bluish hue or discoloration that is visible under the skin from superficial placement of HA filler [90]. Another consideration is inadvertent filler location placement, for example, above the annular retaining ligament, resulting in an exaggerated eye bag or more generalized eye bag swelling. Another consideration is the unintended migration of properly placed cosmetic filler, even when appropriate injection technique was utilized, such as in the case of properly injected supraperiosteal injection of HA filler below the malar fat pad in the cheek. The supraperiosteal malar injection of cheek filler can be problematic, particularly in patients with underdeveloped cheek bones (also referred anatomically as the zygomatic or malar bone). In cases of unwanted HA filler, precision guided ultrasound techniques could be used to administer hyaluronidase in order to dissolve unwanted filler [91; 92].

Of the two commonly used temporary cosmetic fillers available commercially, HA filler is the most widely recognized and used [93]. Hydrated HA filler has an anechoic to hypoechoic appearance (similar to simple fluid), and stands out as distinctly darker than surrounding tissues, such as skin, dermis, and muscle. Some heterogeneity within the filler could be encountered, depending on age and maturity of the filler, probably the result of biointegration into surrounding tissues [94].

In clinical experience, the use of hyaluronidase can prove highly effective. Hyaluronidase are enzymes (endoglycosidases) can depolymerize HA leading to degradation by hydrolyzing the disaccharide linkages. Hyaluronidase should only be administered by a board-certified medical professional, and only FDA-approved brands should be used, such as Hydase, Hylenex, Amphadase, and Vitrase [95]. Under no circumstance should hyaluronidase be used from an unverified source. Literature references

TARGETED ULTRASOUND OF AN AREA OF DISSOLVED FILLER



Source: Author

Figure 4

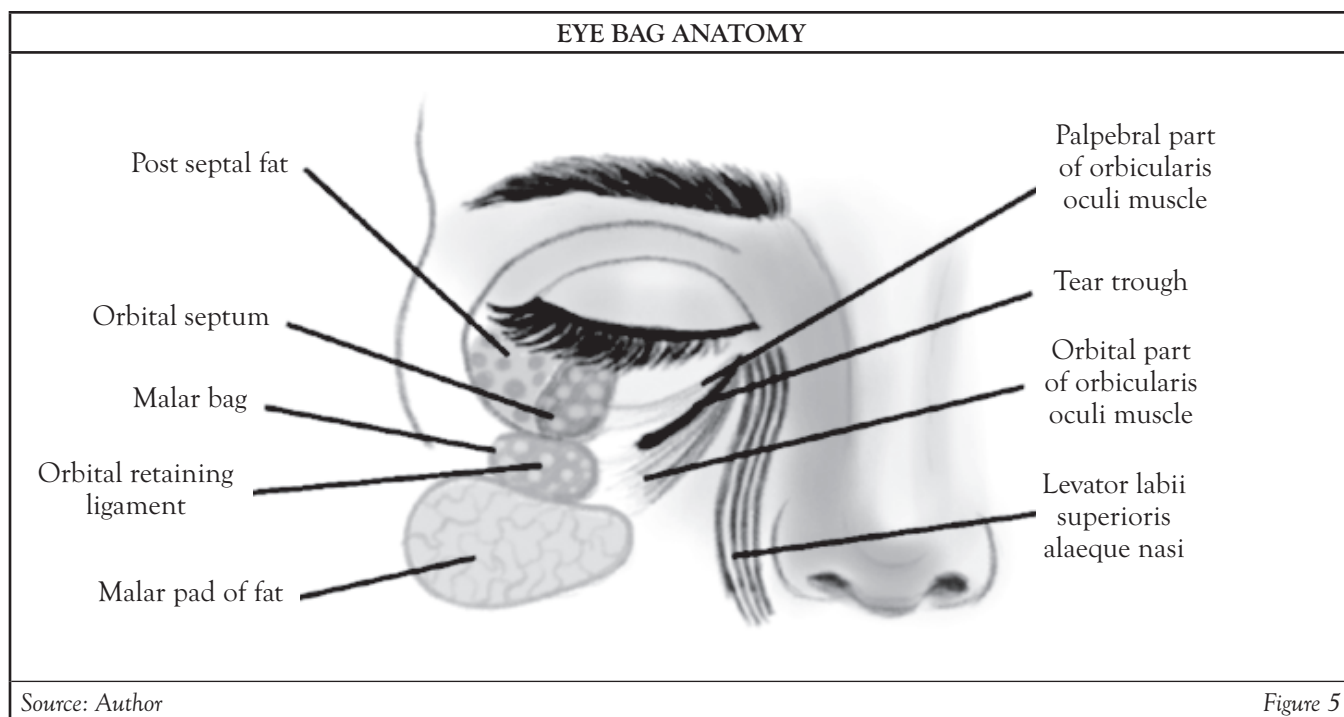
suggest 5 IU of hyaluronidase for each 0.1 mL of HA [96; 97].

