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Comparison of septal strain patterns in dyssynchronous heart failure between speckle tracking echocardiography vendor systems

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Abstract

Aim: To analyze inter-vendor differences of speckle tracking echocardiography (STE) in imaging cardiac deformation in patients with dyssynchronous heart failure.
Methods and results: Eleven patients (all with LBBB, median age 60.7 years, 9 males) with implanted cardiac resynchronization therapy devices were prospectively included. Ultrasound systems of two vendors (i.e. General Electric and Philips) were used to record images in the apical four chamber view. Regional longitudinal strain patterns were analyzed with vendor specific software in the basal, mid and apical septal segments. Systolic strain (SS), time to peak strain (TTP) and septal rebound stretch (SRS) were determined during four pacing settings, resulting in 44 unique strain patterns per segment (total 132 patterns). Cross correlation was used to analyze the comparability of the shape of 132 normalized strain patterns. Correlation of strain patterns of the two systems was high (R^2 median: 0.68, interquartile range: 0.53–0.82). Accordingly, strain patterns of intrinsic rhythm were recognized equally using both systems, when divided into three types. GE based SS (18.9 ± 4.7%) was significantly higher than SS determined by the Philips system (13.4 ± 4.3%). TTP was slightly but non-significantly lower in GE (384 ± 77 ms) compared to Philips (404 ± 83 ms) derived strain signals. Correlation of SRS between the systems was poor, due to minor differences in the strain signal and timing of aortic valve closure.
Conclusions: The two systems provide similar shape of strain patterns. However, important differences are found in the amplitude, timing of systole and SRS. Until STE is standardized, clinical decision making should be restricted to pattern analysis.

Keywords: Speckle tracking echocardiography; Longitudinal strain; Strain patterns; CRT; Vendor comparison; Heart failure; Dyssynchrony; SRS; Septum; Correlation

Introduction

The introduction of speckle tracking echocardiography (STE) has brought new possibilities to the field of myocardial deformation analysis [1]. STE allows calculating myocardial deformation patterns from B-mode grayscale images in an ultrasound beam angle-independent manner [2]. The application field of STE is still growing, ranging from myocardial infarction to dyssynchrony, congenital heart disease and cardiomyopathies [3–6].

Several vendors have developed software packages for STE deformation analysis, to be used in combination with their own ultrasound machines. Unfortunately, the implemented algorithms are not publicly available and investigators lack insight about the exact method of strain calculation. Moreover, some studies suggest that estimated strain values differ, not only between ultrasound equipment, but also when applying various analysis tools to the same signals [7–11].

An area where strain measurements are increasingly used is assessment of dyssynchrony. In this area, highly complicated

Abbreviations: ApIS, apical inferoseptal; BIS, basal inferoseptal; MIS, mid inferoseptal; AVC, aortic valve closure time; CRT, cardiac resynchronization therapy; SRS, septal rebound stretch; SS, systolic strain; STE, speckle tracking echocardiography; TTP, time to peak strain.

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strain patterns are found. To assess cardiac status in these patients, not only strain amplitude (e.g. peak systolic strain) is used, but also various indices of mechanical dyssynchrony, such as time to peak strain (TTP), septal rebound stretch (SRS) and septal strain patterns [12–14]. Septal deformation patterns translate to interventricular dynamics and have shown to predict response and outcome of cardiac resynchronization therapy (CRT) [6,15]. These results were obtained by EchoPac strain analysis on General Electric (GE) acquired echocardiographic studies. Discrepancies in estimated strain parameters caused by vendor specific differences could therefore lead to conflicting data from different centers and even to misdiagnosis.

The purpose of the present study was to compare strain patterns and derived parameters obtained by ultrasound equipment and software of two widely used vendors, i.e. GE and Philips. Strain patterns were compared, with respect to their global strain pattern shape, and inter-vendor, intra- and interobserver agreement of absolute strain amplitude (SS), and commonly used indices like TTP and SRS. Our hypothesis is, based on other studies and own observations, that absolute values differ between vendors while patterns may be more alike.

