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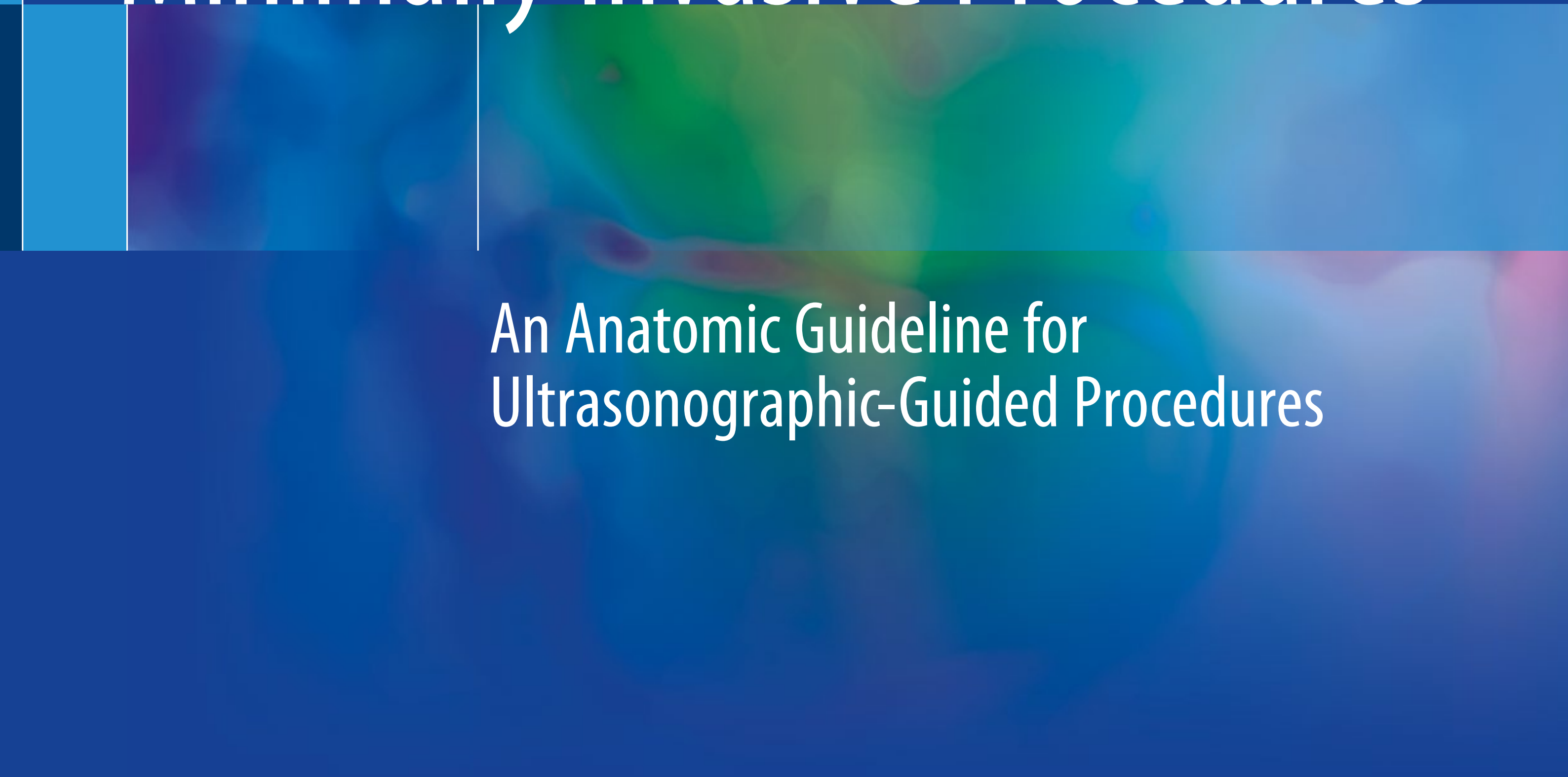
Ultrasonographic Anatomy of the Face and Neck for Minimally Invasive Procedures



An Anatomic Guideline for Ultrasonographic-Guided Procedures

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Preface

There has never been a book like this.

This is the very first book to describe the superficial anatomical structure of the face and neck by detailed ultrasonography. The reason is this structure is very complicated, and anatomical structures such as fat, blood vessels, and nerves of the face and neck are intermingled together. Therefore, it was difficult to explain the three-dimensional superficial structures instead of the two-dimensional anatomical descriptions shown through the classical anatomical studies.

This book is written based on the results of our ultrasonographic studies over the past 5 years. Though I have been doing anatomical studies in this field for the past 25 years, it was difficult to describe the anatomical structures from ultrasonographic images at the start of our research project. However, the ultrasonographic facial anatomy has been clarified one by one by the passionate research of the faculty of my lab. The data obtained from our ultrasonographic studies have already been published or are being published in many papers; it is intended to be released in a visible atlas format. The first words of a salesperson who set up the ultrasonography device in our laboratory were very impressive and unforgettable. “If you would open your mind, and the ultrasonographic images will be visible.” Because of all these factors, ultrasonographic imaging has a large academic characteristic along with a big learning curve.

Ultrasonography has recently been utilized in various diagnoses, monitoring, and treatments of skin diseases. The generalized application of ultrasonography in musculoskeletal areas has been developed in the last 15 years. However, aesthetic medicine is in its nascent stage, and it is speculated that its utilization will soon be broadened. Limitedly, many clinicians use US as an adjunctive tool during minimally invasive procedures, and patients’ expectations have been raised.

Ultrasonography allows clinicians to use less amounts of botulinum toxin to achieve optimal outcomes by precisely targeting the exact muscle. In addition, ultrasonography allows one to find the accurate layer during filler injections and thread lifting procedures to minimize various complications. Conventional blind techniques without the use of ultrasonography may cause vascular complications such as bleeding, hematoma, bruising, and skin atrophy. These so-called minimally invasive procedures have relied on the clinicians’ understanding of the anatomy and skills to minimize vascular complications. Only ultrasonography can help clinicians detect the anatomical variations of the muscles and vessels for satisfying procedural results; we believe that the role of ultrasonography in aesthetic procedures will be strengthened. The authors would like to strongly provide a basic guidance for US-guided aesthetic procedures.

Based on these backgrounds, this book consists of ten chapters with 537 illustrations and US images, integrating both the basic and clinical sciences. The basics are explained in the introductory Chapters 1 and 2, entitled the basic principles of US and general clinical anatomy. Chapters 3 through 7 describe in detail the interpretation of US images for each part based on the clinical anatomy of the face and neck. The reference lines and points used in this book were based on our research projects that have been conducted in our lab, and the points used in this book have been published in many articles. In fact, the US anatomy of the superficial face and neck is difficult to understand without a detailed anatomical knowledge. For this reason, a detailed knowledge of the anatomy and an understanding of many anatomical variations are required. The last three chapters consist of the US anatomy conjoined with minimally invasive procedures. Basic clinical procedures and US interpretations and the novel techniques of US-guided procedures for safe botulinum toxin, filler injection, and threading insertion are described and illustrated. Detailed items related to US-guided clinical procedures will be described in depth in our upcoming publications.

I would like to acknowledge the authors who had a crucial role in the making of this book. First, I would like to give infinite thanks to Prof. Kwan-Hyun Youn for providing all of the visuals for this book. I believe that Prof. Youn has raised the field of medical illustration to that of world-class standards. Many thanks to the effort of the MedArt team. Many clear, simple, and creative visual contents in this book are made possible by Ms. Hyewon Hu and Mr. Hyeong-Seok Choi led by Prof. Youn. I also wish to thank Dr. Ji-Soo Kim for organizing all the critically important clinical information and tips. Without his own novel US-guided injection techniques and enormous clinical experiences, the clinical chapters could not be disclosed in this book. Likewise, I thank Dr. You Soo Kim for his insightful inquisitions and questions that made coming up with creative contents possible. In addition, I appreciate Prof. Sung Ok Hong for editing and arranging the manuscript. I would like to express my respect and appreciation to Dr. Jongju Na, an aesthetic physician and a CEO of Viol Co. Ltd., for his brilliant idea on US applications and for providing full support to our authors and illustration team. Without the efforts and enthusiasm of the aforementioned co-authors in providing clinical manuscripts and in revising all of the visuals despite their busy clinical schedules, this book's text and artwork would not be possible.

In addition, I would like to thank Mr. Young Cheol Hwang, a managing director of Alpinion Medical Systems and Iljin Holdings Co. Ltd, and Mr. Eui Chul Kwon, a team manager of Alpinion Medical System Co. Ltd, for their US equipment and technical supports.

Above all, I also thank our staff, Professor Kyung-Seok Hu and You-Jin Choi, and my PhD and graduate students, Hyung-Jin Lee, Ji-Hyun Lee, Kang-Woo Lee, Hyungkyu Bae, Kyu-Lim Lee, Hyun Jin Park, Hyo-Sang Ahn, Jin-Won Kim, and Alonso Hormazabal-Peralta, from Yonsei University College of Dentistry who actively helped create the anatomical visual contents and aided in revising works for this book. Special thanks to Kyu-Ho Yi who helped us in overseeing the general architecture of the book. Also, big thanks to my beloved daughter Soyeon Kim who revised the English language of this book.