Typical ultrasound appearance of unwanted or residual HA filler is anechoic to hypoechoic, suggesting that the filler is reasonably well hydrated. One protocol consists of targeted treatment using micro-injections of 15 IU, not exceeding 150 IU in total, administered in a radial pattern within unwanted (anechoic or hypoechoic) hydrated filler, dependent on volume of residual HA filler. Large quantities of HA filler (greater than 3 mL) could require repeat injections at one- or two-week intervals. Use of high-dose dose hyaluronidase flooding protocols (greater than 150 IU in a single session) is discouraged because of potential leakage into surrounding body tissues, risking an extended area of potential tissue

breakdown. The effects of treatment are generally immediate, and a follow-up targeted ultrasound of the area shows no residual HA filler (**Figure 4**) [98].

Ultrasound is also suitable for more problematic cases. Integrated or scarred HA filler placements show a less dark streak-like appearance on ultrasound (more on the isoechoic tissue spectrum), indicating a probable more fibrous rather than hydrated appearance. In clinical experience, these are generally resistant to hyaluronidase treatment and would require other methods of treatment (such as RF-microneedling).

In contradistinction, CaHa filler is composed of calcium-matrix and shows prominent acoustic shadowing (similar to bone), which is typical of a material



with characteristically poor acoustic impedance [99]. CaHa is exceedingly difficult to dissolve chemically [100]. A preclinical pilot study using sodium thiosulfate showed statistical decreases in volume (attributed to dispersion), but with additional risks of tissue necrosis and hemorrhage; the study was terminated early due to side effects [101]. There are currently no long-term prospective studies justifying future continued use of sodium thiosulfate.

NONSURGICAL BLEPHAROPLASTY (RF-MICRO NEEDLING) SCREENING CONSIDERATIONS

The orbicularis retaining ligament forms the superior border of the nasolabial and medial fat compartments. These two compartments combine to form the malar fat pad, an important structure in midface aging [102]. Elevation and repositioning of the malar fat pad is the primary target for midface aesthetic enhancement [103].

Blepharoplasty is a procedure to rejuvenate the upper and lower eyelids, either by surgical or non-surgical methods, and represents the fourth most

common cosmetic surgical procedure in the United States [104]. RF-micro needling (such as AGNES technique) offers a viable non-surgical alternative for achieving long-term youthful and natural appearance to the eye and periorbital area [105]. Volume preservation and enhancement, rather than excessive tissue removal, define the modern blepharoplasty methodology [106]. The goal in the upper lid is to decrease eyelid laxity and increase visibility of the pretarsal space by micro-contouring [107]. The goal in the lower lid is to create a smooth lower lid surface and seamless transition into the cheek, combining micro-contouring with fat removal of the eye bag, if required [108].

The contents of the eye bag (**Figure 5**) are an important part of the screening protocol for non-surgical versus surgical blepharoplasty planning in which ultrasound can promising diagnostic utility. The contents of the eye bag (principally the distinction between fluid edema from fat) are equally important to elucidate during the screening procedure. The distinction of periorbital edema and fluid from normal fat can be tricky clinically, but easily elucidated

with ultrasound.

Another indication for ultrasound is to address excessive periorbital swelling related to over-correction/over-filling of the tear trough area under the eye using cosmetic filler. This is the result of incorrect placement versus migration of filler above the orbicularis retaining ligament or due to superficial filler placement under the skin [109]. The mechanism of this phenomenon is unclear and difficult to treat clinically [110]. The only solution is to dissolve the filler and then replace the filler using modified (superolateral) technique [111]. The orbicularis retaining ligament forms the superior border of the nasolabial and medial fat compartments, which combine to form, collectively, the malar fat pad, a recognized structure affected by midface aging [102]. Cosmetic fillers attempt to rejuvenate the midface by elevating and repositioning the malar fat pad via supraperiosteal injection [103].

Three distinct ultrasound gray-scale appearances can be anticipated in ultrasound screening evaluations of the malar fat pad. Periorbital edema/fluid is anechoic (appears dark on the scans), with posterior wall acoustic enhancement due to low acoustic impedance of water [112]. HA is anechoic to hypoechoic (appears dark to a shade less darker than fluid), a property that is variable, with mixed acoustic impedance, based on the type/viscosity, age of the filler, and degree it has integrated into the surrounding soft tissues [113]. Fat is hyperechoic (appears bright on the scans), due to high acoustic impedance, and easily distinguished from both fluid and HA filler [114].

