ORIGINAL ARTICLE

Eastern Journal of Medicine

East J Med 25(1): 36-40, 2020
DOI: 10.5505/ejm.2020.16878

The Influence of Loud Crying On Pulmonary Gradients Obtained By Transthoracic Echocardiography In Children With Pulmonary Valve Stenosis

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ABSTRACT

Pulmonary valve stenosis (PS) is the obstruction of blood outflow from the right ventricle of the heart at the level of the pulmonary valve. Crying is associated with an increase in venous return and it has been known to have some acute effects on cardiovascular system, the data about the alterations in echocardiographic findings during crying is limited. To explore the influences of loud crying in evaluation of transvalvular gradient obtained by Doppler echocardiography in children with pulmonary valve stenosis (PS).

Our study group included a total of 48 children, aged between 2 and 43 months who were diagnosed with pulmonary valve stenosis based on the clinical signs and laboratory (Echocardiography) findings in our hospital. We compared the pulmonary gradients obtained by echocardiography while the children were crying and while they were calm.

Totally 48 patients (23 male, 25 female) diagnosed with PS in our hospital were included in the study. The mean age of the patients was 19.27 ± 11.14 months (range: 2-43 months). During crying, both maximum and mean pulmonary gradients were statistically significantly higher compared with the results obtained while the patients were calm ($p < 0.001$, $p = 0.001$, respectively).

In conclusion, significant increases in both maximum and mean pulmonary gradients were determined during loud crying. Since these parameters are the main determinants of management of patients with PS, this condition should be kept in mind and if possible these measurements should be obtained while the children are in a calm state. Larger prospective studies are warranted to support our findings.

Key Words: Crying; Doppler Echocardiography; Pulmonary valve stenosis

Introduction

Pulmonary valve stenosis (PS) is the obstruction of blood outflow from the right ventricle of the heart at the level of the pulmonary valve. In general, PS accounts for approximately 10% of all congenital heart diseases. The most common cause of PS is congenital (1,2). Pulmonary valve stenosis can be due to isolated valvular (90%), subvalvular, or peripheral (supravalvular) obstruction, or it may coexist with some other congenital heart disorders (3). Isolated valvular PS is the most common type, and is due to the partial fusion of the valve commissures resulting in a conical or dome-shaped structure with a narrowed central orifice. Most children with mild-to-moderate PS are asymptomatic with a systolic murmur; but dyspnea and fatigue may be reported in patients with severe PS. Severe PS could progress to significant hypertrophy and secondary stenosis in the infundibulum. Especially for that reason, an effective method for timely diagnosis of PS is essential (4).

Exercise, tachypnea, and agitation were suggested to cause an increase in venous return to the heart which in turn may increase the blood volume on right heart chambers resulting in an increase in blood volume passing through the pulmonary valve (5). In that aspect, due to the exercise-induced changes in valve hemodynamics, ventricular function, and pulmonary artery pressure, together with symptomatic responses to exercise; exercise induced echocardiography has been suggested to provide more information about valvular heart diseases (6). On the other hand, although crying was also suggested to be associated with an increase in venous return and it has been known to have some acute effects on cardiovascular system, the data about the alterations in echocardiographic findings during crying is limited.

Young children may certainly be agitated and start crying in unfamiliar environments and it is not effortless to perform an echocardiography in agitated children. The present study aimed to explore the influences of loud crying in evaluation of transvalvular gradient obtained by Doppler echocardiography in children with PS.

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Received: 17.07.2019, **Accepted:** 02.12.2019

Materials and Methods

This cross-sectional study was conducted in a University Hospital, between September 2016 and May 2017 years. The study was approved by the local ethical committee with reference number of B.30.2.YYU.0.01.0000/90. Informed consent was obtained from the parents of all participants.

Our study group included a total of 48 children, aged between 2 and 43 months who were diagnosed with pulmonary valve stenosis based on the clinical signs and laboratory findings in our hospital. The following criteria were used for exclusion: acquired or congenital heart diseases (other than PS), primary pulmonary hypertension, any systemic disease, obesity, craniofacial anomaly, children who are quite calm and not agitated before starting the examination and genetic syndromes.

Echocardiography: Echocardiography was performed in the left lateral decubitus and supine position with an ultrasound machine Vivid 6S (GE-Vingmed Ultrasound AS, Horten, Norway) and 6S probe.

In all patients, first the echocardiography was performed for the evaluation of pulmonary valvular gradients while the children were agitated and crying extensively. And then, approximately 20 minutes later, echocardiography was performed for the second time when the children were quiet and calm. If the children did not become calm, nasal midazolam with a dose of 0.5 mg/kg was given to the children and then the 2nd echocardiography was performed.

