Assessment of right ventricular function in children with congenital heart disease

Doppler tissue imaging

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ABSTRACT

الأهداف: تقييم عسر وظيفة البطين الأيمن لدى الأطفال ممن يعانون من مرض خلقي في القلب بقياس السرعة الانقباضية الحلقية للصمام الثلاثي الشرف بتصوير الأنسجة بجهاز الدوبلر.

الطريقة: أجريت دراسة محكومة للحالات على 141 طفلا يعانون من مرض خلقي في القلب أحيلوا إلى مستشفى علي أصغر – زاهيدان – إيران، لإجراء قسطرة للقلب خلال الفترة من أبريل 2004م وحتى ديسمبر 2005م. تم قياس سرعة التدفق في الصمام الثلاثي الشرف (A/E ratio) والسرعة الانقباضية الحلقية للصمام الثلاث الشرف (Aa/Ea ratio) بتصوير الأنسجة بجهاز دوبلر. بعد ذلك اجريت القسطرة للمرضى، وتم تحليل البيانات التراكمية بالربط بين مجموعات الاختبارات (SPSS).

النتائج: تبين وجود ارتباط ذو دلالة بين نسبة سرعة الدم الانقباضية (Aa/Ea ratio) حسب تصوير الأنسجة بجهاز دوبلر ومعايير حركة الدم المستقاة من القسطرة. كما تم تشخيص حالة 77 مريضاً من 141 مريضاً بأنها عسر وظيفة البطين الأيمن حسب صور الأنسجة بجهاز دوبلر، بينما أتضح وجود هذه المشكلة لدى 74 مريضاً منهم من خلال القسطرة. وقد كانت حساسية هذه الطريقة لتقييم عسر وظيفة البطين الأيمن بمعدل 95%، والتحديد بنسبة 98%. بلغت النسبة التنبؤية الموجبة 95% والنسبة التنبؤية السالبة 98%.

خاتمة: أظهرت نتائج هذه الدراسة إمكانية استخدام تصوير الأنسجة بجهاز دوبلر لتشخيص عسر وظيفة البطين الأيمن لدى الأطفال الذين يعانون من مرض خلقي في القلب ويمكن استخدامه بدلا من القسطرة خاصة للمرضى من ذوي الحالات غير المستقرة.

Objective: To assess right ventricular dysfunction in children with congenital heart disease (CHD) by measurement of tricuspid annular diastolic velocity (Aa/Ea ratio) by doppler tissue imaging (DTI).

Methods: A case-control study was performed on 141 children with CHD who were referred to Aliasghar Hospital of Zahedan, Iran for cardiac catheterization from April 2004 to December 2005. Tricuspid inflow velocity (A/E ratio) and Aa/Ea ratio was measured by DTI. Patients were catheterized afterwards. Cumulative data were analyzed by Statistical Package for Social Sciences and evaluated using t-test and correlation.

Results: There was significant correlation between Aa/Ea ratio by DTI, and hemodynamic criteria derived at catheterization. It was also diagnosed that 77 patients of 141 had right ventricular dysfunction by DTI, whereas 74 of them showed this problem at catheterization. The sensitivity of this method for evaluation of right ventricular dysfunction was 95%, and specificity was 98%. The positive predictive value 95%, and negative predictive value 98% were assessed.

Conclusion: Finding of this study showed that we can use DTI for diagnosis of right ventricular dysfunction in children with CHD, and it can be used instead of catheterization especially in unstable patients.

