Maturational Patterns of Systolic Ventricular Deformation Mechanics by Two-Dimensional Speckle-Tracking Echocardiography in Preterm Infants over the First Year of Age

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Background: The aim of this study was to determine the maturational changes in systolic ventricular strain mechanics by two-dimensional speckle-tracking echocardiography in extremely preterm neonates from birth to 1 year of age and discern the impact of common cardiopulmonary abnormalities on the deformation measures.

Methods: In a prospective multicenter study of 239 extremely preterm infants (<29 weeks gestation at birth), left ventricular (LV) global longitudinal strain (GLS) and global longitudinal systolic strain rate (GLSRs), interventricular septal wall (IVS) GLS and GLSRs, right ventricular (RV) free wall longitudinal strain and strain rate, and segmental longitudinal strain in the RV free wall, LV free wall, and IVS were serially measured on days 1, 2, and 5 to 7, at 32 and 36 weeks postmenstrual age, and at 1 year corrected age (CA). Premature infants who developed bronchopulmonary dysplasia or had echocardiographic findings of pulmonary hypertension were analyzed separately.

Results: In uncomplicated preterm infants (n = 103 [48%]), LV GLS and GLSRs remained unchanged from days 5 to 7 to 1 year CA (P = .60 and P = .59). RV free wall longitudinal strain, RV free wall longitudinal strain rate, and IVS GLS and GLSRs significantly increased over the same time period (P < .01 for all measures). A significant base-to-apex (highest to lowest) segmental longitudinal strain gradient (P < .01) was seen in the RV free wall and a reverse apex-to-base gradient (P < .01) in the LV free wall. In infants with bronchopulmonary dysplasia and/or pulmonary hypertension (n = 119 [51%]), RV free wall longitudinal strain and IVS GLS were significantly lower (P < .01), LV GLS and GLSRs were similar (P = .56), and IVS segmental longitudinal strain persisted as an RV-dominant base-to-apex gradient from 32 weeks postmenstrual age to 1 year CA.

Conclusions: This study tracks the maturational patterns of global and regional deformation by two-dimensional speckle-tracking echocardiography in extremely preterm infants from birth to 1 year CA. The maturational patterns are ventricular specific. Bronchopulmonary dysplasia and pulmonary hypertension leave a negative impact on RV and IVS strain, while LV strain remains stable. (J Am Soc Echocardiogr 2017;■:■-■.)

Keywords: Cardiac function, Prematurity, Strain imaging, Echocardiography

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Abbreviations

2D = Two-dimensional

BPD = Bronchopulmonary dysplasia

CA = Corrected age

FWLS = Free wall longitudinal strain

FWLSRs = Free wall longitudinal systolic strain rate

GLS = Global longitudinal strain

GLSRs = Global longitudinal systolic strain rate

hsPDA = Hemodynamically significant patent ductus arteriosus

IVS = Interventricular septal wall

LPA = Left pulmonary artery

LS = Longitudinal strain

LV = Left ventricular

LVFW = Left ventricular free wall

PDA = Patent ductus arteriosus

PH = Pulmonary hypertension

PMA = Postmenstrual age

RV = Right ventricular

RVFW = Right ventricular free wall

RVSP = Right ventricular systolic pressure

SLS = Segmental longitudinal strain

SRs = Systolic strain rate

STE = Speckle-tracking echocardiography

Ventricular performance is an important prognostic determinant of clinical status and long-term outcomes in preterm neonates.[1-3] Ventricular mechanics begin to undergo maturational changes in the early and late postnatal periods that can have a long-term impact on cardiac function beyond the first year of age.[2,3] The exposure of an immature preterm heart to a sustained increase in hemodynamic load of postnatal circulation, at a time in the development when the heart primarily supports a low-resistance circulation, induces myoarchitectural adaptation that may lead to ventricular remodeling.[4,5] The proper evaluation of ventricular function in preterm infants by echocardiography has been limited by the lack of reliable quantitative parameters.[1] Furthermore, there is paucity of longitudinal studies on prematurity-related alterations in the maturation of cardiac function beyond the early neonatal period. The establishment of sensitive indices of cardiac function in birth cohorts affected by prematurity and its common cardiorespiratory complications is a necessary prerequisite for the clinical adoption of a normative references patterns for use in evaluating pathologic changes and progression.

