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An Overview for Echocardiography Techniques-An Updated Review for Modern and Advanced Techniques and Innovations

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Abstract:

Background: Echocardiography has evolved significantly since its inception in the 18th century, with foundational contributions from Lazzaro Spallanzani and practical applications pioneered by Hertz and Edler in 1954. Initially reliant on M-mode imaging, the field has advanced to incorporate Doppler imaging, three-dimensional (3D) reconstruction, and contrast-enhanced techniques, making it a cornerstone of cardiac diagnostics. Echocardiography is now indispensable for assessing cardiac structure, function, and hemodynamics, offering real-time, non-invasive imaging without radiation exposure. **Aim:** This review aims to provide an updated overview of echocardiography techniques, focusing on modern advancements, innovations, and their clinical applications. It highlights the evolution from basic 2D imaging to advanced modalities like 3D echocardiography, speckle-tracking, and artificial intelligence (AI)-assisted imaging, emphasizing their role in improving diagnostic accuracy and patient outcomes. **Methods:** The review synthesizes historical developments, technological advancements, and clinical applications of echocardiography. It explores the principles of ultrasound physiology, imaging modes (M-mode, 2D, 3D, Doppler), and their integration into clinical practice. The article also discusses the indications, contraindications, and complications associated with transthoracic (TTE) and transesophageal echocardiography (TEE), as well as the equipment and personnel required for effective echocardiographic examinations. **Results:** Echocardiography has transformed cardiac diagnostics, offering unparalleled insights into cardiac anatomy and function. Innovations such as 3D imaging, speckle-tracking, and contrast-enhanced echocardiography have enhanced diagnostic precision, while AI and portable devices have improved accessibility and efficiency. TEE has become invaluable in surgical and interventional settings, despite its invasive nature and associated risks.

Conclusion: Echocardiography remains a vital tool in cardiology, with continuous advancements expanding its diagnostic and therapeutic applications. Its integration of modern technologies ensures its relevance in both routine and complex clinical scenarios, ultimately improving patient care and outcomes.

Keywords: Echocardiography, 3D imaging, Doppler, speckle-tracking, artificial intelligence, cardiac diagnostics.

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Introduction:

The fundamental ideas of echocardiography originate from the 18th century when Lazzaro Spallanzani clarified the phenomena of reflected echoes from inaudible sound waves [1]. The application of ultrasound in cardiac assessment was initiated by Hertz and Edler in 1954, representing the inaugural use of an industrial ultrasonic defect detector to record transcutaneous, time-varying echoes for the continuous observation of heart motion. This advancement resulted in the first clinical use of echocardiography, particularly for assessing the mitral valve by M-mode imaging [2,3]. In the following decades, echocardiography experienced significant advances, becoming an essential instrument for heart assessment. The field, originally dependent on B-mode imaging, has gradually integrated advanced technologies including Doppler imaging and three-dimensional (3D) reconstruction, leading to more thorough and detailed assessments [4-6]. The implementation of echocardiographic contrast agents and transesophageal probes has significantly improved diagnostic sensitivity, especially for valve reconstruction in cardiac procedures [7][8]. Despite the emergence of additional imaging modalities, echocardiography continues to be the primary initial diagnostic instrument for evaluating heart anatomy and function. In specific instances, innovative technologies have replaced conventional ways, whilst in other cases, they have been used to enhance current functionalities. This chapter aims to present an overview of ultrasound physiology, essential echocardiographic terminology, various imaging modalities, and basic echocardiographic perspectives, highlighting the persistent significance of echocardiography in modern cardiology.

Anatomic Position of the Heart:

The heart is typically situated in the central mediastinum, with about one-third of its mass lying to the right of the midline. The longitudinal axis stretches diagonally from the base, located near the right shoulder, to the apex, oriented toward the left hypochondrium [9]. Cardiac placement variations are affected by body habitus, and minor positional alterations may transpire during respiration. Pathological circumstances, such as lung ailments, pleural disorders, or afflictions of other mediastinal organs, can markedly displace the heart, complicating imaging capture and interpretation. In echocardiographic imaging, specifically in parasternal long-axis views, the right ventricular free wall is the most anterior structure, whereas the left ventricular posterior (inferolateral) wall is the most posterior structure. These anatomical linkages are essential for precise echocardiographic evaluation and diagnosis. The heart's location and alignment are critical factors in echocardiography, as they affect the quality and interpretation of imaging investigations. Comprehending these anatomical subtleties is essential for differentiating normal changes from abnormal displacements. In patients with chronic lung illness or pleural effusions, the heart may be displaced or rotated, requiring modifications in imaging procedures to achieve optimal views. Likewise, diseases like pneumothorax or mediastinal masses can further modify heart placement, presenting complications for echocardiographers. The anatomical location of the heart and its alterations resulting from physiological or pathological causes are crucial in echocardiographic imaging. Proficiency in these anatomical specifics guarantees precise interpretation and improves the diagnostic efficacy of echocardiography in clinical settings (**Figure 1**) [9].

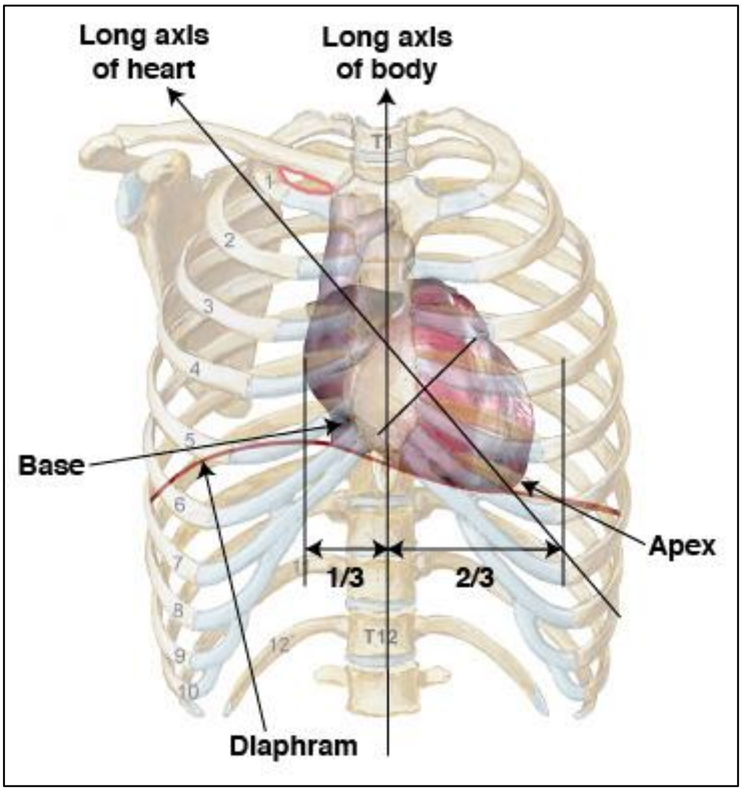

Figure 1: Anatomic Position of Heart [10].

Ultrasound Physiology:

Ultrasound waves, or sound waves with frequencies between 1.5 and 7.5 MHz, are used in echocardiographic probes. Depending on the medium these waves pass through, their velocity changes. For example, sound travels at a speed of around 330 m/s in air and 1540 m/s in heart tissue [11]. The echocardiographic probe's piezoelectric crystals transform electrical oscillations into mechanical (sound) waves, which produce ultrasound waves. On the other hand, mechanical waves that are reflected are converted back into electrical impulses. Ultrasound imaging relies heavily on this bidirectional conversion, also referred to as the piezoelectric effect. Every echocardiography probe has a piezoelectric crystal transducer that, when exposed to different voltages, vibrates and releases ultrasonic waves. The transducer receives reflected ultrasonic waves and produces electrical signals, which the echocardiography machine then analyzes to create images [12]. The ultrasound probe sends sound waves into the desired bodily area during imaging. Tissue borders and interfaces reflect these waves back to the probe. The speed of sound in the tissue and the time it takes for each echo to return are used to determine the distance between the probe and the tissue. The calculated distances and the intensities of the reflected echoes are mapped to create a two-dimensional picture. This procedure serves as the foundation for echocardiographic imaging by making it possible to see cardiac structures and their functional dynamics.

Indications for Echocardiographic Examination

Echocardiographic examination is indicated for a wide range of clinical purposes, encompassing both diagnostic and monitoring applications. Key indications include the evaluation and monitoring of left ventricular systolic and diastolic function, which are critical for assessing cardiac performance and guiding therapeutic decisions [13-15]. Additionally, echocardiography is essential for evaluating valvular function, including the detection of valvular abnormalities, assessment of the functional significance of valvular lesions, and monitoring the structure and function of prosthetic valves. Right ventricular function can also be assessed, providing insights into conditions such as pulmonary hypertension or right heart failure. The quantification and evaluation of cardiac chamber size are fundamental for diagnosing conditions such as cardiomyopathy, hypertrophy, or dilation. Echocardiography is further utilized to evaluate cardiac hemodynamics, including the measurement of pressures and flow dynamics within the heart. In the context of congenital heart diseases, echocardiography plays a pivotal role in diagnosing intracardiac shunts and other structural anomalies. Stress echocardiography is a valuable tool for assessing coronary artery disease, as it helps identify ischemic regions and evaluate myocardial viability. Other important indications include the evaluation of a cardiac source of embolism, which is crucial for patients presenting with stroke or transient ischemic attacks. Echocardiography is also employed to detect and characterize cardiac masses, such as tumors or thrombi, and to diagnose pericardial diseases, including pericardial effusion or constrictive pericarditis. These diverse applications underscore the versatility and indispensability of echocardiography in modern cardiology, making it a cornerstone for the structural and functional assessment of the heart [13-15].

