

Editor/Editör: **Prof. Dr. Dilek KAZANCI**

ANESTHESIOLOGY
FAST REVIEW
ANESTEZİYOLOJİYE HIZLI BAKIŞ

Türkiye Klinikleri

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ULTRASOUND AND ECHOCARDIOGRAPHY IN ANESTHESIA PRACTICE

ANESTEZİ PRATİĞİNDE ULTRASON VE EKOKARDİYOGRAFİ

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ABSTRACT

- The increasing use of ultrasound and echocardiography in anesthesia practices significantly facilitates both diagnosis and treatment.
- Access to anatomically vital structures has been made easier with ultrasound, providing significant guidance for simultaneous procedures. This situation significantly reduces the complication rates.
- It is used in many procedures such as peripheral nerve block applications, central venous access, calculation of gastric residual volume, evaluation of the airway, imaging of lung parenchyma, and calculation of certain properties of vascular structures.
- Intraoperative transesophageal echocardiography allows for real-time evaluation of the heart, especially in cardiac surgery.
- It plays a critical role in the evaluation of ventricular functions, valve structures, and hemodynamic changes.
- They can quickly identify unexpected situations encountered during surgery and guide the surgical team.

Keywords: *Ultrasonography; Echocardiography; Anesthesia applications; Transesophageal echocardiography*

ÖZET

- Anestezi uygulamalarında ultrason ve ekokardiyografi kullanımının giderek artması hem tanı koymayı hem de tedaviyi önemli derecede kolaylaştırır.
- Hayati önemi olan anatomik yapılara USG ile daha kolay ulaşım sağlanmış ve eş zamanlı yapılan girişimlere önemli bir kılavuzluk oluşturmuştur. Bu durum komplikasyon oranlarını önemli oranda azaltır.
- Periferik sinir blok uygulamalarında, santral venöz erişimde, gastrik rezidüel hacim hesaplamasında, hava yolunun değerlendirilmesinde, akciğer parankiminin görüntülenmesinde, vasküler yapıların bazı özelliklerinin hesaplanması gibi birçok işlemde kullanılmaktadır.
- İntraoperatif transözafageal ekokardiyografi özellikle kardiyak cerrahide kullanımı ek zamanlı değerlendiile kalbin gerçrmesi yapılabilmektedir.
- Ventrikül fonksiyonlarını, kapak yapılarını ve hemodinamik değişikliklerin değerlendirmesinde kritik rol oynar.
- Cerrahi sırasında karşılaşılan beklenmedik durumları hızlı bir şekilde tespit edip cerrahi ekibe yol gösterici olabilmektedir.

Anahtar Kelimeler: *Ultrason; Ekokardiyografi; Anestezi uygulamaları; Transözofageal ekokardiyografi*

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ESSENTIAL ULTRASONOGRAPHY

Formation of Sound Waves

Understanding how ultrasonography and echocardiography operate is crucial to understanding these procedures completely. The human ear can detect sound waves with frequencies ranging from 20 to 20,000 Hertz (Hz). Ultrasonic sound waves are those that have frequencies higher than this range. These ultrasonic so-und waves are used in ultrasonic devices. A sound wave must be produced before an ultrasound image can be produced. The device transforms the electrical energy it receives into sound waves. The ultrasonic probe's piezo-electric crystals are used in this conversion process. In order to transform electrical energy into mechanical energy and produce sound waves, these crystals-known as piezoelectric crystals-are layered in a particular pattern and thickness. The "piezoelectric effect" is the term used to describe this energy transformation.[1]

Image Formation Ultrasound Interaction with Tissues

The image displayed on the ultrasound device's screen is the result of ultrasound waves interacting with the tissues under examination. As the ultrasound wave travels through tissues, it loses amplitude (and thus energy). Attenuation refers to the reduction in amplitude. Absorption (the conversion of acoustic energy into heat), ref-lection, and refraction of ultrasound waves all contribute to attenuation.

Absorption

Absorption is the transfer of an ultrasound beam's energy to the medium through which it passes. This causes the production of heat, which accounts for the majority of energy attenuation.

Reflection

When an incoming ultrasound pulse passes through the interface of two body tissues with different acoustic impedances, the sound energy is reflected back to the transducer. When an ultrasound wave strikes an object smaller than its wavelength, it scatters in multiple directions (diffuse scattering). When it strikes smooth struc-tures, such as fascial planes, the wave is largely reflected back in a linear (direct) direction to the transducer. Most waves with an incident angle close to 90° are reflected back to the transducer, resulting in clear images. However, when the angle of incidence is less than 90°, the proportion of reflected waves increases, resulting in lower quality images reflected away from the transducer. This explains why there is poor needle visualization in ultrasound when the needle enters at a steep angle. Some needle manufacturers have added "reflective" needles to their designs. Many of these have notches at different angles on their surfaces to increase the proportion of waves reflected back to the transducer. This makes these needles more "echogenic."[2]

Refraction

Refraction is a change in the direction of a wave when it reaches the interface of two tissues with different sound transmission speeds. It is caused by a change in speed rather than acoustic impedance variations. Refraction is one of the most frequent causes of artifacts in ultrasound images.[1]

Reduction of Sound Wave Intensity

The attenuation of a specific ultrasound wave is contingent upon several factors, including the following:

Tissue type: It is elevated for denser tissues such as adipose and osseous tissue. It is diminished for fluidic environments such as cysts or cavities containing blood or liquid.