Great anatomy will be forever …

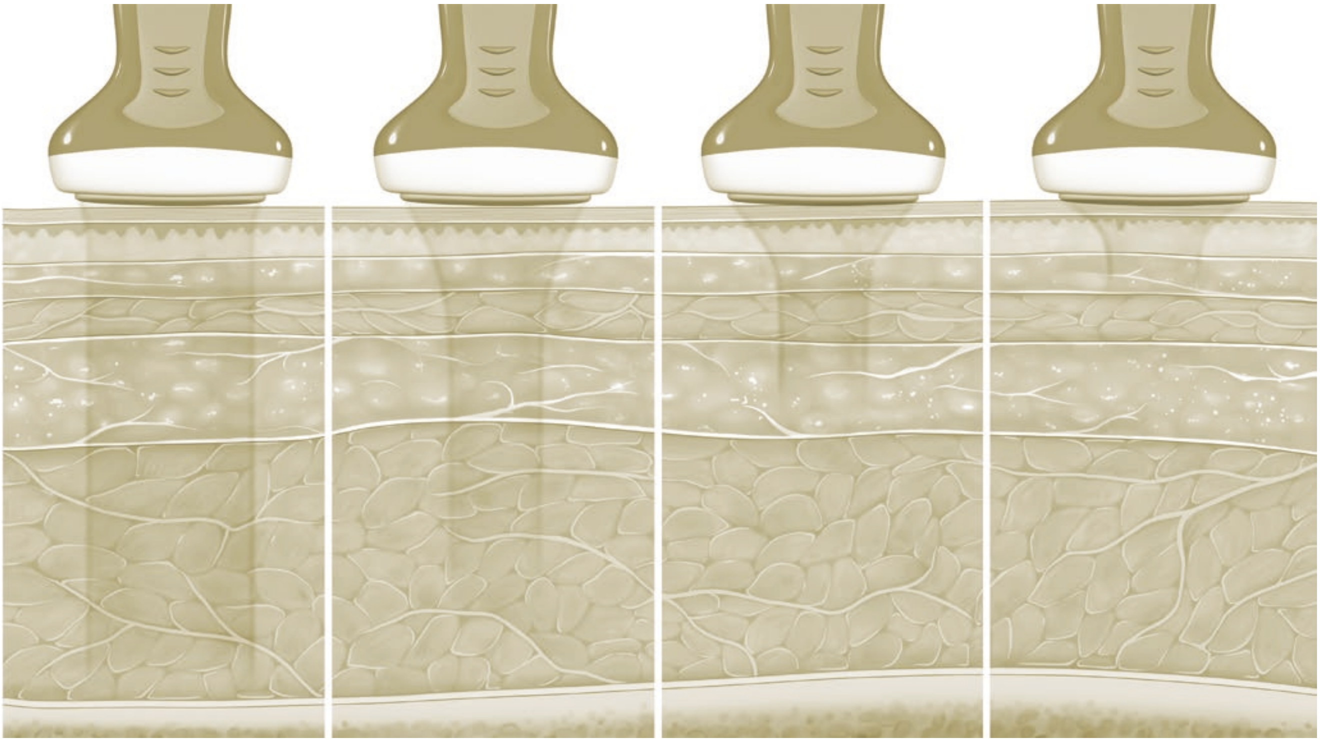
Seoul, Korea (Republic of)
March, 2020

Hee-Jin Kim
On behalf of the authors

Contents

Basic Principles of Ultrasonographic Imaging

1



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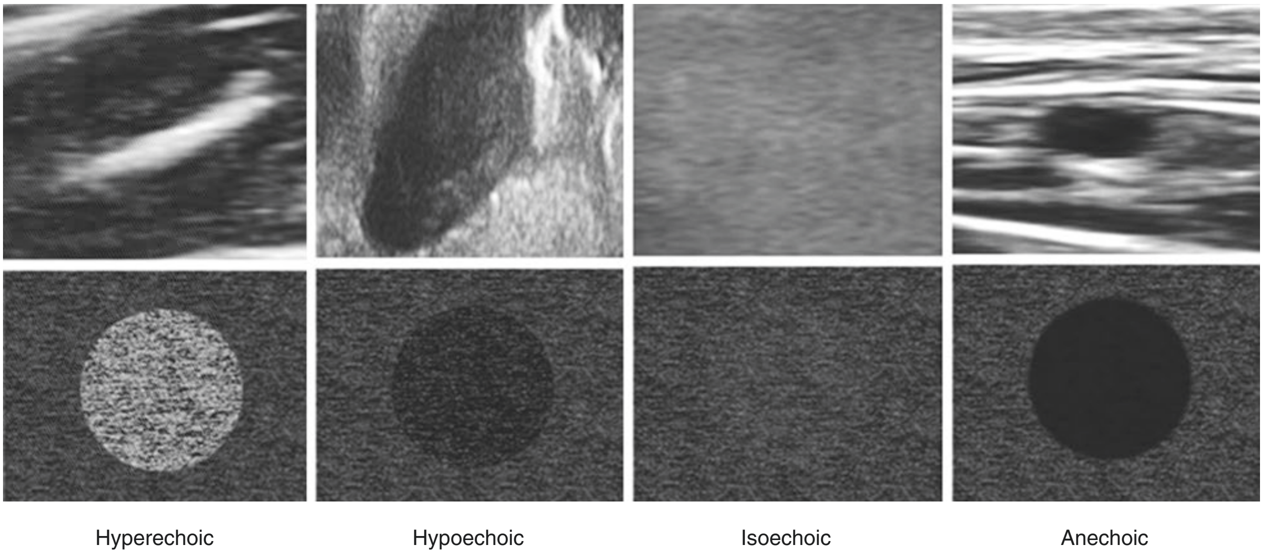


Fig. 1.1 Types of echogenicity. Echogenicity means the ability to reflect or transmit the ultrasonographic waves in the context of the surrounding tissue. The images show hyperechoic in white, hypoechoic in gray, and anechoic in black. (Published with kind permission of © Hee-Jin Kim 2020. All Rights Reserved)

Imaging by ultrasonography (US) utilizes the interaction of sound waves with tissue to produce an image or to determine the velocity of moving contents such as blood in the Doppler image. Furthermore, US has been used in many different fields to detect objects and measure distances. US waves are produced by a transducer, which can both emit US waves and detect reflected US echoes.

The US is a frequently used device in hospital settings; however, in the field of aesthetics, it is not commonly used. This chapter starts off by focusing on the basics of the US for the face and neck aesthetic procedures.

1.1 Physics and Techniques of US Imaging

1.1.1 Echogenicity

The principle theory of US imaging is that the transducer emits US waves from 3 to 25 MHz and receives reflected sound from the acoustic interface and then is digitally visualized. When the probed tissues produce similar images as the surrounding structures, they are referred to as isoechoic. When no echoes are reflected from the tissue, they are dark images called anechoic. Vessels and filler materials are shown as anechoic images. Hypoechoic images are weak echoes demonstrated as dark gray color in muscles and cartilages. On the contrary, hyperechoic structures are strong echoes that appear white such as ligaments, fasciae, and the surface of the bone (Fig. 1.1).

1.1.2 Optimized Images

To acquire the optimal image, a transducer with an adequate frequency that reflects in proper resolution and penetration is necessary. When the US wave frequency is high, the spatial resolution is bigger, and the depth of penetration is smaller. Conversely, when the frequency is low, the depth of penetration is bigger, and the spatial resolution is smaller. The 10–15 MHz linear transducer penetrates 2–5 cm, which is generally recommended in the facial area. Wave frequencies over 22 MHz are usually used for skin diagnosis (Fig. 1.2).

The ability to differentiate between two structures with disparate depths is called time resolution or depth resolution. Differentiation between two adjacent structures is called lateral resolution. The focal zone has the highest axial resolution, which is formed in the area where the sound beam is the narrowest. As the wave shoots away from the transducer, the region where wave diameter decreases is called the near field and where it increases is called the far field, respectively. The resolution is best at the focal zone (point) and decreases at the far-field area where resolution artifacts are seen (Fig. 1.3).

The focal zone (point) is more superficial when the frequency is higher, deeper when the frequency is lower. The US image shown in Fig. 1.4 is the masseter m. at 7.5 MHz and 15 MHz frequency, respectively. At 7.5 MHz, the masseter m. appears slightly blurry, but using the 15 MHz frequency, it is shown in higher resolution (Fig. 1.4).

Adjustment of the gain changes the brightness of the images. By increasing the gain value, electrical signals are amplified, which increases the brightness of the entire image. However, an increase in background noise can also potentially raise artifacts and lower the lateral resolution (Fig. 1.5).

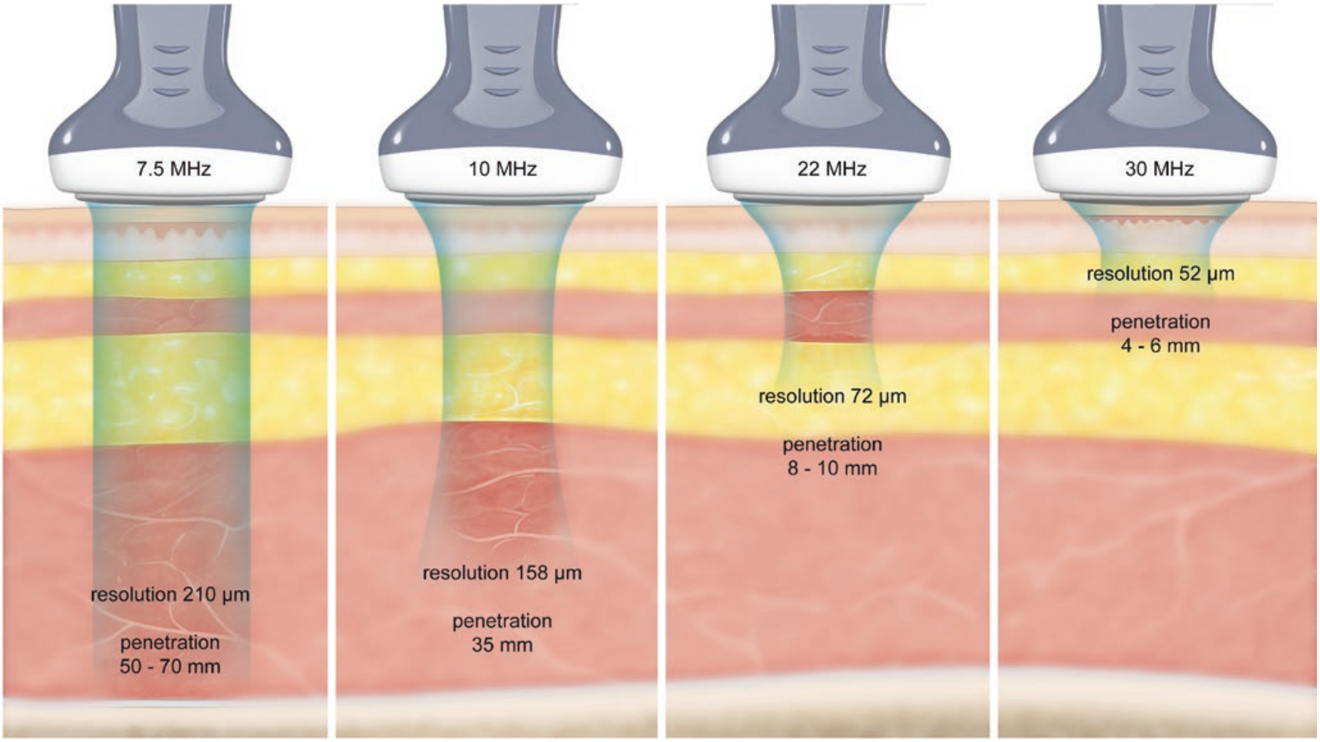


Fig. 1.2 Selections of optimal ultrasonographic wave frequency. Transducers with higher frequency show less penetration depth, which is better to observe superficial structures. (Published with kind permission of © Kwan-Hyun Youn 2020. All Rights Reserved)

