JACC: CARDIOVASCULAR IMAGING VOL. 4, NO. 4, 2011

ISSN 1936-878X/$36.00
PUBLISHED BY ELSEVIER INC. DOI:10.1016/j.jcmg.2010.12.007

Endocardial Surface Area Tracking for Assessment of Regional LV Wall Deformation With 3D Speckle Tracking Imaging

Yoshihiro Seo, MD,* Tomoko Ishizu, MD,* Yoshiharu Enomoto, MD,†
Haruhiko Sugimori, MD,† Kazutaka Aonuma, MD*
Tsukuba, Japan

OBJECTIVES The aim of this experimental study was to validate area tracking by 3-dimensional (3D) speckle tracking imaging (STI) as a method to measure changes in regional left ventricular (LV) endocardial surface area with sonomicrometry and to assess the usefulness as a wall motion evaluation method compared with 1-dimensional strain parameters.

BACKGROUND A 3D-STI allows for tracking a regional endocardial surface area during a cardiac cycle. Area tracking is a new concept that regional wall motion is quantified through the magnitude of deformation in an endocardial surface area.

METHODS In each of 8 anesthetized sheep, sonomicrometry crystals were implanted on the endocardium at the LV mid and apical anterior walls. Area change ratio (ACR) that was a novel parameter obtained by area tracking was measured as percentage change in a segmental area during systole. Segmental longitudinal (LS) and circumferential strain (CS) also were measured by 3D-STI. The ACR, LS, and CS were compared with those by sonomicrometry at baseline and during pharmacological stress tests (dobutamine and propranolol infusion) and acute myocardial ischemia induced by occlusion of mid-left ascending artery.

RESULTS The strong correlation was observed between ACR measurements by 3D-STI and those by sonomicrometry ($Y = -4.20 + 0.84X$, $r = 0.87$, $p < 0.001$). The ACR showed significant relations with both LS and CS (LS: $Y = -15.1 + 1.73X$, $r = 0.73$, $p < 0.001$; CS: $Y = -5.85 + 1.06X$, $r = 0.79$, $p < 0.001$). ACR showed significant differences among baseline, pharmacological stress, and acute myocardial ischemia. In contrast, LS and CS were reduced significantly during acute ischemia studies compared with those during the other studies; no differences were observed among baseline, propranolol infusion, and dobutamine infusion studies.

CONCLUSIONS Area tracking by 3D-STI can estimate changes in LV regional area and might be promising for regional wall motion evaluations. (J Am Coll Cardiol Img 2011;4:358–65) © 2011 by the American College of Cardiology Foundation

From the *Cardiovascular Division, Institute of Clinical Medicine, Graduate School of Comprehensive Human Sciences, University of Tsukuba, Tsukuba, Japan; and the †Department of Cardiovascular Surgery, Institute of Clinical Medicine, Graduate School of Comprehensive Human Sciences, University of Tsukuba, Tsukuba, Japan. Dr. Seo was supported by a research grant from Toshiba Medical Systems Corporation. All other authors have reported that they have no relationships to disclose.

Manuscript received July 19, 2010; revised manuscript received December 6, 2010, accepted December 9, 2010.

Left ventricular (LV) regional wall motion has been assessed by regional deformation measurements, which are separated into 3 components: longitudinal, circumferential, and radial strain. Speckle tracking imaging (STI) has been focused as a useful modality to assess myocardial deformation (1–4). Because of complex 3-dimensional (3D) wall deformations including longitudinal entire heart motion and circumferential rotation during the cardiac cycle, a 3D-STI system might have an advantage in assessing accurate regional deformation. Recently, a robust 3D-STI system was developed and introduced on a commercially available ultrasound system (5,6). We previously validated strain measurements by the 3D-STI system against data obtained by sonomicrometry to assess regional myocardial function (7). In addition, this system allows tracking a regional endocardial surface area during a cardiac cycle. Area tracking is the new concept that regional wall motion is quantified through the magnitude of deformation in an area. Area tracking has combined data for 2 directional deformations, longitudinal and circumferential components, which might decrease the tracking error and emphasize synergistically the magnitude of deformation. Therefore, area tracking might be more sensitive in assessing LV regional deformation compared with 1-dimensional (1D) strain parameters. This experimental study aimed to validate area tracking as a novel method to measure changes in regional LV endocardial surface area with sonomicrometry and to assess the usefulness of area tracking as a wall motion analysis method compared with 1D strain parameters.

METHODS

Animal preparation. Eight male hybrid Suffolk sheep (Japan Lamb, Ltd., Hiroshima, Japan) were used for this study. After receiving approval from the Institutional Animal Experiment Committee of the University of Tsukuba, we carried out all experiments in a humane manner and in accordance with the "Regulation for Animal Experiments" of our university and the "Fundamental Guideline for Proper Conduct of Animal Experiment and Related Activities in Academic Research Institutions" under the jurisdiction of the Ministry of Education, Culture, Sports, Science and Technology. Anesthesia was induced with thiopental sodium (10 to 15 mg/kg IV), and the animals were intubated. Anesthesia was maintained with isoflurane (1.5% to 2%) and oxygen. All animals underwent left thoracotomy under aseptic conditions. Polypropylene snares were loosely placed around the appropriate coronary arteries. A fluid-filled catheter was inserted via a femoral artery for continuous monitoring of systemic arterial pressure and heart rate.

Echocardiography. Echocardiographic examinations were performed with an Artida ultrasound system (Toshiba Medical Systems, Tochigi, Japan). Full-volume, electrocardiography-gated, 3D datasets were acquired from apical positions with a matrix array 2.5-MHz transducer, which was fixed in an ultrasound gel-filled latex bag and placed on the apical epicardium. To obtain these datasets, 4 or 6 sectors were scanned and automatically integrated into a wide-angle (70° × 70°) pyramidal data image covering the entire LV. Frame rate of each image was set at approximately 30 Hz.

The data were stored and transferred to a computer (INSPIRON 1300, Dell, Inc., Round Rock, Texas) for offline analysis. The images were analyzed with software (3D Wall Motion Tracking, Toshiba Medical Systems) specific for the analysis of data acquired by the Artida. First, the endocardial border of the 4-chamber image at end-diastole was traced manually, followed by manual tracing of the epicardial border. Second, the same tracing processes were repeated in the 2-chamber image. After these long-axis tracings were complete, 3D myocardial surfaces were automatically reconstructed, and fine adjustments were made to the traced borders on the short-axis images.

ABBREVIATIONS AND ACRONYMS

ACR = area change ratio
CS = circumferential strain
LAD = left anterior descending coronary artery
LS = longitudinal strain
LV = left ventricle/ventricular
STI = speckle tracking imaging

Wall motion tracking algorithm. First, the tracking points are distributed on the 3D curved surfaces (Fig. 1). Alternatively, motion estimation points where the image has features appropriate for tracking are located automatically in a region of myocardium in each volume frame. Each tracking point is moved on the basis of the motion information obtained from nearby motion estimation points. The motion vector for each motion estimation point between consecutive volume frames is detected by template matching technique. In the template matching process, the template volume in the current frame is generated from an approximately 10 × 10 × 10-mm cube in which the motion estimation point is centered. The most similar point in the next volume is searched for by comparing a template volume with the cube in the next volume. We used the 3D sum of squared differences method to test image similarity. Finally,