

Clinical Algorithm for Ultrasound-guided Facial and Neck Rejuvenation

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Abstract

The global rise in demand for minimally invasive esthetic procedures has underscored the need for enhanced precision and safety. This study presents a novel clinical algorithm integrating real-time ultrasound (US) guidance into facial and neck rejuvenation treatments to improve procedural outcomes. Conducted over four years with 56 patients, the study utilized high-frequency B-mode imaging, Doppler functionality, and superb microvascular imaging (SMI) to map anatomical structures, optimize treatment planning, and guide interventions. The algorithm follows a systematic, step-by-step protocol encompassing patient selection, anatomical assessment, procedure execution, and postoperative evaluation. Results indicated a significant improvement in procedural precision, with reduced complication rates and higher patient satisfaction. Notably, 85% of patients rated their outcomes as "much improved" or "very much improved" on the Global Aesthetic Improvement Scale (GAIS). The US-guided approach enabled more accurate filler placement, minimized vascular complications, and improved outcomes compared to traditional techniques. These findings support the integration of US diagnostics in esthetic practice to enhance safety, optimize results, and contribute to the evolving standards of care in non-surgical facial rejuvenation.

Keywords: Aesthetic medicine, facial rejuvenation, neck rejuvenation, ultrasound-guided procedures

INTRODUCTION

Minimally invasive esthetic procedures have seen a significant rise in popularity globally, particularly over the last decade. These treatments offer numerous benefits, including reduced recovery times, fewer complications, and lower costs compared to traditional surgical methods.^[1] This trend is evident in both Western and East Asian populations, where facial rejuvenation treatments are increasingly sought after, reflecting the growing emphasis on anti-aging and youthfulness.^[2] In East Asia, cultural and anatomical factors have heavily influenced the development of specific facial rejuvenation techniques that cater to the unique needs and preferences of the population.^[3] As the demand for esthetic procedures continues to grow, so does the challenge of ensuring precision and accuracy in treatment delivery.

Traditional methods for guiding these procedures, such as physical examination and surface anatomy, often fall short in

providing the detailed insights needed to navigate complex facial anatomy. These limitations can lead to suboptimal outcomes and increased risks of complications, particularly when critical structures such as blood vessels and nerves are not accurately identified.^[1] To address these challenges, ultrasound (US) imaging has emerged as a valuable tool in esthetic medicine. By offering real-time visualization of soft-tissue structures, US enables clinicians to perform interventions with greater precision, enhancing both the safety and efficacy of these procedures.^[4] US's ability to provide detailed imaging of neurovascular structures ensures that vital vessels, such as the supratrochlear artery and angular artery, are visualized and avoided during injections, reducing complications such as vascular occlusion and embolic events.^[5] In addition, US aids in planning the volume of intervention required and the precise placement of fillers or adipose tissue.^[6]

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Abbreviations

AI	Artificial Intelligence
GAIS	Global Aesthetic Improvement Scale
HIFU	High-Intensity Focused Ultrasound
MHz	Megahertz
PCL	Polycaprolactone
PLGA	Poly-L-Glycolide
PLLA	Poly-L-Lactic Acid
SMAS	Superficial Musculoaponeurotic System
SMI	Superb Microvascular Imaging
US	Ultrasound

The application of US has revolutionized facial and neck rejuvenation procedures. It enables practitioners to dynamically observe target structures in real time, ensuring accurate placement of injectables in the intended tissue layers while avoiding critical anatomical structures.^[7] US also allows for dynamic visualization of superficial muscles like the frontalis and orbicularis oculi, ensuring precise targeting for botulinum toxin injections and other procedures.^[7] This precision significantly reduces the risk of adverse outcomes, such as vascular occlusion or filler migration.^[8] Moreover, US is instrumental in managing complications from previous esthetic treatments by identifying and correcting issues such as malpositioned fillers, thereby improving patient outcomes.^[9] Beyond its clinical utility, US serves as a powerful educational tool, helping practitioners, particularly those with less experience, to better understand the complex and variable anatomy of the face and neck.^[10]

This technical note introduces a novel clinical algorithm that integrates US diagnostics into procedures for the rejuvenation of the lower face and neck. Leveraging technologies such as high-frequency B-mode imaging and Doppler functionality, this approach enhances diagnostic accuracy and treatment precision. Advanced techniques such as superb microvascular imaging (SMI) provide detailed vascular mapping, further enhancing preprocedure planning and ensuring safe injections.^[5] By utilizing US to guide these interventions, the algorithm aims to optimize patient safety and maximize esthetic outcomes, aligning with the evolving standards of care in esthetic medicine.^[2,11] Devices such as the Philips Epiq 5 or Samsung RS85, equipped with high-frequency transducers, provide detailed anatomical visualization and vascular assessment, making them invaluable tools in modern esthetic practices.^[7] This paper seeks to contribute to the growing body of evidence supporting US as an integral component of esthetic treatments.