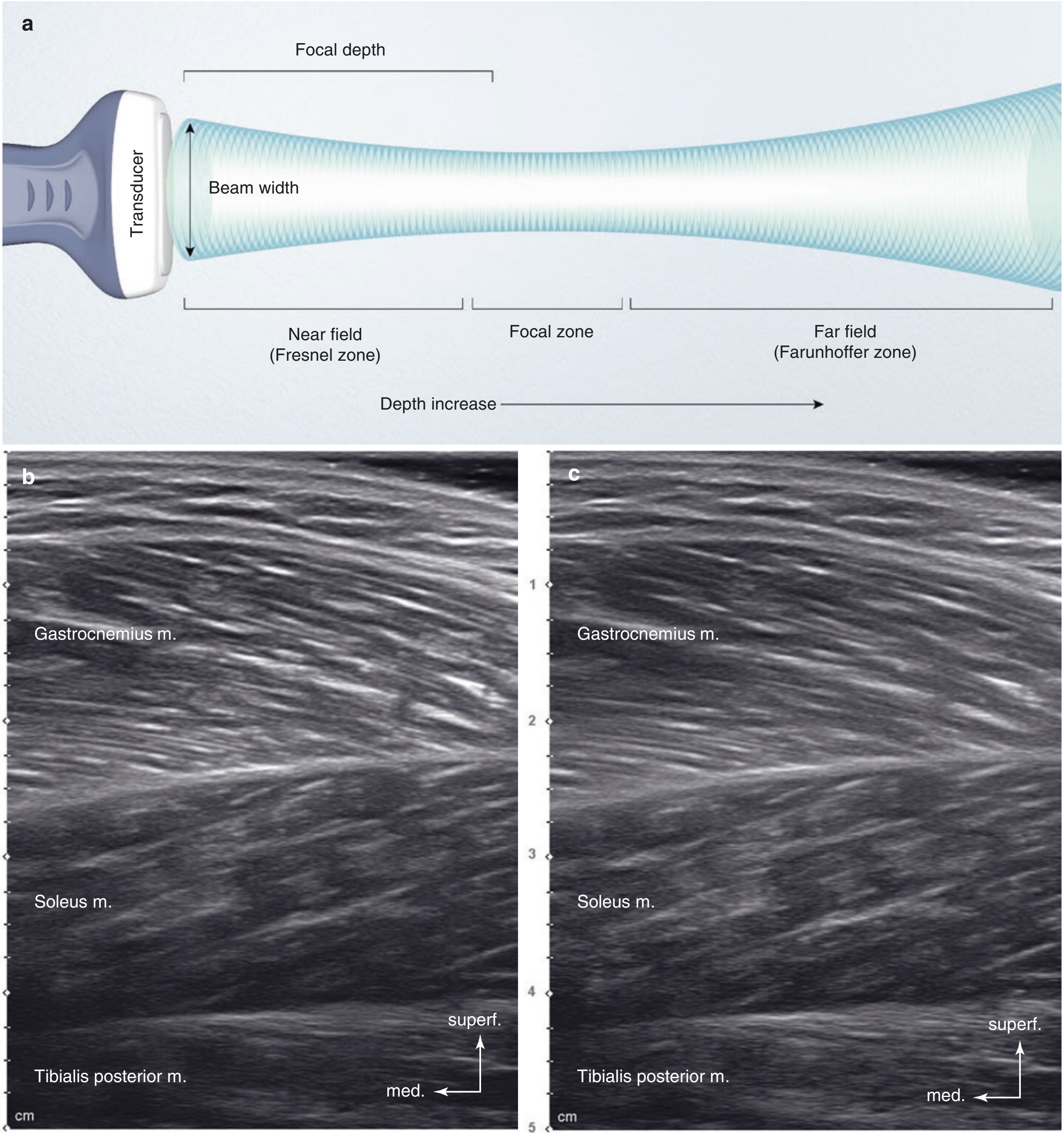


Fig. 1.3 Adjusting the focal zone and focus. (**a**) Illustration representing the stream of the ultrasonographic wave, (**b**) ultrasonographic image focused superficially (2 cm in depth), and (**c**) ultrasonographic image focused deeply (4 cm in depth). (Published with kind permission of © Hee-Jin Kim and Kwan-Hyun Youn 2020. All Rights Reserved)

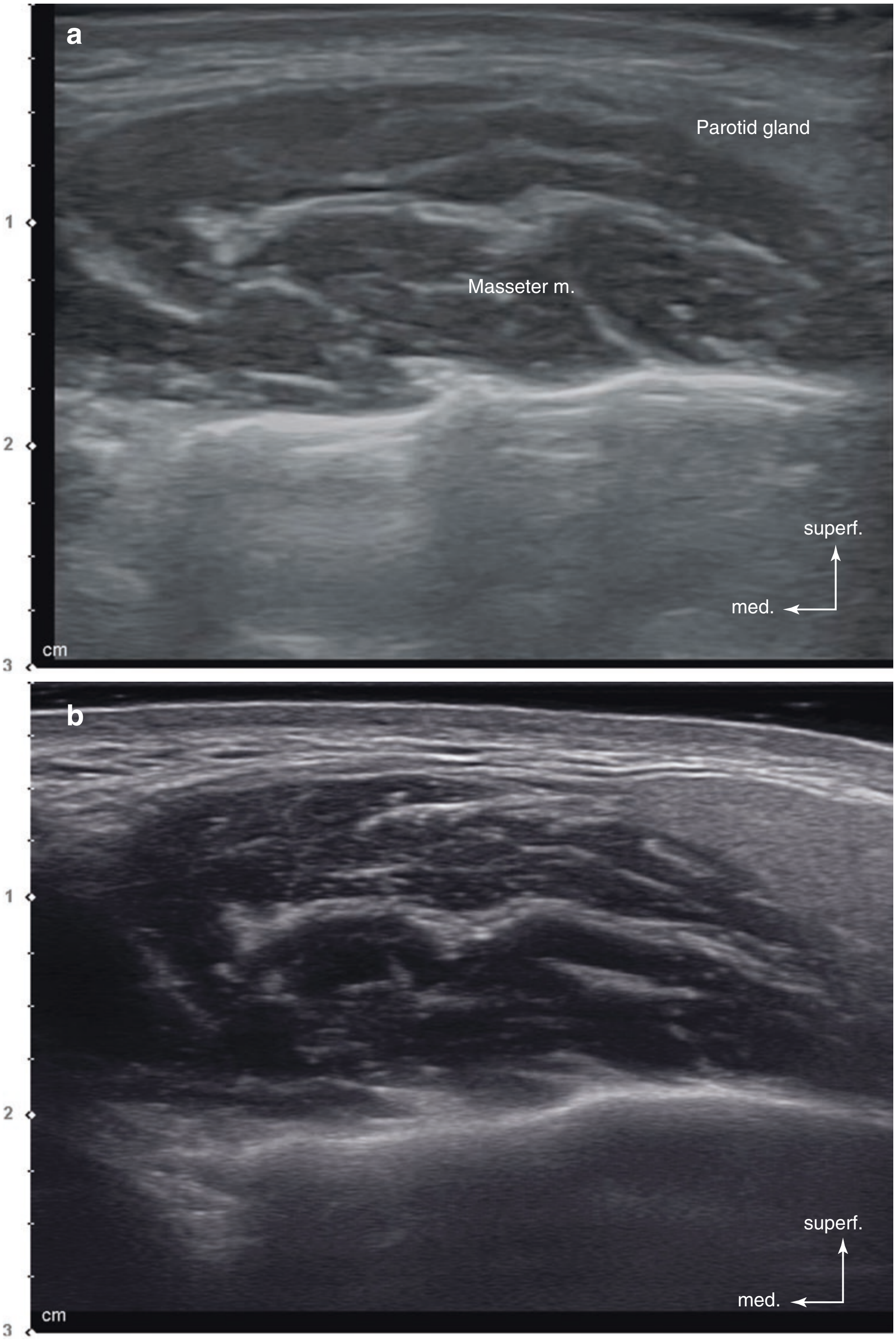


Fig. 1.4 Selection of optimal transducer frequency (MHz). (**a**) 7.5 MHz frequency and (**b**) 15 MHz frequency. (Published with kind permission of © Hee-Jin Kim 2020. All Rights Reserved)