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Congenital heart disease (CHD) is a leading cause of death during the first year of life. Cardiac anomalies occur in approximately 8 of 1000 live born infants. As the majority of severe cases now are being managed successfully, most of these patients survive into their reproductive years. Studies have shown that the offspring of women with CHD are at much greater risk of having cardiac malformation.[1] The non invasive evaluation of cardiac function is an important aspect of

clinical echocardiography. Mitral, and Tricuspid inflow velocity (A/E ratio) are commonly used to evaluate left and right ventricular diastolic function. These velocities are recorded easily, and provide quantitative information about ventricular filling in a variety of conditions.[2-5] However, as inflow velocities depend on preload, some patients with severe diastolic dysfunction may exhibit a pseudo normal pattern of filling.[6] The doppler tissue imaging (DTI) is a new technique, which can optimize the anatomical, and functional aspects of CHD.[7] The annular velocity reflect the shortening and lengthening plane, and a decrease in early diastolic velocity recorded at the annulus. It has been shown to be associated with left ventricular pathology.[8,9] Nagaueh et al[10] demonstrated that diastolic annulus velocity is an index of left ventricular relaxation that is independent of preload. These reports have focused on the DTI pattern in left ventricular pathology, and little is known on the right ventricle (RV).[10] Our study focused on right ventricular dysfunction. We aimed to compare 2 methods of DTI and conventional pulsed doppler method for evaluation of right ventricular function with the data derived from catheterization, and show that the annular velocity of tricuspid measurement by DTI is a non-invasive index of right ventricular function in patients with CHD.

Methods. The study was carried out from April 2004-December 2005 at Pediatric Cardiac Research Center, Aliasghar Hospital, Zahedan, Iran. The study group consisted of 141 patients with CHD with, and without elevated right ventricular pressure. For all 141 patients 3 investigations were carried out. First, conventional doppler echocardiography was performed for the patients followed by DTI, and on the following day catheterization was performed for all, and we compared the data. The congenital anomalies included: aortic stenosis in one, atrial septal defect in 12, complete atrio ventricular septal defect in 2, aortic coarctation in 2, mitral valve stenosis in 3, patent ductus arteriosus in 9, primary pulmonary hypertension in 2, pulmonary stenosis in 6, total anomalous pulmonary venous return in one, single ventricle pulmonary hypertension in one, tetralogy of fallot in 22, double outlet RV in 7, ventricular septal defect in 73. All patients were in sinus rhythm, and the ones who had arrhythmia were excluded from the study. All parents received an explanation of the study and informed consent was obtained. Examinations were performed with subject in the supine position.

Tricuspid inflow. Two dimensional and doppler echocardiographic studies, with a Challenge 7000 Italy ultrasound system using either a 2.5/3.5, or 3.5/5 MHz transducer were performed and recorded on a strip chart recorder at 100 mm/seconds. The right ventricular inflow velocity was recorded from the apical 4 chambers view. The doppler sample volume was placed at the tips of the tricuspid valve leaflets. An electrocardiogram was simultaneously recorded in all patients, at a speed of 100 mm per seconds.

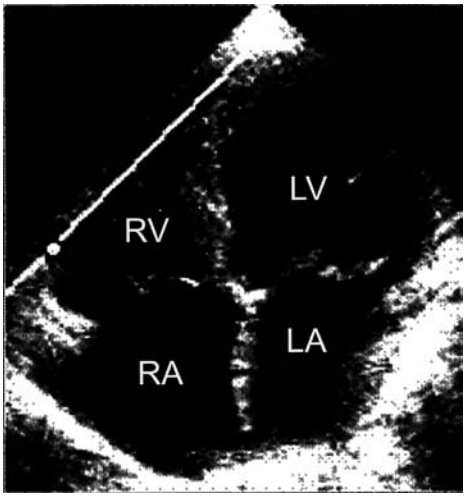

Figure 1 - Sample volume placed at the edge of the lateral tricuspid annulus, determined from the apical 4 chamber view for measurement of the tricuspid annular velocity by doppler tissue imaging. RV - right ventricle, LV - left ventricle, RA - right atrium, LA - left atrium

Table 1 - Pressure data derived at catheterization.

