An enhanced method for left ventricular volume and ejection fraction by triggered harmonic contrast echocardiography

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Abstract

To elucidate the validity and reproducibility of the use of intravenous echo-contrast agent in the evaluation of left ventricular (LV) performance, we measured LV volume and ejection fraction (EF) in 42 patients with triggered harmonic contrast imaging (THCI), compared with continuous harmonic imaging without contrast agent (CHI) and with cineventriculography (CVG). In 10 of 42 patients, THCI improved LV border delineation which could not be obtained even with CHI. LV end-diastolic, end-systolic volumes and EF by both CHI and THCI correlated well with those by CVG. Although LV volumes are underestimated, THCI lessened the mean differences to about in half, compared with CHI. The observer variabilities obtained using THCI were smaller than those by CHI. These results indicate the validity of LV enhancement and the measurement of EF using THCI. We suggest that this method noninvasively provides more accurate LV systolic function with the acceptable reproducibility.

Abbreviations: CHI – continuous harmonic imaging without contrast agent; CVG – cineventriculography; THCI – triggered harmonic contrast imaging

Introduction

The noninvasive estimation of left ventricular (LV) performance is very important in clinical settings. Previous studies have revealed high correlation between LV volumes and ejection fraction (EF) determined by two-dimensional (2D) echocardiography and cineventriculography (CVG) [1–6]. In spite of high correlation coefficients, the underestimation of LV volumes seems to occur [1, 7, 8]. The detection of the endocardial border is essential for the accurate assessment of LV performance. However, technically satisfactory detection of the endocardial border cannot be obtained in 10–15% of patients due to obesity, pulmonary disease, or other patient-related factors [9, 10].

The recent development of echo-imaging techniques has resulted in improved delineation of the LV endocardial border. Harmonic imaging, in which a transducer transmits ultrasound at one frequency and receives it at twice the transmitted frequency, can enhance the backscatter deflected from the endocardial border and detect the endocardium effectively [11–13]. In practice, however, detecting the LV border in some patients is difficult even with this method. Harmonic imaging was initially applied to contrast imaging which can opacify the LV cavity or detect the
endocardial border [14–18]. In a more recent study, the combination of echo-contrast agent and harmonic imaging has enhanced the ability to visualize microbubbles in the blood pool by improving the signal-to-noise ratio of the contrast agent compared to the blood [15]. While it has been shown that ultrasound destroys microbubbles [19], electrocardiogram (ECG)-triggered transmission can decrease bubble destruction [20, 21].

The purpose of this study is to evaluate the validity and reproducibility of measuring LV volume and EF by ECG-triggered harmonic imaging using an intravenous echo-contrast agent (triggered harmonic contrast imaging, THCI), and by continuous harmonic imaging without a contrast agent, compared with CVG.

Methods

Study group

Informed consent for the protocol was obtained from each patient. Forty-two consecutive patients (32 men and 10 women, mean age 62 ± 12 years) with known or suspected various heart disease, and who had undergone CVG, were eligible for this study. There were 31 patients with coronary artery disease, six with valvular heart disease, three with dilated cardiomyopathy, and two with hypertrophic cardiomyopathy. Of the 31 patients with coronary artery disease, 16 had one or more areas of segmental wall motion abnormality. Exclusion criteria were galactosemia, pregnancy, acute myocardial infarction within the past 2 weeks, unstable angina, unstable hemodynamics, mitral valve stenosis, or congenital heart disease. All patients were in regular sinus rhythm and had undergone echocardiographic studies less than 24 h before CVG.

Echocardiographic studies

Transthoracic echocardiographic studies were imaged with a commercially available ultrasound system (SONOS 5500; Agilent Technologies, Andover, MA, USA), using a phased-array broad band (2–4 MHz) transducer. A 20-gauge intravenous catheter was placed in the right forearm. Images were obtained from the apical two- and four-chamber views with the patients in the left lateral decubitus position. The LV cavity size was maximized by placing the transducer as close as possible to the anatomic apex. Similarly, care was taken to scan the heart in a plane that revealed the maximal area of the left ventricle.

Continuous harmonic imaging without contrast agent (CHI). Continuous harmonic imaging was performed with the Harmonic Fusion® setting (harmonic imaging optimized for tissue) using a transmitting frequency of 1.8 MHz and a receiving frequency of 3.6 MHz. The maximal dynamic range, compression settings and post-processing setting were maintained for all experiments. The gain control, gain compensation and lateral gain control were optimized to obtain the best differentiation between the blood pool and the endocardium. A single cardiac cycle from the apical two- and four-chamber views was digitally stored on a magneto-optical disk for later analysis.

Triggered harmonic contrast imaging (THCI). Triggered harmonic imaging was acquired with the harmonic setting for myocardial contrast using a transmitting frequency of 1.8 MHz and a receiving frequency of 3.6 MHz. The instrument settings were adjusted to maximal acoustic power and medium harmonic filter. The focal point was positioned at the center of the LV cavity. The apical two- and four-chamber images were obtained in triggering at end-diastole defined by the peak of the R wave. Those at end-systole were identified from the first high-frequency component of S2 in the simultaneously recorded phonocardiogram. After the CHI study, 1–1.5 ml (depending on the size of the patient) of Levovist® (saccharide-based transpulmonary echo-contrast agent; 300 mg/ml) (Schering AG, Berlin, Germany) was injected intravenously, followed by a rapid flush of 5 ml of 0.9% sodium chloride. After the optimal end-systolic image was obtained, then the triggering interval was changed and the end-diastolic image was taken. These images were digitally stored on a magneto-optical disk for later analysis. The ultrasonic beams were transmitted every cardiac cycle.