Periorbital edema is relatively uncommon in routine outpatient practice. However, a careful screening should be performed to exclude premalar and cheek swelling; in such cases, hypothyroidism should be excluded prior to aesthetic treatments [115].

ULTRASOUND EVALUATION OF POST-SURGICAL LOWER BLEPHAROPLASTY EYE BAG SWELLING

Lower lid blepharoplasty is a special consideration amenable to diagnostic ultrasound evaluation. Two common surgical approaches are the transconjunctival and skin-muscle flap blepharoplasties. The main distinguishing feature between the two procedures is that the transconjunctival approach does not violate the orbicularis oculi muscle, relying on a skin-only incision, in contradistinction to the skin-muscle flap technique that tightens the orbicularis oculi muscle, resembling a SMAS facelift [108].

Irrespective of technique, there are no standardized outcome criteria for either procedure [108]. Postoperative complications after blepharoplasty include hematoma, asymmetry, lagophthalmos, lower lid malposition, scleral show, dry eyes, frank lower lid ectropion, lateral canthal webbing, and chemosis. The most devastating complication after blepharoplasty is blindness that can occur as a result of globe injury, retrobulbar hematoma, and/or fat grafting; these complications are exceedingly rare in experienced hands [108].

While reported complications and reoperation rates in the literature are generally low, they probably do not reflect actual outcomes encountered in common practice, as they are often published in series of experienced surgeons [108]. The duration of postoperative recovery after blepharoplasty is under-reported and probably underestimated [108]. Of particular interest is a phenomenon called chemosis, a bulbar conjunctival swelling that can occur with varying severity, mainly in the setting of lower blepharoplasty, with a reported occurrence of less than 12% and as high as 34% (in a single study) [117; 118]. Multiple etiologies have been proposed for the development of chemosis, including inflammation, exposure, and lymphatic disruption.

Anatomical studies of the periorbital lymphatic drainage suggest the presence of a deep lymphatic drainage system that drains the conjunctiva and

passes deep to the preseptal orbicularis piercing the orbicularis retaining ligament laterally at its junction with lateral orbital thickening. Consequently, procedures involving deep lateral dissection can theoretically increase the incidence of chemosis [108].

Reported treatments, including frequent lubrication of the conjunctiva with wetting drops, topical antibiotic/steroid ointments, and vasoconstrictive agents, are generally effective for mild chemosis, which is benign and self-limited [108]. However, there are no effective treatment strategies for more serious cases [108].

Ultrasound evaluations of eye bag swelling following blepharoplasty can prove useful in establishing a diagnosis of chemosis. Such evaluations should be reserved for cases exceeding six months duration and cleared by the cosmetic plastic surgeon, for which no explanation or viable treatment is offered. In clinical experience, a key diagnostic feature is a thin anechoic/hypoechoic fluid collection (which can be subtle, only 2–3 mm deep) lateral to the mid-pupillary line at the level of the infraorbital fissure, typically in a suprapariosteal location and contained by the orbicularis retaining ligament. Disruption of the lymphatic drainage of the conjunctiva is a potential etiology. Accordingly, treatments should be directed at improving lymphatic drainage (such lymphatic Hydrafacial massage), sometimes combined with cryotherapy, and have found moderate improvement of previously refractory cases. Hydrafacial is patented facial treatment device designed for exfoliation, cleansing, extraction, and hydration to the face using a vortex swirling action, with an additional lymphatic massage setting [119].

EARLY ULTRASOUND AND TREATMENT OF VASCULAR OCCLUSIONS

Vascular occlusion is a legitimate concern given the complex array of facial arterial anastomoses, asymmetry, and anatomic variation. Adverse outcomes appear related to the large number of cosmetic filler injections (more than 3 million procedures performed annually in the United States alone), and can be encountered even with experienced injectors. Most common complications are tissue ulceration, skin necrosis, and, rarely, blindness [120]. The FDA has issued a safety warning since 2015 [120]. The incidence of cosmetic filler related skin necrosis is 1:100,000 (or 0.001%). About 50% of complications occur in the glabellar region due to poor collateral circulation. The most common symptom of vascular occlusion is livedo reticularis, a netlike pattern of reddish-blue discoloration (occurring in 100% of patients), and decreased sensation (in 50% of patients). The most common sites of filler-related skin necrosis are the nose (33%) and nasolabial folds (30%). The most common site of filler-related blindness is the glabella (50% of cases) [121; 122; 123].

One of the principal advantages of HA fillers is their complete reversibility with hyaluronidase, an enzyme consisting of endoglycosidases that cleave the glycosidic bonds, inducing rapid depolymerization [124].

