

Relation of Mean Right Atrial Pressure to Doppler Parameters of Right Atrial and Hepatic Venous Flow in Pediatric Patients with Congenital Heart Disease

Hamid Amoozgar*¹, MD; Khobiar Zare¹, MD; Mohammad Borzooe¹, MD;
Gholamhossein Ajami¹, MD; Saeid Abtahi¹, MD

1. Division of Pediatric Cardiology, Shiraz University of Medical Sciences, Shiraz, IR Iran

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Abstract

Objective: A paucity of data exists regarding the relation of mean right atrial pressure (RAP) to Doppler parameters of right atrial and ventricular filling in pediatric patients with congenital heart disease.

Methods: Fifty patients (30 male and 20 female) with mean age of 4.96 ± 4.05 who were admitted in the pediatric cardiology ward of Nemazee Hospital affiliated to Shiraz University of Medical Sciences, were included in this study. Patients were categorized into two groups according to their RAP measured by cardiac catheterization: Group 1 (40 patients) were those with mean RAP < 8 mmHg and group 2 (10 patients) who had mean RAP ≥ 8 mmHg. Data gathered from hepatic venous flow, tricuspid diastolic flow and pulse tissue Doppler of lateral tricuspid annulus of each patient were then compared with right atrial pressure obtained by cardiac catheterization.

Findings: If change of peak S wave velocity of hepatic vein in respiration was more than 38%, sensitivity and specificity of a RAP more than 8 mmHg was 90% and 51.3% respectively with likelihood ratio (LR) equal to 1.85; a peak S wave velocity of less than 70 mm/sec also showed a RAP more than 8 mmHg with sensitivity and specificity of 70 and 82.1 respectively (LR=3.9). A peak expiratory D wave velocity of hepatic vein more than 63 mm/sec was indicator of RAP more than 8 mmHg with sensitivity and specificity of 60% and 92.3% respectively (LR=7.8).

Conclusion: This study showed that hepatic venous flow can be valuable for estimation of mean RAP in pediatric patients with congenital heart disease.

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* Corresponding Author;

Address: Department of Pediatrics, Namazi Hospital, Shiraz, IR Iran; 71937-11351

E-mail: amozgah@sums.ac.ir

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Introduction

The estimation of right ventricular filling pressure is important clinically for the diagnosis and management of various hemodynamic conditions [1-4]. Furthermore, assessment of right atrial pressure (RAP) is needed in the echocardiography laboratory for estimation of systolic right ventricular-pulmonary artery pressures and left atrial pressure [5-8]. Although clinical evaluation of jugular venous pulsations is usually used to estimate RAP, it may be difficult in children with short neck, and such an examination may not always be feasible in a busy echocardiography laboratory [6,7].

A few studies in selected adult patients have evaluated the right-side hemodynamic correlates of right atrial and right ventricular filling dynamics [9,10,11]. Tricuspid and hepatic venous flow dynamics have been described in patients with restrictive cardiomyopathy [10] and have been used to help differentiate constrictive pericarditis from restrictive cardiomyopathy [11,12]. On the other hand, studies on the changes in the diameter of the inferior vena cava in response to negative intrathoracic pressure have demonstrated a significant relation of this index to RAP [13-19].

Such an approach, however, requires the patient's cooperation and has been limited in mechanically ventilated individuals [15]. A comprehensive evaluation of the relation of echocardiographic and Doppler parameters of right ventricular function, right atrial function, and inferior vena cava to mean RAP in pediatric patients with a variety of clinical conditions has not been performed previously. Because several of these parameters can be obtained from routine cardiac ultrasound examination, it is important to evaluate which of these parameters has the best correlation with RAP and whether a combination of these indexes improve the clinical estimation of right ventricular filling pressure. Accordingly, this study was undertaken to assess the relation of Doppler parameters of hepatic vein, tricuspid inflow and pulse tissue Doppler imaging (TDI) of lateral tricuspid annulus.

Subjects and Methods

Fifty pediatric patients with congenital heart disease who needed right sided interventional or diagnostic cardiac catheterization were enrolled in this study consequently from April 2007 till June 2008.

Echocardiography was performed with a GE vivid 3, 3 MHz probe and TDI software. Hepatic veins systolic (S), diastolic (D), atrial reversal flow (A) and its duration were recorded in inspiration and expiration. Tricuspid early diastolic (E) and late diastolic (A) were also recorded in apical four chamber view in inspiration and expiration. Tissue Doppler imaging was obtained with the sample volume placed at the lateral corner of lateral tricuspid annulus from the apical four chamber view. In each region, systolic (S) wave, early diastolic (Ea), and late diastolic (Aa) velocities were also recorded. Echocardiographic data gathered from echocardiography of each patient was then compared with the result of cardiac catheterization.

