Improved assessment of left ventricular volumes and ejection fraction by contrast enhanced harmonic color Doppler echocardiography

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Abstract

Aims: Test the accuracy of contrast enhanced harmonic color Doppler technique (CHCD) to determine left ventricular volumes and ejection fraction (LVEF) compared to equilibrium radionuclide ventriculography (MUGA).

Methods and results: A total of 35 patients were enrolled (male 74.3%) with the mean age of 64.5 ± 10 years and 6.8 ± 4.9 days between echo and MUGA scans. The correlation of LVEF by CHCD with MUGA was better ($R^2 = 0.89$) than that of harmonic 2D (H2D) and of contrast enhanced harmonic 2D (CH2D) ($R^2 = 0.74$, $R^2 = 0.82$, respectively). The RMS residual of CHCD (0.056) was smaller than that of H2D and CH2D (0.079, 0.067, respectively). The LVED and LVES volumes by H2D, CH2D and CHCD correlate well with MUGA but there was a significant over estimation of LVED and LVES volumes by H2D and CH2D as compared to MUGA. Also, the RMS residuals were the lowest for the CHCD method. The CHCD had the highest mean inter-observer agreement (90.9%) for LVEF compared with H2D and CH2D (78.9% and 88.1%, respectively).

Conclusions: CHCD has been feasible in all patients in the present study and it has shown a good concordance with ejection fraction and volumes provided by MUGA.

Abbreviation: 2D – two dimensional imaging; CH2D – contrast enhanced harmonic 2D imaging; CHCD – contrast enhanced harmonic color Doppler imaging; ED – end diastolic; ES – end systolic; H2D – harmonic two-dimensional imaging; LV – left ventricle; LVEF – left ventricular ejection fraction; MUGA – equilibrium multi-gated radionuclide ventriculography; RMS – root mean square

Introduction

The most serious limitations of ultrasound in the measurement of LV volume and LVEF are poor image quality, the two-dimensional tomographic nature of the technique and the observer’s bias in tracing endocardial borders when the ventricle is heavily trabeculated or when the borders are poorly defined. All these aspects impair the accuracy and reproducibility of 2D echocardiography for the quantification of LV volumes and EF [1]. In clinical settings the visual estimation of the LVEF is popular not just because it is faster than the biplane method, but also because more
imaging planes are used to assess regional and global LV function [2]. Despite its clinical popularity, the visually estimated LVEF can have unpredictable reproducibility errors due to inter-observer variability and the visual technique cannot be used for LV volume quantification.

We propose to use echo contrast and multiplane imaging to overcome the three major weaknesses of the echo technique. Contrast enhanced harmonic color Doppler ultrasound (CHCD) allows for the easy identification of endocardial borders in almost all patients and when combined with multiplane imaging gives a semi-3D assessment of LV volume and LVEF. The hypothesis tested in this study is that CHCD can be used to define the LV cavity at least as well as standard harmonic 2D imaging with contrast (CH2D) or without contrast (H2D) and that the LV volumes and EF determined by CHCD correlate well with values determined by equilibrium radionuclide ventriculography (MUGA).

Materials and methods

Patient population

Unselected patients in sinus rhythm scheduled for routine diagnostic ultrasound and MUGA scans at the Department of Internal Medicine of the University of Genova, Italy, were asked to participate in the study. The protocol was reviewed by the Ethical committee of the University of Genova and completed according to their guidelines. The only enrollment criteria were that the patients be eligible to receive intravenous echo contrast injections using the echo contrast manufacturer’s guidelines as printed in the product insert and that they consent to the procedures.

Ultrasound methods

A standard commercial ultrasound machine capable of harmonic imaging was used for all data acquisition (Acuson Sequoia 256, Siemens, USA). The frequencies of 1.75 MHz transmit and 3.5 MHz receive were chosen as this combination has been shown to optimize LV cavity imaging with and without contrast in typical cardiac cases [3].

All patients had 3 imaging modes performed of the LV: H2D, CH2D and CHCD. The apical four-chamber, two-chamber and three-chamber views were acquired for each imaging mode and ECG R-wave triggered digital loops were created using the built-in image processor. These three imaging planes are separated by roughly 60° of axial rotation and when used together approximate 360° imaging of the left ventricle. Real-time full cycle cardiac loops were created for the non-contrasted H2D images, but for the contrast enhanced CH2D and CHCD imaging, a double trigger was used. The double trigger captured an image at the moment of end diastole (ED) and another image at the moment of end systole (ES). The trigger parameters for the contrast-enhanced images were adjusted for each patient using the mitral valve and the visualized LV cavity size as guides. The ED image was defined by the closure of the mitral valve and the ES image by the smallest LV volume before the opening of the mitral valve. The trigger points for the ED and ES images varied from case-to-case based on the resting heart rate. In general, the ED trigger was delayed +40 ms and the ES trigger roughly +400 ms when measured from the onset of the R-wave. The same criteria were used to select the ED and ES frames from the real-time non-contrasted H2D cine loops.

The ultrasound output power was adjusted to maximum for H2D and CHCD, but reduced by 6 dB for CH2D imaging to limit microbubble loss [4]. For all imaging modes, the ultrasound focus was set to the depth of the mitral valve plane to maximize native tissue and contrast enhanced harmonics but ultrasound depth was maintained fixed for any single tomographic planes in all patients [5]. When in CHCD mode, the Nyquist limit was adjusted to roughly ±21 cm/s (range ±18–24 cm/s depending on heart size and imaging depth).

Following pre-contrast H2D imaging, all patients received two injections of Levovist® (Schering AG, Berlin, Germany). Each injection was 2.5 gm and given by slow IV bolus over about 15 s. The second contrast injection was given about 15 min after the first. Imaging was switched to intermittent (triggered) mode once contrast was clearly seen in the right heart using the apical four-chamber view. Triggered CH2D imaging was