Hyaluronidase is the first line treatment of vascular occlusion [125]. Published treatment protocols range from high-dose flooding regimen with a mean dose of 500 IU for ischemic area of 3 x 3 cm, versus ultrasonically guided pulsing of 35–60 units into the area daily for three to eight treatment sessions until normal skin color returns [126]. High doses increase the risk of retinal toxicity with inadvertent intravascular injections of the enzyme in the periorbital region. In most cases complete recovery is generally encountered in less than 12 hours, somewhat longer in chin necrosis from injury to the larger submental artery. The mean time for complete reversal of vas-

cular occlusion is 72 hours, with a maximum of 7 days. Successfully treated patients encountered no delayed ulceration, crusting, or skin damage [127; 128]. Ultrasound guidance offers a distinct advantage of precision delivery of lower doses, with the benefit of increased safety.

STRATEGIC ANATOMIC LANDMARKS, CONSIDERATIONS, AND DANGER ZONES

Aesthetic ultrasound is particularly useful in arterial mapping to identify potential “danger zones” of vascular occlusion and embolic complications. A discussion of relevant ultrasound-guided anatomic details is organized by zones in the upper, mid, and lower face, adapted from the current literature [129; 130].

UPPER FACE

Superficial Temporal Artery (Facial Danger Zone 2)

The superficial temporal artery is a branch of the external carotid artery and divides into frontal and parietal branches at the cranial portion of the zygomatic arch. The parietal branch is more medial and superficial to the temporal fascia, overlying the temporalis muscle, and must be avoided [131]. Inadvertent direct injection and/or compressive ischemia can cause retrograde embolization of the ophthalmic artery and blindness [132]. The superficial temporal artery must be carefully palpated and marked; cannula placement should be medial when placing polydioxanone (PDO) threads for midface lifts. The superficial temporal artery is visible with color Doppler ultrasound, when performed with proper technique (*Figure 6*).

Supraorbital Groove/Foramen

The supraorbital groove and foramen form a subtle

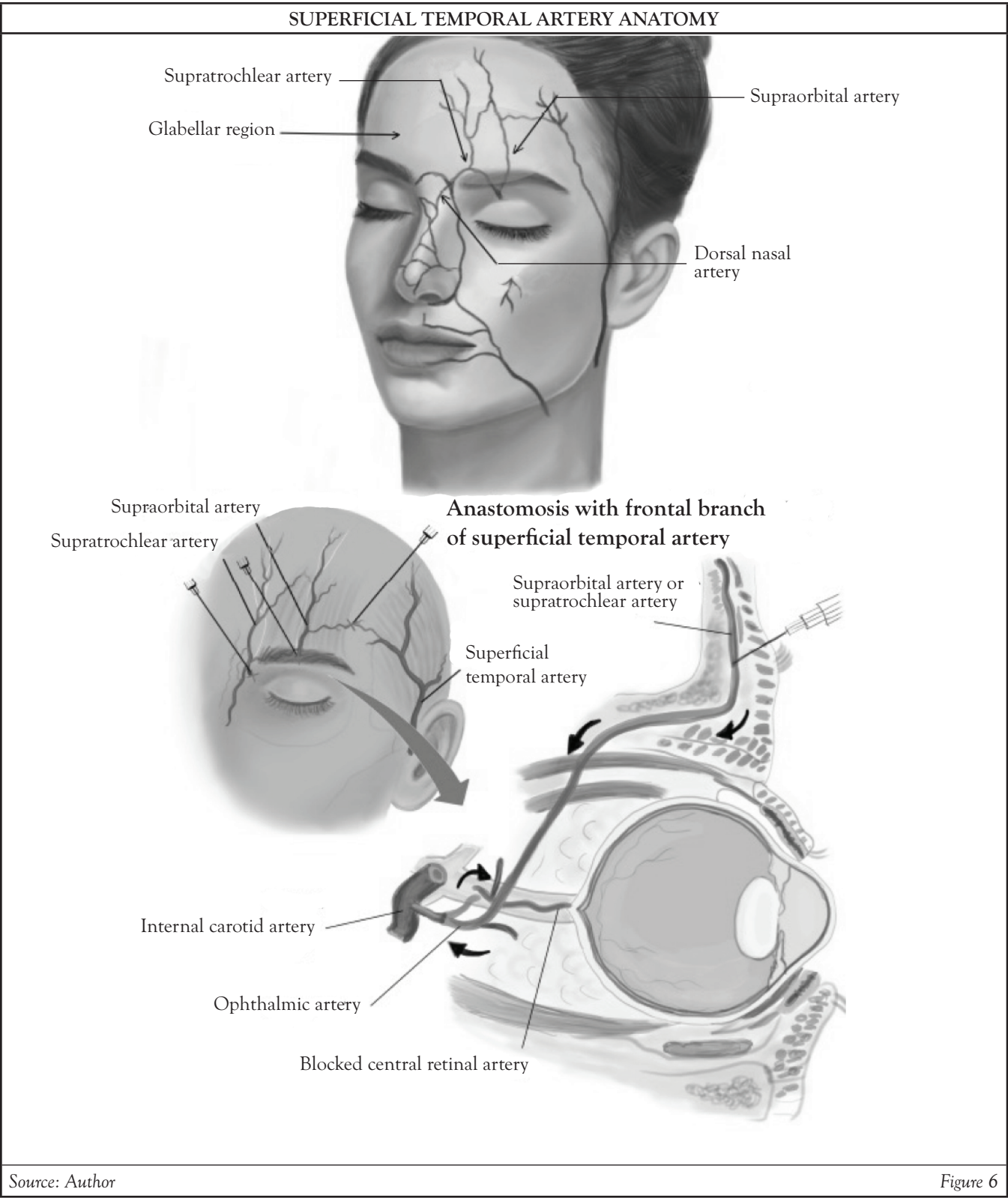
depression in the medial edge of the cranio-orbital margin of the frontal bone. The supraorbital groove and foramen contains the supraorbital artery (the terminal branch of the ophthalmic artery) and supraorbital nerve (first branch of the trigeminal nerve) [133]. The caliber of the supraorbital artery is too small and not amenable to conventional color Doppler ultrasound not otherwise equipped with power Doppler capability. However, the supraorbital groove can be localized on ultrasound and provides a precise location of the supraorbital artery in situations where it is not easily palpated.