Contraindications:

There are no absolute contraindications to the non-invasive imaging technique known as transthoracic echocardiography (TTE). It does, however, have some drawbacks, especially when it comes to individuals who are extremely overweight. Excessive bodily tissue can greatly weaken the transmission of ultrasonic waves, producing less-than-ideal image quality and diagnostic data. However, because transesophageal echocardiography (TEE) is invasive, there are certain contraindications. Esophageal and pharyngeal blockages, known or suspected perforated viscera, active gastrointestinal hemorrhage, and cervical vertebral instability are all absolute contraindications [16]. When inserting and manipulating probes, these circumstances provide serious dangers. Esophageal varices, esophageal diverticula, cervical arthritis, oropharyngeal distortion, bleeding diathesis or coagulopathy, and an uncooperative patient are among the relative contraindications for TEE. Although these circumstances do not completely rule out the use of TEE, they do call for careful evaluation of the advantages and disadvantages, as well as possible adjustments to the process to guarantee patient safety. When deciding if TEE is appropriate for a certain patient, clinicians must consider these variables [16].

Equipment for the Echocardiographic Examination:

A comprehensive echocardiographic examination requires specific equipment to ensure accurate imaging and patient safety. The primary device is the echocardiographic machine, which serves as the central unit for generating, receiving, and processing ultrasound waves. This machine is equipped with various probes tailored to different imaging modalities, such as transthoracic and transesophageal echocardiography. Electrocardiographic (ECG) leads are essential for synchronizing cardiac imaging with the electrical activity of the heart, enabling precise assessment of cardiac cycles and timing. To optimize ultrasound transmission, a coupling gel is applied to the skin, ensuring adequate surface contact between the probe and the patient’s body. Echocardiographic contrast agents may be utilized to enhance image quality, particularly in cases where endocardial border delineation is suboptimal. Saline, when agitated, can be used to create bubble contrast for detecting intracardiac shunts. An intravenous cannula is necessary for administering contrast agents or saline during the procedure. Given the potential for arrhythmias or other cardiac emergencies during echocardiography, a defibrillator must be readily available. This precaution ensures prompt management of life-threatening conditions, such as ventricular fibrillation or tachycardia. Additionally, other emergency equipment, including oxygen supplies and resuscitation medications, should be accessible to address any unforeseen complications. In summary, the essential equipment for echocardiographic examination includes an echocardiographic machine, ECG leads, coupling gel, contrast agents, saline, an intravenous cannula, and a defibrillator. These tools collectively facilitate high-quality imaging, patient monitoring, and emergency preparedness, ensuring the safety and efficacy of the procedure. Proper preparation and availability of this equipment are critical for achieving diagnostic accuracy and maintaining patient care standards [16].

Echocardiography Terms:

Optimizing image acquisition and interpretation requires an understanding of important concepts used in echocardiography. Measured in Hertz (Hz), frequency is the number of mechanical vibrations (sound waves) per unit of time; one Hz is equivalent to one vibration per second. Higher-frequency probes are appropriate for superficial structures because they offer better resolution but have a shallower penetration depth. lesser-frequency probes, on the other hand, are better at penetrating deeper tissues but have a lesser resolution. The amplitude of reflected ultrasonic waves is represented by grayscale imaging, where bright indicates large amplitudes, dark grey indicates low amplitudes, and black indicates no signal. Differentiating tissue densities and structures is aided by this grayscale representation. The imaging area's width and depth are affected by sector and depth changes, respectively. The frame rate is influenced by both parameters; greater frame rates improve temporal resolution. The frame rate can be raised by utilizing life zoom, reducing depth, or shrinking the sector width. While Time Gain Compensation (TGC) accounts for the attenuation of ultrasonic energy at different depths, gain regulates the image's overall brightness. TGC knobs ensure consistent image quality by enabling the selective lightening or darkening of particular depth levels. Temporal resolution is directly impacted by frame rate, which is the quantity of images seen each second. Rapid cardiac motions, like anomalies in wall motion or valve movements, are better captured at higher frame rates. Together, these words serve as the cornerstone of echocardiographic imaging, allowing medical professionals to adjust parameters for precise diagnosis and interpretation. To provide accurate clinical evaluations and produce high-quality photographs, mastery of these ideas is essential [16].

Personnel in Echocardiography:

The successful execution of an echocardiographic examination relies on a team of skilled professionals, each playing a critical role in ensuring accurate imaging and patient care. The echocardiography technologist is a key member of the team, responsible for operating the echocardiographic machine, acquiring high-quality images, and optimizing imaging parameters. Their expertise in handling the equipment and understanding imaging protocols is essential for obtaining diagnostic-quality results. A registered cardiac nurse often assists during the procedure, particularly in monitoring the patient's vital signs, managing intravenous access for contrast administration, and addressing any emergent situations. Their role is vital in maintaining patient safety and comfort throughout the examination. The cardiologist, particularly one with specialized training in echocardiography or cardiac imaging, oversees the procedure, interprets the images, and integrates the findings into the clinical context. Their expertise ensures accurate diagnosis and guides subsequent management decisions. In complex cases, such as transesophageal echocardiography or stress echocardiography, the cardiologist may perform or supervise the procedure to ensure optimal outcomes. Together, this multidisciplinary team collaborates to deliver high-quality echocardiographic services, combining technical proficiency, patient care, and clinical expertise. Their coordinated efforts are essential for achieving accurate diagnoses and improving patient outcomes in cardiovascular care [16].

Preparation for Echocardiographic Examinations:

Depending on the technique being conducted, different preparations are needed for echocardiograms. It is usually not essential to make any particular preparations for normal transthoracic echocardiography (TTE). To guarantee ideal probe contact and enhance image quality, it could be advised for male patients with thick chest hair to shave the area. However, more preparation is needed for transesophageal echocardiography (TEE). To lower the risk of aspiration, patients must fast for at least six hours before the surgery. To make it easier to provide sedatives, contrast media, or other drugs as needed, intravenous access is set up. Throughout the surgery, it is imperative to continuously monitor the heart to identify and treat any hemodynamic abnormalities or arrhythmias. Because the TEE probe insertion can be painful, light sedation is frequently used to improve patient comfort and cooperation. For echocardiograms to be safe, effective, and diagnostically accurate, several preparation measures are essential. By reducing hazards, improving patient comfort, and making it easier to obtain high-quality images, proper preparation empowers medical professionals to make well-informed decisions about diagnosis and treatment [16,17].

Patient Position and Electrocardiography Lead Placement:

Proper posture of the patient is essential for the best echocardiographic images. The patient is positioned in the left lateral decubitus position, with the left arm out behind the head, for parasternal and apical views. By placing the heart closer to the chest wall, the image quality is enhanced. The patient is positioned supine for suprasternal and subcostal views [17]. To track heart rhythm and align imaging with the cardiac cycle, modified electrocardiogram (ECG) leads are positioned. By acting as a time marker, the ECG makes it possible to precisely gate echocardiograms and makes it easier to spot arrhythmias or cardiac events that are connected to timing. Accurate and useful pictures for diagnosis depend on proper posture and ECG lead placement.

Echocardiographic Modes:

M-Mode Echocardiography:

One of the oldest and most basic methods of cardiac ultrasound imaging is M-mode (motion mode) echocardiography. An oscilloscope was used to display the amplitude and depth of reflected signals after echocardiogram images were first obtained using A-mode (amplitude mode), which involves sending ultrasonic waves down a single line. M-mode echocardiography was created by charting these ultrasonography lines over time, giving a dynamic depiction of moving heart structures. M-mode continues to be a useful supplementary tool in cardiac assessment even with the introduction of sophisticated imaging modalities like 2D and 3D echocardiography. M-mode's unusually fast sampling rate, which provides better temporal resolution than 2D imaging, is one of its main advantages. Because of this, M-mode is especially helpful for timing faint cardiac events that 2D exams might overlook. The aortic valve, mitral valve, and endocardial boundaries are examples of rapidly moving structures that display distinctive motion patterns in M-mode, allowing for accurate assessment of their timing and function [18]. Furthermore, M-mode offers superior spatial resolution, which makes it perfect for determining wall thickness and chamber sizes as well as ventricular dimensions during systole and diastole [19]. Graphical representations of M-mode images show the distance from the transducer on the y-axis and time on the x-axis. The top of the image shows structures that are closer to the transducer, while the bottom shows structures that are farther away. M-mode is a trustworthy method for measuring structural and functional characteristics because of its linear representation, which enables an in-depth examination of cardiac motion and dimensions. Even though more sophisticated imaging methods have essentially replaced M-mode, it is still essential for echocardiography, especially in situations that call for accurate measurements and great temporal resolution. The total diagnostic potential of echocardiograms is improved by their combination with contemporary imaging modalities (**Figure 2)** [18,19]**.**

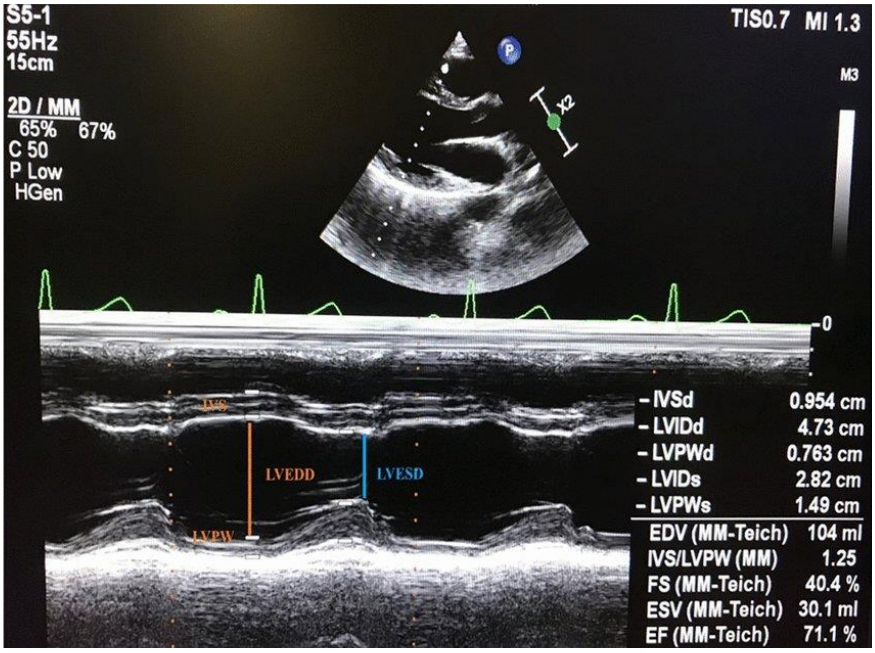

Figure 2: M-mode Echocardiography [20].