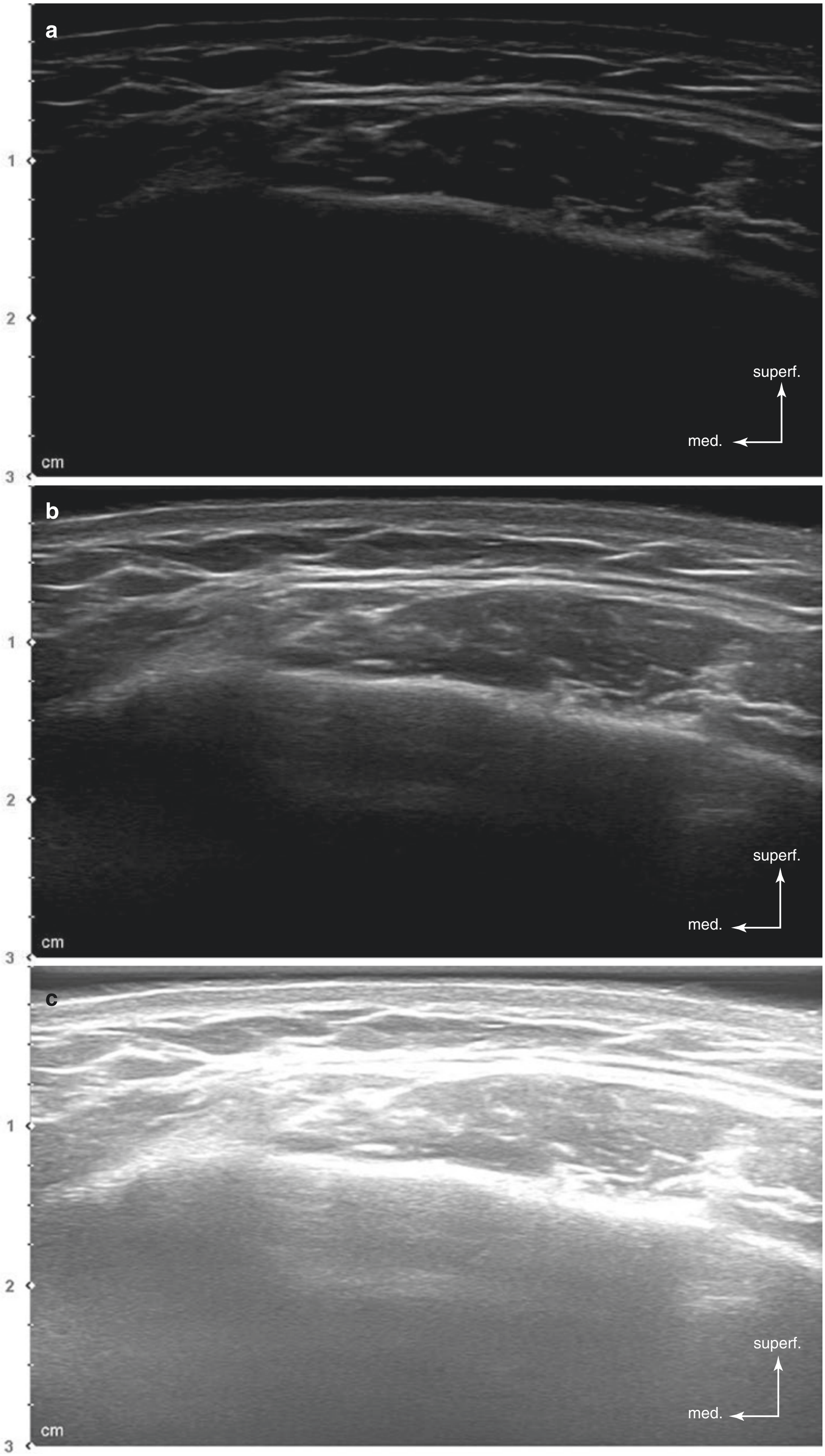


Fig. 1.5 Selection of optimal gain value. (**a**) Dark image with too low gain, (**b**) optimal image with correct gain, and (**c**) bright image with too high gain. (Published with kind permission of © Hee-Jin Kim 2020. All Rights Reserved)

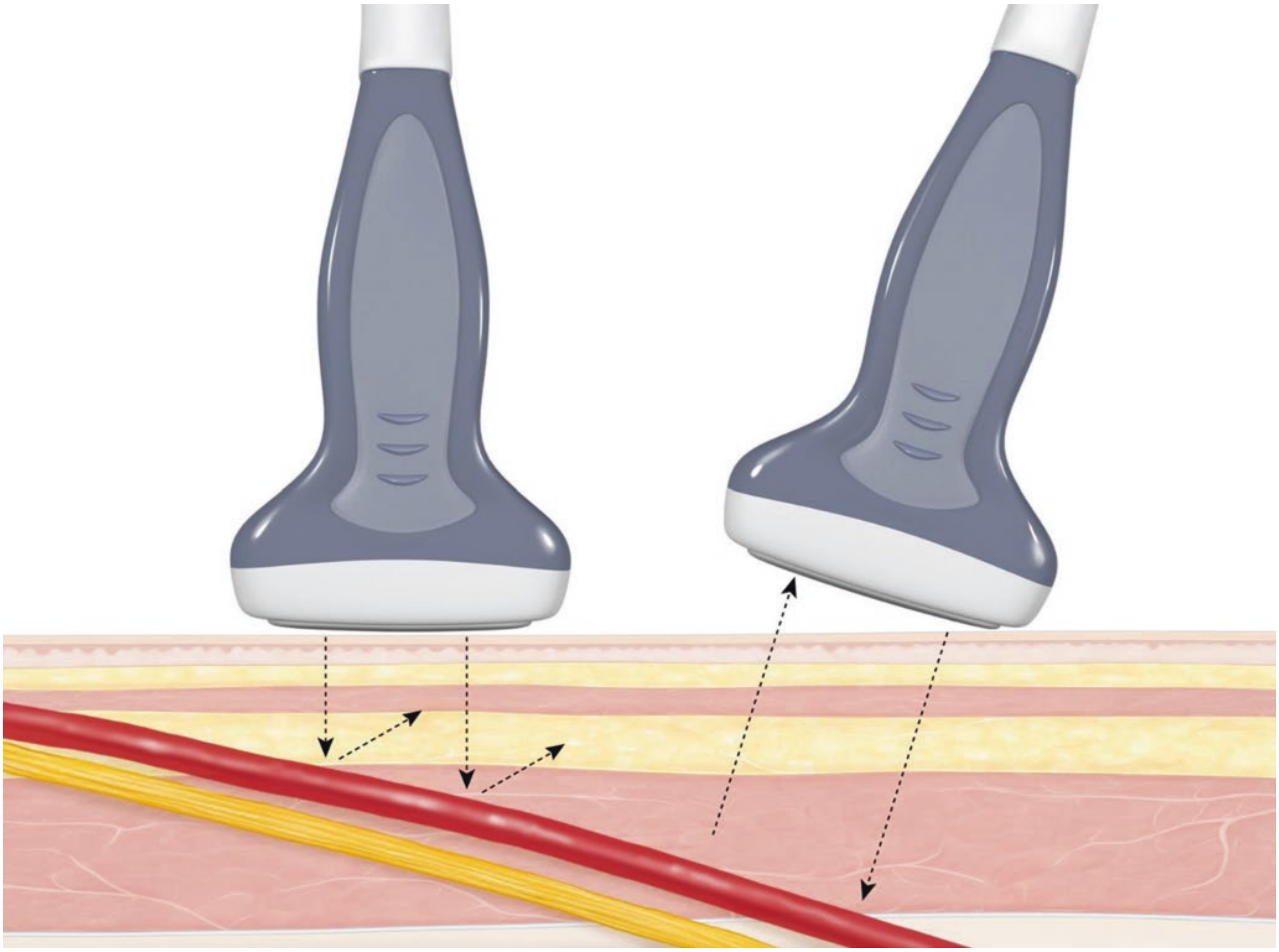


Fig. 1.6 The insonating angle in long-axis view. Vessels and nerves are shown clearly when the transducer is located parallel to these structures with heel-toe maneuver. (Published with kind permission of © Kwan-Hyun Youn 2020. All Rights Reserved)

1.1.3 Angle of Incidence

Penetration and reflection are greatest when the US's insonating angle is 90° of the surface of the anatomical structure. If the insonating angle is oblique and not at the right angle, the resolution decreases. The resolution can be improved using the heel-to-toe maneuver that accesses at 90° of the structure (Fig. 1.6). When observing the vessel and nerve of an area, an oblique insonating angle will make the artery appear in an oval shape and obstruct the visibility of nerves. A 90° insonating angle will reveal the distinct honeycomb appearance of the nerve and round shape of the artery (Fig. 1.7).

1.1.4 Transducer Manipulation

Several transducer manipulation techniques are required to attain appropriate images of the target structure. The pressure technique puts the target structure in place by applying vertical pressure to the transducer. The alignment (sliding) technique moves the transducer antero-posteriorly and laterally aligning the sonic window to the target structure.

Rotation of the transducer will procure an image along the long axis when placed parallel, and along the short axis when rotated at a 90° angle of the target structure. Tilting the transducer will place the insonating angle at 90° and will increase the resolution. These four techniques are the basic and essential transducer manipulation techniques and are called PART, abbreviated by the first letters of each technique (Figs. 1.8 and 1.9).

When observing a specific anatomical structure, the transducer is placed longitudinally to obtain an image along the axis while moving in a proximal and distal direction using the alignment technique. Then, the transducer is shifted 90° using the rotation technique to gain a short-axis view. These images are similar to the AP view and lateral view of an X-ray. Overall, the vessel pathway, shape and location of the target structure, and adjacent anatomical boundaries can be precisely evaluated (Fig. 1.10).