The attenuation per unit distance increases with higher frequency ultrasound waves. This elucidates why higher frequency transducers (generally up to 13-15 MHz) are employed to image superficial structures (up to 5-6 cm deep), whereas lower frequency (2-5 MHz) transducers are requisite for visualizing deeper structures (>6-10 cm deep). The extent of attenuation for any ultrasound wave is directly proportional to the distance traversed.

Impedance of Sound

The product of the medium's density (ρ) and the ultrasonic wave's acoustic speed (c) yields the acoustic impe-dance (Z), which measures how resistant the medium particles are to change as a result of mechanical disturban-ce. The relative difference in acoustic impedance, or resistance at the interface, between two tissues (or media) across an interface determines the

degree of ultrasound wave reflection, or the amount that returns to the trans-ducer to produce an ultrasound image. The reflection coefficient (R) determines this. The air/soft tissue and bone/soft tissue interfaces have a large acoustic impedance difference, which causes extremely high reflection in those regions. In contrast to the soft tissues' comparatively low acoustic impedance, this causes a notable incre-ase in acoustic impedance at the bone surface, which has a very high acoustic impedance. The bone cortex appe-ars hyperechoic (white) as a result. In a similar vein, the pleural surface appears hyperechoic due to a high degree of ultrasound wave reflection. The soft tissues in this latter instance, on the other hand, have a comparatively high acoustic impedance in comparison to the extremely low acoustic impedance of air, which causes a sharp decline in acoustic impedance and the high degree of reflection. The result is a high degree of reflection at the interface that appears hyperechoic, regardless of whether the acoustic impedance difference is increasing or decre-asing. This phenomenon also explains why "acoustic matching" on the transducer surface requires a gel. To put it another way, removing the skin's air/soft tissue interface will cause the ultrasonic wave to reflect heavily and lose the energy it needs to enter surrounding tissues.

Acquisition and Processing of Images

When the crystals receive the echo signals that have returned from the tissues, they produce an electric current (piezoelectric effect). This is then transformed into a pixel, and the brightness of the pixel point in the image determines how much energy the returning wave has. Nevertheless, the following extra steps are needed to create the finished image:

- **Amplification (gain):** In order for the echo signals to be properly displayed on a screen, their amplitude must be at a minimum. As such, it needs to be amplified. Amplification, however, adds to "ambient noise."

The intensity (and consequently brightness) of ultrasonic waves returning from deeper tissues is significantly lower than that of waves returning from nearby tissues due to attenuation. This phenomenon is known as time gain compensation, or TGC. Time gain compensation, which preferentially amplifies the signals coming back from deeper tissues, gets around this. Regardless of depth, the same gray tone is used to represent echoes co-ming back from similar reflectors.

- **Analog to digital conversion:** This removes outside noise and, more crucially, enables signal modification to enhance image quality.
- **Final adjustment:** To get the final image on the screen, this includes methods like adaptive image adjust-ment, edge enhancement, grayscale transfer curves, and frame averaging.

The following definition of the final image is based on how bright or echogenic the structures are:

Areas that seem whiter and have higher energy echoes returning in comparison to the surrounding structures (like muscle tendons and peripheral nerves) are said to be hyperechoic.

- **Hypoechoic:** Dark-gray regions where lower energy echoes from nearby structures (like proximally located spinal nerve roots) return.
- **Anechoic:** Regions that appear black and do not return echoes, such as fluid inside vessels or cysts

Tissues can be penetrated by the sound waves produced by the crystals on the probe; in other words, the sound wave that hits and bounces off the tissues returns to the probe, creating an image. The movement of the sound wave is influenced by the structure of the medium it passes through. Sound waves move differently in envi-ronments that are solid, liquid, and airy. In a solid medium, sound waves move the fastest. As the sound wave enters human tissue, it comes into contact with variously dense structures. The fluid density that is present in these tissues also affects the degree of reflection. In actuality, physical elements like acoustic impedance, angle of incidence, tissue surface structure, and diameter of the tissue reflecting the sound all affect how sound waves travel through tissues.[1]

The sound wave reflects off of various tissues and produces an echo. An image is produced by processing this reflected sound wave, or echo. In this case, the reflective characteristics of the reflective interface are determined by the amplitude of the reflected sound wave. Different methods are used to transform the data into images, including high reflection from a highly reflective surface, low reflection from a low reflective surface, and so on. Three distinct viewing modes are available for general use.[1]

- **Amplitude Modulation (A-Mod):** On a signal-intensity graph, the baseline line representing

the sound wave returning from the tissues has vertical peaks.