The investigational protocol was approved by the research committee at the Shiraz University of Medical Sciences, and written informed consents were obtained from each patient or parents. All data are expressed as means \pm one standard deviation (SD), linear regression was used to examine the relationship between echocardiographic parameters and angiographic mean right atrial pressure. Non parametric tests used for analysis between two independent samples. Pearson product moment correlation was used to compare values obtained by the two methods. Linear correlation was also tested using the Spearman rank method (correlation coefficient with 95% confidence interval).

A receiver operating characteristic (ROC) curve was generated for statistically significant echocardiographic parameters, varying the discriminating thresholds of these parameters to determine the ability of mean right atrial pressure to discriminate between patients with a high right atrial pressure and those without it. MedCalc® 8.0 software was used for statistical analysis.

Findings

From fifty pediatric patients who enrolled in this study 30 patients were male and 20 female. Mean (\pm SD) age of patients was 4.96 (\pm 4.05), mean body surface area 0.56 (\pm 0.25). The diagnoses consisted of tetralogy of Fallot (23), ventricular septal defect (10), pulmonary stenosis (3), atrial septal defect and pulmonary stenosis (2), primary pulmonary hypertension (4), dilated cardiomyopathy (1), ventricular and atrial septal defect (2), coronary fistula (1), patent ductus arteriosus (1), patent ductus arteriosus and coarctation of aorta (1), transposition of great artery and pulmonary stenosis (2).

Patients were categorized in two groups according to their RAP that was measured by cardiac catheterization: Group 1 (40 patients) consisted of cases with mean RAP <8 mmHg and group 2 (10 patients) of those who had mean RAP \geq 8mmHg. Pulse Doppler echocardiographic data of hepatic vein, tricuspid annulus and TDI of lateral tricuspid annulus are recorded in tables 1, 2 and 3.

Due to statistically significant correlation of peak E to A velocity ratio of tricuspid valve in expiration, peak S to D velocity ratio of hepatic vein in expiration and change in a velocity of

tricuspid valve in respiratory cycle, linear regression equation was used as follows:

$$1) \text{ RAP} = [A \text{ tricuspid change} \times (-0.01)] + 6.5 \quad (P < 0.001, r = 0.38)$$

A: velocity of atrial contraction wave

$$2) \text{ RAP} = [S/D \text{ (IVC flow in expiration)} \times 0.96] + 5.01 \quad (P < 0.001, r = 0.43)$$

S: velocity of systolic wave of IVC flow

D: velocity of diastolic wave of IVC flow

$$3) \text{ RAP} = [E/A \text{ (tricuspid flow in inspiration)} \times 1] + 4.85 \quad (P < 0.001, r = 0.37)$$

E: velocity of early diastolic wave of tricuspid

A: velocity of atrial contraction wave of tricuspid flow

ROC curves showed that if S wave velocity change of hepatic vein in respiration was more than 38%, sensitivity and specificity of having a RAP more than 8 mmHg was 90% and 51.3% respectively with positive likelihood ratio (+LR) of 1.85 and negative likelihood ratio (-LR) of 0.19; A peak S wave velocity of less than 70 mm/sec also shows a RAP more than 8 mmHg with sensitivity and specificity of 70 and 82.1 respectively (+LR=3.9, -LR=0.37).

An expiratory peak D wave velocity of hepatic vein more than 63 mm/sec is indicator of RAP more than 8 mmHg with sensitivity and specificity of 60% and 92.3% respectively (+LR=7.8, -LR=0.43).

Table 1: Pulse Doppler velocities of the hepatic veins (All values are mean \pm SD)

Variables ‡	Group 1* cm/sec	Group 2* cm/sec	P value cm/sec
S _I	0.92 (\pm 0.32)	1.12 (\pm 0.38)	0.2
S _E	0.56 (\pm 0.20)	0.82 (\pm 0.26)	0.005
D _I	0.73 (\pm 0.24)	0.99 (\pm 0.44)	0.07
D _E	0.46 (\pm 0.13)	0.80 (\pm 0.39)	0.008
A _I	0.43 (\pm 0.13)	0.49 (\pm 0.19)	0.7
A _E	0.392 (\pm 0.10)	0.46 (\pm 0.13)	0.1
AD (msec)	84.30 (\pm 0.23)	79.89 (\pm 22.01)	0.6

* Group 1 patients with right atrial pressure <8 and group 2 patients with right atrial pressure \geq 8.