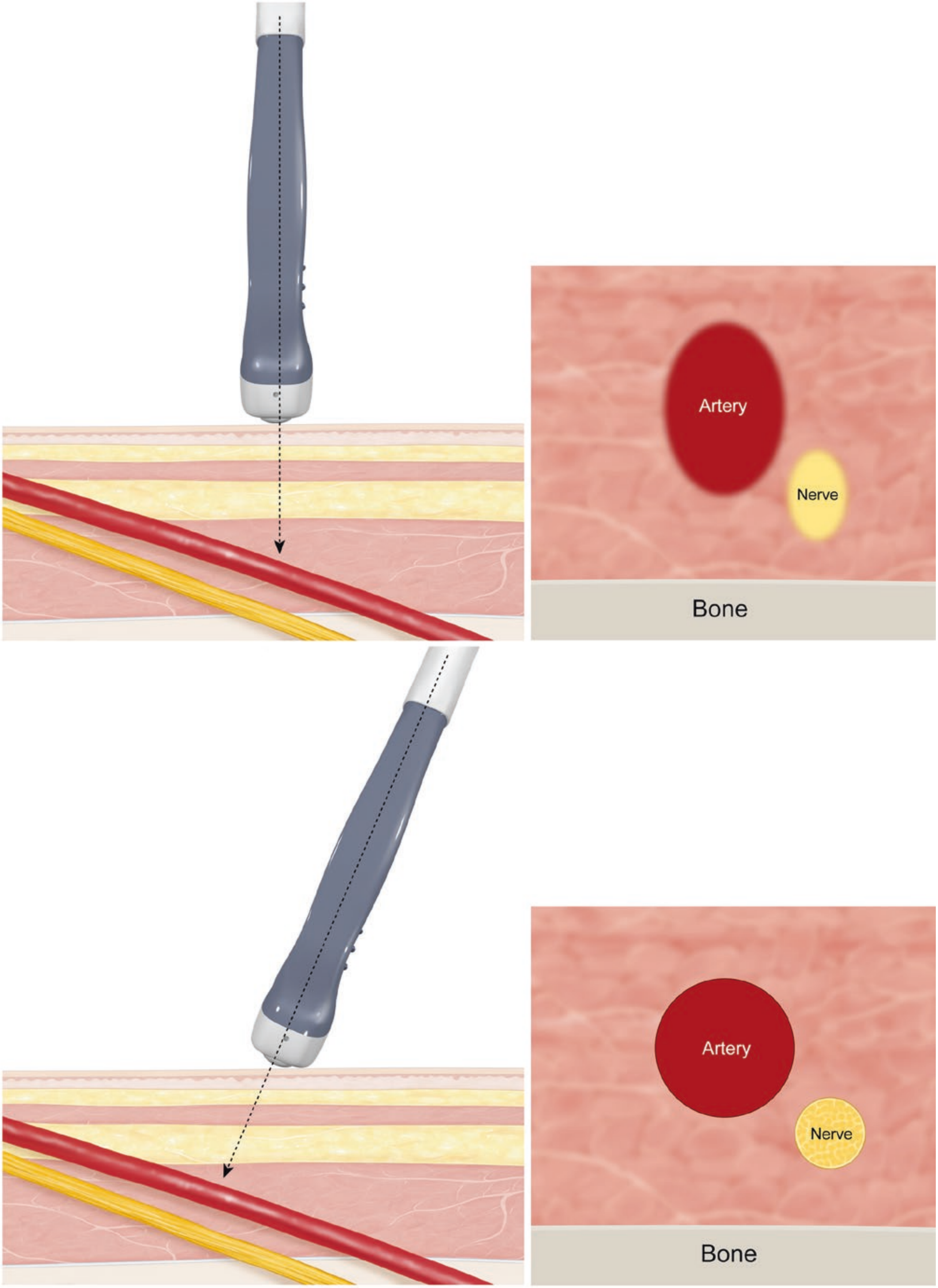


Fig. 1.7 The insonating angle in short-axis view. Vessels and nerves are shown round, not oval when the transducer is located perpendicular to these structures. (Published with kind permission of © Kwan-Hyun Youn 2020. All Rights Reserved)

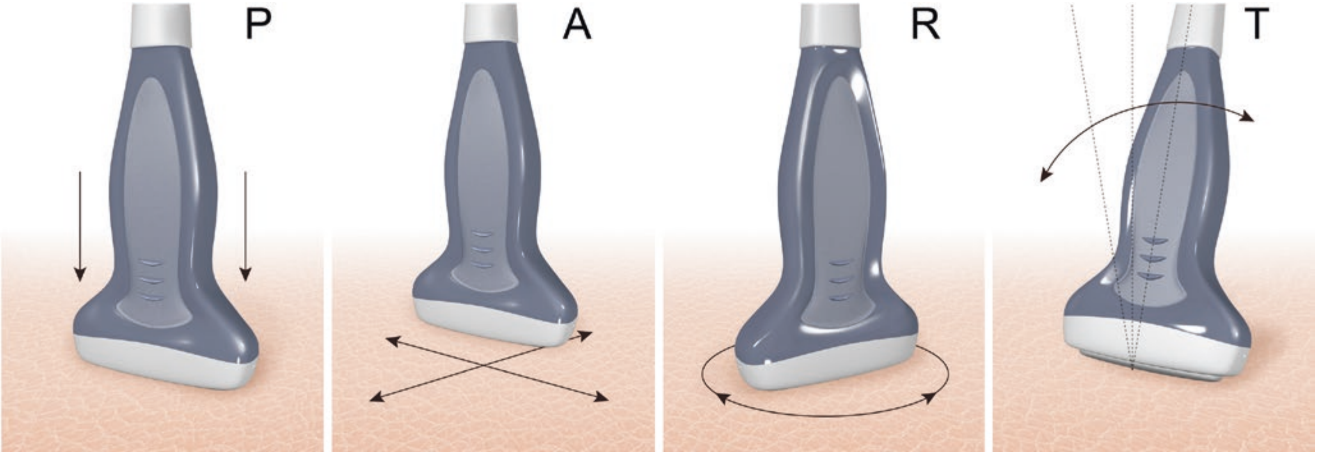
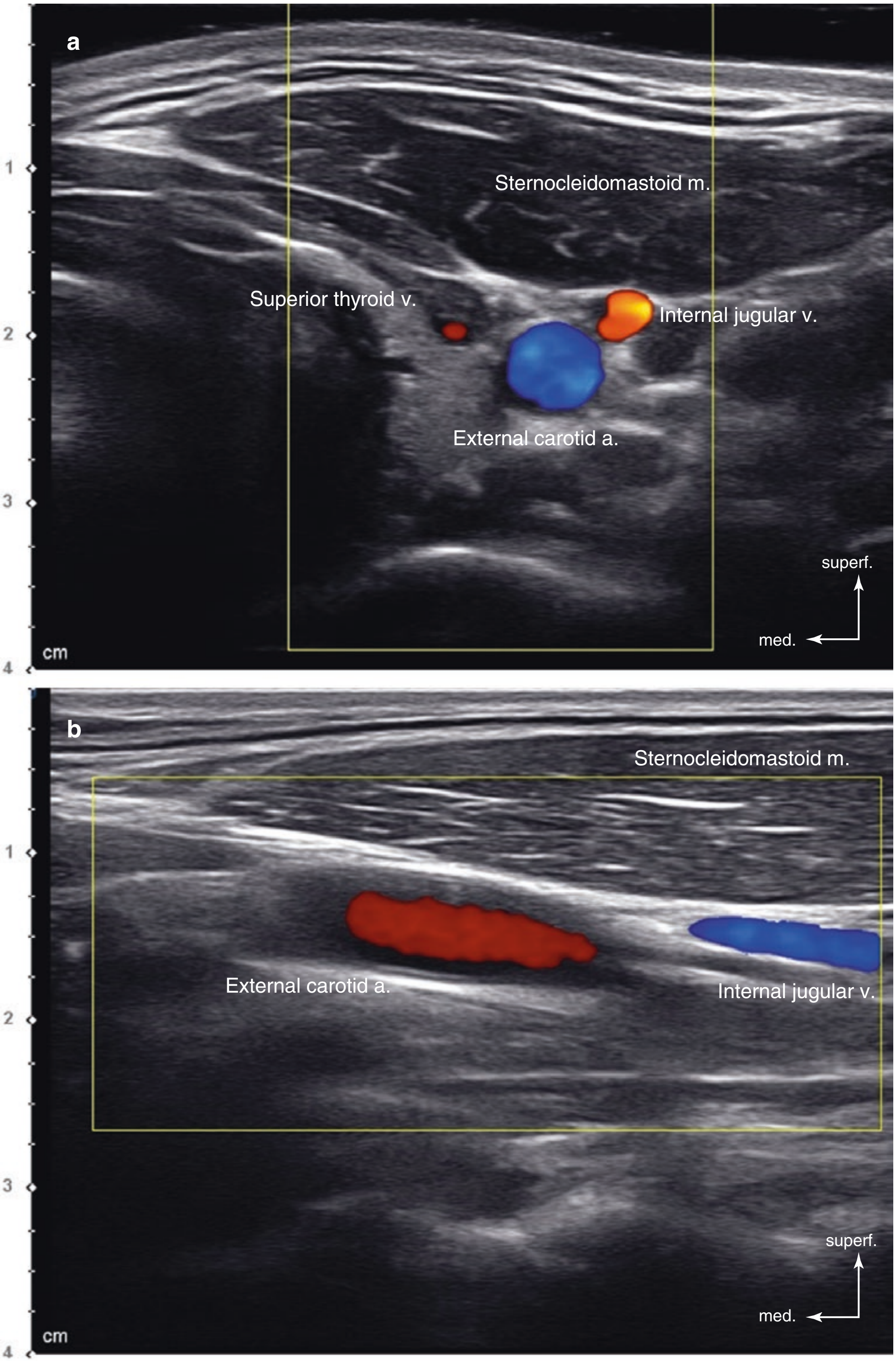


Fig. 1.8 Transducer movement. *P*, pressure; *A*, alignment; *R*, rotation; *T*, tilting. (Published with kind permission of © Kwan-Hyun Youn 2020. All Rights Reserved)

Fig. 1.9 Correct postures for holding the transducer. Transducer should be firmly supported by other fingers that are not holding the transducer. (Published with kind permission of © Kwan-Hyun Youn 2020. All Rights Reserved)

Fig. 1.10 The Doppler image of the carotid triangle. (**a**) Short-axis view and (**b**) long-axis view. (Published with kind permission of © Hee-Jin Kim 2020. All Rights Reserved)