2D Echocardiogram

A basic imaging technique that offers tomographic views of the heart in several planes and a thorough evaluation of cardiac architecture is two-dimensional (2D) echocardiography. In contrast to M-mode, which concentrates on a single line of sight, 2D imaging captures several scan lines by sweeping the ultrasonic beam across an arc. The echocardiography machine processes and reconstructs these data to provide a dynamic, real-time two-dimensional image of the heart. This method facilitates accurate localization and analysis of particular cardiac areas by acting as a guide for M-mode and Doppler echocardiography. Visualizing cardiac anatomy, such as chamber sizes, wall motion, valve morphology, and overall heart function, is made possible via 2D echocardiography. It is essential to echocardiographic exams because it can produce cross-sectional images in real-time, which helps with precise diagnosis and ongoing monitoring of a variety of cardiovascular diseases [21].

Doppler Imaging

Echocardiography has been transformed by the advent of Doppler imaging, which makes non-invasive hemodynamic evaluation possible. According to the Doppler principle, sound waves' frequency rises as they approach the observer and falls as they travel away. This frequency shift, sometimes referred to as the Doppler shift, measures the frequency difference between reflected and transmitted sound waves and offers vital information about the dynamics of blood flow [22]. The Doppler equation improves the precision of velocity measurements by considering the angle (θ) between the ultrasonic beam and the blood flow direction [23]. To determine the resulting velocities and provide accurate hemodynamic assessments, echocardiography equipment usually incorporate this angle. Minimizing the angle between the ultrasonic beam and the blood flow jet—ideally, getting it as near to zero as feasible (because 0° = 1) is crucial for optimizing Doppler measurements. Maintaining an angle of less than 20° is advised when reaching a zero angle is not possible since this reduces velocity underestimation (cos 20° = 0.94), guaranteeing more accurate measurements. Furthermore, off-axis or non-traditional 2D images could occasionally be required to thoroughly assess intricate cardiac structures and functions. To attain diagnostic accuracy, this method requires careful alignment and interpretation. In conclusion, Doppler imaging greatly improves echocardiographic capabilities by increasing diagnostic accuracy and supplying comprehensive hemodynamic information. Reliable and thorough cardiac examinations are ensured by using the best imaging modalities [23].

Spectral Analysis

A crucial component of Doppler imaging is spectral analysis, which offers an in-depth understanding of blood flow properties. "Spectral analysis" refers to the display of Doppler pictures, such as continuous-wave Doppler (CW) and pulsed-wave Doppler (PW). When assessing heart function and hemodynamics, these techniques provide clear benefits.

Pulsed-Wave Doppler (PW Doppler)

The PW Doppler mode allows for the measurement of blood flow velocity at a specific location within a small sample volume by detecting the Doppler shift. This mode is particularly useful for evaluating blood flow in various cardiac structures, such as the pulmonary veins, the left ventricular outflow tract (LVOT) during systole, and mitral inflow velocity at the tips of the mitral valve leaflets (**Figure 3**). A single transducer emits short bursts of ultrasonic waves at a predetermined pulse repetition frequency (PRF) toward the target area. The same transducer then detects the returning sound waves reflected by moving blood cells, enabling the calculation of velocity measurements [24]. However, the accuracy of velocity measurements using PW Doppler is limited by the Nyquist threshold, which represents the maximum frequency shift that can be detected without distortion. This threshold is determined by the time it takes for the ultrasonic wave to travel to and return from the target. If the blood flow velocity exceeds this limit, aliasing occurs, where the signal appears to "wrap around" the baseline, leading to misinterpretation of the actual velocity. Despite this drawback, PW Doppler remains an essential technique for analyzing low-velocity blood flow in specific regions. It provides precise, localized measurements that contribute to the assessment of cardiovascular function and hemodynamics in clinical settings. The ability to obtain detailed data on blood flow patterns makes it a valuable tool for diagnosing various cardiac conditions, improving the accuracy of cardiovascular evaluations [24].

Continuous-Wave Doppler (CW Doppler)

CW Doppler operates using two transducer crystals, with one continuously emitting ultrasonic waves and the other continuously receiving the reflected signals. Unlike PW Doppler, which measures velocity at a specific location, CW Doppler determines the peak velocity along the entire length of the ultrasonic beam without precise spatial localization [25]. This characteristic makes CW Doppler particularly effective for assessing high-velocity blood flow, such as in cases of aortic stenosis, since it is not affected by aliasing (**Figure 4**). The primary distinction between the two Doppler methods lies in their application. PW Doppler is optimal for measuring low-velocity blood flow in specific anatomical regions, whereas CW Doppler is more suitable for evaluating high-velocity flows. The differences between these techniques emphasize their complementary roles in echocardiographic assessments. By integrating both methods, clinicians can obtain a comprehensive evaluation of cardiovascular function, ensuring accurate hemodynamic measurements in a variety of clinical conditions [25].

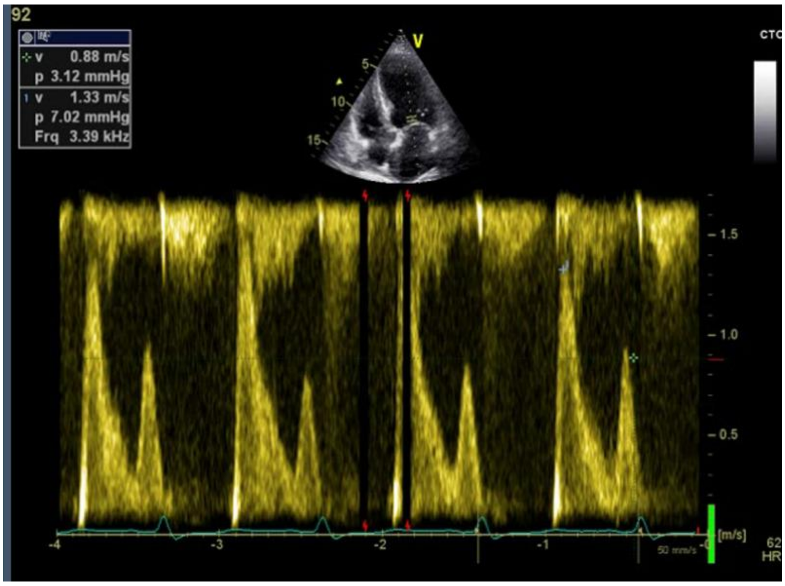

Figure 3: Pulsed-Wave Doppler (PW Doppler) [26].

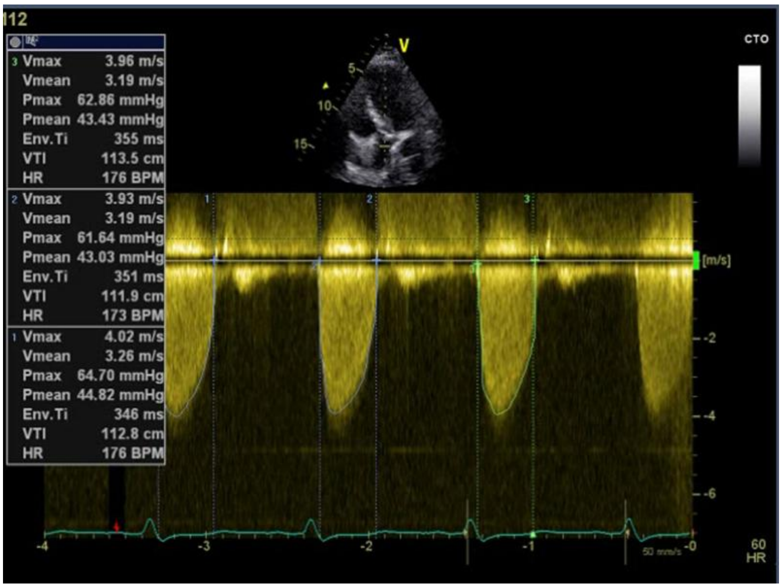

Figure 4: Continuous-Wave Doppler (CW Doppler) [26].

3D Echocardiogram:

Three-dimensional (3D) echocardiography represents a significant advancement in cardiac imaging by enhancing the visualization and assessment of heart anatomy and function. Unlike traditional two-dimensional (2D) imaging, 3D echocardiography employs specialized transducers capable of simultaneously transmitting and receiving ultrasonic data within a volumetric space. These transducers generate either real-time 3D images or simultaneous biplane (orthogonal) 2D views, providing a comprehensive dataset for analysis. The acquired 3D data is further processed using advanced software, allowing for a detailed evaluation of cardiac structures and functional dynamics. Compared to 2D echocardiography, 3D imaging offers greater precision in several key areas. It improves the assessment of right ventricular morphology and function, enhances accuracy in determining left ventricular volumes, and aids in the identification of valvular abnormalities. Due to these advantages, 3D echocardiography is particularly valuable in guiding complex surgical interventions, such as mitral valve repair, and diagnosing congenital heart defects with intricate anatomical variations. The addition of 3D color flow Doppler further enhances its diagnostic capabilities by providing precise quantification of blood flow patterns. This feature allows for accurate measurement of valvular regurgitation through a detailed evaluation of the vena contracta and proximal isovelocity surface area (PISA). In patients with mitral stenosis, 3D echocardiography has been shown to offer a faster and more accurate assessment of the mitral valve area (MVA) compared to traditional 2D planimetry [24,27,28]. This efficiency in quantifying valvular function contributes to more reliable diagnostic outcomes and improved clinical decision-making. Additionally, 3D imaging plays a crucial role in volumetric analysis, allowing for better evaluation of ventricular remodeling and myocardial function. Overall, 3D echocardiography has transformed cardiac imaging by providing unparalleled insights into heart structure and physiology. Its applications in surgical planning, hemodynamic assessment, and volumetric analysis underscore its growing importance in modern cardiology, making it an essential tool for comprehensive cardiac evaluation.