Supraorbital (ophthalmic) nerve blockade is performed with a 27-gauge short needle and administering 2 cc 0.5% bupivacaine (or 50:50 mixture of lidocaine and bupivacaine) superficial to the periosteum upper/medial brow of the supraorbital notch, resulting in a characteristic sensory anesthesia dermatomal pattern [134].

Supratrochlear Artery (Facial Danger Zone 1)

The supratrochlear artery and branches are highly vascular and supplies the glabellar region. Inadvertent direct injection and/or compressive ischemia can cause retrograde embolization of the ophthalmic artery, blindness, and glabellar skin necrosis [135]. The glabella is the most common filler injection site leading to blindness [136]. Techniques for correcting deep rhytids in the glabellar region should include small intradermal microinjections and avoiding over filling [137]. The supratrochlear artery is too small in caliber and not amenable to conventional color Doppler ultrasound not otherwise equipped with power Doppler capability.

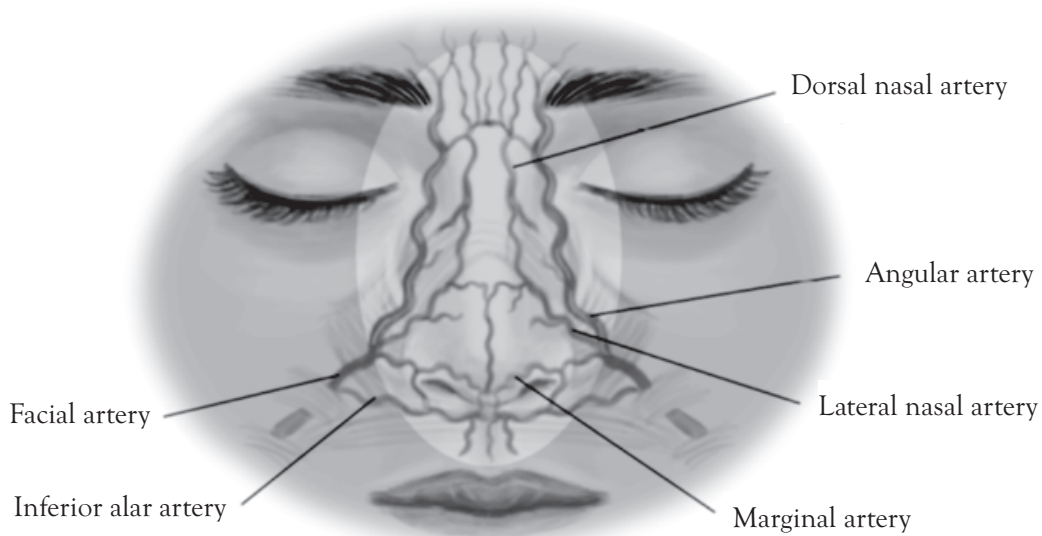
Nasal/Paranasal Septum (Facial Danger Zone 5)



Source: Author

Figure 6

PARANASAL AREA ARTERIES



Source: Author

Figure 7

The nasal and paranasal small network of arteries are too small in caliber and not amenable to conventional color Doppler ultrasound not otherwise equipped with power Doppler capability.