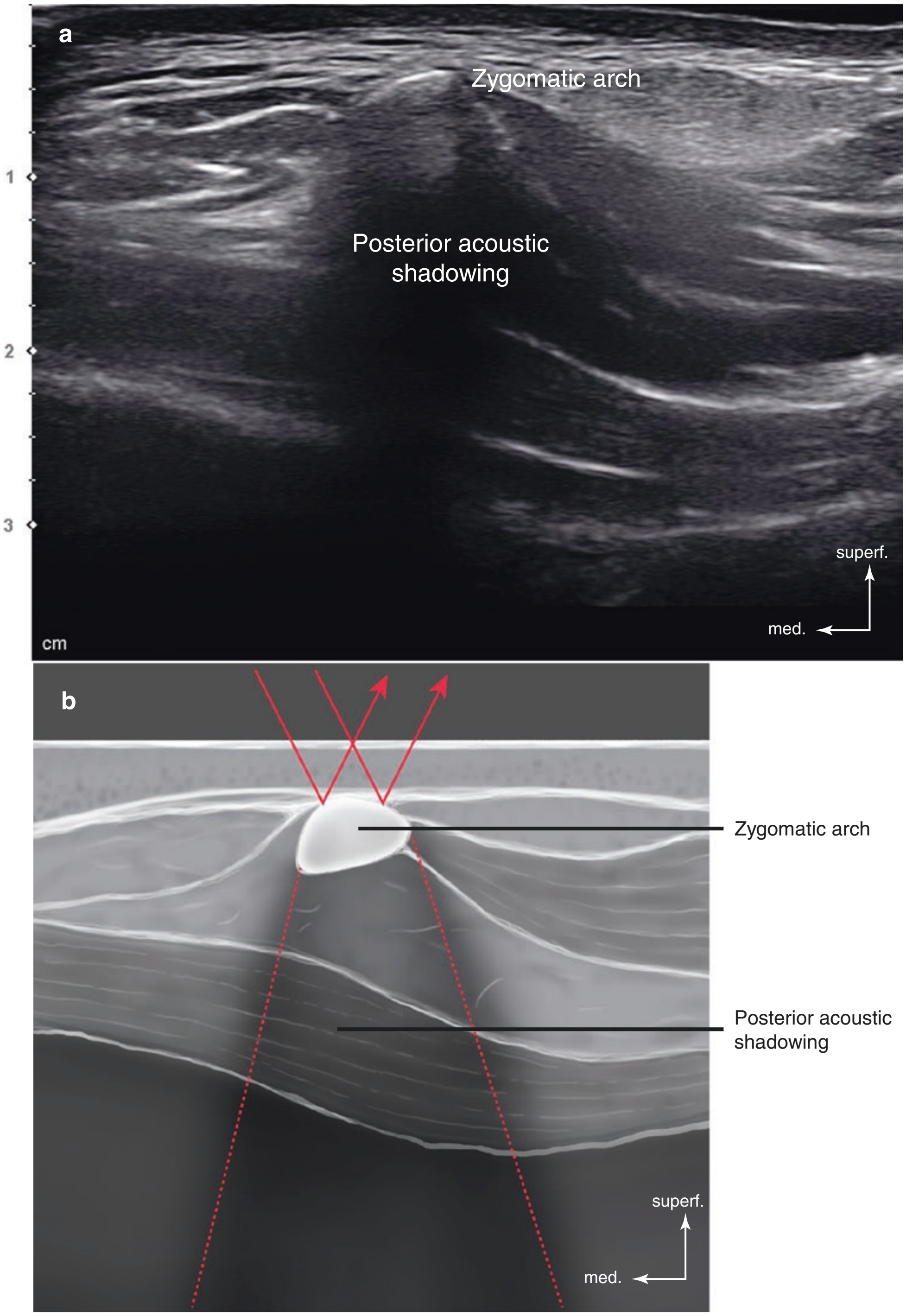


Fig. 1.11 Posterior acoustic shadowing. (**a**) Image of the zygomatic arch shows shadowing deep to the bone structure and (**b**) illustration representing the mechanism of the posterior acoustic shadowing. (Published with kind permission of © Hee-Jin Kim and Kwan-Hyun Youn 2020. All Rights Reserved)

1.1.5 Artifacts

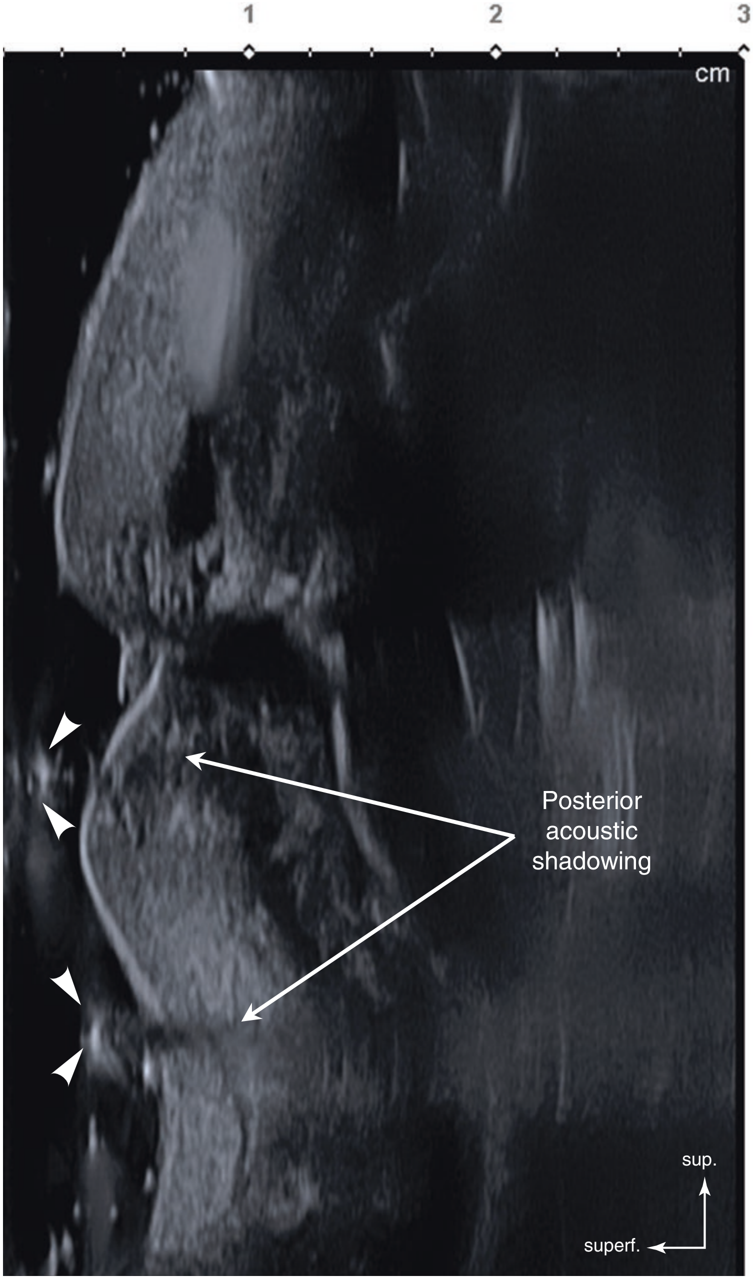
An artifact or a false image in the US can manifest a nonexisting structure or hide an existing structure. This is because the location, size, or echo of the structure can distort the image. In some cases, the artifact can bring confusion to the interpretation of the results and change the diagnosis. Therefore, a comprehension of the artifacts produced by the physical and mechanical mechanisms of the US and adjustment of such artifacts to increase the image quality are required.

The following are some artifacts that may develop in the facial area during US.

1.1.5.1 Posterior Acoustic Shadowing

Shadow artifacts are formed due to either a nonechoic area near the bone or due to a calcified material, or high echo foreign bodies, which are all relatively bright (Fig. 1.11). Air bubbles may also produce a shadow artifact (Fig. 1.12).

Fig. 1.12 Posterior acoustic shadowing (arrows) are formed by air bubbles (arrowheads) in the gel. (Published with kind permission of © Hee-Jin Kim 2020. All Rights Reserved)



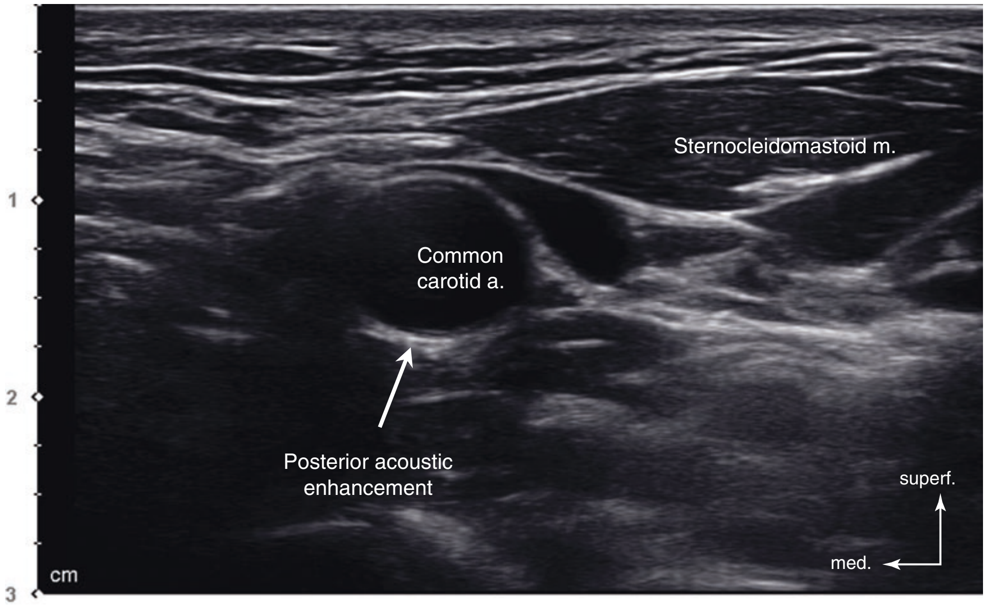


Fig. 1.13 Posterior acoustic enhancement. Image posterior to the common carotid artery shows the increased echogenicity (arrow). (Published with kind permission of © Hee-Jin Kim 2020. All Rights Reserved)

1.1.5.2 Posterior Acoustic Enhancement

This enhancement artifact is formed when the tissues appear hyperechoic relative to the upper adjacent fluid-filled structure. This can occur because of relatively less reflecting echoes from cysts, vessels, and solid soft tissue tumors (Fig. 1.13).

1.1.5.3 Reverberation Artifact

This artifact is made when vertically parallel structures reflect multiple echoes of uniform intervals, which can generally be seen in metallic needle tip reflections (Fig. 1.14).

1.1.5.4 Bayonet Artifact

The needle may also look bent due to the varying speed of ultrasound waves penetrating through different soft tissue such as muscle and adipose tissue.

1.2 Brightness Mode (B Mode)

The brightness mode (B mode) converts reflection echoes into bright dot images, which are utilized in most US diagnostic machines. The brightness of the dots is proportionate to the frequency of the reflected sounds. Anatomical structures and movement are digitalized in real time.

1.3 Doppler Effect Mode

The Doppler effect mode in US is used to find vessels in the body. The received US frequency changes when the transducer reflects echoes that have hit a moving structure such as blood. The differences between the transmitted US waves and received echoes are called frequency shift. The Doppler effect describes the change that occurs between the transducer and reflected structure. Higher frequency can be seen when the reflected structure is nearby. On the contrary, frequency decreases when further away from the transducer (Fig. 1.15).

There are several types of Doppler imaging. The color Doppler displays the vascular flow in red and blue. The vascular flow towards the transducer is in red and towards the opposite direction in blue. This color Doppler image is made by superimposition of the grayscale US images. Color saturation depicts the speed of the vascular flow and is brighter when the flow is faster and darker when the flow is slower. The spectral Doppler analyzes the periodic waveform and provides the quantitative data for vascular flow direction, speed, and amount (Fig. 1.16).

Fig. 1.17a represents anechoic vessels of the neck. The color Doppler represents vessels distinctively (Fig. 1.17b). Distinguishing artery and vein should be evaluated by the anatomical relationship, not by the color. If the anatomy of the targeted area is ambiguous, the compression technique can be used to differentiate between the collapsible vein and noncollapsible artery. The medially located artery is round and pulsatile while the laterally located vein is slightly distorted with no pulse (Fig. 1.17c).

