Early Human Development 89 (2013) 687–692

Contents lists available at SciVerse ScienceDirect

Early Human Development

journal homepage: www.elsevier.com/locate/earlhumdev

Serial change in myocardial tissue Doppler imaging from fetus to neonate

Satoru Iwashima [a,*], Katuyuki Sekii [a], Takamichi Ishikawa [a], Hiroaki Itou [b]

[a] Department of Pediatrics, Hamamatsu University School of Medicine, Hamamatsu, Japan
[b] Department of Obstetrics and Gynecology, Hamamatsu University School of Medicine, Japan

ARTICLE INFO

Article history:
Received 16 October 2012
Received in revised form 23 April 2013
Accepted 30 April 2013

Keywords:
Fetal echocardiography
Tissue Doppler imaging
Fetal circulation
Cardiac performance

ABSTRACT

Background: Our goal was to evaluate the serial change in myocardial performance from fetus to neonate using tissue Doppler imaging (TDI).

Method and results: There were 37 term infants in the present study. The TDI sensor was placed at the level of the lateral mitral annulus (M-TDI), inter-ventricular septum (IVS-TDI) and the lateral tricuspid annulus (T-TDI). We measured TDI parameters from fetus to neonate. On univariate analysis, E′ (cm/s), A′ (cm/s), and S′ (cm/s) of three ventricular walls of TDI parameters excluding E′ IVS-TDI significantly decreased during the transition from fetal to neonatal circulation. E′/A′ ratio, E/E′ ratio and myocardial performance index (MPI) of three ventricular walls of TDI parameters excluding T-TDI MPI significantly increased during the transition from fetal to neonatal circulation. When multiple linear regression analysis with a step-wise procedure during the transition from fetus to neonate for TDI parameters was applied to variables, significant differences were noted for predicting decreases in M-TDI S′ (6.55 to 3.97, $p < 0.001$) and IVS-TDI A′, (6.69 to 4.69, $p < 0.001$), and increases in IVS-TDI E′/A′ ratio (0.77 to 1.02, $p < 0.001$) and IVS-TDI E/E′ ratio (8.25 to 13.65, $p < 0.001$).

Conclusion: In conclusion, we found that the myocardial performances of both ventricles decreased during the transition from fetus to neonate using TDI parameters. In particular, left ventricular systolic performance was affected more than when fetal circulation changed to neonate circulation. Our findings suggest that serial change in TDI can give new information to estimate myocardial performance of the neonate.

1. Introduction

Prior to delivery, the fetus depends on the placenta for gas and nutrient exchange with the maternal circulation. In the fetus, low vascular resistance of the placenta and high vascular resistance of the fetal lungs are present. There are two right-to-left shunts, the foramen ovale and ductus arteriosus that occur in the fetus. To successfully make the transition from intrauterine to extra-uterine life when the umbilical cord is clamped at birth, the neonate must rapidly make physiologic changes in cardiopulmonary function. Although most neonates successfully transition between intra-uterine and extra-uterine life, about 10% will have some difficulty and require resuscitative efforts at birth [1]. Many sick neonates experience cardiovascular dysfunction. Blood pressure monitoring and noninvasive evaluation of myocardial performance are currently used to assess cardiovascular function, but have limitations in quantifying function in preterm neonates [2,3]. Clinical assessment and management of neonates with birth asphyxia, hypotensive shock, or persistent pulmonary hypertension are important. The clinical application of echocardiography for prenatal imaging has the major advantages that it is non-invasive, is easily accessible, and can be used in pregnancy to study the fetus in a truly physiological state.

Tissue Doppler imaging (TDI) represents a new development of the Doppler technique, allowing direct measurement of regional myocardial velocities [4,5]. TDI can be used to measure long-axis functions, which seem to be both more sensitive to minor disturbances in myocardial function and relatively preload-independent [6,7]. Due to the higher sensitivity of this technique, TDI can be useful to detect cardiac dysfunction either alone or in combination with conventional Doppler waveform. Recently, several studies reported the feasibility of TDI for assessing fetal cardiac function, demonstrating myocardial velocity changes in relation to advancing gestational age [8,9]. TDI is a sensitive and promising method of evaluating fetal and neonatal cardiac function [10–12].

The goal of the present study was to evaluate the serial change in myocardial performance during the transition from fetus to neonate using TDI.

* Corresponding author at: Department of Pediatrics, Hamamatsu University School of Medicine, Handayama 1-20-1, Hamamatsu City, 431-3192 Japan. Tel.: +81 53 435 2312; fax: +81 53 435 2311.
E-mail address: iwashima@hama-med.ac.jp (S. Iwashima).