The dorsal nasal artery is a terminal branch of the ophthalmic artery and emerges from the medial orbital rim along the nasal septum [138]. The angular artery is the terminal portion of the facial artery and located at the lateral margin of the ala of the nose [138].

The paranasal area becomes a target in aesthetic practice, particularly with regard to injection of cosmetic fillers in achieving a “liquid rhinoplasty” or nasal contouring (**Figure 7**). Unlike other areas of cosmetic filler injections, midline nasal injections should be injected deep rather than superficial, because vascularity is more superficial, avoiding nasal bridge and ala [139]. Safe zones include midline middle third and lateral zone between the

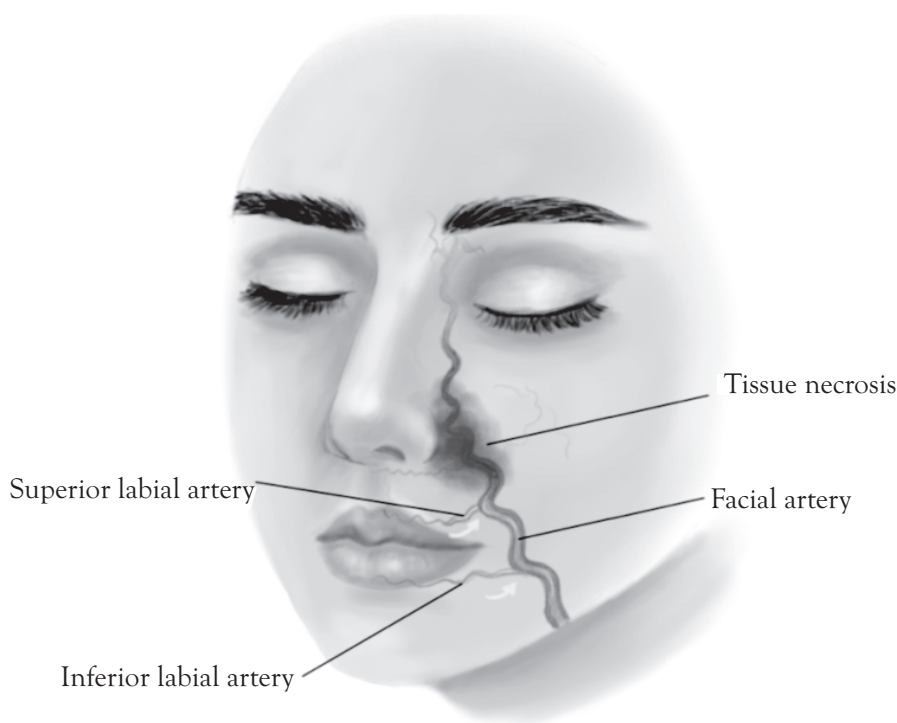
borders of the lateral nose and nasofacial groove. Avoid superficial injections of the alar tip and alar groove (avoid the crease) [139]. Nasal injection is the leading cause of tissue necrosis (**Figure 8**) [139; 140].

MID FACE

Infraorbital Groove/Foramen (Facial Danger Zone 6)

The infraorbital groove and foramen contain the infraorbital artery (a terminal branch of the maxillary artery) and infraorbital nerve (a branch of the maxillary nerve, second branch of the trigeminal nerve) [141]. Approaches to tear trough injections of cosmetic filler in the cheek should be lateral to the mid-pupillary line, avoiding the infraorbital foramen, using lateral entry with preperiosteal needle track and deep retrograde injection technique [142]. The caliber of the supraorbital artery is too small and not amenable to conventional color Doppler

PARANASAL TISSUE NECROSIS



Source: Author

Figure 8

ultrasound not otherwise equipped with power Doppler capability. However, the infraorbital groove can be localized on ultrasound and provides a precise location of the infraorbital artery in situations where it is not easily palpated.

