



## Improving the diagnosis of diastolic dysfunction of heart ventricles in newborns by tissue Doppler imaging

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**Abstract. Background.** Tissue Doppler imaging allows improving diagnostic capabilities of ultrasound examination of the heart. In order to improve the diagnosis of myocardial dysfunction of heart ventricles in newborns in the neonatal period, we have performed pulsed-wave tissue Doppler imaging with determination of diastolic dysfunction types. **Materials and methods.** The study involved 108 healthy infants in the early neonatal period, in whom the diastolic ventricular function markers were determined by tissue Doppler imaging. **Results.** The study determined the types of diastolic dysfunction. Types of diastolic dysfunction (delayed relaxation, pseudo-normalization, restrictive and undetermined ones) require comparison with the symptoms of cardiovascular dysfunction, taking into account the child's days of life and the functioning of the open arterial duct, its hemodynamic significance, and also the open foramen ovale with the subsequent decision on patient's management. **Conclusions.** It is advisable to use all echocardiographic modes (double Doppler method) with a traditional assessment of diastolic profile of transmitral/transcuspids flow and the movement of fibrous rings according to tissue Doppler imaging findings, which in their entirety will help to assess the degree of myocardial dysfunction.

**Keywords:** newborns; tissue Doppler imaging; diastolic dysfunction

### Introduction

Administration of echocardiography to assess the state of cardiovascular system in full-term and pre-term infants is undergoing significant progress. As is known, the aim of echocardiography is to provide deployed hemodynamic information in real time in order to help make a clinical decision, as well as to provide a better understanding of active physiological processes and monitoring the response to treatment [1–3]. The combination of clinical examination and echocardiography findings has been shown to facilitate the adoption of a therapeutic solution [4]. Routine use of echocardiography in the neonatal unit can lead to early detection of cardiovascular abnormalities, which facilitates treatment, potentially improving short-term results [5]. Currently there is even a concept of “bedside” echocardiography,

the use of which is able to improve the quality of diagnosis of cardiovascular disorders in newborns, according to leading specialists. Based on the recommendations for neonatologist performed echocardiography in Europe: Consensus Statement endorsed by European Society for Paediatric Research (ESPR) and European Society for Neonatology (ESN) (2016), neonatologists and pediatric cardiologists should master modern advanced functional methods of cardiac examination, including tissue Doppler imaging (TDI), which proved to be a valuable diagnostic tool in diagnosis of myocardial abnormalities in adults [6]. TDI in newborns demonstrates its usefulness in clinical conditions, but there is lack of such studies [1, 7, 8, 10, 16, 17].

Tissue Doppler imaging helps to evaluate ventricular mechanics by providing information on the

movement of myocardium and fibrous rings, with the assessment of time and velocity indices [9]. Moreover, spectral tissue Doppler imaging provides a more accurate assessment of diastolic function of heart ventricles [10].

In everyday clinical practice, modern diagnosis and timely adequate correction of myocardial dysfunction with the use of instrumental research methods is a key to preventing the development of cardiovascular events in future, starting from the first days of life.

**The purpose of the study:** in order to improve diagnosis of myocardial dysfunction of heart ventricles in newborns in the neonatal period the study implied administration of pulsed-wave tissue Doppler imaging with determination of diastolic dysfunction types.

### Materials and methods

The study involved 108 “conditionally” healthy newborns (55.6 % — boys, 44.4 % — girls), gestation period —  $39.1 \pm 0.8$  weeks, body weight at birth —  $3334.4 \pm 405.2$  g, height —  $50.3 \pm 1.6$  cm, body surface area —  $0.21 \pm 0.2$  m<sup>2</sup>. Apgar score on the first and fifth minutes was 8–9 points. Clinical examination showed satisfactory condition of the newborns; they were first breastfed in the delivery room. Intrauterine development and early neonatal period in the examined patients was without somatic and neurological complications. All the newborns were discharged on 3<sup>rd</sup>–5<sup>th</sup> days of life.

