Assessment of Myocardial Deformation in Children Using Digital Imaging and Communications in Medicine (DICOM) Data and Vendor Independent Speckle Tracking Software

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Background: Analysis of myocardial deformation from data stored in Digital Imaging and Communications in Medicine format using vendor-independent software may be useful for clinical and research purposes but has not been evaluated in children.

Methods: Grayscale images were prospectively acquired on Vivid 7 (GE Healthcare) and iE33 (Philips Medical Systems) ultrasound systems in 49 children. Digital Imaging and Communications in Medicine and raw data were analyzed using vendor-independent software (Cardiac Performance Analysis, Tomtec Imaging Systems) and vendor-specific software (EchoPAC and QLAB) and results compared. In addition, vendor-independent software using images at 30 frames/sec were compared with images at the higher acquisition frame rate.

Results: Measurement of short-axis radial and circumferential strain (ϵ) and apical four-chamber longitudinal ϵ by vendor-independent software was possible in >92% of the children. Intraobserver and interobserver coefficients of variation for global circumferential and longitudinal ϵ ranged from 7.1% to 15.3% and for radial ϵ from 23.9% to 30.2%. Strain values were somewhat higher when using GE images at acquisition frame rates compared with ϵ values using GE images stored at 30 frames/sec. Strain values obtained by vendor-independent software were comparable with those obtained by vendor-specific software for longitudinal ϵ and higher for circumferential ϵ. Radial ϵ values obtained by vendor-independent software were lower than ϵ values by EchoPAC and higher than ϵ values by QLAB.

Conclusions: Vendor-independent software–derived ϵ is feasible and potentially valuable for measuring myocardial deformation in research and in multicenter studies using images from different ultrasound systems, especially for longitudinal deformation. However, a systematic bias for circumferential ϵ and a high variability in radial ϵ measurements remain concerns. (J Am Soc Echocardiogr 2011;24:37-44.)

Keywords: Myocardial deformation, Vendor-independent software, DICOM data, Child

Myocardial deformation imaging by echocardiography might lead to a more objective assessment of global and regional myocardial function.[1] Assessment of myocardial performance by speckle-tracking echocardiography, which tracks the B-mode natural acoustic markers (speckles) frame by frame throughout the cardiac cycle, has increased, as this technique allows relatively accessible and angle-independent analysis of myocardial strain (ϵ) and ϵ rate by dedicated software.[2] To date, this analysis has required software that is proprietary to the ultrasound machine on which the images were obtained.[3-7] Hence, deformation analysis from echocardiographic data acquired on a GE machine can be done only using EchoPAC software (GE Healthcare, Milwaukee, WI), and deformation analysis on Philips images requires QLAB software (Philips Medical Systems, Best, The Netherlands). More recently, speckle-tracking echocardiography ϵ can also be analyzed from images stored in Digital Imaging and Communications in Medicine (DICOM) format regardless of which system was used to capture the data, referred to in this report as vendor-independent software (Cardiac Performance Analysis; TomTec Imaging Systems, Unterschleissheim, Germany). This application has potential practical implications for multicenter studies using different ultrasound machines as well as for the retrospective analysis of myocardial function from previously acquired images stored in DICOM format. Furthermore, the availability of a common, nonproprietary analysis system presents a unique opportunity to compare commonly used deformation analysis programs. However, the use of vendor-independent software for deformation analysis has not

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Abbreviations

DICOM = Digital Imaging and Communications in Medicine

ϵ = Strain

been extensively studied. In addition, it is unknown whether myocardial ϵ values by vendor-independent software using images acquired on different ultrasound machines are comparable. Therefore, the purposes of this study were (1) to assess the feasibility and reliability of ϵ measurements by vendor-independent software in children, (2) to compare vendor-independent software-derived ϵ values using DICOM data from two common ultrasound systems, and (3) to compare deformation results obtained by vendor-independent software with those derived from vendor-specific software.

METHODS

Study Participants

Children with or without heart disease were prospectively enrolled between February 2009 and October 2009. The wide range of congenital and acquired cardiac diagnoses is shown in Table 1. Participants were recruited in the outpatient clinic when scheduled to undergo clinically indicated echocardiography and from healthy volunteers. Children with single-ventricle physiology and cardiac arrhythmias were excluded. No children were excluded a priori on the basis of expected poor echocardiographic windows. The study was approved by the institutional research ethics board, and written informed consent was obtained from participants and their legal guardians.

Echocardiographic Image Acquisition

Participants were scanned with GE Vivid 7 (GE Healthcare) and Philips iE33 (Philips Medical Systems) ultrasound systems within a 30-min time frame, by a single sonographer (C.S.). An S4 or S5 curved-array transducer was used for the GE system and an S5 curved-array probe for the Philips system.