The power Doppler mode presents all Doppler echoes as one uniform color regardless of its direction and speed. The power Doppler is more sensitive to smaller and lower flow vessels since all vascular flow data are reported. It has advantages in analyzing the inflammation and infectious lesions while detecting dilated small vessels. However, it cannot be used to measure the vascular flow and speed due to its high sensitivity (Fig. 1.18).

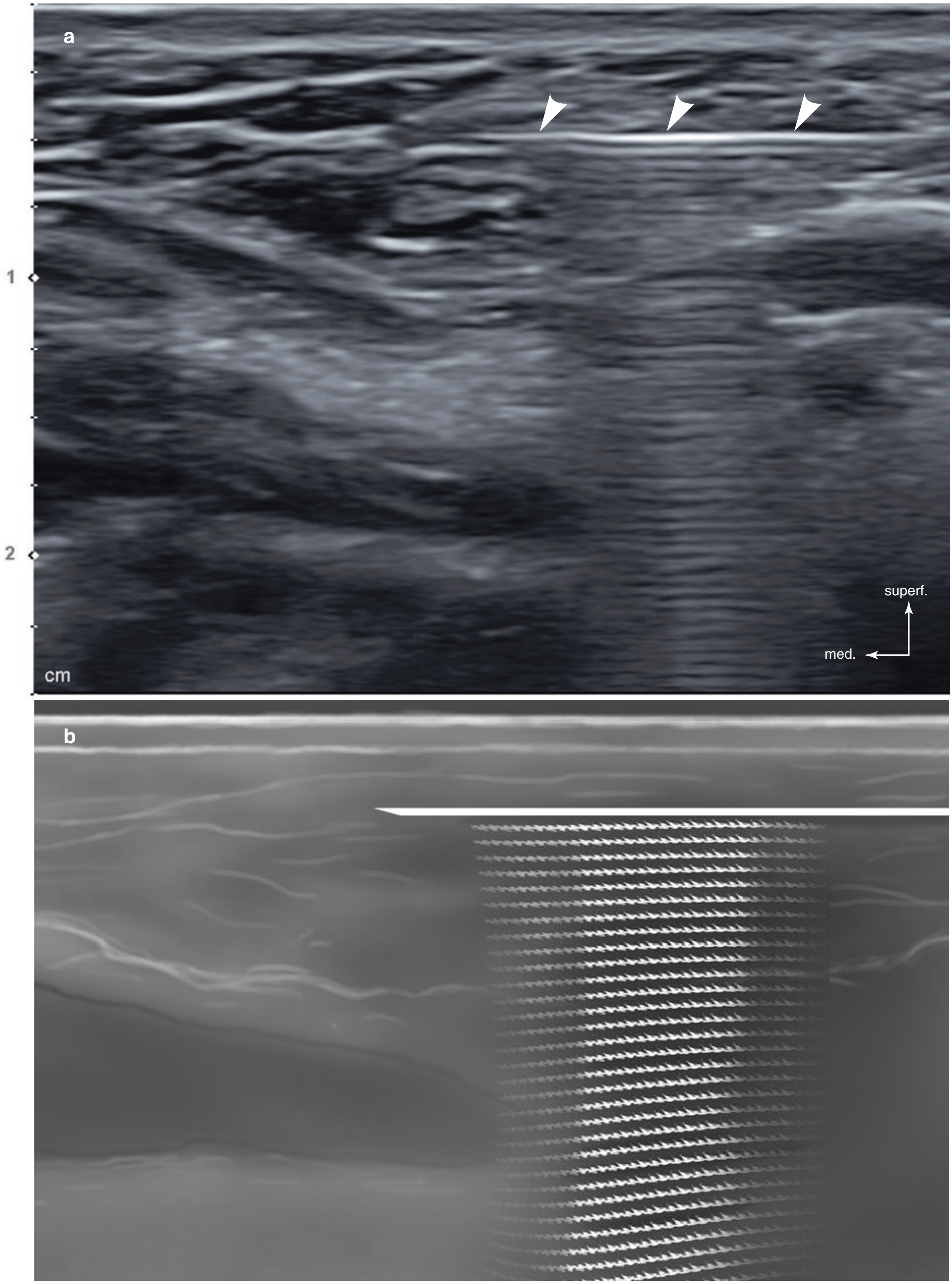


Fig. 1.14 Reverberation artifact. (**a**) Series of linear reflective echoes deep to the needle (arrowheads) are seen at subcutaneous tissue of the neck and (**b**) illustration representing the reverberation artifact. (Published with kind permission of © Ji-Soo Kim and Kwan-Hyun Youn 2020. All Rights Reserved)

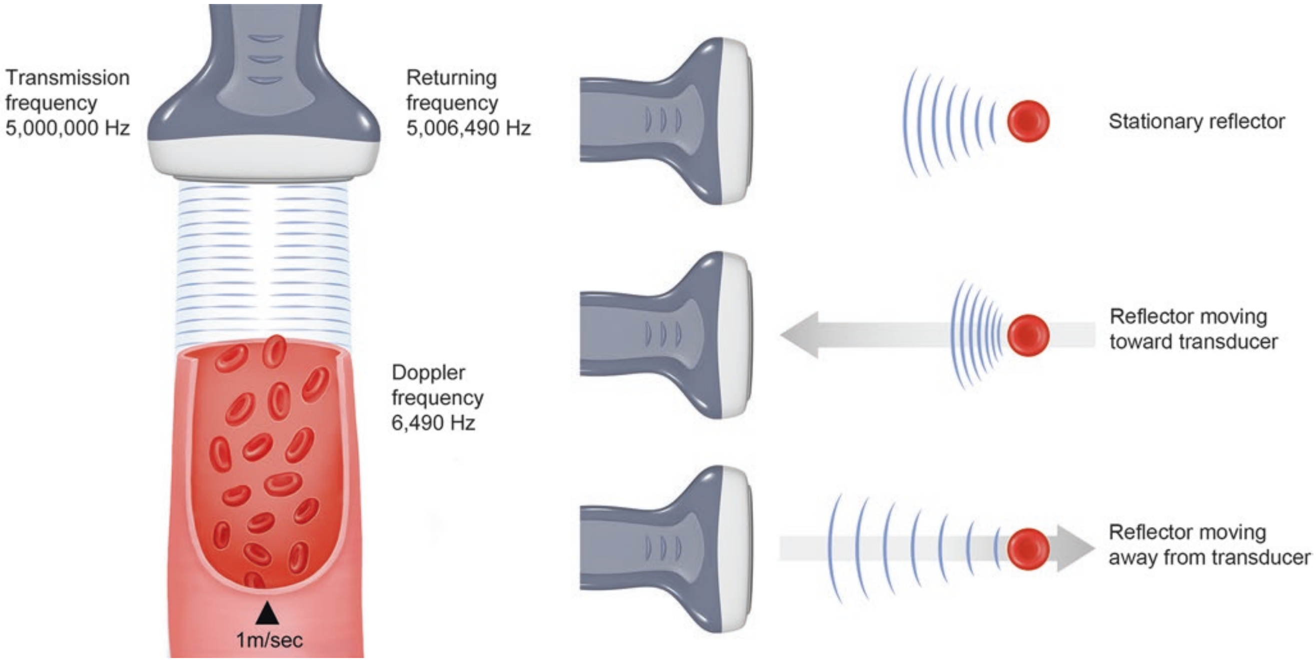


Fig. 1.15 Mechanism of Doppler effect. As the blood cell moves toward transducer, frequency of reflected ultrasound increases. On the contrary, frequency decreases as it moves away from transducer. (Published with kind permission of © Kwan-Hyun Youn 2020. All Rights Reserved)

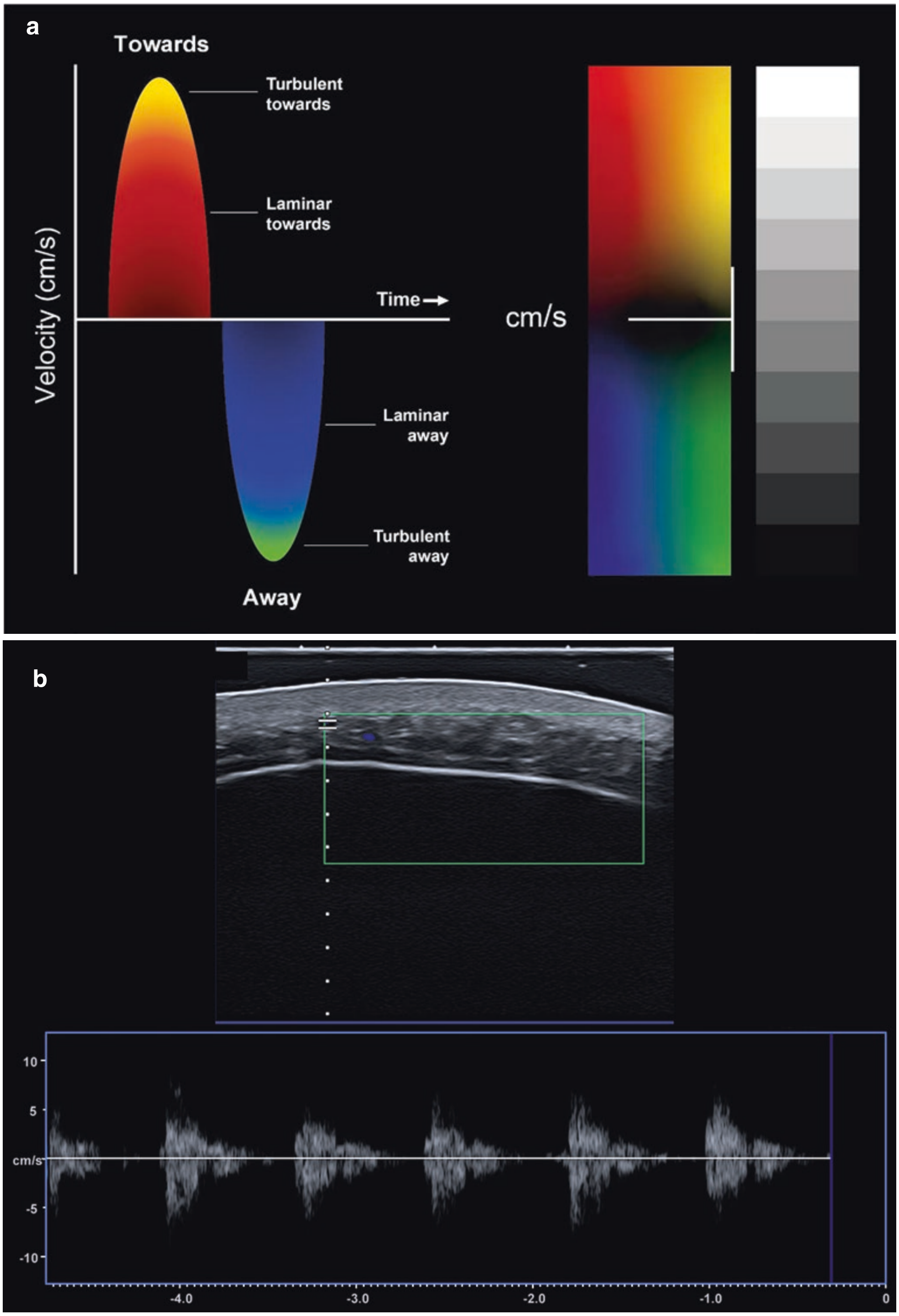


Fig. 1.16 Color and spectral Doppler. (**a**) Illustration of color Doppler and (**b**) artery in normal triphasic flow spectrum. (Published with kind permission of © Hee-Jin Kim and Kwan-Hyun Youn 2020. All Rights Reserved)