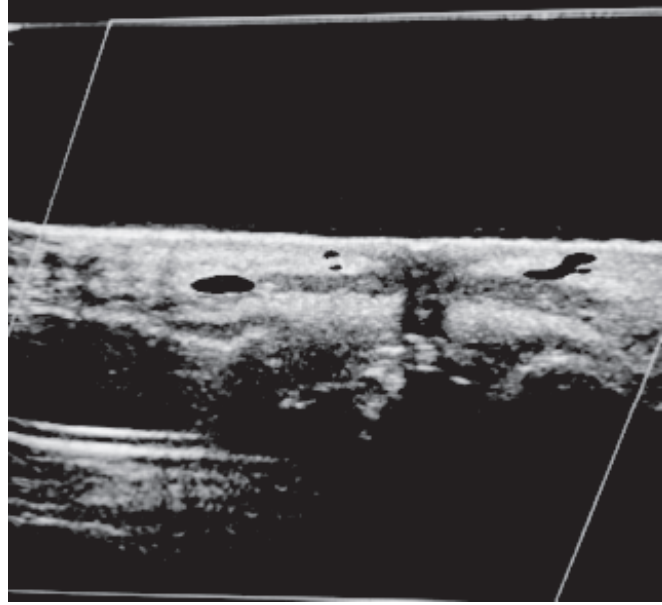
Infraorbital nerve blockade (percutaneous approach) is performed with a 27-gauge short needle and administering 2 cc 0.5% bupivacaine (or 50:50 mixture of lidocaine and bupivacaine) superficial to the periosteum medial mid-pupillary line just below the infraorbital ridge, resulting in a characteristic sensory anesthesia dermatomal pattern [143].

Facial Nerve

The path of the facial nerve originates at the brain stem, to temporal bone, via facial nerve canal, and exits the skull base via the stylomastoid foramen, superficially to the parotid gland, between the superficial and deep lobes at the level of the mandibular ramus [144]. Inadvertent injection of the parotid gland can cause temporary facial nerve paralysis (typically days to weeks) [145].

Facial Artery (Facial Danger Zone 4)

DOPPLER ULTRASOUND OF THE FACIAL ARTERY



Source: Author

Figure 9

The facial artery is a branch of the external carotid artery, emerging superficial to the posterior belly of the digastric muscle, stylohyoid muscle, and submandibular gland, and coursing in a continuous oblique plane (1.5 cm) from the lateral commissure of the mouth to nasal ala along the lateral border of the nasolabial fold [146]. Proper injection technique for injecting cosmetic filler to the nasolabial fold is medial and very superficial, targeting the lower two-thirds intradermal plane, avoiding the nasal ala, where facial artery is most superficial [147]. Inadvertent direct subcutaneous intravascular facial artery injection and/or compressive ischemia in the upper third of the nasolabial fold can result in an ocular embolism, blindness, and necrosis of the alar and malar region of the nose and cheek [148]. The facial artery is visible with color Doppler ultrasound when using proper technique (**Figure 9**).

LOWER FACE

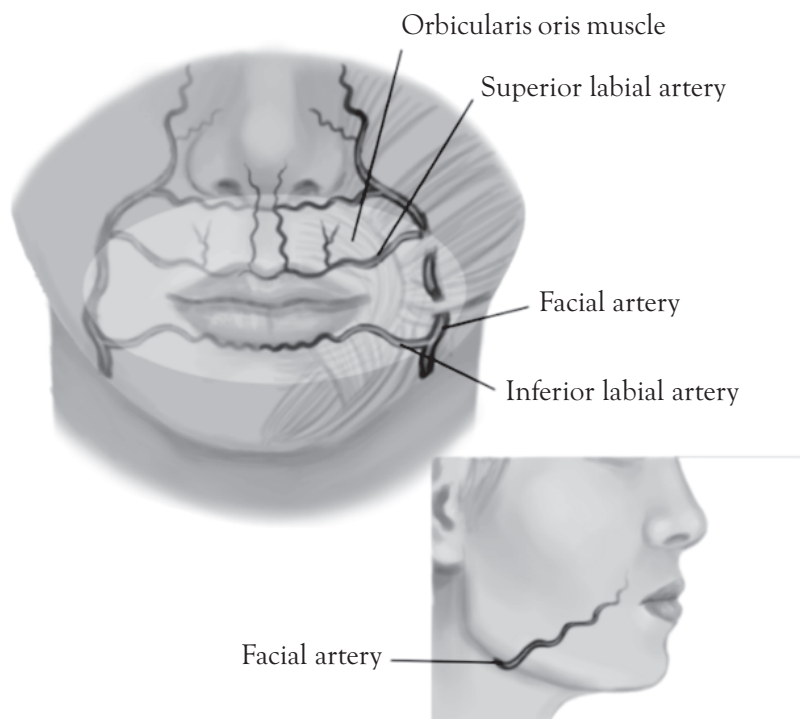
Labial Arteries (Facial Danger Zone 3)

The facial artery is located 15 mm lateral to the lip commissure and divides into the superior labial artery in the upper lip and inferior labial artery of the lower lip (**Figure 10**). These arteries are typically deep and run between the orbicularis oris muscle and oral mucosa [149]. General rules when addressing this facial area are [20; 149]:

- Always inject superficially and low-pressure injection
- Never inject deeper than 3 mm from the skin or vermillion border (avoiding muscle)
- Stay within a thumb width of the lip commissure
- Inject slowly using retrograde technique

In addition, one should avoid the interior of the Cupid's bow, or philtrum [20; 149]. The labial

LABIAL ARTERIES



Source: Author

Figure 10

arteries are too small in caliber and not amenable to conventional color Doppler ultrasound not otherwise equipped with power Doppler capability.