Pressure in cardiac chambers	No. of patients	Standard deviation	Mean
RVPS	141	37.82584	69.4357
RAPS	141	2.77917	7.1825
RAPM	141	1.59856	3.9416
RAPD	141	1.08849	3.5362
PAPD	141	16.97241	19.4748
DTI_T	141	0.39750	1.0968
RVPD	141	3.49898	9.0000
PAPM	141	25.31348	30.1007
PAPS	141	35.40013	44.1079

RVPS - right ventricular peak systolic pressure, RAPS - right atrial systolic pressure, RAPM - right atrial mean pressure, RAPD - right atrial diastolic pressure, PAPD - pulmonary artery diastolic pressure, RVPD - right ventricular diastolic pressure, PAPM - mean pulmonary artery pressure, PAPS - pulmonary artery systolic pressure

Doppler tissue imaging. The doppler tissue echocardiographic data were also obtained with Challenge 7000 Italy ultrasound using either a 2.5/3.5 or 3.5/5 MHz transducer. In each subject, the DTI of the right ventricular diastolic velocities was obtained from the apical echocardiographic window using 4-chamber view. The sample volume was placed at the

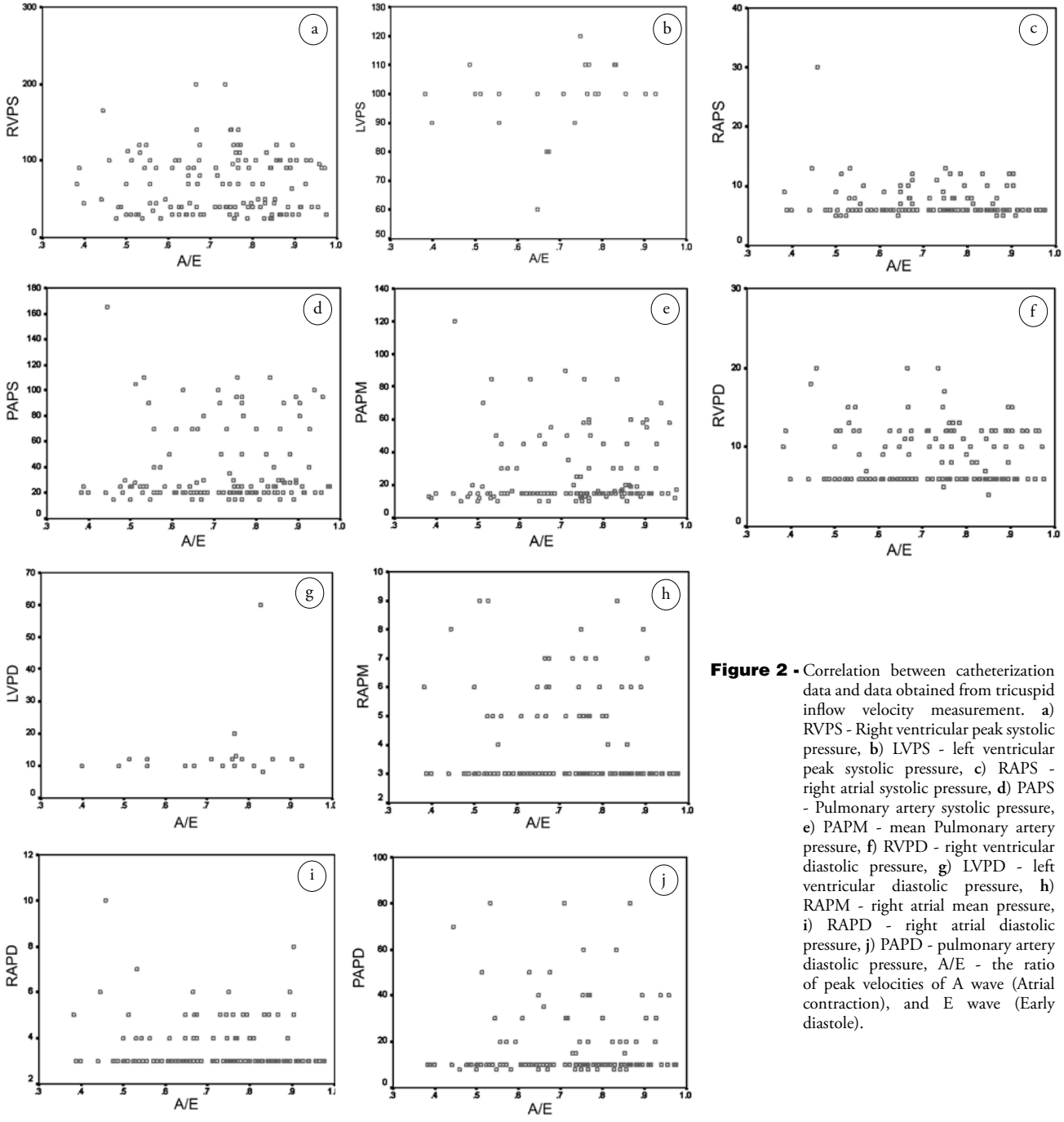

Figure 2 - Correlation between catheterization data and data obtained from tricuspid inflow velocity measurement. **a**) RVPS - Right ventricular peak systolic pressure, **b**) LVPS - left ventricular peak systolic pressure, **c**) RAPS - right atrial systolic pressure, **d**) PAPS - Pulmonary artery systolic