0378-3782/$ – see front matter © 2013 Elsevier Ireland Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.earlhumdev.2013.04.017

2. Methods

2.1. Study population

The subjects were patients admitted to the Maternal–Fetal and Neonatal Care Center of Hamamatsu University School of Medicine between July 2010 and June 2011. Excluded were preterm infants with a gestational age less than 37 weeks, twins, infants with congenital disease, and infants with chromosomal abnormalities. There were a total of 37 infants in the present study. Our cases included 30 normal infants, 6 with a birth weight of less than 2300 g, and 1 with congenital cytomegalovirus infection. No patient was treated with inotropic drugs.

Informed consent was obtained from the parents or legal guardians of the fetuses before examination. The study protocol was approved by the Ethics Committee of Hamamatsu School of Medicine. The study was conducted according to the principles of the Declaration of Helsinki.

2.2. Echocardiographic evaluation

For data acquisition, a Philips HD11 equipped (Philips Medizin Systeme GmbH, Tokyo, Japan) with a S8-3 sector array transducer (3.0–8.0 MHz) or Vivid-I (GE Healthcare Japan, Tokyo, Japan) with S-7 sector array transducer was used. In fetal echocardiography, measurements were performed with the mother in the supine or lateral decubitus position, and in neonatal echocardiography, measurements were performed in the resting state and the spontaneous closure of the patent arterial duct was confirmed by color Doppler echocardiography before the examination in all neonates. The maximum duration of the ultrasound was limited to 15 min in each case. The TDI program was set to pulsed-wave Doppler mode. The ultrasound beam was focused as parallel to the longitudinal myocardial wall motion as possible, and kept at an angle of less than 30°. No angle correction was used. Ventricular myocardial velocities were measured from the basal or apical four-chamber view. The monitor sweep speed was set at 100 mm/s and the wall filter was set at the lowest selection. A 2.5–2.9 mm Doppler sample volume was placed at the level of the lateral mitral annulus (M-TDI), at the level of the inter-ventricular septum (IVS-TDI), and then at the level of the lateral tricuspid annulus (T-TDI). All recordings in fetuses were obtained in the absence of fetal movements and breathing movements, when the fetal heart rate was between 120 and 160 beats per minute. Fetal heart rate was calculated from the time interval between the onsets of the myocardial shortening velocity waveform during ventricular systole in three consecutive cardiac cycles measured by TDI. We measured the peak E wave, peak A wave from transmitral and transtricuspid Doppler imaging, the myocardial peak velocities during early diastole (E′), late diastole with atrial contraction (A′), and systole in the ejection phase (S′) by tissue Doppler imaging, the myocardial performance index (MPI), and heart rate. The E′/A′ ratio was calculated as E′ divided by A′. The E/E′ ratio was calculated as E divided by E′. The Doppler-derived MPI, which is also known as the Tei index, is a measure of the combined systolic and diastolic function of the ventricles [13]. The MPI is defined as (a–b)/b, where ‘a’ is the interval between the end and the onset of systemic ventricular inflow, and ‘b’ is the ejection time of the systemic outflow by pulsed Doppler determination. Three or 4 images of the best quality were chosen for each study subject. The stored digital scans were analyzed by a reader blinded to the subjects' details (K.S. and S.I.).

2.3. Data analysis

Results were expressed as mean, median and range. Regarding the serial change in TDI parameters during the transition from fetus to neonate, analysis was performed using the Wilcoxon's rank sum test. Factors found to be significant on univariate analysis were subjected to multivariate analysis using stepwise logistic regression. In all statistical analyses, $p < 0.05$ was considered significant. The PASW Statistics 18 software (SPSS Inc., Chicago, IL, USA) was used for statistical analyses.

Table 1
Characteristics of neonates and their mothers (n = 37).

			Mean	(Median)	Range
CS delivery			19/37		
Sex	(Male/female)		17/20		
Maternal age		(Years)	33.9	(34.5)	21.8–40.8
Gestational age		(Weeks)	38.0	(38.0)	37.0–40.6
Apgar scores		(5 min)	9.1	(9)	7–10
Neonate height		(cm)	49.2	(49.5)	42.5–54.0
Neonate weight		(g)	2852	(2920)	1830–4152
Fetal echo exam.		(Hours)	37	(27)	7–78
Neonate echo exam.		(Hours)	38	(48)	24–120
pH		(n = 46)	7.285	(7.288)	7.129–7.423
PCO2	(mm Hg)	(n = 43)	49.6	(50.7)	32.7–63.5
PO2	(mm Hg)	(n = 43)	18.7	(16.7)	6.0–57.0
Hb	(g/dL)	(n = 43)	15.7	(15.8)	13.7–20.9
Ht	(%)	(n = 43)	48.0	(48.2)	42.0–64.0
BE	(mmol/L)	(n = 43)	−4.3	(−3.7)	−12.0–0.0
Na	(mEq/L)	(n = 43)	133.3	(133.0)	127.0–138.0
K	(mEq/L)	(n = 43)	4.2	(4.1)	3.7–5.5
i-Ca^{2+}	(mmol/L)	(n = 43)	1.40	(1.40)	1.02–1.51
BS	(mg/dL)	(n = 43)	70.1	(74.0)	34–111

