

Right ventricular systolic longitudinal function in infants: correlation of TAPSE with gestational age and body weight

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Abstract

Introduction: A tricuspid annular plane systolic excursion (TAPSE) reflects longitudinal myocardial shortening and represents an echocardiographic parameter to assess right ventricular systolic function.

Aim: To determine relationship between TAPSE and gestational age and body weight in neonates, establishing method for prediction the normal TAPSE values in neonates based on gestational age and body weight.

Patients and methods: The prospective study group consisted of 97 neonates from 24 to 40 weeks of gestation, with a weight of 625-4,340 g and normal echocardiographic results with determination of TAPSE based on gestational age and body weight.

Results: The TAPSE range was 6.45-9.80 mm (with average value 8.07 ± 1.89 mm) in male and 6.95-8.50 mm (with average value 7.9 ± 1.86 mm) in female babies, depending on gestational age. There was no statistically significant difference of normal TAPSE values between female and male patients ($p = 0.586$). TAPSE is affected by increasing birth weight and increasing gestational age. The TAPSE values have had strong and positive correlation with gestational age ($p = 0.0001$, $\rho = 0.692$) as well with body weight ($p = 0.0001$, $\rho = 0.786$). Regression equation relating body weight and TAPSE is: $\text{TAPSE predicted} = 4.738 + (\text{body weight} * 0.002)$; equation relating gestational age and TAPSE is: $\text{TAPSE predicted} = -4.163 + (\text{gestational weeks} * 0.385)$.

Conclusions: It is possible to adequately predict TAPSE based on gestational age. As TAPSE is easy to measure and highly reproducible, we consider it a useful quantitative parameter to assess right ventricular longitudinal function in premature baby.

Keywords

Tricuspid annular plane systolic excursion, infants, right ventricular systolic function, gestational age, body weight.

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Introduction

Echocardiographic assessment of right ventricle (RV) function is known to be difficult, because of its complex shape, contraction pattern and response to overload, in both children and adults [1].

Although the fetus has a higher indexed myocardial mass, the fetal myocardium is less organized at the cellular level, with fewer sarcomeres per unit mass, different isoforms of contractile proteins, a developing sarcoplasmic reticulum, an overall higher water content and a decreased number of mitochondria. In addition, the heart is enclosed within a poorly compliant thorax. As a result of these factors, the fetal heart is less compliant and less contractile than a term newborn or adult heart [2]. The fetal right and left ventricles also differ in myofiber architecture throughout gestation, with the RV less tolerant to increases in afterload, despite the fact that it contributes slightly more to the combined ventricular output than the left ventricle during fetal life [3]. During normal gestation, a large increase in fetal cardiac output is facilitated and a gradual increase in cardiac contractility, sympathetic innervation, growth of cardiac chambers, growth of the lungs and the pulmonary vasculature, and redistribution of flow to the various fetal organs take place. If this process is interrupted, as in the case of premature birth, further development occurs under very different and often adverse circumstance [3].

During the postnatal period, the RV switches from being a thick-walled chamber that provides 66% of cardiac output into the systemic circulation through the ductus arteriosus to being the thin-walled, crescent-shaped chamber that supplies the lower pressure pulmonary circulation [4]. After birth, the left ventricle enlarges and left

ventricular output exceeds RV output until closure of the ductus arteriosus. In the first two days of life the RV volume decreases in healthy neonates [5]. In ventilated neonates it has been shown that RV volumes decrease, while RV ejection fraction (RVEF) increases in the first days of life [6] and in hypotensive preterm neonates the RV performance changes when neonates are treated with inotropes [7]. RV performance is an important prognostic determinant of clinical status and long term outcome in preterm infants with cardiopulmonary pathology [8]. Presently, there is no echocardiographic “gold standard” of RV functional assessment. Recent pediatric and neonatal echocardiographic guidelines recommend performing quantitative measurements of RV systolic function using at least one of the following echocardiographic measures: RV fractional area of change (FAC), tricuspid annular plane systolic excursion (TAPSE), RV myocardial performance index (MPI), RV systolic tissue Doppler velocity (RV s0), tissue Doppler-derived basal longitudinal strain (RV BLS) [2, 9-11]. TAPSE reflects longitudinal myocardial shortening, the main component of RV contraction in normal hearts. Measurement of TAPSE has provided an opportunity to assess RV function in a simple, repeatable, and highly reproducible way [12]. American and European guidelines for chamber quantification recommend that assessment of RV systolic function should be part of the echo examination [7, 12]. Adult reference values of TAPSE measurements are available in the literature, with recently published reference intervals of TAPSE values in the pediatric age group [12, 13]. However, TAPSE is a regional parameter that can only be used to measure longitudinal shortening in the lateral free wall of the RV [14].