Echocardiographic Tomographic Views

Parasternal Views

The transducer is positioned at the left sternal border in the third or fourth intercostal gap while the patient is in the left lateral decubitus position to obtain parasternal images. Sometimes, in order to maximize imaging, a hybrid posture between the supine and steep left lateral orientations may be required. This arrangement makes it easier to see the heart's long and short axis, offering thorough anatomical and functional understanding [29,16].

Parasternal Long Axis (PLAX) View

In a standard transthoracic echocardiogram, the parasternal long-axis (PLAX) view is typically the initial imaging plane used for cardiac assessment. The ultrasound beam is aligned with the patient's left flank and right shoulder to obtain this view. In the resulting image, the aorta is positioned on the right, the inferolateral (posterior) wall is at the bottom, the cardiac apex appears on the left, and the right ventricular outflow tract (RVOT) is at the top. The anteroseptal wall is located between the left ventricular (LV) cavity and the RVOT, providing a clear visualization of cardiac structures (**Figure 5**). By making slight adjustments to the transducer angle, additional anatomical details can be examined. Rotating the transducer slightly clockwise toward the left shoulder shifts the image to include the right ventricular (RV) inflow tract. This adjustment enables the evaluation of key structures such as the tricuspid valve, right ventricular apex, and right atrium. The PLAX view is particularly useful for assessing tricuspid valve function and measuring tricuspid regurgitation (TR) velocity, which plays a crucial role in diagnosing right-sided heart dysfunction. This imaging technique provides essential information about cardiac morphology and function, making it an important tool in echocardiographic evaluation. The ability to visualize multiple structures within a single imaging plane allows for a comprehensive assessment of ventricular function, valvular abnormalities, and overall cardiac hemodynamics [25].

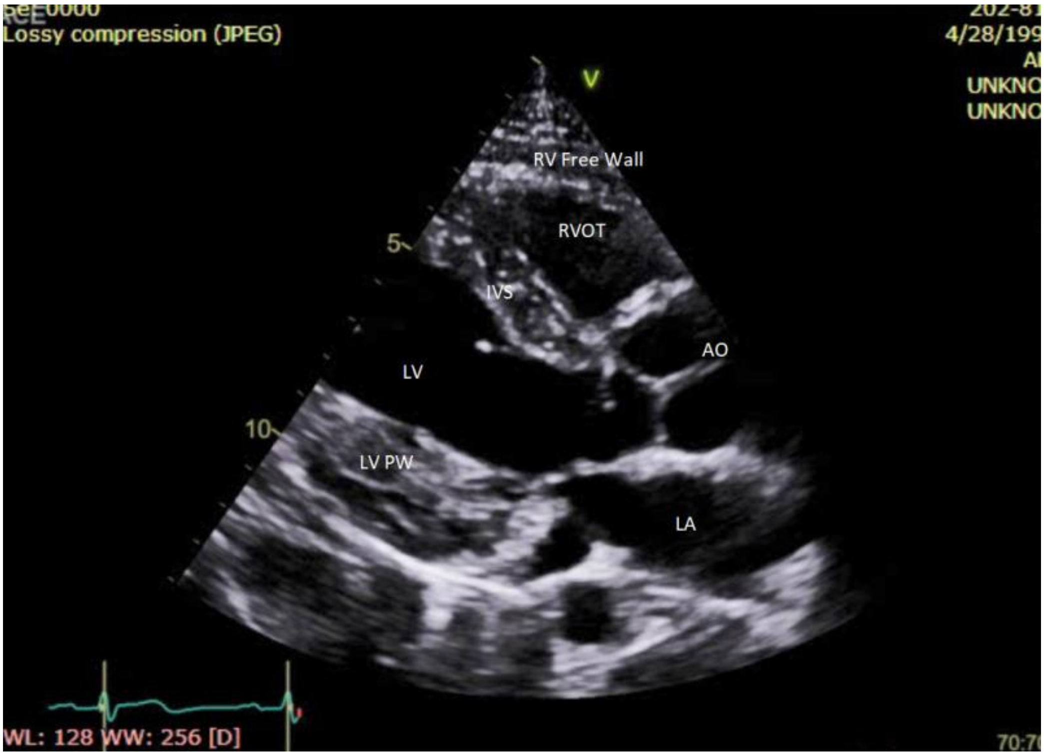

Figure 5: Parasternal Long Axis (PLAX) View [25].

Parasternal Short Axis (PSAX) View

The parasternal short-axis (PSAX) view is obtained by rotating the transducer approximately 90 degrees clockwise from the parasternal long-axis (PLAX) position. In this orientation, the ultrasound beam is directed from the left shoulder toward the right flank. Adjusting the transducer angle allows for imaging of the heart at different levels, providing detailed visualization of various cardiac structures. Tilting the transducer inferiorly reveals key anatomical landmarks such as the mitral valve, mid-ventricle at the level of the papillary muscles, and the left ventricular (LV) apex. This adjustment is particularly useful for assessing ventricular function and detecting abnormalities in myocardial contractility. Tilting the transducer superiorly displays the aortic valve and right ventricular outflow tract (RVOT), facilitating the evaluation of valve morphology and hemodynamics. PSAX views play a critical role in identifying regional wall motion abnormalities, assessing valvular structure, and analyzing ventricular function. By integrating both PLAX and PSAX perspectives, echocardiographic imaging provides a comprehensive assessment of cardiac anatomy and physiology. These imaging techniques are fundamental in diagnosing cardiovascular conditions and guiding clinical decision-making. A thorough understanding of parasternal views is essential for accurate interpretation and effective patient management [25].

Apical Tomographic Views

Apical views provide a comprehensive visualization of the heart's long axis, making them essential in a detailed echocardiographic evaluation. To obtain these views, the transducer is placed at the point of maximal apical impulse while the patient is positioned in the left lateral decubitus position. This setup optimizes the imaging of the heart's longitudinal structure and functional dynamics, allowing for an accurate assessment of chamber dimensions, ventricular function, and valvular motion [29,16]. These views are particularly useful for evaluating global and regional left ventricular systolic function, detecting wall motion abnormalities, and measuring ejection fraction. Additionally, they allow for precise Doppler assessment of blood flow across the mitral and aortic valves, aiding in the diagnosis of valvular disorders. Apical views also enable the measurement of left and right ventricular volumes using techniques such as Simpson's biplane method, enhancing the accuracy of cardiac function analysis. By integrating apical views with other echocardiographic perspectives, clinicians can obtain a complete understanding of cardiac anatomy and hemodynamics. Mastery of this imaging approach is essential for accurate diagnosis and effective management of cardiovascular diseases [25].

Apical Four-Chamber (A4C) View

The apical four-chamber (A4C) view is obtained by positioning the ultrasound beam in a superior-inferior direction while transecting the thorax. In most echocardiography labs, the transducer is oriented to display the right ventricle (RV) on the left side of the screen and the left ventricle (LV) on the right. Regardless of orientation, the atria appear at the bottom of the image, while the cardiac apex is positioned at the top. This view provides a detailed assessment of the apical region, as well as the inferoseptal and anterolateral walls of the LV. It is particularly useful for detecting regional wall motion abnormalities and evaluating ventricular function. The A4C view also plays a crucial role in assessing RV size, contractility, and overall function, making it an essential part of a comprehensive cardiac examination. Additionally, it allows for Doppler analysis of mitral and tricuspid valve flow, aiding in the diagnosis of valvular pathologies. By integrating A4C imaging with other echocardiographic views, clinicians can obtain a complete evaluation of cardiac structure and function. Mastery of this view enhances diagnostic accuracy and supports effective clinical decision-making in cardiovascular care (**Figure 6**) [25].

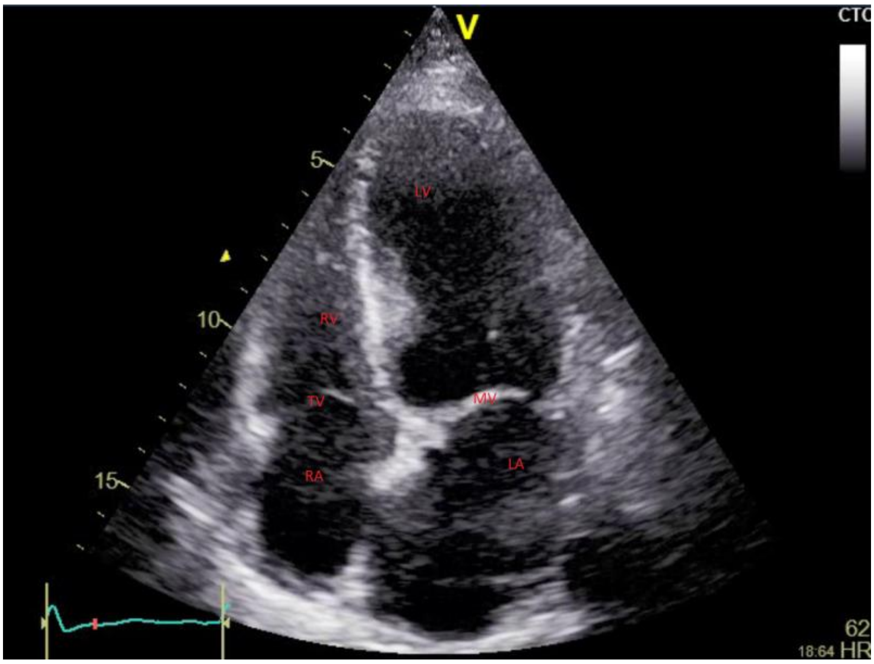

Figure 6: Apical Four-Chamber (A4C) View [25].

