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Speckle tracking echocardiography in very preterm infants: Feasibility and reference values☆

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ABSTRACT

Background: Speckle tracking echocardiography (STE) applies computer software analysis on images generated by conventional ultrasound to define and follow a cluster of speckles from frame to frame and calculates parameters of motion (velocity, displacement) and deformation (strain, strain rate). We explored STE of the left ventricle in stable very preterm infants.
Methods: Apical 4 chamber clips (4CH) and short axis clips (SAX) at the level of the papillary muscle were analyzed using TomTec software with manual tracing of cardiac borders. The software automatically segmented the ventricle into 6 equidistant segments and provided segmental and global analysis of deformation parameters. Tracking accuracy was scored visually.
Results: Seventy-four clips from 51 infants with a median gestational age of 28 weeks were analyzed. Feasibility of 4CH was 95.5% for longitudinal and 96.2% for radial parameters. The reliability of longitudinal and circumferential deformation parameters was good, but radial parameters were less reliable. 4CH mean (SD) global peak systolic longitudinal and radial strain (%) and strain rate (s^{-1}) were −18.7(2.6), −1.73(0.28), 23.6(9.1) and 1.94(0.65), and SAX circumferential and radial strain and strain rate were −19.5(3.7), −1.97(0.46), 32.1(14.4) and 2.37(0.80).
Conclusion: STE is feasible in preterm infants. Optimal image acquisition is paramount. Longitudinal parameters in 4CH and circumferential in SAX were most robust.

1. Introduction

Echocardiography is the most commonly used diagnostic modality for cardiovascular assessment in the neonatal intensive care. It is an easy, non-invasive bedside method to study cardiac structure and provide an estimate of cardiac function. However, measuring cardiac mechanics is complex. The myocardium moves and changes its position and will undergo deformation and change its shape as not all parts move with the same velocity. Newer echocardiography techniques such as tissue Doppler have made it possible to measure deformation, but with some limitations [1]. Speckle tracking echocardiography (STE) is a new technique that applies computer software analysis on images generated by conventional ultrasound techniques. The Doppler ultrasound signal generates artifacts due to random reflections called speckles. These speckles stay stable during the cardiac cycle and can act as natural acoustic markers. Speckle tracking software can define and follow a cluster of speckles from frame to frame to calculate parameters of motion (displacement and velocity) and parameters of deformation (referred to as strain and strain rate) [2]. Strain, expressed as the percent change from its original length, and strain rate, the change of strain per unit time, are measurements of wall shortening normalized for the length of the wall and provide a direct measurement of myocardial shortening. In physiology, preload conditions and contractility determine myocardial fiber shortening; hence, strain does not equate to contractility [3]. However, this novel technology provides a direct measure of wall shortening instead of relying on geometric changes and can simultaneously measure ventricular volumes. The obtained information can add to the complexity of non-invasive measurement of ventricular function. The technique has several advantages over other methods of quantifying ventricular function. STE provides multi-directional global and segmental information. The possibility of segmental analysis with STE with increased sensitivity in detecting abnormal myocardium helped establish STE as diagnostic modality in detecting and quantifying myocardial ischemia and reperfusion viability

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[4]. Other clinical applications in adults include early detection of global ventricular dysfunction in valvular disease, cardiomyopathy and volume overload [5]. As the technique is not based on geometric assumptions, it can be used for functional assessment of congenital heart disease [6]. The angle independency of STE and its relative ease of use has attracted a growing interest in assessing fetal cardiac pathology [7]. A recent review on STE summarizes the available data on accuracy, reliability and normal values of global and regional STE strain measurements in pediatric patients [8]. The authors reported a lack of data in the neonatal age group, possibly due to technical difficulties of a high heart rate and small myocardial area with a reduced number of speckles produced. The aim of this study is to explore the feasibility of 2D speckle tracking echocardiography of the left ventricle in a cohort of stable preterm infants and provide some reference values as prerequisite for evaluating pathology.

2. Methods

2.1. Study population

Preterm infants less than 32 weeks of gestation in our neonatal intensive care who were referred for routine echocardiographic examination for a ductus arteriosus or other hemodynamic or anatomical assessment between June 2012 and March 2013 were retrospectively analyzed for their eligibility for inclusion in this study. Stable preterm infants on no or minimal respiratory support were eligible, defined as continuous positive airway pressure (CPAP) or nasal cannula with less than 30% oxygen. Exclusion criteria were clinical suspicion of an infection within 48 h after data collection, a patent ductus arteriosus with a diameter of more than 1.5 mm, presence of hypotension, using inotropes for any indication or had a significant congenital abnormality with or without congenital heart disease. Approval for this study was obtained from our local ethics committee.

