Three-Dimensional Speckle Tracking Echocardiography for Automatic Assessment of Global and Regional Left Ventricular Function Based on Area Strain

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Objective: We evaluated the ability of a novel automatic index based on area strain to reliably quantify global and regional left ventricular (LV) function and accurately identify wall motion (WM) abnormalities using three-dimensional speckle tracking echocardiography.

Methods: A total of 140 consecutive patients underwent two- and three-dimensional echocardiography. Segmental WM assessment by area strain was compared with visual assessment of two-dimensional images by two experienced echocardiographers. For global LV function assessment, area strain was validated against LV ejection fraction (EF) and wall motion score index (WMSI). Observer reliability was assessed in all patients, whereas test–retest reliability was evaluated in a subgroup of 50 randomly selected patients. Normal reference values of area strain were determined in 56 healthy subjects.

Results: Agreement of WM scores between area strain and visual assessment was found in 94% of normal, 55% of hypokinetic, and 91% of akinetic segments (κ-coefficient 0.88). Sensitivity, specificity, and accuracy of area strain to distinguish abnormal segments from normal segments were 91%, 96%, and 94%, respectively. In regard to global LV function assessment, area strain was highly correlated with EF and WMSI ($r = 0.91$ and 0.88, respectively). Observer and test–retest reliability of area strain for quantitative assessment of global and regional LV function were good to excellent (all intraclass correlation coefficients $\geq$0.77). Intraobserver and interobserver reliability of semiquantitative segmental WM analysis by area strain (κ-coefficients 0.87 and 0.73) were comparable to visual assessment by experienced echocardiographers (0.85 and 0.69, respectively).

Conclusion: Area strain represents a promising novel automatic index that may provide an accurate and reproducible alternative to current echocardiographic standards for quantitative assessment of global and regional LV function. Area strain seems to adequately identify regional wall motion abnormalities compared with the clinical standard of visual assessment by experienced echocardiographers. (J Am Soc Echocardiogr 2011;24:314-21.)

Keywords: Echocardiography, Left ventricular function, Speckle tracking, Three-dimensional imaging

Accurate and reproducible evaluation of global and regional left ventricular (LV) function is of vital importance for the determination of diagnosis, prognosis, and therapeutic options of multiple cardiovascular diseases.[1-5] However, in daily clinical practice the echocardiographic evaluation of regional LV function is mainly performed by visual estimation on two-dimensional echocardiographic images, which is known to be subjective and insufficiently reliable for sequential use.[6,7]

The newly developed three-dimensional speckle tracking echocardiography (STE) provides a fast and comprehensive quantitative assessment of LV myocardial dynamics in all four dimensions, and does so with all LV segments in their spatial and temporal relation to each other within the same data set.[8] With the development of three-dimensional STE technology, area strain was introduced as a novel automatic index

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Conflicts of interest: None.

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Abbreviations

EF = Ejection fraction

ICC = Intraclass correlation coefficient

LV = Left ventricular

STE = Speckle tracking echocardiography

WM = Wall motion

WMA = Wall motion abnormality

WMSI = Wall motion score index

for quantitative echocardiographic evaluation of global and regional LV function. During LV contraction, the endocardial surface area decreases in size because of longitudinal and circumferential shortening, and radial myocardial thickening. Area strain reflects this change in the endocardial surface area and quantifies it by giving the percentage change in area from its original dimensions (Figure 1).

Because the change in endocardial surface area should be related to wall motion (WM) and the simultaneous change in LV volume used for the respective measurements of the wall motion score index (WMSI) and LV ejection fraction (EF), a strong relationship between area strain and these traditional parameters of global LV function is expected. More important, this parameter should be sensitive for detecting attenuating effects of ischemia and scar on regional WM, which are commonly most pronounced in the subendocardial layer of the myocardium. Thus, it may provide a fast and reproducible automatic assessment of wall motion abnormalities (WMAs) that is as accurate as visual assessment by experienced echocardiographers.

The primary objectives of this study were to (1) validate area strain with traditional parameters of global and regional LV function, in particular its ability to identify WMA compared with visual assessment by experienced echocardiographers; (2) determine its observer and test–retest reliability in patients with cardiac disease with a wide range of LV function; and (3) establish normal reference values in a healthy population.

