Methods for Assessment of Left Ventricular Systolic Function in Technically Difficult Patients with Poor Imaging Quality

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The assessment of left ventricular (LV) systolic function is often the most important information obtained during clinical echocardiography. Although LV systolic function may be visually estimated in many patients with or without contrast opacification, technically difficult patients may require alternative methods for evaluating LV systolic function. In this review, the authors describe several surrogate echocardiographic methods that might be helpful for the evaluation of LV systolic function in patients with poor image quality, including endocardial border delineation by contrast agents, mitral annular plane systolic excursion, mitral annular velocity derived from tissue Doppler, systolic time intervals, mitral regurgitation–derived LV dP/dt, and estimation of cardiac output by Doppler echocardiography. After a short introduction to the various issues involved, the authors propose a method for suitable measurement. In addition, indications and clinical implications, as well as limitations, of the different methods are discussed. (J Am Soc Echocardiogr 2013;26:105-13.)

Keywords: Poor image quality, Contrast echocardiography, Mitral annular plane systolic excursion, Doppler echocardiography, Tei index

As one of the most widely used diagnostic examinations in cardiology, echocardiography has been routinely used for diagnosing and monitoring patients with suspected or known cardiovascular disease. In daily clinical echocardiography, left ventricular (LV) systolic function can be correctly assessed using various echocardiographic imaging methods in the majority of patients. However, the assessment of LV systolic function remains a challenge in a small proportion of patients with poor image quality, caused mainly by obesity, lung disease, tachycardia, or cardiac translocation. The quantitative assessment of ventricular function in these patients is still difficult despite the use of transducers with variable frequencies and harmonic imaging as well as the application of various advanced echocardiographic techniques, such as strain rate imaging, speckle-tracking imaging, and three-dimensional echocardiography. Besides poor image quality, there are other situations that make the determination of LV systolic function difficult, such as in patients with atrial fibrillation, LV hypertrophy, or mitral regurgitation. The purpose of this review is to summarize the clinical applications and limitations of several echocardiographic methods that can be used to evaluate LV systolic function in patients with poor image quality.

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CONTRAST ECHOCARDIOGRAPHY

Contrast echocardiography using ultrasound contrast agents plays an essential role in clinical diagnosis in patients with technically suboptimal echocardiographic images.[1-3]

Contrast Agents

Contrast echocardiography involves the interaction of microscopic gas bubbles with ultrasonic waves to enhance the recognition of the blood pool and/or the blood-tissue interface. The first agents capable of left-heart contrast after intravenous injection (first-generation agents) were air bubbles stabilized by encapsulation (Albunex; Molecular Biosystems, Inc., San Diego, CA) or by adherence to microparticles (Levovist; Bayer Schering Pharma AG, Berlin, Germany). In second-generation agents, replacing air with a low-solubility fluorocarbon gas stabilized the bubbles (Optison, GE Healthcare, Waukesha, WI; Definity, Lantheus Medical Imaging, North Billerica, MA; SonoVue, Bracco Diagnostics Inc., Princeton, NJ), further increasing the duration of the contrast effect. The aforementioned agents are untargeted microbubbles, and targeted microbubbles are presently in preclinical development.

Implementation of Contrast Agents

Details of the implementation of contrast agent, including joint training of physicians, sonographers, and nurses, have been introduced in recent guidelines.[4] Briefly, contrast enhancement is indicated in difficult-to-image patients at rest when echocardiographic image

Abbreviations

CO = Cardiac output

DTI = Doppler tissue imaging

EF = Ejection fraction

ET = Ejection time

LV = Left ventricular

LVOT = Left ventricular outflow tract

MAPSE = Mitral annular plane systolic excursion

PEP = Preejection period

SV = Stroke volume

quality does not permit the adequate assessment of cardiac structure and function. Specifically, contrast enhancement for stress echocardiography is not recommended for all patients but should be considered on a case-by-case basis, depending on image quality.[5] To ensure quality control and maximize benefit to patients, the American Society of Echocardiography recommends that contrast echocardiography be performed by appropriately trained cardiac sonographers and physicians with level 2 or level 3 training in laboratories that have been successful in establishing contrast agent use.[4]

Optimization and Clinical Applications

The mechanical index reflects the output acoustic power. Standard clinical echocardiography imaging uses a mechanical index of about 1.0, but a lower setting (<0.6) is usually optimal for LV opacification during contrast echocardiography to avoid bubble destruction.[6] Common causes of setting artifacts include inadequate focus position, inadequate ultrasound transmit frequency, and excessive receive gain.[7] Tissue signals in the left ventricle may not be distinguishable from the contrast signals, because of inadequate contrast dose (the so-called anticontrast effect) and can be avoided by injecting a slightly larger contrast dose.[7] Attenuation is particularly problematic in parasternal windows, in which dense opacification of the right ventricle may obviate visualization of the left ventricle, and can be prevented by using apical views, in which attenuation is lowest and usually subsides by waiting for contrast washout. Attenuation can also be caused by rapid infusion or high-concentration contrast agent. Instead of a bolus, continuous slow infusion and slow flush are recommended.[7,8] Swirling artifacts may result from high mechanical index, high frame rate, insufficient contrast agent, or LV dysfunction with low flow at the apex.[7] Moving the focus position toward the base may help avoid attenuation and swirling. Adjusting the transducer position along the rib space or holding respiration during image acquisition can help reduce chest wall artifacts and wall motion artifacts.[7,8]