2.2. Echocardiographic image acquisition

Images were obtained with a 12 MHz phased-array transducer using an iE33 echocardiographic scanner (Philips Medical Systems, the Netherlands) by one of 2 operators (KW and AL). Gray scale images were acquired and stored in digital imaging and communications in medicine (DICOM) format at a frame rate of 30 Hz. Images from 4 cardiac cycles triggered by the R wave of the QRS complex were digitally saved.

2.3. Conventional echocardiography parameters

Echocardiographic measurements were obtained in standard precordial positions with focus on the left ventricle and its endocardial borders. Left ventricular ejection fraction (EF) and fractional shortening (FS) were measured (Teichholz) by M-mode echocardiography in the parasternal long-axis position. Cardiac output and input measurements were obtained using the methodology as described by Evans et al., and where flow was calculated using the formula of flow = outflow area × velocity time integral × heart rate / weight and expressed in ml/kg/min. [9,10] The ductus arteriosus was viewed from the high left parasternal view. The minimum diameter of the colour flow jet closest to the entry to the main pulmonary artery was taken as ductal diameter. The foramen ovale was viewed from the subcostal view, and the diameter of the colour flow jet across the septum was measured at the level of the atrial septum [11].

2.4. 2D Strain echocardiographic acquisition and analysis

Offline speckle-tracking analysis was performed using vendor-independent software (Cardiac Performance Analysis, version 1.1; TomTec Imaging Systems, Germany) installed on a windows computer. Apical 4 Chamber (4CH) views and short axis views (SAX) at the level of the papillary muscles were analyzed. After selecting a clip with optimal image quality, we traced the endocardial border as a sequence of points on a single frame, usually starting at end systole, where the trace was placed slightly within the endocardium border. The software would then track the endocardial trace from frame to frame throughout the cardiac cycle. Tracking of the endocardial border was visually inspected and manually adjusted if necessary. Two or 3 adjustments were commonly necessary. No filtering was used.

The software automatically divided the cross-sectional image into six equidistant segments, which were named according to international standards [12]. The left ventricular segments to be analyzed were the apical, mid and basal segments of the septal and the lateral wall of the 4CH view, and in the SAX view the analyzed segments were the anteroseptal, anterior, lateral, posterior, inferior and septal wall segment. The software then rendered segmental curves for velocity, displacement, strain and strain rate (SR). For each parameter, the peak systolic value is reported for each of 6 segments, and as a global average. For 4CH images, the longitudinal (base-to-apex shortening) and radial (inwards thickening) deformation parameters are reported, and for SAX images, the circumferential (radial shortening) and radial (inwards thickening) parameters are reported.

Images were subjectively categorized on the basis of a combination of image quality (clear view of the endocardial border of all 6 segments), tracking performance (visual frame by frame segmental analysis of tracking accuracy) and the quality of strain curves obtained (segmental pattern uniformity and segmental distribution). Previous research indicated that radial parameters are not as reliable in pediatric 2D STE analysis [8], so we used the longitudinal (4CH) or circumferential (SAX) strain curves for quality assessment. For each item, 0 to 2 points (poor, adequate, excellent) could be given based on appearance with a maximum score of 6 overall. Images with a score of 3 or less were not used for analysis. The quality of the radial strain curves were analyzed separately for eligibility of the data obtained. We used the number of segments tracked and the segmental pattern uniformity as key items for radial quality assessment. The complete process of offline analysis could take up to 10 min per scan.

The STE software also provides end systolic volume (ESV) and end diastolic volume (EDV) using Simpson's rule and a calculated ejection fraction.

2.5. Statistical analysis

Global peak systolic strain and SR were blindly measured in 12 selected patients by two investigators (KW and FO) for inter-rater reliability analysis. One investigator (KW) repeated the measurements after 1 week for intra-rater and test–retest reliability. Intra- and inter-rater agreement was calculated using the Bland-Altman approach with calculation of mean bias (average difference between measurements) and the lower and upper limits of agreement. We also determined the coefficient of variation (the standard deviation of the difference of paired samples divided by the average of the paired samples). Test–retest reliability was explored with intraclass correlation.

Segmental differences in strain and SR were explored using a Student's *t*-test. Correlations between parameters of deformation and clinical patient variables, hemodynamic parameters and conventional echocardiography parameters were explored using a scatterplot and Spearman's rank order correlation. For correlations, longitudinal and circumferential strain and SR were transformed into positive values. P values < 0.05 were considered to indicate significance. Statistical analyses were performed using SPSS for Windows version 16.0 (SPSS, Inc., Chicago, IL).

3. Results

During the study period, 121 infants less than 32 weeks gestation were admitted to our unit. Ninety-eight infants were referred for