All echocardiographic Doppler measurements were performed using the averages of three consecutive cycles. The 2D and M-mode echocardiographic techniques were used to take the images from parasternal and apical positions. The measurements were done by the same experienced cardiologist. The following variables were measured: interventricular septum diameter (IVSD), left ventricle (LV) diameter, LV posterior wall thickness (LVpWD), right ventricle end-sistolik diameter (RVesD), right ventricle end-diastolic diameter (RVedD). IVSD and LVpWD were measured at the end of diastole in parasternal long axis. Left ventricular end-diastolic (LVedD) and end-systolic diameter (LVesD) were measured at the end of systole and diastole in parasternal long axis.

Right ventricle (RV) size measurement was obtained in apical 4C image basally between septum at the level of the tricuspid valve and RV free wall (basal diameter) at the end of diastole and systole. The Pulmonary valve peak and mean gradient was obtained using the continuous wave Doppler with the continuous wave sample volume placed within the RV outflow tract.

Statistical Analysis: Statistical analysis was performed by SPSS ver. 21.0 software (SPSS Inc., Chicago, Ill, USA). The categorical variables were displayed as frequencies and percentages, the continuous variables were shown by mean ± standard deviation. Paired samples t test was performed to determine the alterations in mean and maximum pulmonary gradients while the children were crying and while they were calm. $P<0.05$ was considered as statistically significant difference.

Results

Totally 48 patients (23 male, 25 female) diagnosed with PS in our hospital were included in the study. The mean age of the participants was 19.27±11.14 months (range: 2-43 months). General characteristics and echocardiographic findings of study participants are summarized in Table 1.

Nasal midazolam with a dose of 0.5 mg/kg was required in 14 children before the 2nd echocardiography.

We compared the pulmonary gradients obtained by echocardiography while the children were crying loudly and while they were calm. The results are summarized in Table 2 (Figures 1 and 2). Regarding these data, during crying, both maximum and mean pulmonary gradients were statistically significantly higher compared with the results obtained while the patients were calm.

Discussion

In this study, we have evaluated the influences of loud crying on pulmonary valve gradient in children younger than 4 years of age. To the best of our knowledge, for the first time in literature, it was determined that there was a significant increase in both mean and maximum pulmonary gradients obtained by transthoracic echocardiography during loud crying in young children. Since pulmonary valve gradients are the main determinants in follow-up of patients with PS, this finding should be taken into account during evaluation and management of children with PS.

Resembling Valsalva maneuver, crying has been known to cause an increase in heart rate and blood pressure, a reduction in oxygen level, and it initiates the stress response (7,8). In a study on female students, increase in heart rate during crying that rapidly subsided after crying onset was reported and crying has been suggested as an arousing distress signal (9). Resting cardiac vagal control was shown to

Table 1. General characteristics and echocardiographic findings of study participants

	Mean ± SD	Range
Age (months)	19.27 ± 11.14	2 - 43
Weight (kg)	7.97 ± 2.63	2.90 - 13
Height (cm)	73.19 ± 12.55	46 - 100
SBP (mmHg)	97.23 ± 12.25	64 - 124
DBP (mmHg)	60.13 ± 12.66	33 - 89
LVedD (mm)	23.55 ± 3.78	17 - 33
LVesD (mm)	14.39 ± 2.75	8 - 21
IVSD (mm)	2.69 ± 0. 4741	1.60 - 3.60
LVPWD (mm)	2.53 ± 0.49	1.40 - 3.50
RVedD (mm)	17.68 ± 2.75	13 - 25
RVesD (mm)	12.02 ± 3.00	5 - 18
Pulmonary annulus (mm)	11.11 ± 2.15	6.40 - 15.00
Aortic annulus (mm)	11.08 ± 1.96	6.40 - 15.70

SBP, systolic blood pressure; DBP, diastolic blood pressure; LVesD, left ventricle end-systolic diameter; LVedD, left ventricle end-diastolic diameter; LVpWD, left ventricle posterior wall diameter; IVSD, interventricular septum diameter, RVesD, right ventricle end-systolic diameter; RVedD, right ventricle end-diastolic diameter, SD: Standard Deviation

Table 2. Comparison of heart rates and pulmonary gradients while the children were crying and while they were calm

	Crying (n=48)	Calm (n=48)	p
Maximum pulmonary gradient (mmHg)	37.71 ± 12.05	31.46 ± 10.83	0.001
Mean pulmonary gradient (mmHg)	20.67 ± 7.08	17.88 ± 6.46	0.001
Heart rate (beats/min)	158.27 ± 8.56	132.37 ± 8.06	0.001

be positively related to sad mood and crying (10). Moreover, crying was also determined to increase pulmonary resistance to the blood flow (11). In a recent study performed in 19 adults with mild-to-moderate pulmonary valve stenosis, a linear increase in gradient with increasing flow was demonstrated (12). Similarly, we also determined a significant increase in heart rate during crying. Regarding all those alterations on cardiovascular system during crying, it is reasonable to propose some alterations in echocardiographic findings in patients while crying.