pressure, **e**) PAPM - mean Pulmonary artery pressure, **f**) RVPD - right ventricular diastolic pressure, **g**) LVPD - left ventricular diastolic pressure, **h**) RAPM - right atrial mean pressure, **i**) RAPD - right atrial diastolic pressure, **j**) PAPD - pulmonary artery diastolic pressure, A/E - the ratio of peak velocities of A wave (Atrial contraction), and E wave (Early diastole).

edge of the lateral tricuspid annulus (**Figure 1**). From the pulsed doppler recordings, the peak velocity during early diastole (peak E wave), and during atrial contraction (peak A wave), and the ratio of peak velocities of A and E waves (peak A/E ratio) were measured. From the DTI the tricuspid annular velocity (Aa/Ea ratio) during early diastole (Ea wave), during atrial contraction (Aa wave), and ratio Aa/Ea ratio were measured. To minimize the effect of respiration on the variability in ventricular filling, Doppler measurements were obtained from 5-7 consecutive cardiac cycles.

Cardiac catheterization. Cardiac catheterization was performed in all patients on the following day after echocardiographic examinations. The following parameters were recorded: Right ventricular peak systolic pressure (RVPS), the right ventricular end diastolic pressure (RVEDP), pulmonary artery diastolic pressure (PADP), pulmonary artery systolic pressure (PASP),