- **Brightness Mod:** Signals are graded based on amplitude and shown in various shades of gray for each degree of brightness (B-Mod, 2-D, Gray-scale ultrasonography). White is used to represent the highest reflection, black for the lowest, and various shades of gray for intermediate reflections. The pictures are shown here in two dimensi-ons. It is the clinical ultrasonography mode that is most frequently utilized.
- **Time Motion Mod (M Mod):** The amplitude-time curve is transformed into a moving image from the signals. It is widely utilized, particularly in echocardiography. A cross-sectional image of the region to be displayed will be produced in this mode. The vertical axis displays the depth of the structures, and the horizontal axis records time. Clear information regarding the thicknesses of the heart walls, the sizes of the heart chambers, and the pericardium can be obtained using the M Mode imaging technique. Apart from these imaging modes, ultraso-nography can also make use of the Doppler mode. This mode allows for the calculation of blood flow velocity, direction, and rate within the heart and vascular structures (Figure 1).

Ultrasonography Terminologies

The ultrasound device has certain specialized equipment. The processor, probe, and monitor are these. The devi-ce has a keyboard and mouse pad to allow users to make the necessary adjustments for its use. The processor processes the data from this probe before sending it to the monitor. By using the probe to scan the relevant tissue, the image can be clarified and displayed on the monitor. If we look at a few terms that are important to understand regarding the device.

Probe frequency: The sizes and frequency ranges of probes vary. These probes are used at different frequencies depending on the depth of the tissue and the area of use. When choosing a probe, the frequency value is crucial. High-frequency probes have better images of superficial tissues but less penetration. While penetration is higher with low-frequency probes, image quality is lower. Because echocardiography requires a particular crystal arran-gement to obtain the image between the ribs, a specialized low-frequency probe is used. Convex probes are used for peripheral nerve blocks, whereas linear probes are typically used for imaging deep tissues such as the abdo-men.[2]

Gain: By altering the time composition, ultrasonic devices can change the sound waves' intensity. This ad-justment, also referred to as gray scale gain, will improve the image quality because the sound wave's intensity drops as it interacts with the tissues.

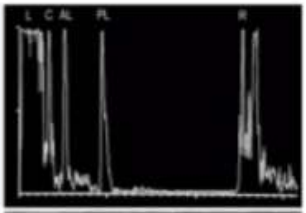
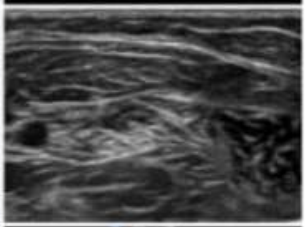
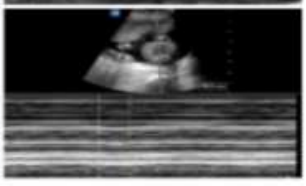
A-Mode	Amplitude-Intensity Mode	• Signals are shown as intensity graphs. • Plots where the sent wave reflects on the graph.	
B-Mode	Bright-ness-mode (Gray scale Ultrasonogra-phy)	• Signals are rated according to ampli-tude and a brightness tone is assigned to each degree. • The highest reflection is white, th low-est reflection is black, and intermediate reflections are displayed as shades of gray.	
M-Mode	Motion- Mode	• Signals are converted into a moving image from the amplitude -time curve. • It is frequently used in echocardiogra-phy.	

Figure 1. Ultrasound modes.

Equipment and Devices for Ultrasound

These days, portable ultrasound devices are designed to be easy to use. Depending on their intended use, they can be manufactured in a variety of sizes. The equipment used for anesthesia procedures in the operating room needs to be robust and portable. A transmitter that produces ultrasonic waves, a transducer that transforms elect-rical energy into sound waves, a processor that receives and interprets the signals sent back to the transducer, and a screen are the typical components of USG devices. The transducers (probe) are the most crucial part of the USG apparatus. They can be made as linear, convex (curved-array), or echo probes, depending on how the crys-tals are arranged and configured on the transducers. In linear probes, the sound wave travels linearly, perpendicu-lar to the tissue, and the crystals are arranged parallel to one another. The screen displays the image in a rectan-gular format. Linear probes have high frequencies and are produced in the 6-15 MHz range. The arrangement of the crystals in convex probes is curved. The image in these probes seems to progressively enlarge. The image's peak is curved as well. They are produced in the 2-6 MHz range and have low frequencies. Despite having a similar arrangement to a convex probe, the echo probe produces a sound wave from a single point that is extre-mely close to one another. This sound wave then gradually expands and penetrates the tissues. The ability to visualize the heart, which is situated between the ribs beneath the rib cage, is the main advantage of being pro-duced in this manner. Like a convex probe, it is produced at a low frequency.

Use of Transducer in Ultrasound

The use of the probe is extremely important in ultrasound. Especially, the sound wave emitted from the linear probe, which travels in a straight and parallel direction, should be perpendicular to the target tissue. If an inter-ventional procedure is to be performed (for example, a peripheral block), this situation should be well unders-tood in the visualization of the needle.For obtaining this image, the positioning of the transducer is of great importance.

Holding the transducer: A linear transducer is generally held between the thumb and fingers, and the palmar side of the palm or the ulnar side of the hand is placed on the patient to provide stability during scanning. A curved-linear transducer can be held by wrapping it around the fingers, supported by the ulnar side of the scan-ning hand.