MATERIALS AND METHODS

Patients and Healthy Subjects

A total of 140 consecutive patients visiting our laboratory for echocardiographic examination were enrolled in this study. Twenty-six patients (19%) were excluded after echocardiographic acquisitions because of poor image quality (defined as >4 non-visualized segments) ($n = 16$), irregular heart rhythm ($n = 7$), or a failure in data exportation from the scanner ($n = 3$). Of the remaining 114 patients in the study group (67 men, mean age 59 ± 16 years, mean LV EF 51% ± 13%), 48 had ischemic heart disease, 44 had various diagnoses of heart disease (e.g., valvular, congenital, and nonischemic forms of cardiomyopathy), and 22 had suspected cardiac disease, but no cardiac abnormalities were identified during echocardiographic examination.

To determine normal reference values for area strain, 56 selected healthy subjects were included in the study. The healthy subjects (44 men, mean age 40 ± 15 years, mean LV EF 61% ± 4%) satisfied the following criteria: no history of cardiac symptoms, hypertension, or diabetes; no use of medication; and normal physical examination, electrocardiogram, and echocardiogram results. All subjects gave informed consent, and the local ethics committee approved the protocol.

Echocardiographic Imaging

Three-dimensional STE imaging was performed from an apical position using a commercial scanner (Artida 4D, Toshiba Medical Systems, Tustin, CA) with a fully sampled matrix array transducer (PST-25SX). Wide-angled acquisitions were recorded, in which six wedge-shaped subvolumes were acquired over seven consecutive cardiac cycles during a single breath-hold. While retaining the entire LV within the pyramidal volume, depth and sector width were decreased as much as possible to improve the temporal and spatial resolution of the images, resulting in a mean temporal resolution of 21 ± 2 volumes per second.

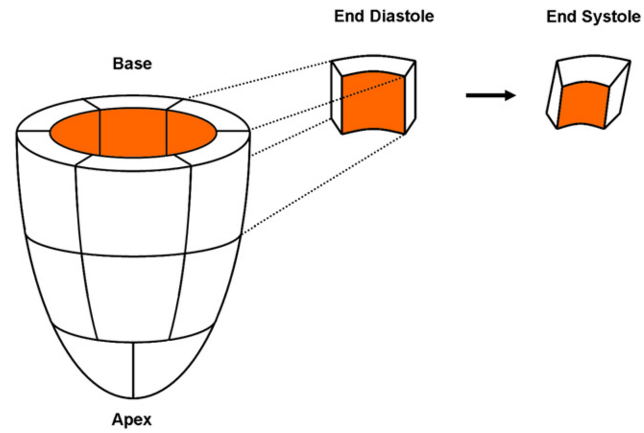

Figure 1 Area strain. Schematic representation of a myocardial segment of the left ventricle is shown with its endocardial surface depicted in orange. At end diastole, the endocardial surface area is represented in its unstressed original dimensions. During contraction, the size of the endocardial surface area decreases because of deformation of the myocardial segment. At end systole, deformation of the endocardial surface area reaches its maximum. Thus, contrary to directional strains such as radial, circumferential, and longitudinal strain, which are calculated from changes in distance in their respective directions, area strain represents the percentage change in endocardial surface area from its original dimensions.

A standard two- and three-dimensional echocardiographic examination was performed using a different commercial scanner (iE33, Philips, Amsterdam, The Netherlands). Two-dimensional echocardiographic images were optimized for segmental WM assessment by modifying the gain, compress, and time-gain compensation controls, after which cine-loops of three consecutive beats were recorded, while making an effort to avoid foreshortening. The methodology of acquiring three-dimensional echocardiographic data sets was similar to that of three-dimensional STE data sets with the exception of acquiring seven wedge-shaped subvolumes during a single breath-hold instead of six subvolumes. Three-dimensional STE images were analyzed online, whereas two- and three-dimensional echocardiographic images were stored digitally for offline analysis of segmental WM and LV EF, respectively.

Segmental Wall Motion Analysis

Segmental WM was visually graded in parasternal and apical two-dimensional views by two experienced readers (MFAA, OK) according to the appropriate 16-segment model and scored as follows: normal or hyperkinesis = 1, hypokinesis = 2, akinesis = 3, dyskinesis = 4, and aneurysmal = 5.[9] WMSI was calculated as the average score of all analyzable segments. Because the number of dyskinetic and aneurysmatic segments was small, they were grouped together with akinetic segments for segmental comparisons of area strain versus visual assessment. Segments with agreement between