Apical Five-Chamber (A5C) View

A fifth "chamber" is created in the image by introducing the proximal aorta with a small anterior rotation of the transducer from the A4C location. The aortic valve and left ventricular outflow tract (LVOT) are included in this image, allowing for both hemodynamic analysis of the LVOT and aortic valve as well as qualitative evaluation of the aortic valve's appearance. When evaluating outflow tract dynamics and valvular function, the A5C view is especially helpful [25].

Apical Two-Chamber (A2C) View

The apical two-chamber (A2C) view is acquired by rotating the transducer 90 degrees counterclockwise from the apical four-chamber (A4C) view. This orientation allows visualization of the left atrium, left ventricle (LV) anterior wall, inferior wall, apex, and mitral valve. The A2C view is particularly useful for assessing LV function, detecting regional wall motion abnormalities, and evaluating mitral valve structure and function. It provides critical insight into the longitudinal motion of the LV and enhances the accuracy of ejection fraction measurements when used in conjunction with other apical views. Additionally, it aids in identifying ischemic changes by allowing direct assessment of the anterior and inferior myocardial walls. By integrating the A2C view with other echocardiographic perspectives, clinicians can obtain a more comprehensive understanding of cardiac anatomy and pathology. This view is essential for a thorough evaluation of ventricular performance and mitral valve dynamics, making it a key component of advanced cardiac imaging (**Figure 7**) [25-29].

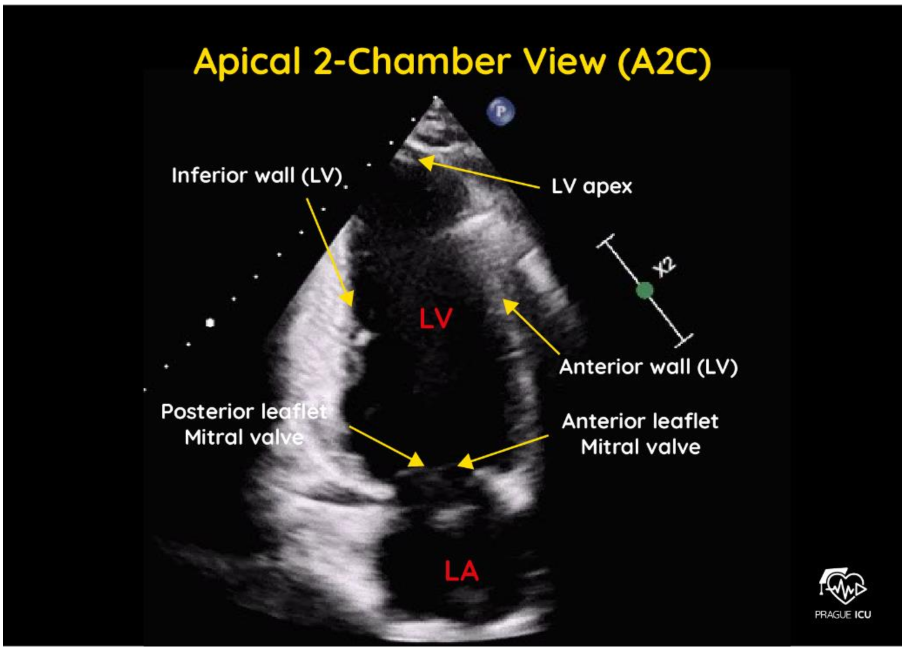

Figure 7: Apical Two-Chamber (A2C) View [30].

Apical Long Axis/Three-Chamber (A3C) View

The A3C, or apical long-axis view, is obtained by rotating the aorta slightly more counterclockwise (by about 30°) from the A2C position. Although it provides a different angle, this view and the parasternal long-axis (PLAX) view have comparable anatomical features. The RVOT usually disappears from the picture, but the cardiac apex is more clearly seen. The A3C view is a useful tool for evaluating left ventricular anatomy and valvular function because it offers more information about the hemodynamics of the mitral and aortic valves (**Figure 8**). In conclusion, echocardiographic imaging relies heavily on apical tomographic views, such as the A4C, A5C, A2C, and A3C. These views improve diagnostic precision and direct clinical decision-making by allowing for a thorough assessment of the heart's chambers, valvular structures, and hemodynamics [25-29].

Subcostal and Suprasternal Tomographic Views

Subcostal Views:

The subcostal view is obtained by positioning the transducer just below the xiphoid process while the patient lies in a supine position. The ultrasound beam is directed toward the spine, with the probe aligned nearly parallel to the patient's long axis. This orientation provides a clear view of cardiac structures from a subcostal approach. In this imaging plane, the left ventricle (LV) appears at the bottom right of the image, while the right ventricle (RV) is positioned at the top right. The corresponding atria are displayed on the left side of the image. By rotating the transducer clockwise and tilting it inferiorly, the hepatic veins and the inferior vena cava (IVC) become visible. This allows for right-sided hemodynamic assessments, including right atrial pressure estimation and IVC collapsibility evaluation. The subcostal view is particularly useful when transthoracic imaging is limited due to poor acoustic windows. It plays a critical role in bedside echocardiography, trauma assessments, and evaluations of pericardial effusion, right heart function, and volume status. This view enhances diagnostic accuracy in critically ill patients, providing essential hemodynamic information that supports clinical decision-making [31,16].

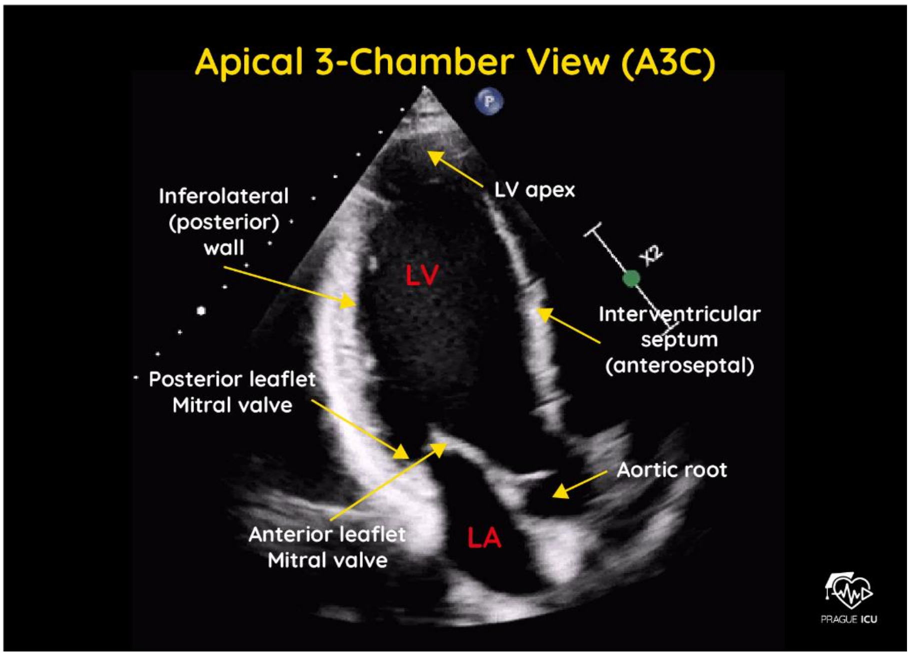

Figure 8: Apical Long Axis/Three-Chamber (A3C) View [30].

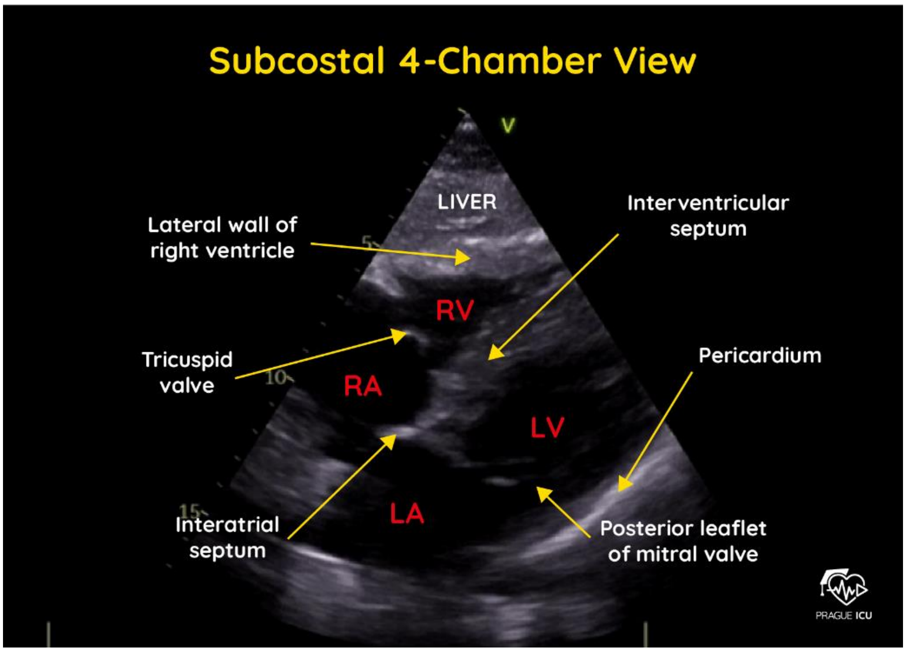

Figure 9: Subcostal 4-chamber View [30].

Suprasternal Views:

The transducer is positioned in the suprasternal notch and angled inferiorly to acquire the suprasternal view. When assessing the ascending, descending, and aortic arch, this view is especially helpful. It helps characterize aortic regurgitation (AR), patent ductus arteriosus (PDA), and aortic coarctation by providing vital hemodynamic data. By providing a distinct viewpoint on aortic anatomy and pathology, the suprasternal view enhances other echocardiographic views and is essential for the diagnosis of both acquired and congenital aortic disorders [16,31]. In conclusion, by adding extra imaging planes for evaluating cardiac and vascular structures, subcostal and suprasternal views enhance echocardiography's diagnostic potential. These perspectives are crucial for thorough anatomical characterization and hemodynamic assessment, especially in intricate clinical situations.