According to modern requirements, the first echocardiogram should be comprehensive in order to reliably confirm the normal structural anatomy [6] with the evaluation of systolic and diastolic functions of the myocardium. The pulsed-wave spectral mode of TDI allows to record the maximum movement rate of separate portions of the myocardium that fall into the control volume throughout the entire cardiac cycle, as well as to determine the acceleration and deceleration of the motion of the structure under investigation. The main disadvantage of TDI is that only one part of the myocardium can be visualized at the same time [11]. In neonatal practice, in our opinion, it is important to investigate the motion of fibrous rings, which is informative for diagnosis of diastolic dysfunction.

The area of our research involved the study of the movement of fibrous rings of mitral and tricuspid valves. To evaluate diastolic function of heart ventricles according to findings of pulsed-wave TDI we studied the motion of atrioventricular rings, lateral ventricles and interventricular septum (left and right ventricles). We analyzed such indices as: S — peak systolic velocity, cm/sec; E — maximum rate of early transmitral/trans-tricuspid blood flow, cm/sec; E' — rate of early diastolic relaxation, cm/sec; A' — peak rate in atrial systole phase, cm/sec; IVRT — isovolumic relaxation time, ms and IVST — isovolumic contraction time for this portion of myocardium, ms. We also calculated the ratio of diastolic “peaks” of the motion of atrioventricular rings (E'/A') and the ratio of E/E' to maximum rate of early transmitral or transcuspid blood flow to the rate of early diastolic relaxation.

In order to record the most reliable velocity and time rates of fibrous rings motion, the study was conducted in a state of rest with registration of the true heart rate, that is, during physiological sleep of the children.

Statistical processing of the data was carried out using software Microsoft Excel 2010 for Windows. The difference in rates was considered to be significant at  $p < 0.05$ .

### Results and discussion

Table 1 presents the results of longitudinal diastolic function assessment of the left and right ventricles (LV and RV, respectively) using pulsed-wave tissue Doppler mapping in healthy patients during the first days of life, which subsequently became reference indices and helped to determine the types of diastolic dysfunction.

Thus, in early neonatal period pulsed-wave TDI showed lower velocity of early diastolic relaxation (E') than peak velocity in the atrium systole (A'), which led to  $E'/A' < 1$  ( $p \leq 0.05$ ), which was probably less than E / A ratio in the study of transmitral flow according to traditional detection in pulsed-wave mode (E/A LV =  $1.2 \pm 0.2$ ). E'/A' ratio in lateral RV portion and E/A of transcuspid flow (RV =  $0.8 \pm 0.1$ ,  $p \geq 0.05$ ) did not differ significantly during early neonatal period. These data indicate the difference in adaptation of heart ventricles to postnatal life of newborns. With

**Table 1. Normal velocity and time rates of fibrous rings motion of mitral and tricuspid valves according to tissue Doppler mapping in healthy newborns during early neonatal period (M ± m), n = 108**

LV	Septum portion						
	S, cm/sec	E', cm/sec	A', cm/sec	E'/A', unit	IVRT, ms	IVCT, ms	E/E', unit
	$5.90 \pm 0.95$	$6.5 \pm 1.1$	$8.2 \pm 1.4$	$0.8 \pm 0.2$	$54.7 \pm 7.6$	$34.8 \pm 4.6$	$8.1 \pm 1.1$
RV	Side (lateral) portion						
	$6.1 \pm 0.8$	$7.1 \pm 1.2$	$8.2 \pm 1.6$	$0.9 \pm 0.2$	$56.5 \pm 7.0$	$37.6 \pm 4.2$	$7.5 \pm 1.1$
RV	Septum portion						
	$5.90 \pm 0.95$	$6.1 \pm 1.0$	$9.0 \pm 1.8$	$0.7 \pm 0.2$	$57.5 \pm 6.9$	$35.6 \pm 4.5$	$7.1 \pm 1.2$
RV	Side (lateral) portion						
	$7.2 \pm 1.1$	$7.5 \pm 1.2$	$10.1 \pm 1.7$	$0.8 \pm 0.1$	$55.1 \pm 6.0$	$35.7 \pm 4.8$	$6.5 \pm 1.2$

this end in view, we additionally determined time and velocity parameters of the motion of fibrous ring of the septum portion, both from the mitral and tricuspid valves, in order to compare the indices that indirectly make it possible to estimate the contribution of the altered hemodynamic load on heart ventricles. The tendency to an increase in E/E' in the mitral valve is especially noteworthy as a criterion indicating the likelihood of developing left ventricular diastolic dysfunction. E'/A' ratio ( $p \leq 0.05$ ) in newborns is significantly less than in adults, which indicates a lower rate of myocardial relaxation and elastic properties of myocardium in neonates.