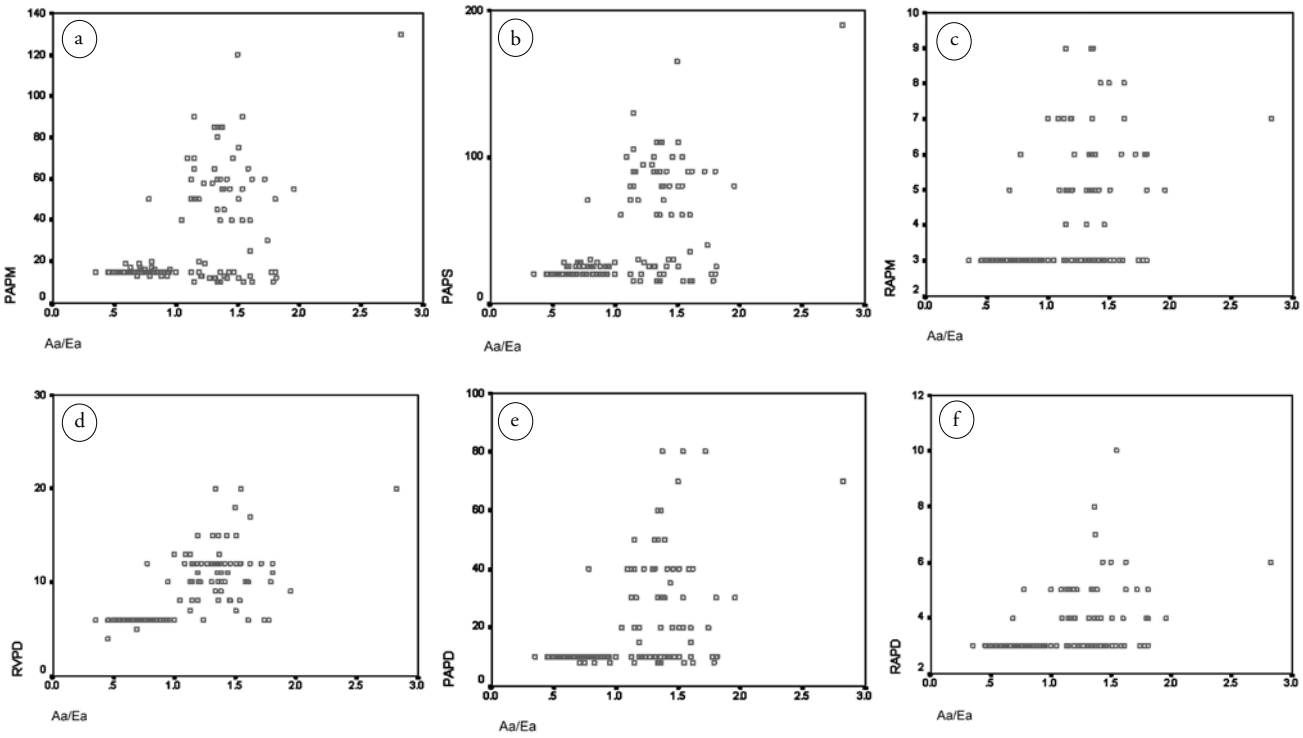

Figure 3 - Correlation between catheterization data and data obtained from Doppler Tissue Imaging. **a**) PAPM - mean Pulmonary artery pressure, **b**) PAPS - pulmonary artery systolic pressure, **c**) RAPM - right atrial mean pressure, **d**) RVPD - right ventricular diastolic pressure, **e**) PAPD - pulmonary artery diastolic pressure, **f**) RAPD - right atrial diastolic pressure, and Aa/Ea - The ratio of peak velocities of Aa wave (Atrial contraction) and Ea wave (Early diastole).

mean pulmonary artery pressure (MPAP), systolic atrial pressure (SAP), diastolic atrial pressure (DAP) and mean atrial pressure (MAP). Results are expressed as mean ±SD. The relationships between Aa/Ea ratio, and A/E ratio were determined by linear regression analysis in patients with CHD. Correlations were computed between hemodynamic variables of right ventricular function (RVPD, RVPS, PAPD, PAPS, PAPM, RAPD, RAPS, and RAPM), $p<0.05$ was considered statistically significant (**Table 1**).

Results. In this study, 141 patients with CHD were evaluated. The study was performed on 81 (57.48%) boys, and 60 (42.6%) girls with the age of 41± 39 months. All of them underwent conventional doppler echocardiography measuring A/E ratio and DTI was calculated. The day after echocardiographic examinations, catheterization was performed on all patients. The patients were divided into groups: with diastolic dysfunction, and without diastolic dysfunction. Unvaried analysis for comparison the mean of A and E and (A/E), Aa, and Ea, and (Aa/Ea) between the groups was used ($p<0.0001$). Tuki test was used to show significant difference between patients with CHD and diastolic dysfunction in comparison to the other group $p<0.0001$. Among 141 patients who underwent conventional doppler echocardiography none had diastolic dysfunction.