Transesophageal Echocardiogram (TEE):

A specialized imaging method called transesophageal echocardiography (TEE) is used when transthoracic echocardiography (TTE) is unable to offer enough diagnostic information or when the results of TTE and clinical findings differ. In situations where transthoracic imaging is not ideal, TEE is also used to acquire higher-quality pictures or to further identify diseases found on TTE. Because of the esophagus's close proximity to the heart, posterior cardiac components such the left atrium, mitral valve, and aortic root can be seen more clearly. Additionally, the use of higher-frequency transducers, which greatly improve picture resolution, is made possible by the decreased distance between the heart and the TEE probe. TTE is better for evaluating some anterior structures, like the pulmonic valve, and for particular Doppler measurements because TEE's imaging planes are somewhat constrained by the relative positions of the esophagus and cardiac structures [32]. Both the operating room and the cardiac catheterization lab benefit greatly from the use of TEE. TEE is frequently utilized in cardiothoracic surgery to analyze the mechanism underlying valvular anomalies and the efficacy of valve replacement or repair techniques. For example, TEE can direct the aortic cross-clamp's positioning during surgery, lowering the risk of embolization by assisting in avoiding areas with significant atheromatous plaque. Additionally, it offers vital information about regional wall motion anomalies and left ventricular function, both of which are crucial for intraoperative decision-making. TEE is commonly used in congenital cardiac surgery to evaluate the sufficiency of surgical repairs before the procedure's completion. TEE has grown in significance for directing intricate procedures in the cardiac catheterization lab. It helps with percutaneous valve implantation, transseptal punctures, and catheter placement. Additionally, TEE is utilized to close periprosthetic leaks, atrial septal defects (ASDs), ventricular septal defects (VSDs), and patent foramen ovale (PFO) as well as install left atrial appendage occlusion devices. For a procedure to be successful, it is essential to prevent and identify difficulties early on, such as thrombus formation or device malposition [33]. TEE deserves a distinct chapter to fully examine its methods, perspectives, and clinical relevance because of its wide range of applications and the intricacy of imaging planes. This would offer a thorough understanding of its function in contemporary cardiology and interventional techniques (**Figure 10**).

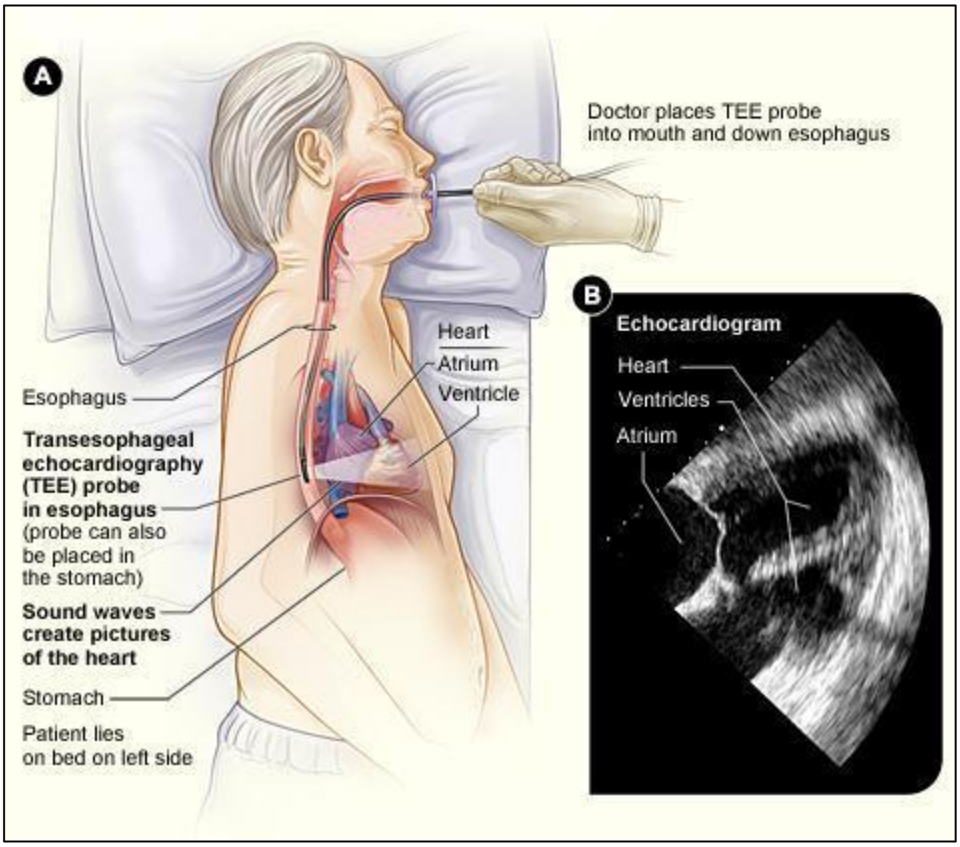

Figure 10: Transesophageal Echocardiogram (TEE) [34].

Complications:

Transthoracic echocardiography (TTE) is a non-invasive procedure with an excellent safety profile. Other than rare instances of allergic reactions to the coupling gel used during the examination, TTE is not associated with significant complications. This makes it a widely preferred imaging modality for evaluating cardiac structure and function. In contrast, transesophageal echocardiography (TEE), while highly effective for detailed cardiac imaging, carries a slightly higher risk profile due to its invasive nature. Rare complications associated with TEE include trauma in the teeth, oral mucosa, and esophagus. These risks are minimized by careful patient selection, proper technique, and the use of appropriate sedation. However, more severe complications, such as esophageal rupture, vasovagal reflex, and aspiration pneumonia, have been reported, albeit infrequently. Esophageal rupture is an exceptionally rare but potentially life-threatening complication, emphasizing the need for meticulous procedural care. The vasovagal reflex, triggered during probe insertion, can lead to bradycardia and hypotension, requiring prompt recognition and management. Aspiration pneumonia, though uncommon, can occur in patients with inadequate fasting or impaired swallowing reflexes, underscoring the importance of adhering to pre-procedural fasting guidelines. Despite these risks, TEE remains an invaluable diagnostic tool, particularly when transthoracic imaging is insufficient. The benefits of obtaining high-resolution images and detailed hemodynamic information often outweigh the potential complications, especially when performed by experienced operators in a controlled setting. In summary, while TTE is virtually complication-free, TEE requires careful consideration of its risks and benefits, ensuring patient safety and optimal outcomes [35].

Clinical Significance:

Echocardiography is a cornerstone in cardiovascular diagnostics, offering a reliable, non-invasive, and versatile imaging modality for assessing cardiac structure, function, and hemodynamics. Its widespread use is attributed to several advantages over other imaging techniques. Unlike computed tomography (CT) or nuclear imaging, echocardiography does not expose patients to ionizing radiation, making it a safer option for repeated evaluations. Additionally, it is relatively inexpensive and widely accessible, with portable echocardiographic machines enabling bedside examinations for critically ill or immobile patients, enhancing its utility in acute clinical settings. The ability to provide real-time, dynamic images allows for immediate interpretation and decision-making, which is particularly valuable in emergency scenarios such as cardiac tamponade, acute valvular dysfunction, or cardiogenic shock. Despite its operator-dependent nature, echocardiography's diagnostic accuracy is comparable to other advanced imaging modalities, such as cardiac magnetic resonance imaging (MRI) or CT, particularly for evaluating valvular abnormalities, ventricular function, and congenital heart disease [34]. Its integration with Doppler imaging further enhances its capability to assess blood flow dynamics, intracardiac pressures, and valvular regurgitation or stenosis. In summary, echocardiography's clinical significance lies in its accessibility, cost-effectiveness, safety, and ability to provide real-time, comprehensive cardiac evaluation. These attributes make it an indispensable tool in both routine clinical practice and complex diagnostic scenarios, solidifying its role as a first-line imaging modality in cardiology [35].

Enhancing Healthcare Outcomes:

A comprehensive echocardiographic examination necessitates a collaborative approach involving a multidisciplinary team, including an imaging cardiologist and an echocardiography technician. The process begins with obtaining a thorough patient history and conducting a detailed physical examination to identify the appropriate indications for the procedure. This foundational step ensures that the echocardiogram is tailored to address specific clinical questions and optimize diagnostic yield. Effective communication among the referring physician, echocardiography technician, and cardiologist is critical throughout the process. This collaboration is particularly important when discrepancies arise between clinical findings and echocardiographic results, as it facilitates accurate interpretation and integration of imaging data with the patient's overall clinical context. The echocardiography technician plays a pivotal role in acquiring high-quality images, while the cardiologist provides expertise in interpreting the findings and correlating them with the patient's clinical presentation. Furthermore, a cohesive team approach enhances diagnostic accuracy, reduces errors, and ensures that the echocardiographic examination aligns with the patient's diagnostic and therapeutic needs. Regular interdisciplinary discussions and case reviews can further refine imaging protocols and improve patient outcomes. By fostering a culture of collaboration and open communication, the healthcare team can deliver more effective, patient-centered care, ultimately improving the quality and reliability of echocardiographic evaluations [35].