Myocardial strain is a measure of tissue deformation, and strain rate is the rate at which deformation occurs. Longitudinal deformation by two-dimensional (2D) speckle-tracking echocardiography (STE) has been validated as a reproducible measure of ventricular function in premature infants.[6-8] Initial data indicate that measuring deformation values in this population could have clinical implications, as they appear to have superior prognostic value for assessing and potentially predicting major adverse cardiopulmonary events compared with conventional measurements (i.e., shortening and ejection fractions).[9,10] Maturational patterns of 2D STE–derived longitudinal strain (LS) measures during the transitional period through the first month of age have recently been established in preterm infants.[7,8,11-14] However, the evolution of ventricular strain mechanics from birth to 1 year of age for clinical application has not been comprehensively described in a large longitudinal preterm cohort.[13,15] Disturbances in myocardial function may also affect neonatal morbidity and mortality, but there is limited information on how different prematurity associated cardiopulmonary conditions, such as bronchopulmonary dysplasia (BPD), pulmonary hypertension (PH), and a persistent patent ductus arteriosus (PDA), influence the normal changes in longitudinal cardiac function.[16]

Because the right ventricle (RV) and left ventricle (LV) are embryologically and structurally distinct, and their functional roles change in the postnatal period,[17] we hypothesized that (1) prematurity-related maturational changes in RV and LV deformation measures would have uniquely different trajectories, and (2) prematurity-associated cardiopulmonary conditions would influence changes differently in LV and RV mechanics. Accordingly, we aimed to determine the maturational (age- and weight-related) changes in LV, RV, and interventricular septal wall (IVS) strain mechanics by 2D STE in healthy uncomplicated preterm infants not affected by significant cardiopulmonary abnormalities and study the influence of the cardiopulmonary abnormalities on the maturational changes in myocardial deformational indices from birth through 1 year corrected age (CA).

METHODS

Study Population

All data were prospectively obtained as part of an observational research study that included patients who were enrolled between August 2011 and January 2016 at hospitals affiliated with two academic institutions (Washington University School of Medicine, St. Louis Children's Hospital, and the Royal College of Surgeons in Ireland, Rotunda Hospital). Two hundred thirty-nine preterm infants (born at 23-0/7 to 28-6/7 weeks gestation) were recruited at birth and longitudinally followed until 1 year CA. The preterm infants enrolled from the Washington University site were among infants participating in the Prematurity and Respiratory Outcomes Program (ClinicalTrials.gov identifier NCT01435187).[18] Infants with any suspected congenital anomalies of the airways, congenital heart disease (except atrial septal defects), chromosomal anomalies, intrauterine growth restriction, or small for gestational age (birth weight < 10th centile for gestation) were excluded from the healthy uncomplicated cohort arm of the study.

At both centers, reference values and maturational patterns of RV fractional area of change from these cohorts have been recently published, but deformation imaging by 2D STE has not been reported.[19,20] At the Washington University School of Medicine site, a small proportion of the deformation data were previously used to test feasibility and reproducibility.[6,21] At the Royal College of Surgeons in Ireland site, deformation imaging by tissue Doppler has been assessed in the transitional period and up to 36 weeks postmenstrual age (PMA).[11,22] The institutional review board of Washington University and the ethics committee on human research at the Royal College of Surgeons approved the protocol. Written informed consent was obtained from the parents or guardians of all participants.

Inclusion Criteria in Uncomplicated Cohort

Only infants with "cardiorespiratory healthiness" were classified as healthy uncomplicated infants in this study.[19,23] In the early neonatal period, a large proportion of premature infants present with acute respiratory failure and often require some sort of respiratory support up to 36 weeks PMA, making it difficult to determine a true definition of "respiratory healthiness."[19,23] Respiratory disease syndrome and the need for invasive and noninvasive ventilation are