The assessment of time and velocity indices of the motion of fibrous rings of the mitral and tricuspid valve did not show any significant differences. At the same time, analysis showed an increase in velocity rate characteristics of the lateral portion of the right ventricle as compared to the left, which suggested certain differences in the development of diastolic function of the ventricles. As early as from the second week of life at the end of hemodynamic adaptation stage, DTI findings showed that the ratio E'/A'LV was  $1.21 \pm 0.30$ , and E'/A' RV =  $0.9 \pm 0.3$ , which corresponded to normal indices in older children. E/E' ratio in lateral portion of the mitral valve in newborns in the early neonatal period tended to increase as compared to the data obtained in the adult population (norm  $\leq 8.0$ ) [12, 13]. This fact can be explained by an increase in the average pressure in the trunk of the pulmonary artery (pulmonary circulation) in newborns at the stage of hemodynamic formation.

In literature, there are reports on the use of TDI in neonatal practice in order to obtain additional information on myocardium functioning in newborns. Thus, the first article on the study of the function of the right and left ventricles in newborns using TDI, belongs to K. Mori, R. Nakagawa et al. (2004) who found differences in normal echocardiographic values of the both ventricles, which may reflect the differences in ventricular adaptation after birth [14]. F. Ekici, S. Atalay et al. (2007) investigated the velocity indices E' and A' [15]. R.J. Negrine et al. (2012) examined 43 newborns of all gestation ages and recommended TDI along with standard echocardiography [16].

According to V.M. Dudnik, V.P. Popov et al. (2014) diastolic dysfunction in newborns during neonatal period is characterized by disruption of relaxation [17]. The issue of norm and pathology at the stage of hemodynamic formation in postnatal life is disputable. In our view, such a hemodynamic condition can be considered as a variant of norm at this stage of adaptation, taking into account the features of the structure of myocardium in newborns.

Thus, to date, there is no universal method for diagnosis of diastolic dysfunction of the ventricles in newborns, so interpretation of findings should be based on the child's age and functioning of the open arterial duct, its hemodynamic significance, as well as the open oval window. It is advisable to use all echocardiographic modes (double Doppler method) with a traditional assessment of diastolic profile of transmitral/transcuspoid flow and the movement of fibrous rings according to TDI findings, which in their entirety will help to assess the degree of myocardial dysfunction. In practice, the diagnostic value, in our opinion, has the following indices: E' is the speed of early diastolic relaxation, cm/sec, the ratio of diastolic "peaks" of the motion of atrioventricular rings (E'/A') and E/E' is the ratio of maximum velocity of early transmitral/transcuspoid flow to early diastolic relaxation rate as a factor that correlates with median pressure in the left atrium. Taking into account the obtained data, pulsed-wave TDI helped to distinguish the following gradations of diastolic dysfunction (table 2).

The types of diastolic dysfunction were determined by empirical and practical methods, taking into account clinical status, age, features of postpartum hemodynamic adaptation, presence of fetal communications with their hemodynamic significance and morphofunctional state of the myocardium with features of the pattern of diastolic function complexes using double Doppler method. The distribution of types of diastolic dysfunction, on the one hand, can be considered as "conditional" and disputable, due to the lack of clear gradations in pediatric population, and on the other hand, there are informative findings indicating a disruption of relaxation processes and requiring pathogenic correction or metabolic support.

**Table 2. Types of diastolic dysfunctions in newborns according to pulsed-waved tissue Doppler imaging**

Diastolic dysfunction type	Delayed relaxation		Pseudonormalization		Restrictive		Undetermined	
	LV	RV	LV	RV	LV	RV	LV	RV
<b>Indices</b>								
E' max, cm/sec (lateral portion)	$\geq 6.0$	$\geq 7.0$	$< 6.0$	$< 7.0$	$< 4.0$	$< 4.0$	$\geq 6.0$	$\geq 7.0$
E'/A'	$< 1.0$	$< 1.0$	$< 1.0$	$< 1.0$	$< 1.0$	$< 1.0$	Different pattern of complexes in different heart cycles	
E/E'	$\leq 7.0$	$\leq 8.0$	7.0–10.0	8.0–10.0	$\geq 10.0$	$\geq 10.0$		
IVRT	$> 62.3$	$> 61.1$	$> 62.3$	$> 61.1$	$< 47.0$	$< 49.0$		

Thus, TDI employment can move to a qualitatively new level of diagnostic capabilities of ultrasound examination of the heart.