Innovations in Echocardiography:

Echocardiography has undergone significant advancements in recent years, driven by technological innovations that have enhanced its diagnostic capabilities, accuracy, and clinical utility. One of the most notable developments is the widespread adoption of three-dimensional (3D) echocardiography, which provides volumetric imaging of cardiac structures with unprecedented detail. Unlike traditional two-dimensional (2D) imaging, 3D echocardiography allows for precise assessment of complex cardiac anatomy, such as valvular abnormalities, congenital heart defects, and ventricular geometry. It has become indispensable in guiding surgical and transcatheter interventions, particularly in mitral valve repair and transcatheter aortic valve replacement (TAVR) [24,25]. Another groundbreaking innovation is the integration of speckle-tracking echocardiography (STE), which enables the quantification of myocardial deformation and strain. STE provides objective measures of global and regional myocardial function, offering early detection of subclinical myocardial dysfunction in conditions such as cardiomyopathy, chemotherapy-induced cardiotoxicity, and ischemic heart disease. This technology has significantly improved the ability to assess left ventricular mechanics and predict adverse cardiac events [35,36].

The advent of contrast-enhanced echocardiography has further expanded the diagnostic potential of this modality. By using microbubble contrast agents, clinicians can enhance endocardial border delineation, improving the accuracy of left ventricular ejection fraction (LVEF) measurements and enabling the detection of myocardial perfusion defects. This technique is particularly valuable in patients with poor acoustic windows or those requiring a detailed assessment of myocardial viability [37]. Artificial intelligence (AI) and machine learning are also revolutionizing echocardiography. AI algorithms are being developed to automate image acquisition, optimize image quality, and assist in the interpretation of echocardiographic data. These tools can reduce operator dependency, enhance diagnostic consistency, and expedite workflow, making echocardiography more accessible and efficient. Lastly, the emergence of portable and handheld echocardiographic devices has transformed point-of-care cardiac imaging. These compact devices enable rapid bedside assessments in emergency departments, intensive care units, and remote settings, facilitating timely diagnosis and management of acute cardiac conditions. In conclusion, innovations such as 3D echocardiography, speckle-tracking, contrast imaging, AI integration, and portable devices have significantly advanced the field of echocardiography. These technologies have not only improved diagnostic precision but also expanded the scope of echocardiography in both clinical and research settings, ultimately enhancing patient care and outcomes [38].

Conclusion:

Echocardiography has undergone remarkable advancements since its inception, evolving from basic M-mode imaging to sophisticated modalities like 3D echocardiography, speckle-tracking, and contrast-enhanced imaging. These innovations have significantly enhanced its diagnostic capabilities, enabling precise assessment of cardiac structure, function, and hemodynamics. The integration of 3D imaging, for instance, has revolutionized the evaluation of complex cardiac anatomy, particularly in valvular heart disease and congenital abnormalities, while also playing a pivotal role in guiding surgical and transcatheter interventions. Similarly, speckle-tracking echocardiography has provided valuable insights into myocardial mechanics, allowing for early detection of subclinical dysfunction and improved risk stratification in conditions such as cardiomyopathy and ischemic heart disease. The advent of contrast-enhanced echocardiography has further expanded the utility of this modality, particularly in patients with poor acoustic windows or those requiring detailed assessment of myocardial perfusion and viability. Additionally, the incorporation of artificial intelligence (AI) and machine learning has begun to transform echocardiography by automating image acquisition, optimizing image quality, and assisting in data interpretation. These advancements not only reduce operator dependency but also enhance diagnostic consistency and workflow efficiency, making echocardiography more accessible and reliable. Transesophageal echocardiography (TEE) has emerged as an indispensable tool in both the operating room and the cardiac catheterization laboratory. Its ability to provide high-resolution images of posterior cardiac structures has made it invaluable for guiding complex interventions, such as mitral valve repair, transcatheter aortic valve replacement (TAVR), and closure of structural heart defects. Despite its invasive nature and associated risks, the benefits of TEE in improving procedural outcomes and patient safety are well-established. Portable and handheld echocardiographic devices have further revolutionized point-of-care cardiac imaging, enabling rapid bedside assessments in emergency and critical care settings. These devices facilitate timely diagnosis and management of acute cardiac conditions, underscoring the versatility and adaptability of echocardiography in modern medicine. In conclusion, echocardiography continues to be a cornerstone of cardiovascular diagnostics, with ongoing innovations ensuring its relevance in an ever-evolving medical landscape. By integrating advanced technologies and fostering interdisciplinary collaboration, echocardiography not only enhances diagnostic accuracy but also improves patient outcomes, solidifying its role as an essential tool in cardiology.

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References:

1. Singh S, Goyal A. The origin of echocardiography: a tribute to Inge Edler. Tex Heart Inst J. 2007;34(4):431-8.
2. Edler I, Hertz CH. The use of ultrasonic reflectoscope for the continuous recording of the movements of heart walls. 1954. Clin Physiol Funct Imaging. 2004 May;24(3):118-36.
3. Mintz GS, Kotler MN, Parry WR, Segal BL. Statistical comparison of M mode and two dimensional echocardiographic diagnosis of flail mitral leaflets. Am J Cardiol. 1980 Feb;45(2):253-9.
4. Bom N, van der Steen AF, de Jong N, Roelandt JR. Early, recent and future applications of echocardiography. Clin Physiol Funct Imaging. 2004 May;24(3):141-6.
5. Coman IM, Popescu BA. Shigeo Satomura: 60 years of Doppler ultrasound in medicine. Cardiovasc Ultrasound. 2015 Dec 23;13:48.

6. Li X, Ashraf M, Thiele K, Bhat AH, Sakaguchi R, Mitchell JC, Brie JA, Young M, Bader RS, Pemberton J, Sahn DJ. A novel method for the assessment of the accuracy of computing laminar flow stroke volumes using a real-time 3D ultrasound system: In vitro studies. Eur J Echocardiogr. 2005 Dec;6(6):396-404.
7. Karagodin I, Genovese D, Kruse E, Patel AR, Rashedi N, Lang RM, Mor-Avi V. Contrast-enhanced echocardiographic measurement of longitudinal strain: accuracy and its relationship with image quality. Int J Cardiovasc Imaging. 2020 Mar;36(3):431-439.
8. Han JC, Zhang HB, Gao S, Yu SM, Han J, Meng X, He YH. [Evaluation of the intraoperative transesophageal echocardiography for the aortic valve reconstruction]. Zhonghua Yi Xue Za Zhi. 2018 Oct 16;98(38):3064-3067.
9. Anderson RH, Razavi R, Taylor AM. Cardiac anatomy revisited. J Anat. 2004 Sep;205(3):159-77.
10. Anatomy Tutorial - anterior | Atlas of Human Cardiac Anatomy. (2023). https://www.vhlab.umn.edu/atlas/anatomy-tutorial/anterior.shtml
11. Holmes JH. Diagnostic ultrasound during the early years of A.I.U.M. J Clin Ultrasound. 1980 Aug;8(4):299-308.
12. Krishnamoorthy VK, Sengupta PP, Gentile F, Khandheria BK. History of echocardiography and its future applications in medicine. Crit Care Med. 2007 Aug;35(8 Suppl):S309-13.
13. American College of Cardiology Foundation Appropriate Use Criteria Task Force. American Society of Echocardiography. American Heart Association. American Society of Nuclear Cardiology. Heart Failure Society of America. Heart Rhythm Society. Society for Cardiovascular Angiography and Interventions. Society of Critical Care Medicine. Society of Cardiovascular Computed Tomography. Society for Cardiovascular Magnetic Resonance. American College of Chest Physicians. Douglas PS, Garcia MJ, Haines DE, Lai WW, Manning WJ, Patel AR, Picard MH, Polk DM, Ragosta M, Parker Ward R, Weiner RB. ACCF/ASE/AHA/ASNC/HFSA/HRS/SCAI/SCCM/SCCT/SCMR 2011 Appropriate Use Criteria for Echocardiography. A Report of the American College of Cardiology Foundation Appropriate Use Criteria Task Force, American Society of Echocardiography, American Heart Association, American Society of Nuclear Cardiology, Heart Failure Society of America, Heart Rhythm Society, Society for Cardiovascular Angiography and Interventions, Society of Critical Care Medicine, Society of Cardiovascular Computed Tomography, Society for Cardiovascular Magnetic Resonance American College of Chest Physicians. J Am Soc Echocardiogr. 2011 Mar;24(3):229-67.
14. Doherty JU, Kort S, Mehran R, Schoenhagen P, Soman P, Dehmer GJ, Doherty JU, Schoenhagen P, Amin Z, Bashore TM, Boyle A, Calnon DA, Carabello B, Cerqueira MD, Conte J, Desai M, Edmundowicz D, Ferrari VA, Ghoshhajra B, Mehrotra P, Nazarian S, Reece TB, Tamarappoo B, Tzou WS, Wong JB, Doherty JU, Dehmer GJ, Bailey SR, Bhave NM, Brown AS, Daugherty SL, Dean LS, Desai MY, Duvernoy CS, Gillam LD, Hendel RC, Kramer CM, Lindsay BD, Manning WJ, Mehrotra P, Patel MR, Sachdeva R, Wann LS, Winchester DE, Wolk MJ, Allen JM. ACC/AATS/AHA/ASE/ASNC/HRS/SCAI/SCCT/SCMR/STS 2017 Appropriate Use Criteria for Multimodality Imaging in Valvular Heart Disease: A Report of the American College of Cardiology Appropriate Use Criteria Task Force, American Association for Thoracic Surgery, American Heart Association, American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Rhythm Society, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Computed Tomography, Society for Cardiovascular Magnetic Resonance, and

Society of Thoracic Surgeons. J Am Soc Echocardiogr. 2018 Apr;31(4):381-404.