The effects of gestational age and birth weight on normal TAPSE values have been analyzed in neonates during a prospective study in 2009 and 2010 in a cohort of preterm and term neonates [13, 15].

The aim of this study was to determine relationship between TAPSE and gestational age and body weight in neonates, for predicting the normal TAPSE values in neonates.

Methods

The prospective study group consisted of 97 neonates (53 male, 44 female) from 24 to 40 weeks of gestation, with a birth weight of 625-4,340 g and normal echocardiographic results (except for patent

foramen ovale or nonsignificant patent arterial duct). All patients with birth asphyxia, suspected intrauterine infection, sepsis or septic shock, congenital heart disease, chromosomal syndromes, bronchopulmonary dysplasia, pulmonary hypertension or with need for inotropic support as well as for blood transfusion were excluded from analysis. Patients were examined in a resting state without prior sedation. All premature babies needing intubation and mechanical ventilation were excluded, except those below 28 weeks of gestation with nasal continuous positive airway pressure (NCPAP) therapy and need of additional inspired oxygen up to 30%.

Echocardiographic techniques

Echocardiographic examination was performed within 72 h after birth. Echocardiograms were performed using echocardiographic systems (Viid I, GE, USA) using transducers of 5-10 MHz depending on patient weight. TAPSE was measured by two-dimensional echocardiograph-guided M-mode recordings from the apical four-chamber view with the cursor placed at the free wall of the tricuspid annulus as previously recommended. Care was taken to align the sample volume as vertical as possible with respect to the cardiac apex. Angle correction and respiratory gating were not used. Maximal TAPSE was determined by the total excursion of the tricuspid annulus from its highest position after atrial ascent to the lowest point of descent during ventricular systole.

Statistical analysis

SPSS® 17.0.3 (SPSS Inc., Chicago, Ill., USA, 2009) was used for data analysis. Data are presented

as mean \pm 2 standard deviations (SD). In a first step the correlation structure between gestational age, TAPSE and birth weight was analyzed with Pearson's correlation coefficient. A stepwise linear multiple regression was used to estimate TAPSE from gestational age and body weight.

Results

The study included 97 patients of both sexes in a steady relationship ($\chi^2 = 0.385$, $p = 0.361$).

There was no statistically significant difference of normal TAPSE values between female and male patients ($p = 0.586$). The TAPSE range was 6.45-9.80 mm (with average value 8.07 ± 1.89 mm) in male and 6.95-8.50 mm (with average value 7.9 ± 1.86 mm) in female patients, depending on gestational age.

TAPSE is affected by increasing birth weight and increasing gestational age. TAPSE, gestational age and birth weight are strongly correlated: Pearson's correlation coefficient was 0.69 for gestational age and TAPSE ($p < 0.001$), 0.78 for birth weight and TAPSE ($p < 0.001$) (**Tab. 1**).

The TAPSE values have had strong and positive correlation with gestational age ($p = 0.0001$, $\rho = 0.692$). The TAPSE values have had strong and positive correlation with body weight ($p = 0.0001$, $\rho = 0.786$).

Model A (**Tab. 2**) presents statistically significant dependence of TAPSE from body weight ($p = 0.0001$). Model A is representative and explains 61.7% of the variance. Based on parameters (constant and B1) regression equation was constructed, relating body weight and TAPSE (**Fig. 1**).

Model B presents statistically significant dependence of TAPSE from gestational age. Model B

Table 1. Correlation of the tricuspid annular plane systolic excursion (TAPSE), gestational age and body weight.

		TAPSE (mm)	Gestational age (weeks)	Body weight (g)
TAPSE (mm)	Pearson's correlation		.692 ^a	.786 ^a
	p		.0001	.0001
	N		97	97
Gestational age (weeks)	Pearson's correlation	.692 ^a		.838 ^a
	p	.0001		.0001
	N	97		97
Body weight (g)	Pearson's correlation	.786 ^a	.838 ^a	
	p	.0001	.0001	
	N	97	97	

TAPSE: tricuspid annular plane systolic excursion.

^aCorrelation is significant at the 0.01 level (2-tailed).

Table 2. Linear regression equation relating body weight, gestational age and tricuspid annular plane systolic excursion (TAPSE): model A presents statistically significant dependence of TAPSE from body weight; model B presents statistically significant dependence of TAPSE from gestational age.