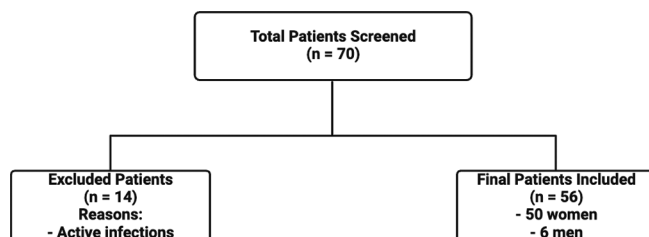


Figure 1: Patient recruitment flowchart

MATERIALS AND METHODS

Patient selection

The patient studies were conducted at the Department of Radiology of the Russian Medical University of the Ministry of Health of the Russian Federation from April 2020 to August 2024 with an observation period that spanned from 6 to 18 months. Participants were recruited based on referrals from the dermatology and plastic surgery clinics of the department. Inclusion criteria involved patients with visible signs of aging in the lower face and neck, aged 30–60, and willing to undergo esthetic procedures. Exclusion criteria included active infections and uncontrolled systemic diseases^[7] [Figure 1].

Ultrasound equipment and settings

The US equipment used in this study was a MINDRAY system with a linear transducer operating at 10–15 MHz. The choice of frequency allowed for optimal visualization of superficial structures, including the skin, subcutaneous fat, and underlying muscles. The system was equipped with color Doppler imaging to help identify vascular structures, ensuring safe navigation during procedures.^[8] US settings were adjusted according to the patient's specific anatomy, with particular attention paid to enhancing the resolution of the target tissue layers.^[4] The US equipment was adjusted to individual anatomical variations. For superficial structures, imaging was enhanced by increasing resolution settings. Doppler settings were optimized to visualize vascularization patterns, using techniques such as color Doppler and energy Doppler, and SMI. These adjustments ensured precise mapping of vascular structures.

Step-by-step algorithm

The clinical algorithm developed for this study was designed to guide practitioners through the process of using US diagnostics in conjunction with esthetic procedures. The algorithm consists of the following steps and visualized in Figure 2.

Initial patient assessment

A comprehensive clinical evaluation was conducted, including a detailed history and physical examination focused on identifying age-related changes in the lower face and neck. The patient's esthetic goals and expectations were also discussed.^[3]

Ultrasound evaluation

US imaging was performed to assess the patient's anatomy in detail. This included evaluating the thickness of the skin, the distribution of subcutaneous fat, the condition of the platysma muscle, and the location of critical vascular structures. The imaging results were used to map the treatment area and identify any potential risks.^[8]

Classification of age-related changes

Based on the US findings, patients were classified according to the severity of their age-related changes. Mild aging signs were defined by skin thickness >3 mm and minimal laxity, while significant aging signs were defined by skin thickness <3 mm and severe laxity. This classification helped in determining the appropriate techniques to be employed. Patients with mild changes were considered for less invasive procedures, while