15. Writing Group Members. Doherty JU, Kort S, Mehran R, Schoenhagen P, Soman P, Rating Panel Members. Dehmer GJ, Doherty JU, Schoenhagen P, Bashore TM, Bhave NM, Calnon DA, Carabello B, Conte J, Dickfeld T, Edmundowicz D, Ferrari VA, Hall ME, Ghoshhajra B, Mehrotra P, Naqvi TZ, Reece TB, Starling RC, Szerlip M, Tzou WS, Wong JB, Appropriate Use Criteria Task Force. Doherty JU, Dehmer GJ, Bailey SR, Bhave NM, Brown AS, Daugherty SL, Dean LS, Desai MY, Duvernoy CS, Gillam LD, Hendel RC, Kramer CM, Lindsay BD, Manning WJ, Patel MR, Sachdeva R, Wann LS, Winchester DE, Wolk MJ. ACC/AATS/AHA/ASE/ASNC/HRS/SCAI/SCCT/SCMR/STS 2019 Appropriate Use Criteria for Multimodality Imaging in the Assessment of Cardiac Structure and Function in Nonvalvular Heart Disease: A Report of the American College of Cardiology Appropriate Use Criteria Task Force, American Association for Thoracic Surgery, American Heart Association, American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Rhythm Society, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Computed Tomography, Society for Cardiovascular Magnetic Resonance, and the Society of Thoracic Surgeons. J Am Soc Echocardiogr. 2019 May;32(5):553-579.
16. Hilberath JN, Oakes DA, Shernan SK, Bulwer BE, D'Ambra MN, Eltzschig HK. Safety of transesophageal echocardiography. J Am Soc Echocardiogr. 2010 Nov;23(11):1115-27; quiz 1220-1.
17. Mitchell C, Rahko PS, Blauwet LA, Canaday B, Finstuen JA, Foster MC, Horton K, Ogunyankin KO, Palma RA, Velazquez EJ. Guidelines for Performing a Comprehensive Transthoracic Echocardiographic Examination in Adults: Recommendations from the American Society of Echocardiography. J Am Soc Echocardiogr. 2019 Jan;32(1):1-64.
18. Feigenbaum H. Role of M-mode technique in today's echocardiography. J Am Soc Echocardiogr. 2010 Mar;23(3):240-57; 335-7.
19. Ersoy Dursun, F., Açıksarı, G., Özkök, S., & İncealtın, O. (2022). Evaluation of electrocardiography, echocardiography and cardiac T2* for cardiac complications in beta thalassemia major. *The International Journal of Cardiovascular Imaging*, *38*(3), 533-542.
20. Kühl HP, Hanrath P, Franke A. M-mode echocardiography overestimates left ventricular mass in patients with normal left ventricular shape: a comparative study using three-dimensional echocardiography. Eur J Echocardiogr. 2003 Dec;4(4):312-9.
21. Bonagura JD, Blissitt KJ. Echocardiography. Equine Vet J Suppl. 1995 Sep;(19):5-17.
22. Naredo E, Monteagudo I. Doppler techniques. Clin Exp Rheumatol. 2014 Jan-Feb;32(1 Suppl 80):S12-9.
23. Pellett AA, Kerut EK. The Doppler equation. Echocardiography. 2004 Feb;21(2):197-8.
24. Mao YK, Zhao BW, Zhou L, Wang B, Chen R, Wang SS. Z-score reference ranges for pulsed-wave Doppler indices of the cardiac outflow tracts in normal fetuses. Int J Cardiovasc Imaging. 2019 May;35(5):811-825.
25. Ahmed, I., & Sasikumar, N. (2023). Echocardiography imaging techniques. In StatPearls [Internet]. StatPearls Publishing.
26. Bolger AF, Eidenvall L, Ask P, Loyd D, Wranne B. Understanding continuous-wave Doppler signal intensity as a measure of regurgitant severity. J Am Soc Echocardiogr. 1997 Jul-Aug;10(6):613-22.
27. Mowers KL, Fullerton JB, Hicks D, Singh GK, Johnson MC, Anwar S. 3D Echocardiography Provides Highly Accurate 3D Printed Models in Congenital Heart Disease. Pediatr Cardiol. 2021 Jan;42(1):131-141.

28. Lakatos BK, Tokodi M, Kispál E, Merkely B, Kovács A. Morphological and Functional Assessment of the Right Ventricle Using 3D Echocardiography. J Vis Exp. 2020 Oct 28;(164)
29. Sugimoto T, Dulgheru R, Marchetta S, Ilardi F, Contu L, Go YY, Lancellotti P. What Does 3D Echocardiography Add to 2D Echocardiography in the Assessment of Mitral Regurgitation? Curr Cardiol Rep. 2017 Aug 24;19(10):90
30. Prague ICU. (n.d.). https://www.pragueicu.com/echo-content/apical-views
31. Remenyi B, Davis K, Draper A, Bayley N, Paratz E, Reeves B, Appelbe A, Wheaton G, da Silva Almeida IT, Dos Santos J, Carapetis J, Francis JR. Single Parasternal-Long-Axis-View-Sweep Screening Echocardiographic Protocol to Detect Rheumatic Heart Disease: A Prospective Study of Diagnostic Accuracy. Heart Lung Circ. 2020 Jun;29(6):859-866.
32. Denault AY, Langevin S, Lessard MR, Courval JF, Desjardins G. Transthoracic echocardiographic evaluation of the heart and great vessels. Can J Anaesth. 2018 Apr;65(4):449-472.
33. Flower L, Madhivathanan PR, Andorka M, Olusanya O, Roshdy A, Sanfilippo F. Getting the most from the subcostal view: The rescue window for intensivists. J Crit Care. 2021 Jun;63:202-210.
34. CVC. (2023). Transesophageal Echocardiogram (TEE). Cardiovascular Consultants, LTD. https://cvcheart.com/transesophageal-echocardiogram-tee/
35. Zhang XY, Cao TS, Yuan LJ, Liu J, Duan YY. Value of the echocardiographic suprasternal view for diagnosis of patent ductus arteriosus subtypes. J Ultrasound Med. 2012 Sep;31(9):1421-7.
36. Hahn RT, Abraham T, Adams MS, Bruce CJ, Glas KE, Lang RM, Reeves ST, Shanewise JS, Siu SC, Stewart W, Picard MH. Guidelines for performing a comprehensive transesophageal echocardiographic examination: recommendations from the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists. J Am Soc Echocardiogr. 2013 Sep;26(9):921-64.
37. Mahmood F, Shernan SK. Perioperative transoesophageal echocardiography: current status and future directions. Heart. 2016 Aug 01;102(15):1159-67.
38. Chiriac A, Kadkhodayan A, Pislaru SV, Dailey EJ, Scott CG, Buechler TE, Newman JS, Pellikka PA. Clinical Importance of Transthoracic Echocardiography with Direct Input from Treating Physicians. J Am Soc Echocardiogr. 2016 Mar;29(3):195-204

(الايكو)- مراجعة محدثة للتقنيات الحديثة والمتقدمة والابتكارات( )نظرة عامة على تقنيات تخطيط صدى القلب

الملخص:

الخلفية :شهد تخطيط صدى القلب تطورًا كبيرًا منذ نشأته في القرن الثامن عشر، حيث أسهم لازارو سبالانزاني في وضع الأسس، بينما قاد هيرتز وإدلر التطبيقات العملية في عام 1954. في البداية، اعتمد المجال على التصوير بأسلوب(M-mode) ، لكنه تطور ليشمل تقنيات التصوير بالموجات دوبلر، وإعادة البناء ثلاثي الأبعاد(3D) ، والتصوير المحسن بالتباين، مما جعله أداة أساسية في تشخيص أمراض القلب. يُعد تخطيط صدى القلب الآن ضروريًا لتقييم بنية القلب ووظيفته والديناميكا الدموية، حيث يوفر صورًا فورية وغير باضعة وخالية من الإشعاع.

الهدف :تهدف هذه المراجعة إلى تقديم نظرة محدثة حول تقنيات تخطيط صدى القلب، مع التركيز على التطورات الحديثة والابتكارات وتطبيقاتها السريرية. تستعرض المراجعة الانتقال من التصوير ثنائي الأبعاد (2D) الأساسي إلى الأساليب المتقدمة مثل تخطيط صدى القلب ثلاثي الأبعاد(3D) ، وتقنية تتبع البقع(Speckle-tracking) ، والتصوير المدعوم بالذكاء الاصطناعي، مع تسليط الضوء على دورها في تحسين دقة التشخيص ونتائج المرضى.

المنهجية :تستعرض المراجعة التطورات التاريخية، والتقدم التكنولوجي، والتطبيقات السريرية لتخطيط صدى القلب. تناقش المبادئ الفيزيولوجية للأمواج فوق الصوتية، وأوضاع التصويرM-mode) ، D2، D3، دوبلر (ودمجها في الممارسة السريرية. كما تغطي المؤشرات الطبية، وموانع الاستخدام، والمضاعفات المرتبطة بتخطيط صدى القلب عبر الصدر (TTE) وعبر المريء(TEE) ، بالإضافة إلى المعدات والكوادر المطلوبة لإجراء الفحوصات بشكل فعال.

النتائج :أحدث تخطيط صدى القلب تحولًا في تشخيص أمراض القلب، حيث وفر رؤى غير مسبوقة حول تشريح القلب ووظيفته. ساهمت الابتكارات مثل التصوير ثلاثي الأبعاد، وتقنية تتبع البقع، والتصوير المحسن بالتباين في تعزيز دقة التشخيص، بينما حسّنت تقنيات الذكاء الاصطناعي والأجهزة المحمولة إمكانية الوصول والكفاءة. أصبح تخطيط صدى القلب عبر المريء (TEE) أداة لا غنى عنها في البيئات الجراحية والتداخلية، رغم طبيعته الباضعة والمخاطر المرتبطة به.

الخاتمة :لا يزال تخطيط صدى القلب أداة أساسية في طب القلب، حيث تضمن التطورات المستمرة توسع تطبيقاته التشخيصية والعلاجية. يضمن دمج التقنيات الحديثة استمراريته كوسيلة فعالة في الحالات السريرية الروتينية والمعقدة، مما يحسن رعاية المرضى ونتائجهم.

الكلمات المفتاحية :تخطيط صدى القلب، التصوير ثلاثي الأبعاد، دوبلر، تتبع البقع، تخطيط صدى القلب عبر المريء، الذكاء الاصطناعي، تشخيص أمراض القلب.