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Effects of respiration on left ventricular diastolic function in healthy children

F. K. Alehan, S. Özkutlu and D. Alehan

Cardiology Unit, Department of Pediatrics, Hacettepe University Faculty of Medicine, Ankara, Turkey

Pulsed Doppler echocardiographic indices of mitral valve filling were measured in 20 healthy children, between 3 and 12·5 years old, in order to evaluate the effects of spontaneous respiration on left ventricular diastolic filling patterns. There were significant respiratory variations in four parameters of left ventricular diastolic function: The peak early filling velocity, the ratio of early to late peak filling velocity, and the ratio of early to late diastolic velocity–time integral decreased significantly during inspiration (mean decrease 7%, $P<0·05$; 16%, $P<0·01$; and 12%, $P<0·05$, respectively). On the other hand there was a significant increase in late peak filling velocity with inspiration (10% increase, $P<0·05$). Other variables of left ventricular diastolic filling were unchanged with inspiration. These results suggest that assessment of left ventricular diastolic function in children should be standardized with regard to respiratory phases in any clinical application.
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Key Words: Pulsed Doppler echocardiography, diastolic function, left ventricle, respiration, children.

Introduction

In recent years, there has been increased interest in the detection of abnormalities of left ventricular diastolic function in patients with various heart diseases. The study of diastolic filling velocities by Doppler echocardiography has, in particular, provided increasing insights into our understanding of left ventricular diastolic performance[1–6]. Recently the demonstration of diastolic abnormalities in the absence of overt systolic dysfunction has resulted in widespread assessment of diastolic filling in various disease states[7]. However, diastole is a complex process and diastolic functions are known to be influenced by some physiological variables, such as heart rate, age and loading conditions[8–10]. Respiration is another physiological factor that may affect diastolic filling, but contrary to well known effects of respiration on right ventricular diastolic functions, its influence on left ventricular diastolic functions is still controversial. Furthermore most of these studies, concerning effects of respiration on ventricular filling, deal with adults and there are only a few investigations performed in children.

Therefore, using pulsed Doppler echocardiography, this study was designed to assess the influence of respiration on left ventricular diastolic filling patterns in healthy children.

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Correspondence: Dr Süheyla Özkutlu, Department of Pediatric Cardiology, Hacettepe University, Faculty of Medicine, 06100, Ankara, Turkey.

Method

Study group

The study group consisted of 20 normal children with a mean age of $6·6 \pm 2·52$ years (range 3 to 12·5 years), and no history or evidence of cardiovascular, pulmonary or systemic disease and all had a completely normal physical examination, electrocardiogram, chest X-ray, and echocardiogram.

Echocardiographic examination

Complete two-dimensional and Doppler echocardiographic examinations were performed on each subject using a Toshiba Sonolayer SSH 160 A echocardiographer with 2·5, 3·7, and 5 MHz transducers. Examinations were recorded on a standard VHS videotape and measurements were made from the replay.

Each subject underwent a pulsed Doppler echocardiographic examination of the mitral valve from an apical four-chamber view. The Doppler cursor was placed in the left ventricular inflow, almost parallel to the direction of flow and just distal to the valve anulus. We simultaneously recorded the subjects' electrocardiogram, phonocardiogram and respiration (using a pressure transducer placed over subphrenic region) (Fig. 1). Inspiratory and expiratory cardiac cycles were measured at end-inspiration and end-expiration, respectively. Care was taken to keep the positions of the body and transducer unchanged during the recording.

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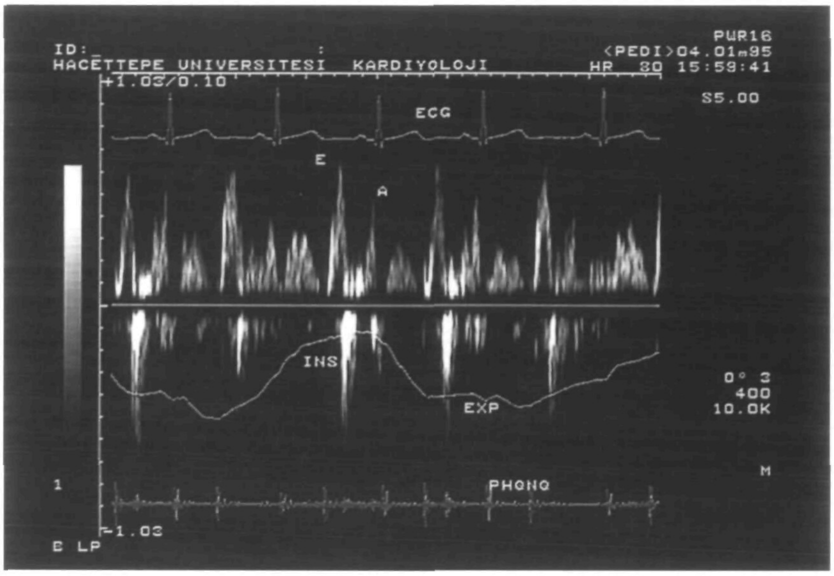