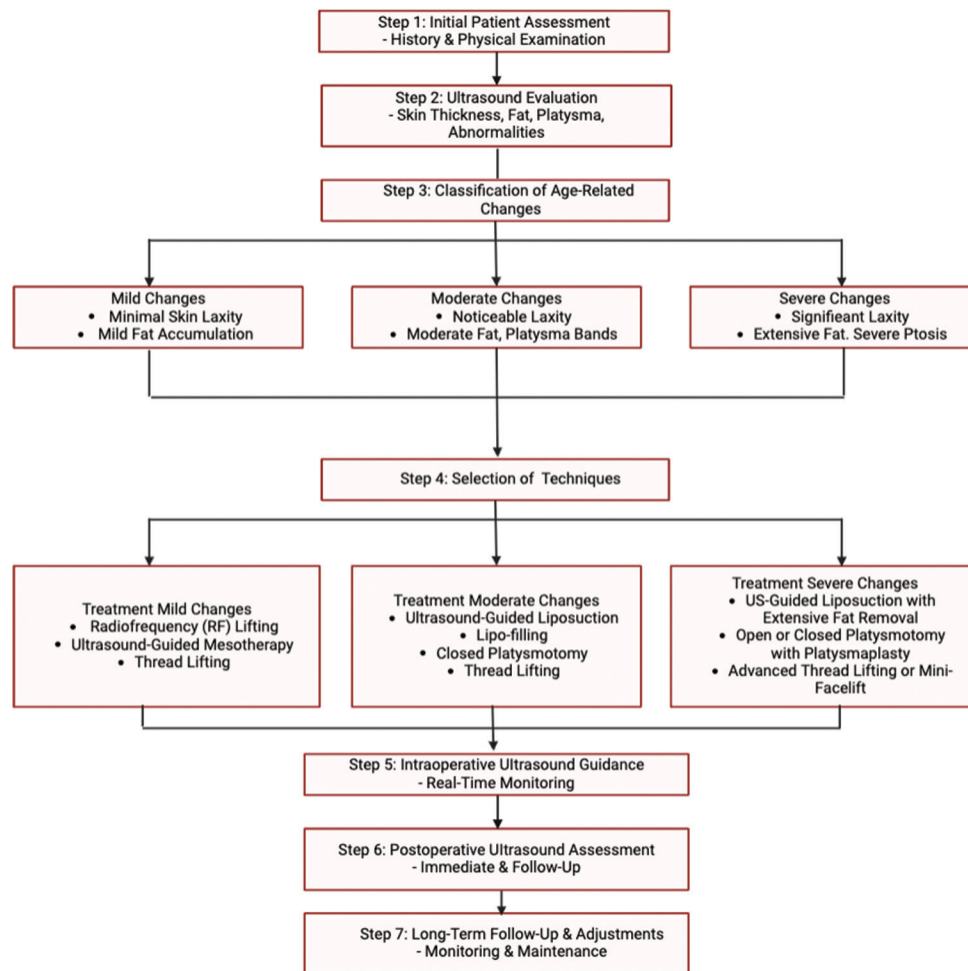


Figure 2: Clinical algorithm for ultrasound-guided esthetic facial and neck rejuvenation procedures

those with more significant aging signs were recommended for more comprehensive treatments.^[2]

Selection of techniques

The choice of treatment was guided by the US findings and the patient's classification. Techniques such as thread lifting, liposuction or lipofilling and energy-based skin tightening were selected based on the specific needs of each patient. For instance, patients with prominent skin laxity might receive poly-L-lactic acid)/(poly-L-glycolide polymer suspension sutures, while those with volume loss could be treated with lipofilling.

Intraoperative ultrasound guidance

During the procedures, US was used in real-time to guide the placement of needles, cannula, and other instruments. This step was crucial for avoiding vital structures and ensuring the precise delivery of treatment. Color Doppler was used to avoid vascular structures, particularly during lipofilling.^[10]

Postoperative ultrasound assessment

Immediately following the procedure, US imaging was repeated to assess the outcomes and ensure that the treatment was delivered accurately. Any potential complications were identified and managed promptly. This step also allowed for immediate correction if needed.^[12]

RESULTS

Clinical outcomes

A total of 56 patients were included, with 50 women (89.3%) and six men (10.7%). Their ages ranged from 30 to 60 years, with an average of 45 ± 5 years (mean $\pm$ standard deviation). Clinical outcomes were evaluated using standardized metrics such as patient satisfaction scales (e.g., Global Esthetic Improvement Scale [GAIS]) and complication rates. The implementation of the US-guided algorithm resulted in consistently positive clinical outcomes across the patient population. A significant improvement in the precision of procedures was observed, with US guidance allowing for more accurate placement of fillers, suspension sutures, and other materials used in facial rejuvenation, as well as when determining the scope of surgical intervention for more radical interventions. The real-time visualization provided by US minimized the risk of complications, such as vascular occlusion, which are common concerns in traditional, nonguided procedures.^[8]

The algorithm's effectiveness was particularly evident in patients with complex anatomical variations or those with a history of previous esthetic treatments. In these cases, US provided critical insights into the underlying structures,

enabling the customization of treatment plans that directly addressed the patients' specific needs. This approach led to more predictable and satisfactory results, with patients reporting higher levels of satisfaction compared to those who underwent procedures without US guidance.