Abbreviations: CS, Cesarean section; fetal echo exam, fetal echocardiography exam before delivery; neonate echo exam, neonate echocardiography exam after birth; Hb, hemoglobin; Ht, hematocrit; BE, base excess; and BS, blood sugar.

Table 2
Characteristics of cardiac parameters from fetus to neonate (n = 37).

		Fetal period		Neonate period	
		Mean (median)	Range	Mean (median)	Range
HR		140 (140)	(120–165)	121 (124)	(106–136)
Doppler parameters					
Mitral A wave		51.6 (51.8)	(34.2–69.7)	52.6 (52.0)	(33.4–73.9)
Mitral E wave		39.6 (38.7)	(24.2–56.9)	60.2 (58.9)	(45.0–79.7)
Mitral E/A ratio		0.78 (0.76)	(0.55–1.03)	1.18 (1.22)	(0.73–1.86)
Tricuspid A wave		61.2 (64.0)	(35.8–81.8)	58.0 (59.0)	(10.0–94.9)
Tricuspid E wave		45.7 (46.7)	(28.4–68.2)	47.7 (46.2)	(29.1–73.3)
Tricuspid E/A ratio		0.76 (0.76)	(0.54–1.06)	0.93 (0.79)	(0.56–5.47)
TDI parameters					
M-TDI	E′	6.71 (6.69)	(4.06–9.68)	6.23 (5.90)	(3.70–13.00)
M-TDI	A′	7.98 (7.78)	(5.10–13.70)	6.08 (6.20)	(2.70–9.00)
M-TDI	S′	6.55 (6.47)	(5.40–8.36)	3.97 (4.00)	(2.40–6.10)
M-TDI	E′/A′	0.86 (0.89)	(0.48–1.27)	1.03 (0.96)	(0.68–1.67)
M-TDI	E/E′	6.07 (5.70)	(2.85–10.47)	10.21 (9.95)	(3.46–16.71)
M-TDI	MPI	0.52 (0.52)	(0.39–0.71)	0.61 (0.65)	(0.21–1.21)
IVS-TDI	E′	4.97 (4.99)	(2.73–13.00)	4.69 (4.85)	(3.00–6.80)
IVS-TDI	A′	6.69 (6.54)	(3.97–10.90)	4.69 (4.33)	(3.00–7.40)
IVS-TDI	S′	4.91 (4.90)	(3.72–6.50)	3.12 (3.10)	(1.80–4.44)
IVS-TDI	E′/A′	0.77 (0.69)	(0.45–1.32)	1.02 (1.00)	(0.56–1.67)
IVS-TDI	E/E′	8.25 (7.32)	(5.20–16.41)	13.65 (12.76)	(7.69–23.65)
IVS-TDI	MPI	0.50 (0.50)	(0.34–0.68)	0.63 (0.65)	(0.24–1.21)
T-TDI	E′	8.06 (7.71)	(5.06–13.00)	7.00 (6.90)	(3.90–15.20)
T-TDI	A′	10.23 (9.89)	(5.70–16.00)	7.85 (7.80)	(4.00–12.10)
T-TDI	S′	6.93 (6.91)	(5.18–8.75)	5.38 (5.30)	(3.60–9.00)
T-TDI	E′/A′	0.80 (0.79)	(0.57–1.28)	0.92 (0.86)	(0.58–1.69)
T-TDI	E/E′	5.85 (5.98)	(3.73–9.06)	7.12 (6.91)	(3.10–11.51)
T-TDI	MPI	0.52 (0.52)	(0.41–0.68)	0.54 (0.54)	(0.24–0.91)

Abbreviations: HR, heart rate; TDI, tissue Doppler imaging; M-TDI, TDI of lateral mitral annulus; IVS-TDI, TDI of inter-ventricular septum; T-TDI, TDI of the lateral tricuspid annulus; E′, E′ wave; A′, A′ wave; S′, S′ wave; E′/A′, E′/A′ ratio; E/E′, Doppler E wave/E′ ratio; and MPI, myocardial performance index.