‡ S_I: S wave velocity in inspiration; S_E: S wave velocity in expiration; D_I: D wave in inspiration; D_E: D wave in expiration; A_I: A wave in inspiration; A_E: A wave in expiration; A_D: A wave duration

Table 2: Pulse Doppler velocities of tricuspid valve (All values are mean \pm SD)

Variables ‡	Group 1* cm/sec	Group 2* cm/sec	P value cm/sec
E _I	1.05 (\pm 0.25)	1.18 (\pm 0.29)	0.2
E _E	0.24 (\pm 0.82)	0.90 (\pm 0.19)	0.3
A _I	0.77 (\pm 0.21)	0.72 (\pm 0.30)	0.8
A _E	0.62 (\pm 0.15)	0.69 (\pm 0.17)	0.3
AD (msec)	118.13 (\pm 34.19)	123.67 (\pm 40.32)	0.8

* Group 1 patients with right atrial pressure <8 and group 2 patients with right atrial pressure \geq 8.

‡ E_I: E wave velocity in inspiration; E_E: E wave velocity in expiration; A_I: A wave in inspiration; A_E: A wave in expiration; AD: A wave duration

An inspiratory E to A velocity of tricuspid wave more than 1.88 is indicator of RAP more than 8 mmHg with sensitivity and specificity of 60% and 82.5% respectively (+LR=3.43, -LR=0.48), and inspiratory Ea to E velocity ratio more than 11.8 is indicator of RAP more than 8 mmHg with sensitivity and specificity of 60% and 87.5% respectively (+LR=4.8, -LR=0.46).

Discussion

Estimation of RAP is helpful in the overall management of patients with hemodynamic disorders and in the derivation of pulmonary

artery pressure or left atrial pressure with Doppler echocardiography [20].

The phases of hepatic venous flow in normal individuals were described [15]. Determinants of the systolic forward flow include atrial relaxation, descent of the tricuspid annular plane toward the ventricular apex, and RAP [21,22,23]. In higher RAP, the pressure gradient between the hepatic veins and the right atrium will be lower and thus the forward systolic flow will be lower. This observation was described previously in patients with restrictive heart disease and elevated filling pressures [24,25]. In the present study, decrease in systolic (S) forward flow parameters and increase in diastolic venous flow (D) had fine relation to mean RAP and

Table 3: Pulse tissue Doppler velocities of lateral tricuspid annulus (All values are mean \pm SD)

Variables ‡	Group 1* cm/sec	Group 2* cm/sec	P value cm/sec
Sa	0.12 (\pm 0.03)	0.11 (\pm 0.02)	0.4
Ea	0.16 (\pm 0.05)	0.19 (\pm 0.05)	0.2
Aa	0.16 (\pm 0.12)	0.15 (\pm 0.05)	0.4
AD (msec)	80.41 (\pm 20.11)	71.67 (\pm 15.67)	0.2

Group 1 patients with right atrial pressure <8 and group 2 patients with right atrial pressure \geq 8.

‡ Sa: S wave velocity; Ea: E wave velocity; Aa: A wave velocity; AD: A wave duration

allowed a good estimation of atrial pressure in patients with a variety of underlying clinical conditions.

With respiratory variability present in any right-side Doppler velocity recording, measurements were performed as an average of several consecutive beats, which yields results similar to those obtained during end-expiratory apnea^[16]. This allowed assessment of RAP in patients with dyspnea or on mechanical ventilation in whom the relation of systolic filling fraction with RAP proved to be similar to those without assisted ventilation. Exclusions related mostly to nonsinus rhythms and occasional technical difficulties in patients in the Intensive Care Unit. Unlike recordings of pulmonary vein flow^[26], Doppler assessment of hepatic vein flow with transthoracic approach is simpler and feasible in the majority of patients even in Intensive Care Units, as shown in this study, thus allowing assessment of RAP in most patients. The present study showed good correlation between cyclic respiratory changes in peak S wave velocity and mean RA pressure.

Although there were statistically significant correlations between Peak E to A velocity of tricuspid valve in expiration, peak S to D velocity of hepatic vein in expiration and change in A velocity of tricuspid valve in respiratory cycle, linear regression equation showed not a strong estimation of mean RA pressure by this model. This data is against the studies in adult patients without structural heart disease^[18].

Among all parameters tested, hepatic vein systolic wave velocity, diastolic wave velocity and changes of S wave velocity phasic changes during respiratory cycle have provided useful yet simple indexes for the assessment of mean RAP in pediatric patients with CHD. Determination of these parameters provided a reasonable estimate of high mean RAP. Doppler recordings of tricuspid inflow, however, are also important in the overall evaluation of right-sided hemodynamics and hepatic venous flow. Assessment of these parameters corroborates findings of atrial filling dynamics and is important when

derivation of mean RAP cannot be performed noninvasively.

Conclusion

This study showed that hepatic venous flow can be valuable for estimation of mean RAP in pediatric patients with congenital heart disease. It is noteworthy to mention the characteristics of patients in whom the observed relations in this study may not be applicable; these include patients with non-sinus rhythm, pericardial diseases and also patients with severe tricuspid regurgitation, who usually have reversal of systolic hepatic venous flow, were not included in this study.

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