Figure 1 **Doppler mitral flow velocity during inspiration (INS) and expiration (EXP). E, peak E; A, peak A; ECG, electrocardiogram; phono, phonocardiogram.**

Doppler analysis

The pulsed Doppler recordings were analysed using an off-line computer system. For the determination of left ventricular filling dynamics, the cardiac cycles with the most clearly defined flow velocity waveform and the maximum early diastolic filling velocity were chosen. The following parameters were obtained from the spectral display. Peak early filling velocity (peak E) (in $cm . s^{-1}$) and peak late (atrial) filling velocity (peak A) (in $cm . s^{-1}$) from which the ratio of early to late peak filling velocity (peak E/A ratio) was derived; early diastolic velocity–time integral (E area) (in cm) and late diastolic velocity–time integral (A area) (in cm), from which E/A area was derived; total diastolic filling period, defined as the interval between the onset and termination of diastolic filling velocity; the acceleration time, defined as the interval between the onset of diastolic flow and peak E; deceleration time, defined as the interval between peak E and termination of early diastolic filling; early acceleration slope; early deceleration slope; and isovolumic relaxation time defined as the interval between closure of aortic valve determined from phonocardiogram and onset of diastolic flow.

Data analysis

All Doppler measurements reported are the average of three cardiac cycles at end-inspiration and three at end-expiration. All values are reported as mean ± 1 SD. To evaluate the effects of respiration, end-inspiratory cycles were compared with end-expiratory cycles and a two-tailed paired t-test was used for statistical analysis; $P<0.05$ indicated a significant difference between the groups.

Intra-observer variability

All echocardiographic studies and measurements were performed by the same cardiologist (S. Ö.). Intra-observer variability was calculated as described previously[11] and was low for most of the Doppler indices. For Doppler velocity measurements r=0·99, for all time interval measurements r=0·99, for velocity–time integral measurements r=0·98, and for acceleration and deceleration slope r=0·97.

Results

There were significant respiratory variations in four parameters of left ventricular diastolic filling in the study group (Table 1). The peak E velocity was significantly lower during end inspiration than during end expiration (mean decrease 7%, $P<0.05$). In addition, the ratio of early to late peak filling velocity (peak E/A ratio) and the ratio of early to late diastolic time-velocity integral (E/A area) also decreased significantly with inspiration (mean decrease 16·1%, $P<0.01$; and 12·14%, $P<0.05$; respectively). On the other hand, a 12·14% increase was detected in the mean peak A velocity during end inspiration ($P<0.05$). These variations are illustrated in Figs 2 to 5 respectively. The mean heart rate was slightly, but not significantly, greater during inspiration. None of the other parameters of left ventricular diastolic functions was significantly influenced by respiration.

Discussion

The use of transmitral Doppler recordings in assessing left ventricular diastolic function has received increased

Table 1 ***Effects of respiration on left ventricular filling***

	Expiration	Inspiration	Change (%)	*P* value
Peak E (cm . s^{-1})	60·46 ± 11·47	56·14 ± 12·2	7·14	<0·05
Peak A (cm . s^{-1})	40·54 ± 6·83	44·64 ± 5·76	10·11	<0·05
Peak E/A ratio	1·49 ± 0·23	1·25 ± 0·22	16·1	<0·01
E area (cm)	4·69 ± 1·2	4·5 ± 1·3	4·05	NS
A area (cm)	2·19 ± 0·6	2·39 ± 0·4	9·13	NS
E/A area	2·14 ± 0·51	1·88 ± 0·46	12·14	<0·05
AT (ms)	70·3 ± 12·2	67·2 ± 13·1	4·4	NS
DT (ms)	89·2 ± 16·4	86·3 ± 19·4	3·25	NS
TDF (ms)	294·5 ± 40	288 ± 31·6	2·03	NS
EF slope (cm . s^{-2})	5·44 ± 1·5	5·37 ± 1·2	1·28	NS
OE slope (cm . s^{-2})	9·48 ± 2·1	9·92 ± 2·3	4·64	NS
IVRT (ms)	49·7 ± 8·9	51·4 ± 12·1	3·42	NS

AT=acceleration time; DT=deceleration time; TDF=total diastolic filling period; EF slope=early deceleration slope; OE slope=early acceleration slope; IVRT=isovolumic relaxation time.