There are three pulmonary semilunar valves that are attached to the wall of the artery by their convex margins in pulmonary valve. Their free borders are directed upward into the lumen of the vessel. Pulmonary valve obstruction results in hypertrophy of right ventricular muscle that is associated with the severity and duration of the obstruction. Later right ventricular cavity becomes to be dilated. Similarly, the main pulmonary artery is dilated in almost all cases due to the high-velocity jet flow across the stenotic valve (13,14). In transthoracic echocardiographic evaluation of patients with PS, the pulmonary valve leaflets may be defined as thickened and fused establishing a conical or domed pulmonary valve (15). With continuous flow Doppler evaluation, a turbulent flow across the valve may be determined (16). Calculating peak instantaneous and mean pressure gradients from Doppler signals obtained from the pulmonary valve orifice is essential for grading PS (17). Nowadays, the main treatment option in PS is the balloon valvuloplasty (18). In treatment choice, maximum instantaneous gradient across the pulmonary valve or mean gradient play central roles

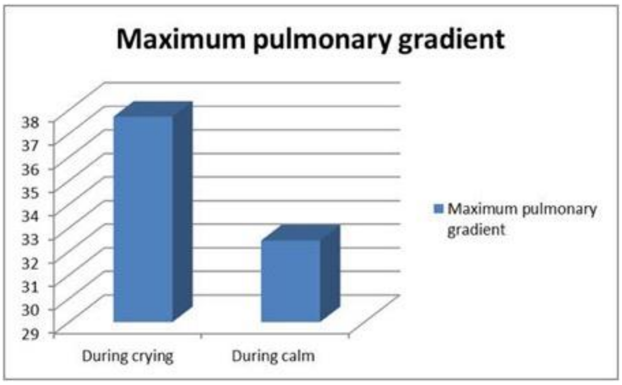

Fig.1. Alterations in maximum pulmonary gradient during crying and calm

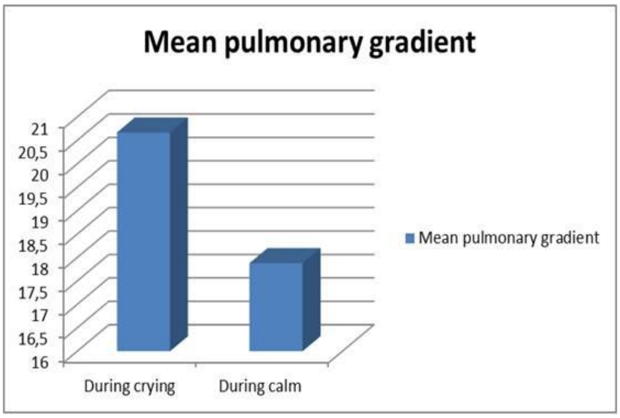

Fig. 2. Alterations in mean pulmonary gradient during crying and calm

in the decision for time of valvuloplasty and follow-up examinations (19). Proper identification of PS severity is essential in follow-up. In that aspect any alterations in assessment of gradients may also alter the treatment choice of patients.

Cardiac output is mainly determined by the heart rate and stroke volume. In patients with PS, due to the obstruction of ejection from right ventricle, right ventricular pressure increases causing right ventricle hypertrophy and dilatation and subsequent end result is the decreased cardiac output. Lurz et al. (20) reported a marked increase in left ventricle cardiac output during exercise, which was mainly driven by an increased heart rate in patients with PS. Similarly, crying is also another condition defined to increase heart rate and similar changes may be expected during crying in children with PS.

In general practice, younger children are crying and agitated during echocardiographic examinations, however this possible effect on the gradient pressure changes does not taken into account by physicians. So this may alter the decision to perform intervention for valvuloplasty earlier or to perform unnecessary invasive procedures. When we searched in the literature, we could not find any study that deal with the effect of crying on pressure gradient changes during echocardiography. Therefore, to the best of our knowledge, this study is the first study that found the higher pulmonary valve gradient pressure in crying status than calm status in children. However, this findings should be clarified in larger studied.

There are some limitations that should be mentioned regarding our study design. The relatively small sample size represents an important limitation of this study. Secondly, we did not sub-group the patients regarding the pulmonary valvular gradient. The effects of crying on valvular gradient may be different on different stages of the disease; which may be the subject of another investigation. And lastly, all children do not cry similarly and crying levels of children may be different which may make our groups heterogeneous. However, during crying or during calm, the standard deviations of the heart rate were not high; which may be regarded as an indicator about the homogeneity of the groups.

In conclusion, the effect of crying on pressure gradients of pulmonary valve during echocardiographic examination found to be significant in our study. The echocardiographic results of calm children were found to be lower than crying status. Since these parameters are the main determinants of management of patients with PS, this condition should be kept in mind and if possible these measurements should be obtained while the children are in a calm state. Larger prospective studies are warranted to support our findings.

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