Patient satisfaction

Patient satisfaction was measured using the GAIS, a standardized postprocedure questionnaire that assesses various factors, including the achievement of esthetic goals, comfort, safety, and overall satisfaction with the results. The majority of patients expressed high levels of satisfaction, with 85% rating their results as "much improved" or "very much improved." Notably, the use of US contributed to a greater sense of security during the procedure, particularly for patients who had undergone previous treatments and experienced complications. These patients felt more reassured by the real-time monitoring provided by US, which enhanced their confidence in the safety and precision of the procedure. The ability to visualize the treatment area before and after the procedure also played a key role in enhancing patient confidence. Patients appreciated being shown US images of their facial anatomy and understanding how the treatment would be precisely targeted to achieve their desired outcomes. This transparency contributed to greater trust in the procedure and the practitioner.

Comparison with traditional methods

A comparative analysis was conducted to evaluate the outcomes of the US-guided algorithm against traditional, nonguided methods. The results indicated a clear advantage for the US-guided approach, with a marked reduction in complication rates and improved overall outcomes. Specifically, the use of US significantly decreased the incidence of adverse events, such as hematomas, overfilling, and asymmetry, which were more common in procedures that relied solely on surface anatomy for guidance.^[12]

In addition to reducing complications, the US-guided approach allowed for more precise corrections during the procedure. For example, if filler material was observed to be migrating or if a vascular structure was inadvertently approached, the US provided immediate feedback, enabling the practitioner to adjust the treatment in real time. This capability was not available in traditional methods, where corrections often had to be made based on visual or tactile cues alone.^[9]

Case studies

Two representative case studies are presented to illustrate the practical application and benefits of the US-guided algorithm.

Case study 1: Excessive accumulation of fatty tissue and sagging skin

Patient I. (38-year-old) had excessive accumulation of adipose tissue and sagging skin of the lower third of the face and submental area [Figure 3a]. US imaging provided the exact location of the fatty tissue, in this case under the skin, and helped determine the location of the vessels [Figure 3b]. The

patient underwent liposuction and radiofrequency lifting [Figure 3c]. The patient reported high satisfaction with the natural results and minimally invasive nature of the treatment.

Case study 2: Surgical correction of the lower third of the face and neck

Patient N. (53-year-old) had sagging skin of the lower third of the face [Figure 4a]. US assessment revealed an accumulation of adipose tissue over the platysma, the lower third of the face [Figure 4b]. Clinically, sagging and excess skin was noted. Treatment included liposuction of the lower third of the face and neck and superficial musculoaponeurotic system-lifting [Figure 4c]. The procedure was successful, the patient expressed satisfaction and a more attentive attitude to her problem.

Overall effectiveness

The US-guided algorithm demonstrated a high level of effectiveness in enhancing the outcomes of facial rejuvenation procedures. By providing a detailed and real-time view of the patient's anatomy, the algorithm allowed for more precise and individualized treatments, which translated into improved esthetic results and higher patient satisfaction. The integration of US into these procedures represents a significant advancement in the field of esthetic medicine, offering a safer and more reliable approach to facial rejuvenation.

DISCUSSION

Advantages of the ultrasound-guided algorithm

The integration of US technology into esthetic procedures offers numerous advantages, particularly in enhancing precision and safety. US has emerged as a critical tool in esthetic medicine, providing detailed real-time visualization of soft-tissue structures. This capability allows practitioners to determine the scope of interventions, and to perform minimally invasive procedures with greater accuracy, thereby reducing the risk of complications.^[13] The ability to distinguish between different layers of skin and underlying structures makes US indispensable for procedures that require precise targeting, such as lipofilling and thread lifts.^[14]

Moreover, Doppler US has proven to be particularly effective in diagnosing and managing vascular complications following esthetic procedures. Its ability to assess blood flow and identify potential issues before they become clinically significant adds a layer of safety that is not available with traditional methods.^[15] This is particularly beneficial in procedures involving hyaluronic acid fillers, lipofilling where the risk of vascular compromise is a major concern.

