Myocardial Deformation Analysis in Contrast Echocardiography: First Results Using Two-Dimensional Cardiac Performance Analysis

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Background: Contrast echocardiography (CE) provides closer agreement with magnetic resonance imaging (MRI) for left ventricular (LV) volumes and ejection fraction (EF) than noncontrast echocardiography. However, the feasibility and role of myocardial deformation analysis on contrast echocardiographic images have not been well established. The aim of this study was to assess the feasibility of deformation analysis on CE using a new software tool that provides simultaneous measurements for LV volumes and EF.

Methods: Data from 52 patients who were recruited for the Alberta Heart Failure Etiology and Analysis Research Team Study (34 men; mean age, 64 ± 9 years) and underwent CE and MRI were considered. Contrast bolus injections were administered for optimal endocardial definition. Offline LV volume analysis was performed by standard manual tracing. A single frame was traced manually for two-dimensional (2D) cardiac performance analysis (CPA), which automatically calculated LV volumes, EF, and global longitudinal strain (GLS). Volumes obtained with 2D CPA were compared with those measured with standard CE and MRI. GLS from noncontrast echocardiographic recordings was also calculated with 2D CPA and compared with CE-derived and MRI-derived GLS.

Results: Tracing of contrast echocardiographic images with 2D CPA was possible in 49 out of 52 patients, and measurements correlated well with standard CE and MRI (EF: $r = 0.93$, $P < .001$, and $r = 0.85$, $P < .001$, respectively). Mean GLS from noncontrast echocardiographic and contrast echocardiographic recordings was −13.4 ± 5.8 and −15.3 ± 4.64, respectively ($P = .056$), and the latter correlated well with MRI-derived GLS ($r = 0.78$ vs 0.81, respectively).

Conclusions: Simultaneous volumetric and deformation analysis on contrast echocardiographic recordings is feasible and reproducible. While volumes and EF obtained with the new software compare well with those obtained from standard CE and MRI, GLS from CE shows a good correlation with strain measured with MRI. (J Am Soc Echocardiogr 2013;■:■-■.)

Keywords: Contrast echocardiography, Volumetric analysis, Speckle-tracking analysis, Cardiac magnetic resonance

Left ventricular (LV) systolic function as assessed by volume and ejection fraction (EF) parameters is a widely validated and strong predictor of outcomes in cardiac patients.[1-3] On the other hand, speckle-tracking imaging is emerging as a complementary technique for the assessment of LV function[4-7] and has been shown to be particularly relevant both in patients with overt[8] as well as subclinical ventricular dysfunction.[9] However, factors such as poor acoustic view with impaired endocardial border identification may often limit proper assessment of LV function in terms of both volumetric[10] and deformation[11] analysis.

The advent of contrast echocardiography (CE) has significantly overcome the difficulties in the assessment of LV volumes and EF.[10,12-14] Nonetheless, strain measurements of contrast recordings performed with Doppler tissue imaging were shown to be unreliable and as such have been discouraging.[15]

Myocardial strain analysis of contrast images was shown to be feasible with speckle-tracking,[16] but the variability between strain measurements of contrast and noncontrast recordings was considered a potential limitation to the technique.

In this study, we sought to test the feasibility of speckle-tracking analysis on contrast images by using a new software tool that provides

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The Alberta Heart Failure Etiology and Analysis Research Team Study is funded by a grant of the Alberta Heritage Foundation. Dr Becher is supported by the Heart & Stroke Foundation of Alberta, Northwest Territories, and Nunavut.

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0894-7317/$36.00

http://dx.doi.org/10.1016/j.echo.2013.08.010

Abbreviations

CE = Contrast echocardiography

CPA = Cardiac performance analysis

EF = Ejection fraction

ESV = End-systolic volume

GLS = Global longitudinal strain

HF = Heart failure

LV = Left ventricular

MRI = Magnetic resonance imaging

2D = Two-dimensional

simultaneous measurements for LV volumes, EF, and myocardial deformation parameters.

METHODS

Data from 52 patients who were recruited for the Alberta Heart Failure Etiology and Analysis Research Team Study (http://www.albertaheartresearch.ca; mean age, 64 ± 9 years; 34 men) between September 2010 and April 2011 were considered for this pilot study. Study patients belong to one of four prespecified categories—(1) systolic heart failure (HF), (2) diastolic HF, (3) diastolic dysfunction, and (4) increased risk for diastolic HF (i.e., patients with known risk factors but no clinical symptoms of HF)—and, as part of the study protocol (unless contraindications are present), undergo both CE and cardiac magnetic resonance imaging (MRI). Exclusion criteria for enrollment in our study were atrial fibrillation or other arrhythmias and contraindication to contrast media administration.