Transducer movements: Providing an appropriate image of the structure under examination requires a systema-tic scanning approach involving major and minor movements. These include pressure, alignment, rotation, and tilt (commonly referred to as the PART maneuver).

Pressure: Applying sufficient pressure during scanning shortens the distance between the transducer and the target, thereby improving image quality. Additionally, it can allow for the compression of a vessel (helping in its identification). Unilateral pressure can also allow ultrasound waves to be directed at the desired angle. However, excessive pressure can cause the target depth to be determined below the estimate.

Alignment (or shifting): This allows the target structure to be centered in the image because it provides the best resolution.Shifting along the long axis also allows us to follow the focal structure proximally or distally (scout scan).

Rotation: Rotating the transducer clockwise or counterclockwise helps determine the correct transverse plane. Additionally, rotating the transducer from a transverse plane to a longitudinal plane allows for better examina-tion of the target and the best needle trajectory.

Tilt: The bending of the transducer along its vertical axis allows for the examination of the target (along its long axis) without the need to move the transducer closer or farther away. Tilting allows for proper visualization of the needle tip.[2]

Use of Ultrasound in Interventional Procedures in Anesthesia Practice

Needle insertion techniques:

"In-plane" and "out-of-plane" needle approaches are the most commonly used: In-plane needle entry: The needle is advanced in the plane of the ultrasound beam to visualize it from the shaft to the tip. A more superficial trajectory provides better visibility.

Out-of-plane needle entry: here, the needle trajectory is perpendicular to the transducer, so that the need-le tip or shaft appears as a hyperechoic point on the screen. This approach offers a shorter route to the target structure (nerve or vessel), but it can be difficult, especially for inexperienced practitioners, to track the exact position of the needle tip in real-time.

Cross (short) axis or longitudinal (long) axis combinations are possible as follows:

1. Short axis plane intra-needle placement.
2. Short axis out-of-plane needle placement.
3. Long axis plane intra-needle placement.
4. Long axis off-plane needle placement.

Short-axis in-plane and short-axis out-of-plane needle placement are commonly used in regional anest-hesia. Placing the needle in the short axis plane out of the plane is useful when inserting perineural catheters. There is no evidence that one method is better than another, and it may be more appropriate to use the most well-known method.[1]

Needle Advancement

Correct needle advancement techniques enable the needle tip to be tracked from its entry point to the target structure. In-plane needle placement: This allows you to track the needle more easily. The needle is initi-ally inserted at a shallow angle to allow for visualization. The advancing needle is then guided deeper into the target structures while remaining in the field of view. If the needle is pointed slightly obliquely, only a portion of it can be seen. The PART maneuver for transducer manipulation allows you to visualize the entire needle.

Out-of-plane needle placement. This technique is more difficult, and it can be performed in two ways:

- **Moving the transducer:** After positioning the needle in the desired trajectory, move the transducer closer to it until the needle tip appears as a hyperechoic point on the screen. The transducer is then moved away from the needle, and the needle tip is advanced until it is visible again on the screen. Such sliding movements allow the transducer to track the needle tip and direct it towards the target structure.
- **Tilting the transducer:** Here, the transducer is kept stationary. The needle is inserted out of the plane, fol-lowing the expected trajectory. The transducer tilts towards the needle, revealing the transducer tip on the screen. The transducer then tilts away from the needle, making the needle tip no longer visible. The needle is advanced until the tip is visible again. This movement is repeated until the needle tip is near the target structu-re. This method can be difficult if the underlying structure is highly anisotropic (a small tilt can result in a poor image of the structure of interest).

Applications of Ultrasonography in Anesthesia Practices

In anesthesia practice, ultrasonography serves both as a diagnostic instrument and as a guide that en-hances the efficacy and safety of interventions. The visual assistance offered by ultrasound guidance in diverse procedures, including peripheral nerve blocks, vascular access, tracheal intubation, and pulmonary assessment, diminishes complication rates and enhances success rates. Many of these interventions enhance patient safety and streamline clinicians tasks through real-time imaging. The extensive application of ultrasonography in anesthesia practices underscores the significance of this technology in healthcare services. The proper and effici-ent application of this technology is promoted via educational initiatives and clinical practices, with an innova-tive methodology presented in the domain of anesthesia.[1]

Regional Anesthesia

USG allows nerve blocks to be performed more safely and effectively by directly visualizing the targeted nerves. Especially in peripheral nerve blocks (e.g., brachial plexus, femoral nerve), ultrasound allows for real-time mo-nitoring of needle placement and the spread of local anesthetics.[3] This increases the success rate while minimi-zing vascular or neurological complications.[4]

Vascular Access

The use of ultrasound (USG) for central venous catheter (CVC) placement or peripheral vascular access provides clear guidance on anatomical structures. Especially in children and patients with difficult peripheral venous access, this method increases the success rate and reduces the risk of complications.[5]

Advantages

- Rapid and safe vascular access in patients with hemodynamic instability.
- Reduction of iatrogenic injuries and arterial punctures.[6]