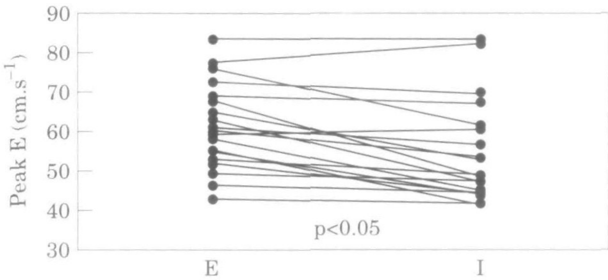

Figure 2 **Reduction in left ventricular peak early filling velocity (peak E) during inspiration in 20 healthy children. E, expiration; I, inspiration.**

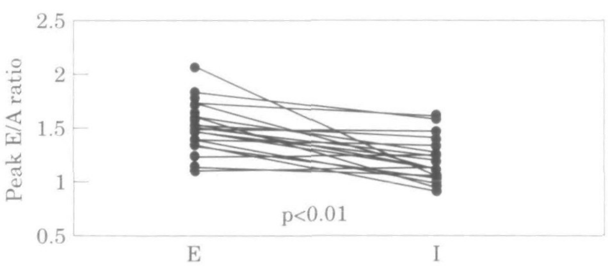

Figure 3 **A diagram representing the reduction in the ratio of early to late peak filling velocity (peak E/A ratio) with inspiration. Abbreviations as in Fig. 2.**

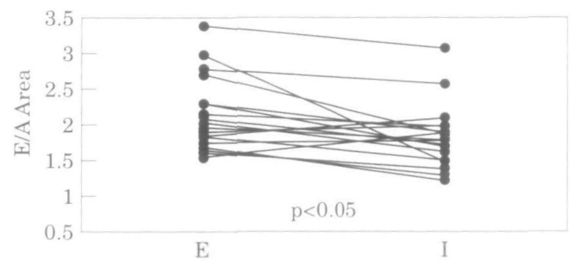

Figure 4 **Reduction in the ratio of early to late diastolic velocity–time integral (E/A Area) with inspiration. Abbreviations as in Fig. 2.**

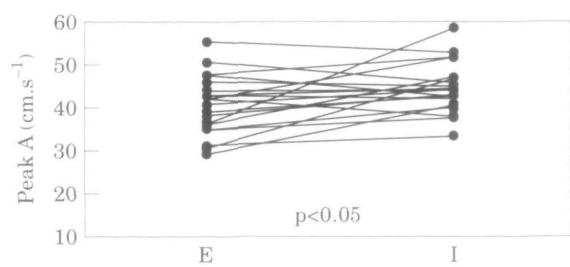

Figure 5 **Increase in left ventricular peak late filling velocity (peak A) with inspiration. Abbreviations as in Fig. 2.**

attention in clinical cardiology, However, diastolic filling is a complex process and diastolic parameters are affected by various factors. The magnitude of these effects is such that they should be taken into account in any echocardiographic measurement of left ventricular diastolic function[12]. Although the effect of respiration on right ventricular diastolic filling has been investigated in various studies, there are only a few controversial studies concerning the effects of respiration on left ventricular diastolic filling.

Zoghbi *et al.* observed a reduction in the total time–velocity integral, peak E, peak A and in the peak A/peak E ratio in healthy adults with respiration[12]. In the study of Dabestani *et al.* early diastolic peak flow velocity decreased in inspiration without any alteration in the ratio of peak A/E[13]. Contrary to these findings Pye *et al.* and Van Dam *et al.* reported no changes in the diastolic filling dynamics with inspiration[14,15]. However, all these studies were performed either in adults or in a heterogeneous population with a wide age distribution. Therefore it may be misleading to apply these findings to children since a significant relation between diastolic function and age has been demonstrated[16,17].

In the only other study in children, Riggs *et al.* reported significant inspiratory decreases in peak E velocity, in the ratio of E/A areas, and in the peak E/A ratio, whereas neonates were found to have no changes in left ventricular diastolic function with respiration[18,19]. Similarly, in our study we demonstrated significant reductions in the frequently used indices of diastolic filling (peak E velocity, ratio of E/A area, and peak E/A ratio), which represent reduced early diastolic filling with inspiration. The demonstration of a significant increase in late diastolic peak velocity (peak A), that has not been reported previously, may thus reflect a compensatory augmentation of late diastolic filling due to the decrease in early diastolic filling.

Our results are compatible with previous M-mode and two dimensional echocardiographic studies, showing inspiratory reduction in left ventricular end-diastolic dimensions and stroke volume that reflects decreased end-diastolic volume[20,21]. Possible explanations for the inspiratory decrease in left ventricular stroke volume include: a decrease in pulmonary venous return due to an increase in venous capacitance of the pulmonary vessels; shifting of the interventricular septum towards the left ventricle, following augmentation of right ventricular filling with inspiration; inspiratory increase in heart rate and therefore a shortened diastolic filling time; and a relative increase in systemic afterload as a result of negative intrapleural and intrathoracic pressure[22–25]. Thus, one or more of these parameters may contribute to the early decrease in left ventricular diastolic filling, as shown in our study.

Although heart rate was found to be an important determinant of Doppler-derived parameters of diastolic filling, the change in mean heart rate of our patients was minor and suggested that heart rate did not have an important role in the documented respiratory variations.

In conclusion, our data indicate that respiration has significant effects on left ventricular diastolic function in normal children, and we think that besides other variables, respiration should also be taken into account and assessment of left ventricular diastolic function should be standardized with regard to respiratory phases in any clinical application.

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