The DTI measurements revealed 77 patients with diastolic dysfunction, and 64 without diastolic dysfunction. At catheterization, 74 patients from 141 had diastolic dysfunction, 3 patients had false positive DTI echo findings, showing diastolic dysfunction, and one false negative. The sensitivity of this test is 95%, specificity 98%, positive predictive value 95%, and negative predictive value 98%, agreement rate with Kappa equation 87.2%, and Mac Nemar test ($p=0.18$). There was no significant difference between 2 methods of DTI, and findings of catheterization. The correlation between the hemodynamic parameters measured by catheterization, and conventional pulsed doppler method with A/E ratio were evaluated and it showed that there was no correlation between A/E ratio, and diastolic dysfunction data of catheterization. The A/E ratio did not correlate with RVP systolic ($p=0.97$), with RAP systolic ($p=0.53$), with PAP systolic ($p=0.7$), with PAP diastolic, ($p=0.7$), with RAP diastolic ($p=0.12$), and with PAP diastolic ($p=0.91$) (**Figure 2**). There was significant correlation between RVP systolic, and DTI ($r=0.69$, $p<0.0001$), RVP diastolic, and DTI ($r=0.69$,

p<0.0001), RAP diastolic, and DTI (r=0.41, p<0.0001), mean RAP, and DTI (r=0.44, p<0.0001), PAP systolic, and DTI (r=0.44, p<0.0001), PAP diastolic, and DTI (r=0.48, p<0.0001), mean PAP, and DTI (r=0.51, p<0.0001) (**Figure 3**).

Discussion. In children there is little information on the A/E ratio, and the DTI. In our study such correlation was examined. The disconnection between A/E and Aa/Ea was most evident in a patient with elevated RVP, and PAP, in whom A/E was low but Aa/Ea was high. This finding can be explained by the fact that Aa/Ea reflects structural mechanics, whereas A/E reflects fluid dynamics, which in turn reflects the ratio of filling that is greatly influenced by the right atrial pressure.[11] Among the best methods for evaluation of diastolic dysfunction is catheterization and direct measurement of pressure in cavities; however, echocardiography and increased ability of doppler for diagnosis, and complications of catheterization should be considered. Among 141 patients with CHD, 77 cases had diastolic dysfunction at DTI, 74 of them were approved by catheterization and one patient had a false positive result by DTI. In a study by Sohn et al[12] measurement of mitral annular velocity by DTI for evaluation of left ventricular diastolic function had a sensitivity of 88%, and specificity of 67%. In another study carried out by Meluzin et al[13] measurement of Ea/Aa for evaluation of right ventricular systolic function sensitivity of 90%, and specificity of 85% were reported. In a study carried out by Watanabe et al,[14] it was concluded that Aa/Ea index in tricuspid valve measured by DTI is a rapid non-invasive method for showing increased ventricular pressure in patients with CHD. In a study by Meluzin et al,[13] only Aa correlated with the mean right atrial pressure but not with the MPAP. There is no correlation between Ea with the MPAP, or with the mean right atrial pressure. Similarly Ea/Aa correlate neither with the MPAP nor with the MRAP. In our study there were no cases with diastolic dysfunction at conventional doppler echocardiography of A/E, but 74 at catheterization. There was no significant correlation between 2 methods. But, there was significant correlation between DTI, and catheterization findings. Of 141 patients, 77 had diastolic dysfunction measured by DTI, and 3 cases had false positive results of having diastolic dysfunction at DTI. Sensitivity, specificity, PPV, and NPV of DTI in comparison with catheterization is 95%, 98%, 95%, and 98%.

As it was assumed in the hypothesis of our study it seems that the accuracy of echo in evaluating diastolic dysfunction is equal to catheterization. Repeating the same study in another center can show the efficacy of DTI. According to the result, it can be proposed that in patients with CHD, DTI can be used for diagnosis of diastolic dysfunction. Even if there is need for diagnosis of anatomic lesions in unstable patients in centers without catheterization facility, echocardiography can be used for evaluating the potential for corrective surgery.

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