Each participant first underwent an extensive initial assessment of cardiac anatomy and cardiac function with one ultrasound system, which included the acquisition of tissue Doppler data and grayscale images optimized for speckle-tracking analysis. Assessment with the other ultrasound system followed. The order in the examinations on the two machines were done was dependent on the clinical indication for the echocardiographic request. Per the clinical protocols instituted in our laboratory, for children with cardiomyopathy and children without heart disease, the first examination was performed on a GE system and the second on a Philips system. For patients who underwent echocardiographic examinations for predominantly anatomic and hemodynamic evaluation, the Philips system was used first, followed by the GE system. Participants were examined at rest in the left lateral decubitus position during sinus rhythm. M-mode images from the parasternal long axis and short axis were acquired to calculate ejection time, R-R duration, left ventricular dimensions, and shortening fraction.

B-mode images were acquired at a frame rate of 55 to 90 frames/sec, as recommended by the vendors for optimal speckle-tracking echocardiography. Parasternal short-axis images at the midventricular level and apical four-chamber and two-chamber images of the left ventricle were obtained from two cardiac cycles. Images were stored as raw data at the acquisition frame rate as well as in DICOM format on a syngo Dynamics version V5.1 server (Siemens Medical Solutions Health Services, Malvern, PA) at a default setting of 30 frames/sec for both GE and Philips. In addition, to compare ϵ analysis at the lower

Table 1 General characteristics and traditional echocardiographic parameters (n = 49)

Variable	Value
Age (years)	12.4 ± 4 (4.4 to 17.7)
Men	31 (63%)
Weight (kg)	42 ± 16 (16.4 to 73.8)
Height (cm)	146 ± 19 (105 to 171)
BSA (m^2)	1.29 ± 0.3 (0.69 to 1.76)
BMI (kg/m^2)	19 ± 4 (12 to 30)
Systolic blood pressure (mm Hg)	102 ± 13 (81 to 114)
Diastolic blood pressure (mm Hg)	57 ± 9 (40 to 61)
Diagnosis	
Normal heart	12 (24%)
Heart transplant recipient	6 (12%)
Systemic arterial hypertension	3 (6%)
Cardiomyopathy	5 (10%)
Post–Kawasaki disease	1 (2%)
Post–anthracycline treatment	1 (2%)
Congenital heart disease	21 (43%)
Heart rate (beats/min)	72 ± 15 (41 to 119)
LV EDD *Z* score	0.73 ± 1.61 (−3.2 to 6.4)
LV ESD *Z* score	0.40 ± 1.56 (−3.3 to 6.9)
Shortening fraction (%)	37 ± 6 (23 to 53)
Ejection fraction (%)	63 ± 7 (46 to 77)
LV ejection time (msec)	296 ± 44 (201 to 458)

Data are expressed as mean ± SD (range) or as number (percentage).

BMI, Body mass index; *BSA*, body surface area; *EDD*, end-diastolic dimension; *ESD*, end-systolic dimension; *LV*, left ventricular.

default storage frame rate of 30 frames/sec with the higher acquisition frame rate, GE raw data (at the acquisition frame rate) were uploaded as DICOM images into the vendor-independent software system. This was not possible for Philips images.

Offline Analysis

Vendor-independent software (Cardiac Performance Analysis, version 1.0; TomTec Imaging Systems) was used. The endocardial border was manually traced at end-systole (minimal volume) in short-axis and apical four-chamber views. Tracking of the endocardial border was visually inspected and manually adjusted if necessary. After obtaining satisfactory endocardial tracking, the epicardial border was added to incorporate the entire myocardial wall. Tracking was reinspected throughout the cardiac cycle and adjusted as necessary. The "average heart cycle" mode was not used as recommended by the manufacturer. Lagrangian ϵ curves were then rendered by the software (Figure 1A). The cardiac cycle with the best tracking and visually most credible ϵ curves was selected for analysis. The maximal ϵ value was recorded in each of 12 segments (radial and circumferential ϵ for the anterior septum, anterior, lateral, posterior, inferior, and septum from short-axis views and longitudinal ϵ for the basal septum, midseptum, apical septum, apical lateral, midlateral, and basal lateral from apical four-chamber views). Because one of the objectives of this study was to compare ϵ curves between systems using a common platform, only segments with ϵ values > 5% were included in the analysis. Images were subjectively categorized as good, reasonable, or immeasurable on the basis of a combination of image quality, tracking performance, and the quality of the ϵ curves obtained for the different vendor-independent software images.