Equation	Model A summary					Parameter estimates	
	R Square	F	df1	df2	Sig.	Constant	B1
Linear	.617	153.054	1	95	.0001	4.738	.002
Equation	Model B summary					Parameter estimates	
	R Square	F	df1	df2	Sig.	Constant	B1
Linear	.479	87.191	1	95	.0001	-4.163	.385

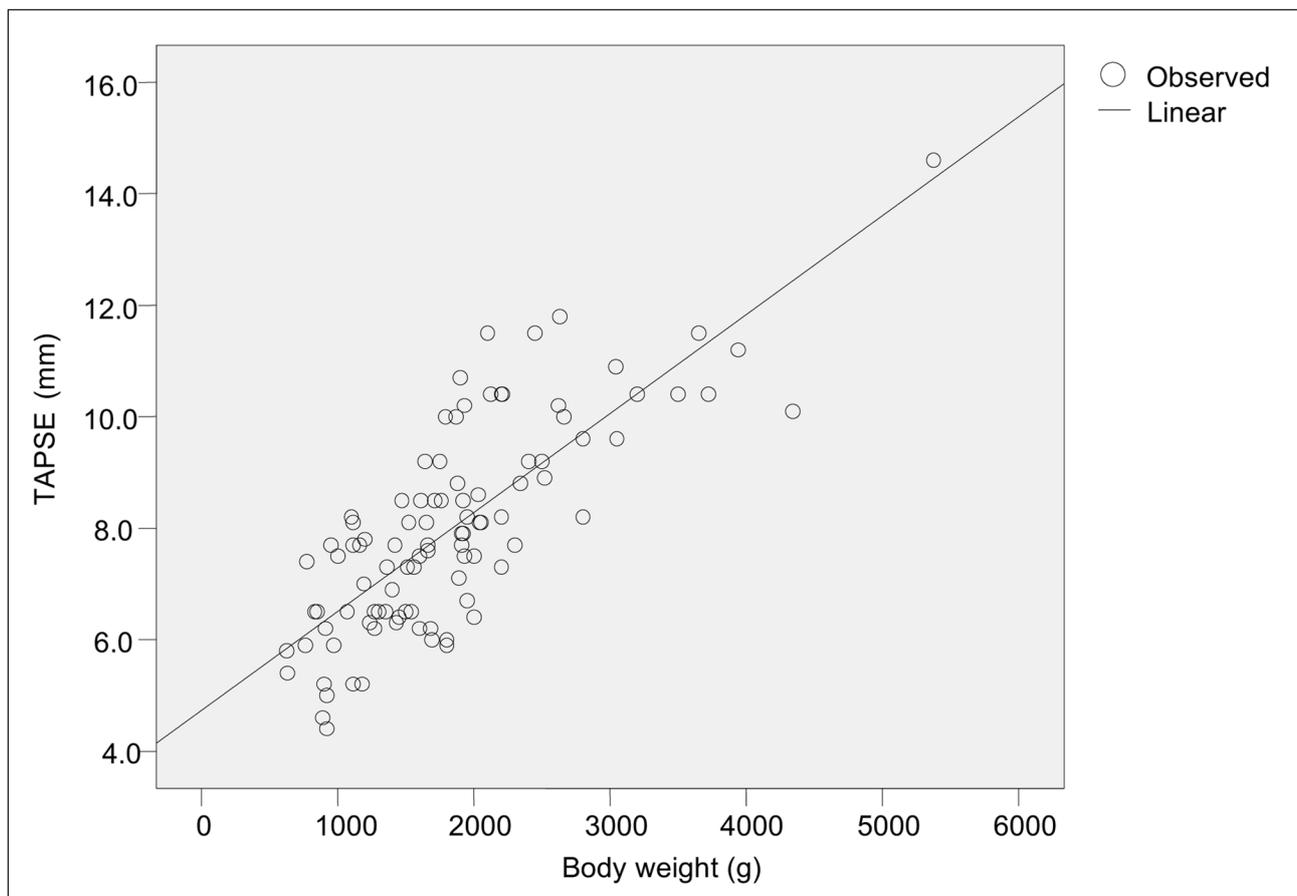


Figure 1. Regression equation relating body weight and tricuspid annular plane systolic excursion (TAPSE) is: $TAPSE_{predicted} = 4.738 + (body\ weight * 0.002)$.

is representative ($p = 0.0001$) and explains 47.9% of the variance. Based on parameters (constant and B1) regression equation was constructed, relating gestational age and TAPSE (**Fig. 2**).