Tracheal Intubation and Airway

Control Ultrasound guidance (USG) is an advanced instrument for evaluating airway anatomy and verifying

intubation. It is primarily utilized in the management of challenging airways, to evaluate sublingual or tracheal anatomy, and to verify tube placement post-intubation. USG is an innovative tool for the analysis of airway anatomy and confirmation of intubation. It is particularly used in the management of difficult airways, to assess sublingual or tracheal structures and to confirm tube placement after intubation. Conventional transcutaneous ultrasonography facilitates the visualization of the airway from the chin to the mid-trachea, in addition to the diaphragm and the pleural surface of the most distal alveoli.[7] The current and prospective uses of airway ultrasonography encompass predicting challenging airways, verifying the accurate placement of the endotracheal tube, visualizing anatomical abnormalities that may hinder airway management (e.g., subglottic hemangioma, stenosis), forecasting obstructive sleep apnea syndrome, estimating the dimensions of endotracheal, endobronchial, and tracheostomy tubes, executing airway nerve blocks, examining the procedural site prior to percutaneous tracheostomy, determining the presence of laryngeal edema, and assessing diaphragm and vocal cord movements to anticipate potential post-extubation complications.

Airway ultrasonography can visualize and assess the tongue, oropharynx, hypopharynx, epiglottis, larynx, vocal cords, cricothyroid membrane, cricoid cartilage, and trachea.[8]

Ultrasonography is an uncomplicated technique for assessing the oral cavity and its components. The tongue is observable within the oral cavity. Positioning a convex probe submentally in the sagittal plane facilitates a longitudinal scan of the floor of the mouth and the tongue, enabling visualization of both structures in a single image.[7]

Monitoring of Neuromuscular Blockade

The real-time evaluation of muscle relaxants' effects improves patient safety in surgical procedures. Ultrasound serves as an adjunctive instrument utilized in conjunction with neuromuscular monitors to evaluate the degree of neuromuscular blockade.[9]

Illustrative Instances:

- Observing diaphragm motions.
- Assessment of the resumption of spontaneous respiration post-surgery.[10]

Pulmonary Evaluation

USG is used to monitor pulmonary functions in the perioperative evaluation of patients with hemodynamic instability, and pleural fluid and lung atelectasis can be detected with lung ultrasound. Pulmonary and pleural ultrasound can be used to quickly diagnose and manage causes of acute respiratory distress that may be encountered during the perioperative period (e.g., pneumothorax, pleural effusion, pneumonia, cardiogenic pulmonary edema, pulmonary embolism, esophageal or endobronchial intubation, or exacerbation of asthma or chronic obstructive pulmonary disease) (Figure 2). In many cases, the diagnostic accuracy of ultrasonography is equal to or superior to that of chest radiography or computed tomography (CT).[10] When equipment and trained personnel are available, point-of-care lung ultrasonography, lung auscultation, and checking the anesthesia machine for possible malfunctions, along with the applied gas mixture and mechanical ventilator settings, can be used as primary tools to evaluate persistent intraoperative hypoxemia. Training in image acquisition and interpretation is necessary to master lung and pleura ultrasonography, but ease of use, speed, repeatability, and reliability have made it a useful perioperative tool. In emergencies, the most likely cause of acute respiratory distress can be very quickly identified by using only selected areas in the left and right hemithorax for the examination.[11]

Areas of Use:

- Evaluation of hypovolemia and tamponade.[12]
- Diagnosis of pulmonary edema or atelectasis.

Trauma and Emergency

In emergency trauma management, intra-abdominal fluid detection and pericardial tamponade assessment are performed using the FAST (Focused Assessment with Sonography for Trauma) protocol. Anesthesiologists effectively use ultrasound to make quick decisions in such emergencies.[13]

Musculoskeletal System Assessment

USG can also be used to evaluate perioperative musculoskeletal structures. It is especially preferred in chronic pain management and ultrasound-guided injections.[14]

Stomach Ultrasound

Gastric ultrasound has been used to evaluate the volume and character of gastric contents, thereby defining preoperative fasting guidelines in selected clinical scenarios when the presence of gastric contents is uncer-

