Right Ventricular Longitudinal Strain Reproducibility Using Vendor-Dependent and Vendor-Independent Software

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Background: Right ventricular peak systolic longitudinal strain (RVLS) has emerged as an approach for quantifying right ventricular function in diseases such as pulmonary hypertension and congenital heart disease. A major limitation in applying RVLS is that strain imaging and analysis are proprietary, which may result in systematic differences from vendor to vendor. The goal of this study was to test the reproducibility of right ventricular strain analysis among selected vendor-specific software (VSS) and vendor-independent software (VIS) on images obtained from different ultrasound scanners, as would be common in clinical practice or in a multicenter clinical trial.

Methods: In this prospective, single-center study, 35 patients (5 healthy subjects and 30 with pulmonary hypertension) each underwent two echocardiographic scans, one using GE (Vivid E9) and the other using Philips (iE33) ultrasound systems. Images were analyzed using both VSS and VIS (TomTec) software for determination of RVLS. A repeated-measures analysis of variance was used to assess for any systematic differences among methods, as well as effects of scanner and software and a possible interaction between scanner and software for each strain measurement.

Results: Differences for global strains were not statistically significant among VSS packages ($P \geq .05$), but some differences were noted between VSS and VIS. Wide variability between regional peak strain measurements was noted, but no systematic differences were found.

Conclusions: Global RVLS values between VSS systems are not significantly different but may differ slightly from VIS. When comparing regional strain between VSS and VIS analyses, there is widespread variability without clear systematic differences. (J Am Soc Echocardiogr 2018;■:■-■.)

Keywords: Right ventricular strain, Echocardiography, Reproducibility, Validation

The ability to accurately and reproducibly measure right ventricular (RV) function has been of great interest both from clinical and research perspectives,[1-4] as RV functional impairment has been associated with negative outcomes in diseases such as pulmonary hypertension (PH)[3,5-7] and congenital heart disease.[8,9] RV function may be assessed using invasive methods such as cardiac catheterization. Noninvasively, the "gold standard" method is currently cardiac magnetic resonance imaging,[10] which is often limited by patient tolerability and institutional availability.[11]

Transthoracic echocardiography, by comparison, is a widely available imaging method that, accordingly, provides ample opportunity to evaluate patients with diseases that may affect RV function. Problematically, most standard Doppler echocardiography–derived parameters, such as pulmonary artery systolic pressure (estimated from tricuspid regurgitation) or RV chamber dimensions do not provide a direct measure of RV function.[4] More advanced quantitative measures of RV function, such as tricuspid annular plane systolic excursion and RV fractional area change, rely on geometric

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Abbreviations

CoV = Coefficient of variation

DICOM = Digital Imaging and Communications in Medicine

LoL = Length of line

LV = Left ventricular

PH = Pulmonary hypertension

RV = Right ventricular

RVLS = Right ventricular peak systolic longitudinal strain

SD_b = SD of the bias

VIS = Vendor-independent software

VSS = Vendor-specific software

assumptions. These, along with the RV Tei index, have not been validated in large trials.[4]

RV peak systolic longitudinal strain (RVLS), measured using two-dimensional speckle-tracking echocardiography, has emerged as an approach for quantifying RV systolic function. RVLS provides more global assessment of RV function[12] and has relative angle independence.[13] Moreover, RVLS has been associated with outcomes in PH[3,6] and other diseases that affect RV function,[8,14] suggesting that it could be used as a standard and reproducible approach to quantify RV function.

Despite these advantages, there are still potential limitations to the application of RVLS. Echocardiographic strain imaging and image analysis methods are mainly proprietary (vendor specific) and subject to variations.[15,16] Although such differences have been studied in left ventricular (LV) longitudinal strain and shown not to be significant,[16-18] this may not be directly applicable to the right ventricle.[19]

Currently, the reproducibility of RV strain across different vendor-specific software (VSS) and vendor-independent software (VIS) platforms (all using different algorithms to calculate two-dimensional speckle-tracking echocardiographic strain) has not been validated. With its complex geometry and different orientation of myocardial fibers compared with the left ventricle,[19] it is unclear whether these varied algorithms for strain would yield similar values for RVLS. Different methodologies may result in systematic differences of RV strain between study intervals when the same systems are not used, limiting the clinical and research applicability of RV global longitudinal strain.