Methods

The study was performed according to the principles of the Declaration of Helsinki. All participants gave fully informed written consent prior to investigation. Eleven CRT patients were prospectively investigated in the Maastricht University Medical Center (MUMC). The device was implanted in the MUMC at least 6 months before entering the study (2006–2012). Prior to CRT, all patients were diagnosed with heart failure (NYHA I-IV), left bundle branch block (LBBB) and QRS duration >150 ms. Patients were selected from two CRT trials, and gave consent to participate in sub-studies. They were selected based on known echocardiographic window and favorable response to CRT (LVEF >35%). Responders were thought to have a bigger difference in strain patterns between the used CRT settings. Other inclusion criteria were; sinus rhythm and age ≥18. Patients with complete AV-block or permanent atrial fibrillation were excluded from participation.

Ultrasound machines of two vendors, GE Vivid 7 (General Electric Healthcare, Milwaukee, USA) and Philips iE33 (Philips Medical Systems, Best, The Netherlands), were used. To avoid interobserver variability during acquisition, the same echocardiography specialist investigated each patient on both machines. Acquisition on both machines was performed successively (i.e. only a few minutes apart) in the MUMC. The order (i.e. acquisition with GE or Philips first) was randomly assigned. To induce a wide range of strain patterns, images were recorded in four conditions: preprogrammed biventricular pacing, single site left ventricular (LV) pacing, single site right ventricular (RV) pacing and during intrinsic rhythm (pacing off). There was a pause of at least 20 seconds between pacing modalities, to reach a new hemodynamic steady state. In every setting, the following images were stored during at least three cardiac cycles: 2D-images of the interventricular septum in the apical four chamber view for STE, and continuous wave Doppler images of the left ventricular outflow tract for offline determination of the aortic valve closure timing (AVC). Images were recorded during breath hold. The frame rate of 2D-images for STE was optimized between 60 and 90 Hz. Systole was defined as the period between the R-wave and subsequent AVC. The R-wave was chosen, instead of the mitral valve closure time due to its higher reproducibility.

We focused on the interventricular septum, because imaging quality of the LV lateral wall is often poor in dilated hearts of heart failure patients. Imaging the septum has a higher reproducibility [16]. Moreover, due to interventricular dynamics, a wide range of septal stain patterns is inducible by altering CRT settings. Septal deformation imaging (i.e. categorization of strain patterns and SRS) can predict response and outcome of CRT.

Offline analysis

Offline analysis of recorded images was performed with corresponding software packages of both vendors. Raw (i.e. non-compressed) echocardiographic data were exported with both systems. QLAB 8.0 (Philips Medical Systems, Best, The Netherlands) was used for all Philips iE33 derived images. EchoPac (PC version 112; GE Healthcare, Milwaukee, USA) was used for all GE Vivid 7 acquired images. 44 longitudinal strain patterns were analyzed from eleven patients in three separate segments, resulting in a total of 132 strain patterns per vendor. Three consecutive beats were selected for both vendors, based on the ECG signal. Timing of reference length (L_0) was defined at the top of the R-wave for both vendors. Exported Philips images started at the R-wave, and therefore L_0 couldn't be placed at a prior point (e.g. QRS-onset). Manual LV border tracing of the septum was performed according to the vendors' preferences (end systolic for GE and end diastolic for Philips). The septum was divided in three segments: apical (ApIS), mid (MIS) and basal (BIS). A segment was neglected if the software could not track displacement, even after repeatedly adjusting the region of interest (ROI). In QLAB, standard settings were used, although the setting of 'mesh' was turned to its highest value, to obtain the highest possible spatial resolution. Standard 'out-of-the-box' settings for filtering and smoothening were used with EchoPac. Analysis was performed blinded for the results of the other vendor.

EchoPac uses an ROI of six segments across the septum and LV free wall in the apical four chamber view, according to the sixteen segment model. QLAB 8.0 has an additional seventh segment, situated at the apex. The latter is according to the recommendations of the American Heart Association [17]. As a result, the position of the segments in QLAB was slightly shifted toward the base. We adjusted the ROI of EchoPac to match the position of the segments of QLAB. For each setting and for each segment, strain values in time were exported to Matlab R2012b for further analysis of strain data with author-written general scripts.

Systolic strain and time to peak strain

SS was chosen as a parameter for spatial deformation, to incorporate the total shortening of each beat. SS was determined