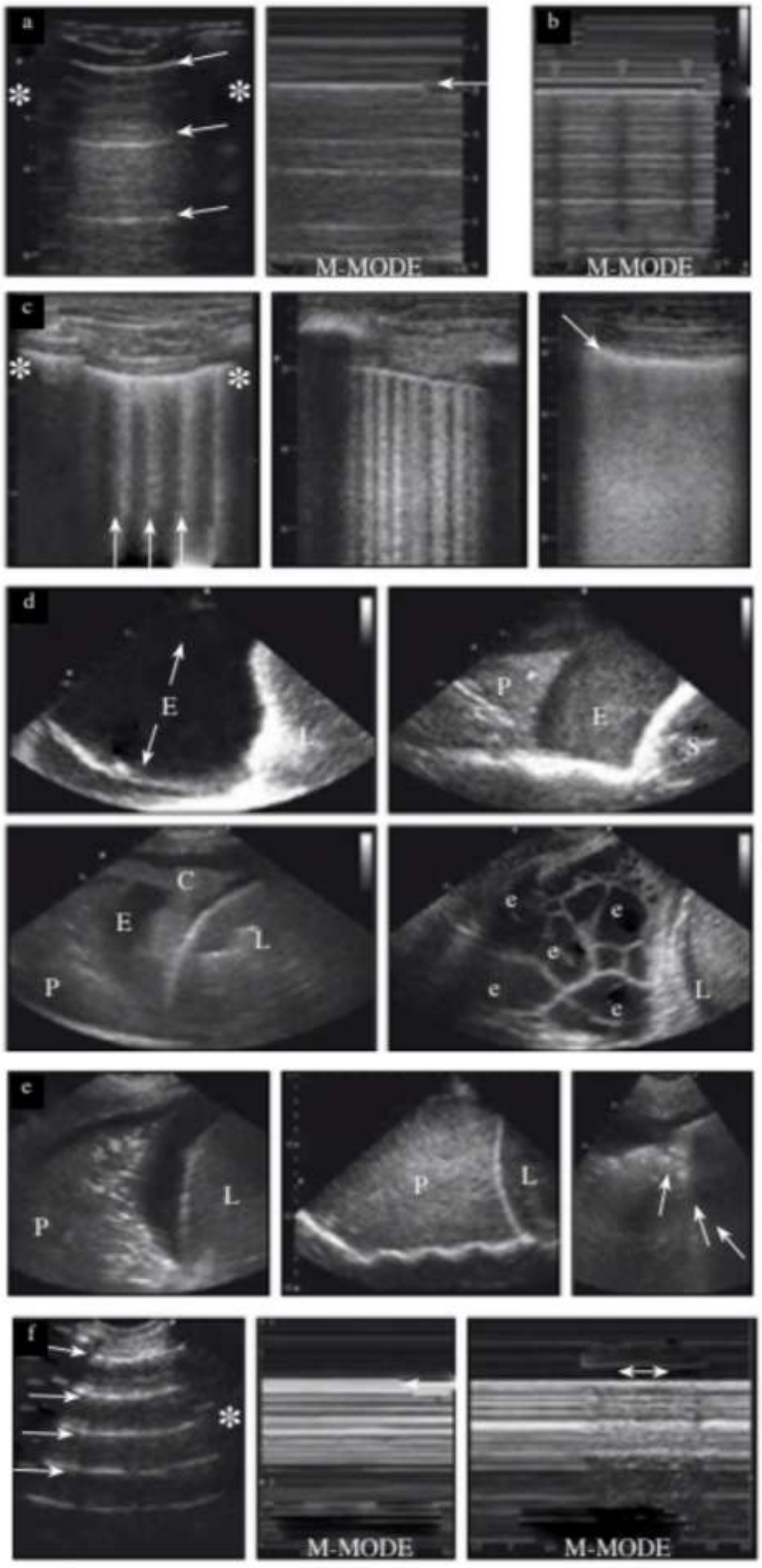


Figure 2. Synopsis of lung ultrasound semiotics. **a) Normal ("A-pattern"):** Two-dimensional/M-mode anterior scans. Pleural line (arrow) + A lines (arrowheads) + lung sliding ("sandy" appearance of M-mode pattern beneath pleural line = "seashore sign"). **b) Lung pulse:** In absence of ventilation, pleural sliding is substituted by heartbeat-synced pleural motion (rhythmic changes in M-mode artifacts beyond the pleural line, arrow). **c) Sonographic interstitial syndrome ("B-pattern"):** Two-dimensional anterior scans. Multiple (>3/intercostal space) B lines (left panel, arrowheads) original from pleural line (arrow), and substitute A lines. B lines can be well-spaced (left panel), crowded (middle panel), or coalescent (right panel; "white lung" pattern). Note pleural line thickening in left and right panels (arrows). **d) Pleural effusion:** Two-dimensional longitudinal scans at the posterior axillary line: diaphragm appears as bright curvilinear boundary on the left of liver (L) or spleen (S). Transductive effusion (E) appears as anechoic space between the pleuras (left upper panel, arrows). Complex exudative effusion (E) with particulated internal echoes (right upper panel, empyema) and consolidated lung (P) inside. Complex hemorrhagic effusion (E) with free-floating clot (C) and consolidated lung (P) inside (left lower panel). Complex septated effusion with multiple loculated collections (e) separated by septa (lower right panel). **e) Consolidation:** Two-dimensional longitudinal scans at the posterior axillary line (left and middle panels). Tissue-like echo-texture of the lung (P), similar to the liver (L). Presence in it of white dots/lines, reinforced at inspiration ("dynamic bronchograms") suggests a patent airway (left panel); their absence equates to atelectasis (middle panel). Small subpleural consolidation (right panel, arrows). **f) Pneumothorax ("A-pattern"):** Two-dimensional parasternal scan (left panel) shows pleural line (arrow) and A-lines (arrowheads). M-mode investigation (middle panel) indicates sliding abolition, representing the artifacts as parallel straight lines ("stratosphere sign") beneath the pleural line (arrow). At a more lateral point, M-mode depicts inspiratory.

