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Echocardiography: Current Problems and Prospects in Modern Diagnostics

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Abstract: This article analyzes modern problems in the practice of echocardiography (EchoCG), which is the primary method in the non-invasive diagnosis of cardiovascular diseases. The dependence of image quality on the patient's constitution, subjectivity in measurements (human factor), as well as issues of standardization of new technologies such as 3D EchoCG and Speckle Tracking are highlighted. The role and prospects of artificial intelligence (AI) technologies in overcoming these problems are evaluated.
Keywords: echocardiography, cardiovascular diseases, ultrasound diagnostics, Speckle Tracking, 3D EchoCG, artificial intelligence.

Introduction Echocardiography (EchoCG) is the most widely used, safe, and highly informative visualization method in modern cardiology and medical radiology. It allows for the evaluation of heart anatomy, hemodynamics, and the function of the valvular apparatus in real time. However, despite the dramatic increase in the technical capabilities of ultrasound devices in recent years, a number of serious problems remain in EchoCG practice that affect clinical decision-making.

1. Anatomical and physiological factors limiting image quality One of the biggest drawbacks of EchoCG is the "acoustic window" problem associated with the physical properties of ultrasound waves.

- **Obesity and metabolic syndrome:** An increase in body mass index in patients leads to the absorption of ultrasound waves and a decrease in image contrast.
- **Chronic obstructive pulmonary disease (COPD) and emphysema:** Increased air in lung tissue creates a barrier for ultrasound waves. In such cases, obtaining a high-quality image from the apical or parasternal approaches becomes sharply difficult.
- **Solutions:** To partially overcome this problem, the use of Tissue Harmonic Imaging and intravenous contrast agents (echocontrast) is recommended; however, the high cost of contrast agents and the risk of allergic reactions hinder their widespread use in daily practice.

2. Subjectivity and operator dependence (The Human Factor) EchoCG is the imaging diagnostic method most dependent on the operator. The angle of image acquisition, sensor placement, and the measurement process directly rely on the specialist's expertise.

- **Interobserver and intraobserver variability:** In the same patient, a discrepancy of up to 10-15% can be observed in the left ventricular ejection fraction (LVEF) or the volume of heart chambers measured by different doctors (or the same doctor at different times).
- **Lack of standardization:** Some clinics use devices from different manufacturers (GE, Philips, Siemens). Differences in their internal calculation algorithms cause varied results.

3. Challenges in implementing new technologies into practice In the last decade, 3D modeling and myocardial deformation assessment (Speckle Tracking Echocardiography - STE) technologies have emerged in EchoCG. While they have revolutionized the assessment of heart function, they have their own specific problems:

- **Speckle Tracking and Global Longitudinal Strain (GLS):** This method is crucial in the early detection of hidden (subclinical) myocardial damage (e.g., in cardio-oncology). However, GLS indicators on different devices vary from each other, and a single international normative base has not yet been fully formed.
- **3D EchoCG:** Three-dimensional images are incomparable in evaluating valve anatomy before surgery. However, this method is strictly dependent on a high-quality 2D image and the patient's ability to hold their breath (to reduce artifacts). In patients with arrhythmias (e.g., atrial fibrillation), the accuracy of 3D EchoCG decreases sharply.

4. Artificial Intelligence (AI) and automation: Hopes and hurdles Artificial intelligence (AI) algorithms are being actively implemented to solve the above problems in EchoCG.

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- **Advantages:** AI allows for the automatic detection of heart chamber borders (segmentation), the calculation of ejection fraction (EF), and global longitudinal strain (GLS) in a matter of seconds, independent of the operator. This saves time and reduces diagnostic errors.
- **Existing problems:** AI models are primarily trained on data from patients with an ideal "acoustic window." AI algorithms frequently make mistakes in patients with severe pathology, obesity, or poor image quality. Additionally, doctors' distrust of AI decisions and issues of legal liability (if AI makes a decision, who is responsible for a mistake?) remain pressing.

Conclusion Echocardiography remains the primary method in diagnosing cardiovascular diseases. However, as the capabilities of the devices increase, specialists face new problems related to image acquisition, processing, and standardization. In the future, the wide implementation of automatic measurement systems based on artificial intelligence in daily practice will serve to reduce operator dependence and take the quality of diagnostics to a new level.

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