Mental Foramen

The mental foramen is lateral to the mental protuberance of the chin at about the level of the lateral commissure of the lower lip, and contains the mental nerve (branch of the mandibular nerve of the third branch of the trigeminal nerve). The mental nerve provides sensation to the chin and lower lip [21].

Retromandibular Groove

The submental artery branch of the facial artery is

seen in the inferior border of the mandible within the retromandibular groove at the mandibular notch, superficial to the mylohyoid muscle, and oriented in the long axis of the body of the mandible [31]. Avoid direct injections in the area of the retromandibular groove when applying local anesthesia to cheek and jawline [50]. The submental artery is visible with color Doppler ultrasound (**Figure 11**).

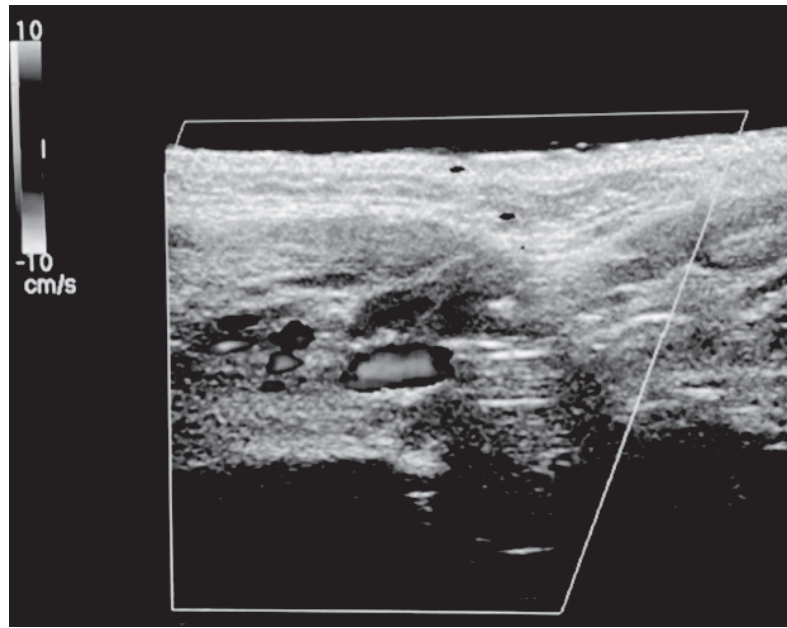
Hypoglossal Nerve

The hypoglossal nerve is the 12th cranial nerve that innervates the tongue muscles and forms a long medial course to the submental artery and vein along the inner body of the mandible, anterior the posterior, from the ear to chin [66]. Avoid direct injections in the area of the retromandibular groove [116].

CONCLUSION

The utility of aesthetic ultrasound as an adjunct

DOPPLER ULTRASOUND OF THE SUBMENTAL ARTERY



Source: Author

Figure 11

modality available to clinicians to understand and elucidate various technical, anatomic, and treatment-related issues has gained increased relevance due to large number of aesthetic procedures performed by healthcare professionals across various medical disciplines. Modern aesthetic ultrasound units offer exceptional portability and convenience that can be used in daily clinic, office settings, and spas. More importantly, these technologies enable detailed and precision visualization that can safeguard potential complications of aesthetic procedures.

Implicit Bias in Health Care

The role of implicit biases on healthcare outcomes has become a concern, as there is some evidence that implicit biases contribute to health disparities, professionals' attitudes toward and interactions with patients, quality of care, diagnoses, and treatment decisions. This may produce differences in help-seeking, diagnoses, and ultimately treatments and interventions. Implicit biases may also unwittingly produce professional behaviors, attitudes, and interactions that reduce patients' trust and comfort with their provider, leading to earlier termination of visits and/or reduced adherence and follow-up. Disadvantaged groups are marginalized in the healthcare system and vulnerable on multiple levels; health professionals' implicit biases can further exacerbate these existing disadvantages.

Interventions or strategies designed to reduce implicit bias may be categorized as change-based or control-based. Change-based interventions focus on reducing or changing cognitive associations underlying implicit biases. These interventions might include challenging stereotypes. Conversely, control-based interventions involve reducing the effects of the implicit bias on the individual's behaviors. These strategies include increasing awareness of biased thoughts and responses. The two types of interventions are not mutually exclusive and may be used synergistically.

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