Tab. 3 shows paired-samples t-test. Differences in values in the first pair are statistically significant ($p = 0.001$), which means that model A (body weight) does not adequately predict the TAPSE values in our sample ($n = 97$). Differences in value in the second pair are not statistically significant ($p = 0.940$), which means that model B (gestational

age) does adequately predict the TAPSE values in our sample ($n = 97$).

Discussion

Normal RV function is highly dependent on longitudinal shortening. One of the easiest ways to study RV longitudinal function is placing an M-mode cursor on the tricuspid valve annulus in the 2D four-chamber echocardiographic view and measuring the annular displacement in the

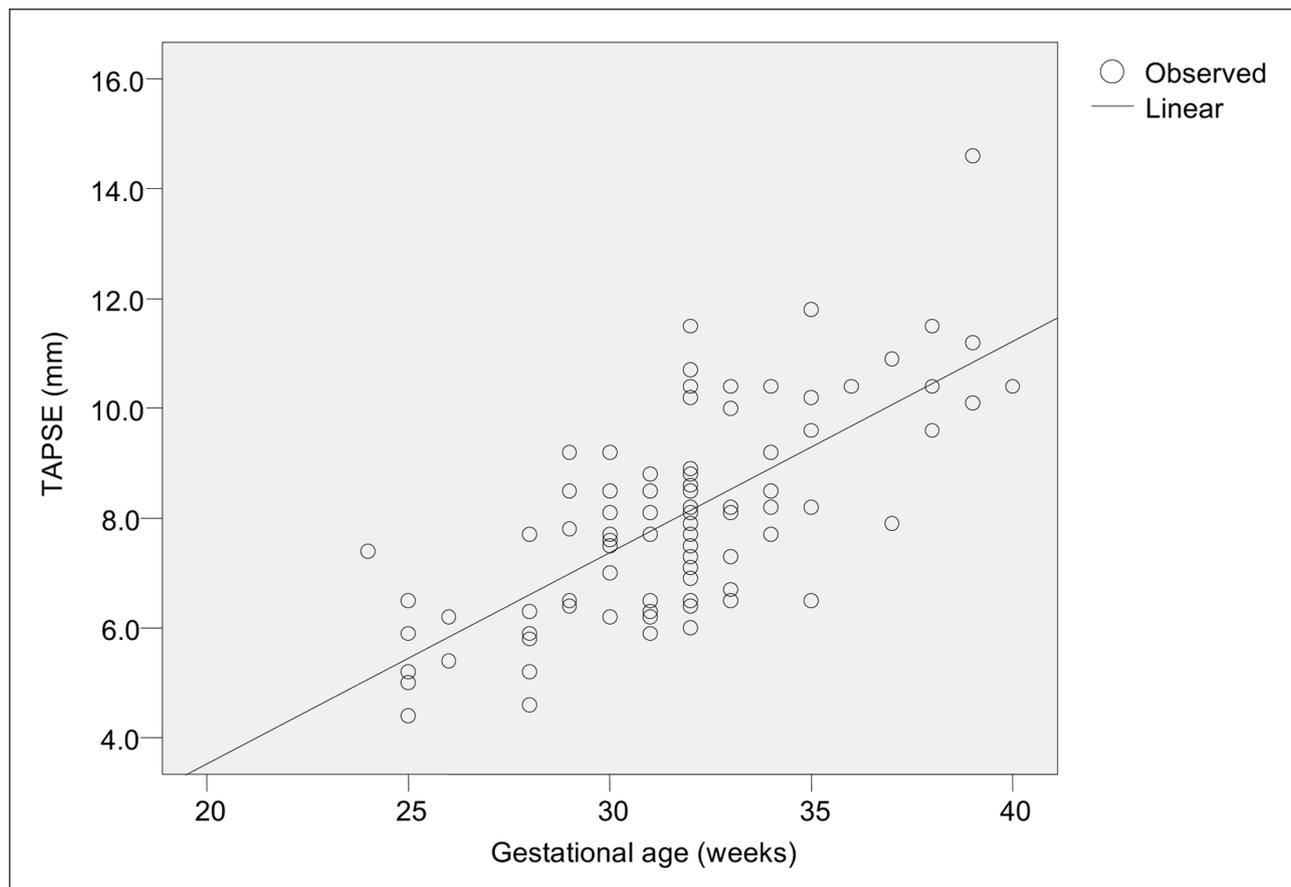


Figure 2. Regression equation relating gestational age and tricuspid annular plane systolic excursion (TAPSE) is: $TAPSE_{predicted} = -4.163 + (gestational\ weeks * 0.385)$.

Table 3. Paired-samples t-test.

