Recent Advances in Echocardiography

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More than 60 years have passed since Inge Edler and Hellmuth Hertz began using M-mode echocardiography as a diagnostic tool for cardiovascular disease in 1953 [1]. Over the past 60 years, echocardiography has evolved from a simple M-mode imaging technique to an array of technologies that include two-dimensional (2D) imaging, pulsed and continuous wave Doppler, color flow and tissue Doppler, transesophageal echocardiography, and three-dimensional (3D) echocardiography [1,2]. Although 3D technique has changed rapidly in recent years, and the time needed for 3D image acquisition and analysis has gradually decreased [3], it is still difficult to incorporate 3D echocardiography into daily clinical practice. Hence, 2D echocardiography remains the first-choice imaging technique in clinical use. When 2D echocardiography is used to assess left ventricular volume and systolic function, good image quality with clear visualization of endocardial border is required for accurate assessment of left ventricular volume and function [4]. However, suboptimal image quality is estimated to occur in approximately 20% of all patients undergoing echocardiography [5]. Suboptimal image quality may lead to misdiagnosis or the need for additional, often unnecessary, and costly tests. In order to overcome this problem, novel 2D echocardiographic imaging technologies have been introduced in recent years, which have significantly enhanced the image quality of 2D echocardiography. In addition, new on-cart 3D quantification software can greatly reduce the analysis time for 3D volume quantification and facilitate the incorporation of 3D quantitative analysis into daily examination workflow. The following is a general overview of two new echocardiographic technologies.

Adaptive contrast enhancement

Conventional echocardiographic imaging is a hardware-based beamforming technique. After the probe sends out an acoustic beam and receives the returning signals, the beamformer amplifies and digitizes the signals, and displays them in a horizontal line format. The adaptive contrast enhancement (ACE) algorithm is a software-based beamforming technique that acquires and temporarily stores multiple sequential datasets from each probe element before analyzing it with parallel processors [6]. With the ACE algorithm, the image pixel is observed over a short period of time to determine whether or not data for this pixel originated from a real structure or noise/artifact. This software strengthens the image pixel from the real structure, and suppresses the image pixel from noise or artifact. Then, a high contrast resolution image is obtained (Figure 1). When the researchers at the Mount Sinai Icahn School of Medicine, New York, compared echocardiographic images obtained using the ACE algorithm with images obtained using standard hardware-based beamforming techniques, they found that the software-based beamformer technique with ACE algorithm significantly improves the visualization of endocardial borders in the anteroseptal, anterolateral, inferolateral, inferior, anterior, and apical wall segments [6]. They also found that this new technology can reduce medical costs by lessening the need for contrast usage and additional diagnostic testing [6].
Automated 3D chamber quantification for left heart (HeartModel\textsuperscript{A.I.})

Previous studies have demonstrated that 3D echocardiography is more accurate and reproducible than 2D echocardiography because direct measurement of volumes can be achieved without the need for geometrical assumptions and limitations associated with foreshortening [7,8]. However, quantitative analysis of 3D volumetric data is more complex and time consuming than that of conventional 2D volumetric data. It is not easy to include 3D quantitative analysis in the daily workflow for routine examination. HeartModel\textsuperscript{A.I.} is a fully automated 3D transthoracic echocardiography analysis software that simultaneously detects left atrial and left ventricular endocardial borders throughout the cardiac cycle, using an adaptive analytics algorithm that consists of knowledge-based identification of initial global shape and orientation followed by patient-specific adaptation. 3D = three dimensional; TTE = transthoracic echocardiography.
knowledge-based identification of initial global shape and orientation followed by patient-specific adaptation [9] (Figure 2). This technology reduces the tedious work for 3D quantitative analysis by simplifying the user interface and analytical steps, and simultaneously measures the 3D volumes and function of the left atrium and left ventricle. Compared with the conventional 3D quantitative methods, the new module (HeartModelA.I.) sharply reduces the time needed for 3D quantitative analysis (from 148 seconds to 17 seconds, reducing analysis time by 82%) and obtains more accurate data with better reproducibility. By greatly reducing the analysis time, this technology dramatically increases the opportunity to incorporate 3D quantitative analysis into routine examinations.

In light of the great progress in artificial intelligence, the ongoing trends toward high contrast resolution, high frame rate, and rapid and automated 3D analysis will facilitate the continued progress of echocardiography during the coming decade. Nowadays, the aforementioned two new technologies are currently owned by different companies. It would be great if these two technologies could be combined in the same platform.

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