The goal of this study was to investigate the agreement and reproducibility of RV strain measurements between VSS and a single VIS package on images obtained from different ultrasound machines.

METHODS

Study Population

In this prospective study, patients sent by their referring providers for clinically indicated echocardiographic examinations were recruited from the Duke University Medical Center echocardiography laboratory. Patients were included if they were adults able to provide consent. Exclusion criteria were as follows: poor imaging windows or image quality that precluded strain analysis (i.e., the walls of the RV apical four-chamber view were not adequately visible throughout the cardiac cycle, and/or two or more wall segments [adjacent or not] were not tracked during the cardiac cycle), arrhythmia (defined as atrial fibrillation or atrial arrhythmias or one or more premature ventricular contractions within a three-beat loop), and the presence of significant congenital heart disease (i.e., large ventricular septal defect or complex cardiac defects such as transposition or single ventricle). When a reliability feedback indicator for tracking was not present in the software, the examiner determined whether regional strain curves were biologically plausible vis-à-vis their relation to neighboring segments.

Patient characteristics were recorded and are presented as median, 25th percentile, and 75th percentile for continuous variables and as frequencies and percentages for categorical variables. Characteristics were assessed on the basis of the health of the subject (healthy or PH) and on the total study group.

Study Design

Each patient underwent two scans, one using a GE Vivid 9 (GE Vingmed Ultrasound, Horten, Norway) and the other using a Philips iE33 scanner (Philips Medical Systems, Andover, MA; Figure 1). The order of scanner use was random, depending on which device was available for the initial clinically indicated examination. After the first scan was complete, a second scan was performed on a different ultrasound machine by the same sonographer within 60 min. All sonographers were experienced in obtaining and optimizing images for strain analysis.

For this study, three previously described RV-focused apical views were obtained by rotation of the ultrasound probe by 60° around the apex of the right ventricle instead of the left ventricle.[2] This approach was developed and validated in this laboratory to provide a comprehensive examination of the right ventricle, as it allows the use of LV strain software for RV analysis. Using this approach, the apical four-chamber position views the RV lateral free wall and septum (except that it is mirrored); the apical two-chamber rotational position visualizes the posterior RV free wall, anterior septum, and outflow tract; and the apical three-chamber view visualizes the anterior free wall, posterior septum, and RV inflow (Figure 2). Thus, the apical four-chamber view contains the six segments of the standard apical RV view. In an earlier study, global strain values from the 18-segment model correlated well with the six-segment model.[12] A limitation of the 18-segment model is in tracking of the RV outflow tract in the apical two-chamber view, but overall, the reproducibility of all segments is similar.[2]

Images were then analyzed using both VSS and VIS, yielding two strain analysis sets for each examination encounter (VSS and VIS for each GE and Philips study), for a total of four sets of regional strain measurements for each subject (GE VSS, GE VIS, Philips VSS, and Philips VIS). To evaluate global strain, two calculation methods available in the TomTec VIS (average and length of line [LoL]) were applied, yielding a total of six measures of global strain per subject (Figure 1).

Strain Analysis

Echocardiographic studies were performed on GE Vivid E9 using a 3.5-MHz probe and a Philips iE33. For this study, the comprehensive three RV-focused apical views were obtained during breath hold in three beat loops and optimized in depth for strain analysis (with frame rates between 45 and 90 Hz).[2,12] Offline analysis of GE images was performed using EchoPAC version BT13 (GE Vingmed Ultrasound), Philips images using on-cart QLAB version