## Conclusions

1) Tissue Doppler imaging expands capabilities in diagnosis of diastolic dysfunction of heart ventricles at preclinical stage; 2) employment of double Doppler method provides additional information on myocardial relaxation; 3) such types of diastolic dysfunction as delayed relaxation, pseudonormalization, restrictive and undetermined type, require a comparison with presentation and decision on further patient management.

## Research perspectives

Diagnosis of myocardial dysfunction and determination of diastolic dysfunction types in newborns with delayed fetal development and after asphyxia in neonatal period in order to prevent the development of cardiovascular events.

**Conflicts of interests.** Authors declare the absence of any conflicts of interests that might be construed to influence the results or interpretation of their manuscript.

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## Удосконалення діагностики діастолічної дисфункції шлуночків серця в новонароджених за даними тканинної доплерометрії

**Резюме. Актуальність.** Використання технології тканинної доплерометрії дозволяє перейти на якісно новий рівень діагностичних можливостей ультразвукового дослідження серця. З метою вдосконалення діагностики міокардіальної дисфункції шлуночків серця в новона-

роджених у неонатальний період проведена тканинна доплерографія в імпульсно-хвильовому режимі з визначенням типів діастолічної дисфункції. **Матеріали та методи.** Обстежено 108 здорових новонароджених у ранній неонатальний період із визначенням показників діа-

столічної функції шлуночків серця за даними тканинної доплерометрії, що стали опорними та дозволили визначити типи діастолічної дисфункції. **Результати.** Типи діастолічної дисфункції (уповільнена релаксація, псевдонормалізація, рестриктивний та невизначений) потребують зіставлення з клінікою з урахуванням доби життя дитини та функціонування відкритої артеріальної протоки, її гемодинамічної значущості, а також відкритого овального вікна з прийняттям рішення про подальше ве-

дення пацієнта. **Висновки.** Бажано використовувати всі ехокардіографічні режими (метод подвійного доплера) із традиційною оцінкою діастолічного профілю трансмітрального/транстрикуспідального потоків та руху фіброзних кілець за даними тканинної доплерометрії, що в сукупності допоможе оцінити ступінь міокардіальної дисфункції.

**Ключові слова:** новонароджені; тканинна доплерометрія; діастолічна дисфункція

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### Совершенствование диагностики диастолической дисфункции желудочков сердца у новорожденных по данным тканевой доплерометрии

**Резюме. Актуальность.** Использование тканевой доплерометрии позволяет перейти на качественно новый уровень диагностических возможностей ультразвукового исследования сердца. С целью совершенствования диагностики миокардиальной дисфункции желудочков сердца у новорожденных в неонатальный период проведена тканевая доплерография в импульсно-волновом режиме с определением типов диастолической дисфункции. **Материалы и методы.** Обследовано 108 здоровых новорожденных в ранний неонатальный период с определением показателей диастолической функции желудочков сердца по данным тканевой доплерометрии, которые стали опорными и позволили определить типы диастолической дисфункции. **Результаты.** Типы диастолической дисфункции (замед-

ленная релаксация, псевдонормализация, рестриктивный и неопределенный) требуют сопоставления с клиникой с учетом суток жизни ребенка и функционирования открытого артериального протока, его гемодинамической значимости, а также открытого овального окна с последующим принятием решения о дальнейшем ведении пациента. **Выводы.** Желательно использовать все эхокардиографические режимы (метод двойного доплера) с традиционной оценкой диастолического профиля трансмитрального/транстрикуспидального потоков и движения фиброзных колец по данным тканевой доплерометрии, что в совокупности поможет оценить степень миокардиальной дисфункции.

**Ключевые слова:** новорожденные; тканевая доплерометрия; диастолическая дисфункция

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