Another significant advantage of US-guided procedures is the potential for improved patient outcomes. Studies have demonstrated that the use of US can lead to higher patient satisfaction, as it allows for more tailored treatments that are closely aligned with the patient's anatomical specifics and esthetic goals.^[16] The enhanced accuracy of



Figure 3: Ultrasound and photographic assessment of the lower face and neck. (a) Photographic images of the patient's lower face and neck in frontal and lateral views, showing pretreatment conditions. (b) Ultrasound images of the submandibular region: (1) Visualization of the dermis and subcutaneous fat. (2) Imaging of the platysma. (3) Visualization of glandula sublingualis with associated vascular patterns. (c) Posttreatment photographic images of the patient's lower face and neck, showing improved contour and rejuvenation results. Transducer placement: The transducer was positioned vertically without pressure over the area of interest for optimal imaging accuracy

US-guided procedures also translates into more consistent and predictable results, further contributing to patient satisfaction.

Limitations and challenges

Despite its many benefits, the use of US in esthetic procedures is not without challenges. One of the primary limitations is the learning curve associated with mastering US technology. Practitioners must develop the skills to accurately interpret US images and integrate this information into their procedural techniques.^[17] This requires additional training and practice, which may be a barrier for some clinicians, particularly those who are accustomed to traditional methods.

Another challenge is the increased time required for US-guided procedures. The process of performing and interpreting US imaging before, during, and after a procedure can extend the overall treatment time. However, this additional time is often justified by the improved safety and outcomes achieved through US guidance.^[15] In addition, the cost of acquiring and

maintaining high-quality US equipment can be prohibitive for smaller practices, which may limit the widespread adoption of this technology.^[17]

There are also concerns about the potential for liability related to the use of US. As with any medical technology, the accuracy of US imaging depends on the skill of the operator. Misinterpretation of images or technical errors can lead to suboptimal outcomes or even harm, raising questions about liability and the need for comprehensive training and certification.^[17]

The learning curve associated with mastering US technology, including Doppler, can be a significant barrier for practitioners. Misinterpretation of images may lead to suboptimal outcomes. While Doppler US is effective for identifying vascular structures, over-reliance may result in severe complications such as stroke or skin necrosis due to false negatives. Practitioners must integrate Doppler with comprehensive clinical judgment.^[18]



Figure 4: Ultrasound and photographic analysis of the lower face and neck. (a) Photographic images of the patient's lower face and neck in frontal and lateral views, showing pretreatment conditions. (b) Ultrasound images illustrating anatomical structures of the lower face and neck: (1) Vascular and muscular structures in the submandibular region, including the glandula sublingualis. (2) Imaging of the platysma. (3) Visualization of the skin, subcutaneous fat, and platysma muscle. (c) Posttreatment photographic images of the patient's lower face and neck, showing improved contours and a reduction in skin laxity. Transducer placement: The transducer was placed vertically along the mandibular angle and submandibular region without pressure for optimal imaging accuracy

Future directions

The future of US in esthetic medicine is promising, with ongoing advancements likely to expand its applications and accessibility. Emerging technologies, such as high-intensity focused ultrasound (HIFU), are pushing the boundaries of what US can achieve in both diagnostic and therapeutic contexts. HIFU, for example, has shown potential not only in noninvasive body contouring but also in treating various cosmetic conditions by targeting deeper tissue layers with precision.^[19]

Further innovations are expected in the integration of artificial intelligence (AI) with US technology. AI could assist in image interpretation, reducing the variability in diagnostic accuracy among practitioners and making US more user-friendly.^[14] The development of portable US devices and the refinement of imaging software are also likely to increase the adoption of US in esthetic practices, particularly in smaller clinics.^[20]

In addition, research into the long-term outcomes of US-guided procedures will be crucial in establishing best practices and

ensuring the highest standards of patient care. Studies that track the effectiveness and safety of these procedures over extended periods will provide valuable data to refine treatment protocols and improve patient outcomes.^[16]

CONCLUSION

The integration of US technology into esthetic facial rejuvenation procedures represents a significant advancement in esthetic medicine. By enhancing precision, personalizing treatments, and improving patient outcomes, US-guided interventions offer a safer and more effective approach to facial rejuvenation. While there are challenges to overcome, including the need for specialized training and the costs associated with US equipment, the benefits of this technology far outweigh these limitations. As the field continues to evolve, ongoing research and technological innovations will likely expand the role of US in esthetic medicine, making it an indispensable tool for practitioners.

Ethics statement

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and its amendments. The authors certify that they have obtained all appropriate patient consent forms. In the form the patients have given their consents for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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