Contrast agent use is particularly valuable for the evaluation of LV structure and function in difficult-to-image patients with reduced image quality for rest or stress echocardiography. It can improve endocardial visualization and the assessment of LV structure and function and reduce variability and increase accuracy in LV volume and ejection fraction (EF) measurement.[9-11] Contrast agent is recommended when two or more adjacent poorly visualized segments are seen on standard echocardiography.[4] Contrast agent use also allows accurate assessment of LV volumes and EF in the intensive care unit when standard tissue harmonic imaging does not provide adequate cardiac structural definition.[10] Stress echocardiography, in combination with contrast agent use, can obtain diagnostic assessment of segmental motion and thickening at rest and stress.[11,12] Other suggested applications include confirming or excluding LV structural abnormalities (apical hypertrophic cardiomyopathy, LV noncompaction, LV aneurysm [Figure 1 and Video 1; available at www.onlinejase.com], pseudoaneurysm, and myocardial rupture) and intracardiac masses (tumors and/or thrombi).[6,13,14]

Safety and Limitations

A large number of studies have proved that contrast echocardiography is safe in clinical practice.[15-18] A large retrospective analysis of 18,000 patients showed that there was no significant difference in mortality between patients who received contrast and those who did not in the acute setting.[16] However, serious allergic reactions have been observed at a very low incidence (1 in 12,000 to 1 in 15,000).[16,17] As shown in the updated guidelines on the safety of echocardiographic contrast agents of the US Food and Drug Administration in June 2008,[4] contraindications to perflutren-containing ultrasound contrast agents (Definity and Optison) include (1) right-to-left, bidirectional, or transient right-to-left cardiac shunts; (2) hypersensitivity to perflutren; and (3) hypersensitivity to blood, blood products, or albumin (Optison only). Additional contraindications include acute myocardial infarction, worsening or unstable heart failure, serious ventricular arrhythmias or high risk for arrhythmia, respiratory failure, severe emphysema, pulmonary emboli, or other conditions that cause pulmonary hypertension.

MITRAL ANNULAR PLANE SYSTOLIC EXCURSION

LV longitudinal shortening is a sensitive parameter reflecting cardiac pump function[19,20] and can be evaluated by measuring long-axis mitral annular plane systolic excursion (MAPSE).[21] The measurement of M-mode-derived MAPSE does not require high imaging quality, because of the high echogenicity in the atrioventricular annulus.

Measurement

MAPSE can be measured from four sites of the atrioventricular plane corresponding to the septal, lateral, anterior, and posterior walls using the apical four-chamber and two-chamber views on M-mode echocardiography. In healthy hearts, the values of lateral MAPSE are usually somewhat higher than those of septal MAPSE.[22] Mondillo *et al.*[23] also demonstrated that MAPSE was lower at the septum and anterior wall in comparison with the lateral and inferior levels in healthy middle-aged individuals. The M-mode cursor should be aligned parallel to the LV walls. The systolic excursion of the mitral annulus should be measured from the lowest point at end-diastole to aortic valve closure (the end of the T wave on the electrocardiogram; Figure 2).

Clinical Implications

The average normal value of MAPSE derived from previous studies for the four annular regions (septal, anterior, lateral, and posterior) ranges from 12 to 15 mm.[21,23,24] MAPSE < 8 mm was associated with a depressed LV EF (<50%), with specificity of 82% and sensitivity of 98%.[21] Mean MAPSE ≥ 10 mm was linked with preserved EF (≥55%), with sensitivity of 90% to 92% and specificity of 87%.[25,26] In addition, mean MAPSE < 7 mm could detect an EF < 30% with sensitivity of 92% and specificity of 67% in patients with dilated cardiomyopathy with severe congestive heart failure.[24] A recent study by Matos *et al.*[27] showed that MAPSE measurement by an untrained observer was a highly accurate predictor of EF determined by an expert echocardiographer.

Limitations

The association between MAPSE and EF is valid only in normal or dilated left ventricles,[28,29] whereas the correlation is rather poor in patients with LV hypertrophy.[30] Another limitation of this parameter is that small localized abnormalities (i.e., small areas of fibrosis) cannot be detected, because MAPSE can evaluate only the longitudinal function of the entire LV wall and is unable to evaluate segmental function.