Main segmental patterns are illustrated (left column) and described in their distinctive features (right column). Reprinted by permission of Edizioni Minerva Medica from: Minerva Anestesiol 2012; 78:1282-96

tain. (Figure 3).[15] In studies conducted on this subject, it was noted that the diagnostic accuracy of gastric ultrasound in detecting a fully filled stomach (i.e., any solid or >1.5 mL/kg clear fluid) is high, with 100% sensitivity (95% CI 93-100) and 98% specificity (95% CI 95-100).[16]

There is no definitive indication for performing a gastric ultrasound. However, the examination can be used to reassure clinicians that the gastric content volume in "at-risk" patients is low enough to minimize the risk of aspiration, or conversely, to support the decision to postpone elective surgery in a patient with



Figure 3. a) Clear fluid in the gastric antrum. **b)** Empty gastric antrum.
***R:** rectus abdominis muscle, **L:** liver, **A:** antrum, **P:** pancreas, **SMA:** superior mesenteric artery, **D:** diaphragm, **AO:** aorta.*

evidence of increased gastric volume in cases such as:

- Concern about the patient adhering to fasting rules before the surgery.[16]
- Unknown fasting history (for example, trauma, cognitive disorder, communication barrier).
- Possible delay in gastric emptying (e.g., pregnancy).[17]

Other possible causes of delayed gastric emptying include certain neuromuscular diseases, pain, chronic opioid use, and diabetes mellitus (especially in patients receiving glucagon-like peptide-1 receptor agonists.[18,19] The American Society of Anesthesiologists recommends taking 'full stomach' precautions or performing an ultrasound evaluation of gastric volume if GLP-1 agonists are not held as advised.[17] If the stomach is empty, proceed as usual. If the stomach is full or the stomach ultrasound does not yield conclusive results, consider delaying the procedure or treating the patient as having a full stomach.

Echocardiography

Echocardiography is a non-invasive imaging method that uses ultrasound technology to examine the structure, functions, and blood flow of the heart.[20] This method works by sending high-frequency sound waves to the heart and analyzing the returning echoes, providing detailed visual information about the heart muscle, chambers, valves, and major vessels.[21] Echocardiography is an important tool in the diagnosis and treatment follow-up of cardiovascular diseases, as it is widely used in the evaluation of conditions such as heart failure, valve diseases, congenital heart diseases, pericardial diseases, and cardiac shock.[22] Additionally, Doppler echocardiography provides more detailed data for the analysis of hemodynamic conditions by offering information about the speed and direction of blood flow.[23] Echocardiography, as a low-risk, non-invasive, and safe method, holds an important place in cardiology practice.

Intraoperative Echocardiography

In the past 25 years, the use of intraoperative echocardiography (IOE) has rapidly increased. Although its usefulness is considered excellent by users, its benefit to patient survival is still debatable. Echocardiography modalities have been rather important for modern cardiology and anesthesiology. Every indication, benefit, and restriction of the test should be considered to guarantee that it is suitable for the clinical environment. Among them are TEE, stress echocardiography, transthoracic echocardiography (TTE), and intramascular ultrasonic sound (IVUS). The echocardiographic method applied is influenced by the patient's condition, the clinical question, and the present knowledge. Technological advances will greatly enhance these techniques and increase their application in diagnosis and treatment. Knowing the details of every kind of echocardiography helps the doctor to maximize this useful instrument, so improving patient care and results.

Common Applications In Cardiac Surgery

Numerous recent studies have evidenced the efficacy of IOE in adult cardiac surgery. These studies have primarily examined whether IOE yields novel information and the frequency with which this information influenc-

es anesthetic and surgical procedures. The occurrence of new information varies between 12.8% and 38.6%, while its influence on treatment spans from 9.7% to 14.6%. Intraoperative TEE is not completely devoid of risk. Hogue et al. established in their research on the independent effects of dysphagia following cardiac surgery that, alongside advanced age and extended intubation duration post-surgery, the utilization of intraoperative TEE serves as a robust independent predictor of dysphagia. In a study, after controlling for other significant risk factors (stroke, LVEF, intubation duration, and operation length), it was demonstrated that patients who received intraoperative TEE experienced dysphagia 7.8 times more frequently than those who did not. A recent case series of seven thousand two hundred patients revealed no mortality linked to intraoperative TEE, although a morbidity rate of 0.2% was noted.[24]

Recommendations for the Use of Intraoperative Echocardiography

Class I

1. In the investigation of acute, life-threatening, and persistent hemodynamic disturbances (when ventricular functions and determinants are unclear and/or do not respond to treatment)
2. In the surgical repair of left ventricular lesions, hypertrophic obstructive cardiomyopathy, and aortic dissections involving the aortic valve
3. Complex valve replacements requiring homograft or coronary reimplantation (e.g., Ross procedure)
4. Surgical intervention for endocarditis when preoperative tests are insufficient or when there is suspected spread to the perivalvular tissue
5. Replacement of intracardiac devices or monitoring their position during other surgical interventions
6. Evaluation of posterior or loculated pericardial effusions during pericardial window procedures

Class II A

1. During surgical procedures in patients with a high risk of developing myocardial ischemia or infarction or hemodynamic disturbances
2. In the evaluation of valve replacements, aortic atheromatous disease, Maze procedure, cardiac aneurysm repair, cardiac tumor removal, intracardiac thrombectomy, and pulmonary embolectomy
3. Detection of air embolism in cardiotomy, heart transplantation, and neurosurgical procedures performed in an upright position.