		N	Ar. mean	SD	SEM	t-test	p
Pair 1	TAPSE	97	8.00	1.87	0.19	-3.473	0.001
	TAPSE (Model A)	97	8.41	1.66	0.17		
Pair 2	TAPSE	97	8.00	1.87	0.19	-0.075	0.940
	TAPSE (Model B)	97	8.01	1.30	0.13		

TAPSE: tricuspid annular plane systolic excursion.

longitudinal direction. TAPSE has been found to correlate well with both RVEF and FAC [16].

Recent advances in echocardiography have led to the development of techniques that directly measure global and regional myocardial function, rather than depend on changes in cavity dimensions. Quantitative assessment of RV function can be obtained using Tissue Doppler Imaging (TDI), strain and strain rate, in addition to RV specific markers of performance including TAPSE and FAC [17]. Assessment of RV performance in preterm infants is gaining considerable interest with an increasing recognition that RV function has important prognostic

implications in various disease states and populations [18].

Publications have shown that TAPSE measurement is better reproducible than other echocardiographic indices of RV function [12]. The ultimate result of our study is establishing the regression equation relating body weight and TAPSE as well as gestational age and TAPSE.

Koestenberger et al. recently showed that TAPSE is a developmental parameter from healthy infants to healthy adolescents [13]. Although TAPSE is a good parameter to assess RV systolic function, it does not take into account segmental RV function. In their opinion, TAPSE alone is

not suitable to predict RV systolic dysfunction in infants and not able to detect abnormal wall motion and distorted RV geometry [13].

TAPSE is a reliable marker of RV function and correlates well with peak systolic tricuspid annular velocity (S') in term and preterm infants as well as in the pediatric population [19]. Koestenberger et al. established reference values for TAPSE in preterm infants (≥ 26 weeks) up to term. However, the group did not present serial values during the first 48 h of life and only presented one value for that time period [9, 20].

No significant differences of TAPSE values were found between male and female subjects in this study (range 6.45-9.80 mm with average value 8.07 ± 1.89 mm in male, and 6.95-8.50 mm with average value 7.9 ± 1.86 mm in female patients, depending on gestational age) similarly to Koestenberger et al. study [9].

It is more likely that both FAC and TAPSE increased due to smaller RV endsystolic dimensions, which likely reflect the decreased afterload imposed on the RV by the decreased pulmonary vascular resistance. Developing a more objective approach to RV functional assessment will help us to better understand the impact of haemodynamic changes on function and be useful in defining disease states and monitoring the response to treatment [21, 22].

Clark et al. [5, 6] showed that RV volumes in term and preterm neonates decrease over the first 2 days of life, while there is no change in RV stroke volumes or RV cardiac output over time. RV is less compliant than the left ventricle in neonates and this has been shown to be more pronounced at earlier gestations [23].

A possible correlation of TAPSE and RVEF values is currently under discussion. Morcos et al. [24] show a weak correlation of TAPSE and RVEF determined by MRI in patients with tetralogy of Fallot. In a study by Chrustowicz et al. [25], TAPSE significantly correlated with RVEF determined by MRI.

Furthermore, the TAPSE has been shown to inversely correlate with the RV end-diastolic diameter.

In previous studies in pediatric patients with tetralogy of Fallot, a positive correlation was seen between the TAPSE measured by echocardiography and the RVEF determined by MRI [15, 26].

In our patients we found that TAPSE values increase with gestational weeks and birth weight in a linear way: Pearson's correlation coefficient was

0.69 for gestational age and TAPSE ($p < 0.001$), 0.78 for birth weight and TAPSE ($p < 0.001$). The TAPSE values have had strong and positive correlation with gestational age ($p = 0.0001$, $\rho = 0.692$) as well with body weight ($p = 0.0001$, $\rho = 0.786$). Our results are similar to results from prior studies that demonstrated correlations of RV function parameters to age [13, 27-29]. TAPSE is affected by increasing birth weight and increasing weeks of gestation.

In pediatric and adult cardiology the right heart is often targeted to evaluate cardiac function changes resulting from alterations in preload or afterload, which affect right heart function [30]. TAPSE is a commonly applied measure of RV systolic function that quantifies its contraction.

In conclusion, it is possible adequately to predict TAPSE based on gestational age. As TAPSE is easy to measure and highly reproducible we consider it as a useful quantitative parameter to assess RV longitudinal function in neonates. Taking into account the fact that TAPSE is a dynamic parameter, our opinion is that a study of quantitative measurements of RV systolic function should be performed for each individual subject in three time periods: during the first 48 hours of life, on the 15th day after birth and at the end of the neonatal period.

Declaration of interest

The Authors declare that they have no conflict of interest.

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