Cardiac MRI Evaluation

All MRI examinations were performed using a 1.5-T Siemens Sonata scanner (Siemens Healthcare, Erlangen, Germany) and a five-element cardiac array for signal reception, as previously described.[17] All image acquisitions were electrocardiographically gated and acquired during breath holds. End-diastolic volume, end-systolic volume (ESV), and EF measurements were derived from manual segmentation of short-axis cine images at end-systole and end-diastole (Argus; Siemens Healthcare), and EF was derived using Simpson's rule. Additionally, the endocardial tracings in conjunction with apical and basal locations from two-chamber, three-chamber, and four-chamber long-axis views were used to generate an endocardial surface of the left ventricle at end-systole and end-diastole. Peak systolic global longitudinal strain (GLS) was calculated using the average of the change in length of the surface from end-diastole to end-systole divided by the lengths at end-diastole.

Echocardiographic Evaluation

After the acquisition of noncontrast echocardiographic images, 0.1 mL Definity (Lantheus Medical Imaging, North Billerica, MA) in slow bolus injections, followed by slow saline flush, was administered for optimal endocardial definition using an iE33 scanner (Philips Medical Systems, Andover, MA). We used standard settings with low to intermediate mechanical index (mean values ranging from 0.3 to 0.4)[18] for contrast recordings, with images optimized to achieve dense and homogenous LV opacification and dark myocardium. The maximum frame rate to achieve LV opacification was used for this study (39 frames/sec). Although higher frames rates would be advantageous for speckle imaging, they cannot be realized with the current scanners and would probably impair LV opacification and endocardial definition. Offline LV volume and EF analysis for noncontrast and contrast images was performed using standard manual tracing of end-systolic and end-diastolic endocardial borders from apical two-chamber and four-chamber images (Xcelera; Philips Medical Systems), and results were obtained using Simpson's biplane method.[19] In addition, echocardiographic recordings were uploaded to the new software, the two-dimensional (2D) cardiac performance analysis (CPA) for speckle-tracking imaging (frame rate, 39 frames/sec; TomTec, Munich, Germany). Two-dimensional CPA has been developed for noncontrast echocardiography. This technique works very similar to Velocity Vector Imaging (Siemens Healthcare).[20] Two-dimensional CPA tracks speckles mainly at the endocardium. This is different from speckle-tracking as implemented in many clinical scanners, and it also tracks speckles in the myocardium. The operator scrolled through the cardiac cycle and, irrespective of cardiac cycle, identified a single frame with good endocardial definition, which was usually during systole. A minimum of 10 border points, at the operator's discretion, were depicted for manual tracking. Then tracing of the endocardial border throughout the cardiac cycle was automatically performed, and LV volumes and EF were computed. In addition, speckles were tracked in a frame-by-frame fashion, and traces depicting segmental longitudinal strain were computed automatically. After the automatic tracking throughout the cardiac cycle, recordings were reviewed to identify studies with inappropriate tracking. No corrections of the tracked contour were made. The tracking was regarded as unsuccessful if the tracked contour on end-diastolic or end-systolic frames was >5 mm away from the visually perceived border of the LV cavity in two or more of six segments in the four-chamber or two-chamber view.

Systolic GLS was obtained by averaging the segmental strain curves at maximum instantaneous peak. Similarly, noncontrast images from the same patients were also analyzed with the software and strain parameters were recorded.

LV volumes and EF derived from 2D CPA were compared with those obtained using MRI and the contrast images analyzed with Xcelera using Simpson's biplane rule. Mean GLS from contrast echocardiographic recordings were compared with those obtained from noncontrast echocardiographic images. Two experienced physicians assessed the image quality for noncontrast recordings, with optimal quality defined as adequate visualization of all myocardial segments. In a subset analysis for GLS, only data from patients with optimal image quality on noncontrast echocardiographic recordings were included for comparison between contrast and noncontrast measurements. In another subset of 22 patients, in which MRI analysis had also been performed, GLS strain data from contrast and noncontrast echocardiographic recordings were correlated with those derived from MRI.

Reproducibility Analysis

All 2D CPA measurements were repeated in a subset of 20 patients by a second physician and by the same primary reader, who were blinded to data. Repeated measurements were performed ≥2 weeks after the first evaluation. As mentioned previously, the selection of the cardiac cycle for the manual border detection was left to the operator's discretion. Interobserver and intraobserver variability was calculated as the absolute difference of the corresponding pair of repeated measurements and as a percentage of their means in each patient and then averaged over the total number of patients, and correlation was tested using intraclass correlation coefficients.

Data are presented as mean ± SD or percentages as appropriate. Student's *t* tests were used for comparisons of continuous