Class II B

1. In the evaluation of suspected cardiac trauma, repair of acute thoracic aortic dissection without left ventricular involvement, and assessment of anastomosis sites during heart and/or lung transplantation
2. Evaluation of regional wall motion abnormalities during and after off-pump CABG surgery
3. The evaluation of pericardiectomy in pericardial assessment
4. In the evaluation of myocardial effusion and the perfusion of pericardial surgery, coronary anatomy, and graft continuity
5. Evaluation of residual ductal flow after closure of the patent ductus arteriosus.

Class III

1. Surgical repair of uncomplicated secundum-type atrial septal defect.

Transesophageal Echocardiography

Transesophageal echocardiography (TEE) is frequently used during heart surgery. There are many advantages to TEE. TOE is available in most hospitals, is a non-invasive method, and provides versatile and comprehensive information; however, despite TOE generally being a safe method, it can also lead to serious adverse events. The complication rate depends on the user's experience and the presence of severe esophageal or gastric diseases. It is mandatory to provide users with specialized training for the correct interpretation of the results.

Myocardial ischemia can be identified by observing disturbances in regional wall motion and wall thickening. The concordance between intraoperative TOE and ECG is generally low. If there is no acute ischemia, both ST segment changes and regional wall motion abnormalities can be observed. If there are left bundle branch block, ventricular pacemaker rhythm, or right ventricular overload, it can be difficult to interpret wall motion abnormalities. If ischemia occurs after myocardial stunning, the resolution of the ischemia may not be observed. It has been shown that episodes of new or worsening wall motion abnormalities are not frequently observed (20%) in high-risk pa-

tients undergoing non-cardiac surgery. These are more commonly seen in patients who have undergone aortic vascular surgery. Episodes have been very minimally associated with postoperative cardiac complications.[24]

In identifying patients at high risk of ischemic outcomes in non-cardiac surgery, routine monitoring of myocardial ischemia with TOE or a 12-lead ECG has a slightly higher clinical value compared to preoperative clinical data and a 2-lead ECG.27 In identifying patients at high risk of ischemic outcomes during non-cardiac surgery, the routine monitoring of myocardial ischemia with TOE or a 12-lead ECG has a slightly higher clinical value compared to preoperative clinical data and a 2-lead ECG. In cases of acute and severe hemodynamic instability or life-threatening disorders developing during or after surgery, TOE is also recommended.[25] During surgery, TEE can be utilized in cases of hypotension. In a prospective study involving 42 adult patients, TOE was performed before any other hemodynamic monitoring in cases of severe hypotension. Severe hypotension, hypovolemia, low ejection fraction, severe embolism, myocardial ischemia, cardiac tamponade, or dynamic SV outflow obstruction have been useful in determining the cause. The role of TEE in hemodynamic monitoring of patients at risk is controversial. There is no evidence that risk is accurately stratified or that outcomes are correctly predicted with hemodynamic monitoring using TOE. In patients with severe valvular disease, TOE can be utilized in the operating room. Functional and ischemic mitral insufficiency generally decreases during general anesthesia. In contrast, organic mitral insufficiency increases. In cases of severe mitral insufficiency, the SV ejection fraction overestimates SV function, and other parameters such as myocardial velocity or deformation detected by tissue Doppler imaging or angle-independent 2D speckle tracking provide more accurate interpretations. These are emerging technologies, but further validation studies are needed before they can be used in routine practice. It is important to provide appropriate preload to patients with severe aortic stenosis during surgery. End-diastolic SV volume monitoring can provide more accurate results than pulmonary capillary pressure. For patients with mitral stenosis and aortic regurgitation, an appropriate heart rate is vital; in the former, a sufficient diastolic period, and in the latter, an appropriate but not prolonged diastolic duration. If heart rate control is not adequately achieved, the results should be evaluated; changes in transmitral mean gradient and pulmonary arterial pressure in mitral stenosis, and changes in SV volume and SV function index in aortic regurgitation.

Transesophageal Doppler (TED) (without echocardiography) can be used to monitor cardiac output. In a government-sponsored systematic review in the US, a strong level of evidence was shown supporting the use of TED in reducing the length of hospital stay and the rate of major complications after major surgery. A similar result was obtained in a separate summary conducted by the National Health Service (NHS) of the UK, where evidence-based procurement was implemented in three NHS hospitals, comparing 626 patients evaluated beforehand and 621 patients who underwent fluid optimization strategies guided by intraoperative TED. The NHS findings showed a 67% reduction in intraoperative mortality, a 4-day reduction in the average postoperative hospital stay, a 23% reduction in the need for central venous catheter placement, a 33% reduction in complication rates, and a 25% reduction in the rate of repeat surgeries.[24]

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