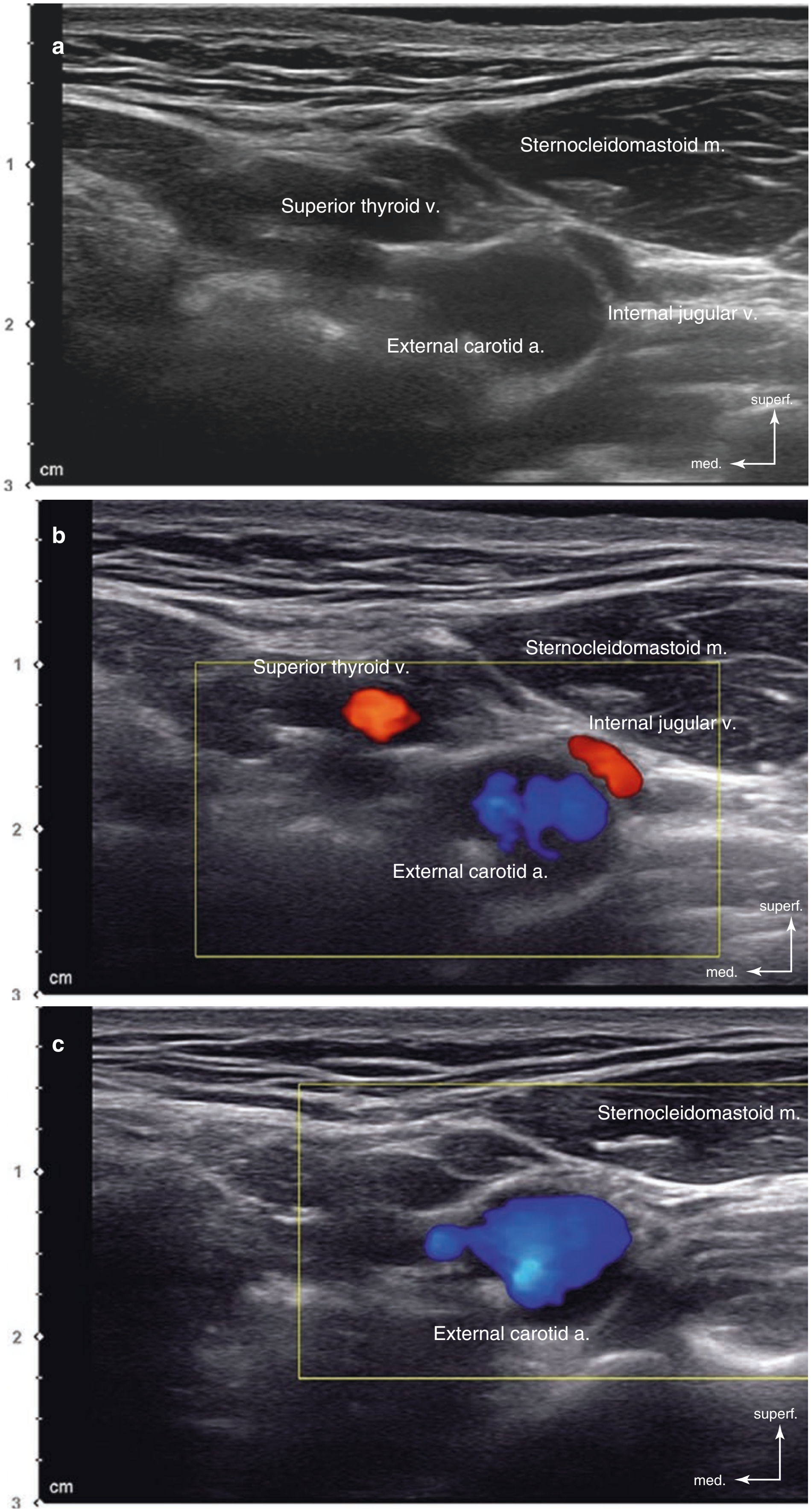


Fig. 1.17 Color Doppler used to locate vessels. (**a**) Ultrasonographic image of neck vessels without color Doppler, (**b**) easy to find facial vessels on a color Doppler image, and (**c**) vein is not seen on the subsequent image of the same region after transducer compression. (Published with kind permission of © Hee-Jin Kim 2020. All Rights Reserved)

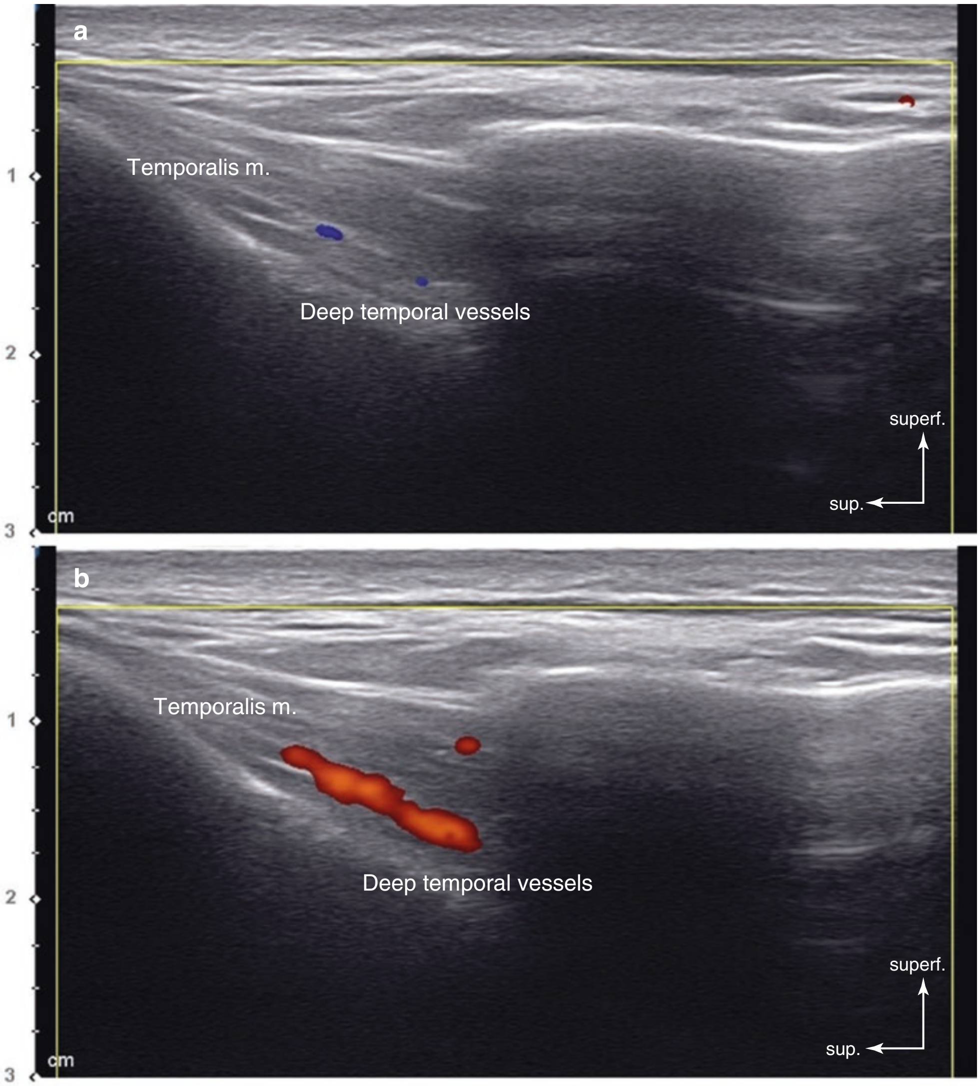


Fig. 1.18 Power Doppler image of deep temporal artery at the temple. (**a**) Color Doppler image and (**b**) power Doppler image. (Published with kind permission of © Hee-Jin Kim 2020. All Rights Reserved)

1.4 How to Start Minimally Invasive Aesthetic Procedures Using US

US in the face and neck area is effective in not only detecting the anatomical structures but also guiding minimally invasive aesthetic procedures such as botulinum toxin injection, filler injection, and thread lifting. Real-time US allows the practitioner to trace the needle tip and guide it to precisely inject in ideal locations.

1.4.1 US View

The needle should be placed in the middle half of the screen during the procedure. The needle will appear hyperechoic under US. The needle should be observed from both short- and long-axis views for accurate positioning. If the needle is placed parallel to the long-axis plane, an image of the needle can be observed. This plane of the image is easy to manipulate; however, the exact location of the needle tip is difficult to detect.

The short-axis view or the out-of-plane view rotates the transducer 90° from the long axis to find the needle tip. The needle tip shines like a bright star among the pitch dark sky. Tracing the needle from the proximal direction is beneficial in finding its precise location (Fig. 1.19).

1.4.2 Improving Needle Visualization

In most cases, the hyperechoic needle tip is obscure in the long-axis view. As previously mentioned, structures are clearly shown when the transducer is placed at 90°. Since the needle is generally inserted obliquely, the insonating angle gets out of