The Doppler echocardiographic assessment of valvular regurgitation in normal children

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SUMMARY: Ayabakan C, Özkutlu S, Kılıç A. The Doppler echocardiographic assessment of valvular regurgitation in normal children. Turk J Pediatr 2003; 45: 102-107.

To determine the frequency of valvular regurgitation, 174 children from birth to 18 years old (mean age 7.42±4.54 years), with structurally normal hearts were analyzed. Flow patterns across the four valves were examined by pulsed-(PW), continuous-wave (CW) and color Doppler.

Regurgitation was detected in 59.7% of the valves. Tricuspid regurgitation (TR) was most commonly found in 32.8% (n=57), pulmonary regurgitation (PR) in 17.2% (n=30), mitral regurgitation (MR) in 8.6% (n=15), and aortic regurgitation (AR) in 1.1% (n=2). The range of peak velocities of the regurgitant flow with CW were as follows: TR:0.98-2.54 m/sec, PR:0.50-1.80 m/sec, MR:0.72-2.30 m/sec, and AR:1.22-1.25 m/sec. The mean peak velocities of the regurgitant flow were similar with CW and PW measurements (p>0.05). The length of the regurgitant flow with color Doppler was less than 1 cm beyond the mitral and aortic valves. It reached up to 1.8 cm behind the pulmonary and 1.83 cm behind the tricuspid valves. Frequency of valvular regurgitation was unchanged with age (p>0.05). Tricuspid regurgitation was more frequent in males (40.9% versus 23.5%; p=0.016).

Regurgitation of tricuspid, pulmonary or mitral valves is relatively common in children with structurally normal hearts. Aortic regurgitation is scarce and the possible pathologic cause should always be carefully sought.

Key words: normal heart, children, physiologic valvular regurgitation.

Doppler echocardiography is currently a reliable, noninvasive, sensitive and specific technique for diagnosing valvular regurgitation[1-6]. The addition of color Doppler enables mapping of the regurgitant flow and guides while placing the Doppler beam parallel to the flow[6,7]. Recent studies have demonstrated that Doppler echocardiography is more sensitive than cardiac auscultation, especially when valvular regurgitation is mild[8-10]. A mild degree of valvular regurgitation is not uncommon in normal adults[1,11-13]. This finding has been a matter of great concern because misinterpretation of physiological valvular regurgitation is possible and can lead to iatrogenic heart disease[14].

To determine the frequency and characteristics of physiological valvular regurgitation in children, we studied 174 children with structurally normal hearts by color-coded, pulsed-and continuous-wave Doppler echocardiography.

Material and Methods

Study Population

The study group consisted of 174 children who were referred to our institution because of heart murmur (76.4%), chest pain (9.2%), syncope (8.6%), palpitation (3.5%) or other (2.3%) reasons. There were 93 male (53%) and 81 female (47%) subjects, ranging in age from 0 to 18 years (mean 7.42±4.54 years, median 7 years). Except for the soft, vibratory, early systolic murmur at the left sternal border in 133 children with innocent murmur, the results of physical examination of the cardiovascular system, the standard echocardiography (ECG) records and the chest x-rays were normal in all subjects.

Echocardiography

The examinations were performed with General

Electric Vingmed System Five Performance using 10 MHz, 3.5 MHz, and 2.5 MHz transducer probes while subjects were lying in supine position. The subjects were thoroughly scanned with M-mode and two-dimensional echocardiography. The definition of structurally normal heart included normal anatomy of the atria, ventricles, and great arteries with no evidence of chamber enlargement, ventricular hypertrophy, wall motion abnormalities or ventricular dysfunction. Valve leaflet morphology was carefully examined and even minor degrees of valve thickening or prolapsus were excluded. Flow patterns across the four valves were examined by continuous-(CW) and pulsed-wave (PW) Doppler imaging techniques. Color-coded Doppler imaging was performed in all instances to verify and quantify the regurgitant signals and to direct the pulsed-and continuous-wave Doppler beam. The pulsed-and continuous-wave Doppler was placed parallel to the regurgitant flow. The 2 mm sample volume of PW was placed at the tip of the turbulent color flow jet. For evaluation of tricuspid regurgitation, the apical four-chamber view was utilized. The apical four-chamber and parasternal long-axis views were used to detect mitral regurgitation. The apical five-chamber and long-axis views were used for detection of aortic regurgitation. Pulmonary regurgitation was examined in the parasternal short-axis view. The averages of the three consecutive measurements of peak CW flow and peak PW flow were taken respectively. The length of the regurgitant color flow jet (average of three consecutive measurements) from the tip of the measured valve was noted.

Statistical Analysis

Data are expressed as mean ± SD. The chi-square test was utilized to compare the frequencies of valvular regurgitation in male and female subjects. The paired t test was used to compare peak velocities of valvular regurgitation detected by PW and CW Doppler techniques. The Spearman's test was performed to assess the relation between valvular regurgitation and age.

Results

Evidence of regurgitation of one or more valves was detected in 93 subjects (53.4%) and in 104 valves (14.9%). Tricuspid regurgitation (TR) was detected in 57 children (32.8%). It was significantly more frequent in boys ($p=0.016$, 38 boys, 19 girls). Pulmonary regurgitation (PR) was found in 30 children (17.2%, 13 boys and 17 girls), mitral regurgitation (MR) in 15 children (8.6%, 8 boys, 7 girls), and aortic regurgitation (AR) in two children (1.1%, 1 boy, 1 girl). The frequency of valvular regurgitation was not correlated with age ($p>0.05$). The frequency of MR, AR or PR did not vary significantly with gender. Ten cases (5.7%) had incompetence of more than one valve. Two valves were involved in nine (tricuspid and pulmonary in 7 tricuspid and mitral 2 children), and three valves (mitral, tricuspid and pulmonary valves) were involved in one. The remaining children had single valve regurgitation, among them tricuspid regurgitation (TR) in 47 of 93 children (50%), pulmonary regurgitation (PR) in 22 cases (24%), mitral regurgitation (MR) in 12 cases (13%), and aortic regurgitation in 2 cases (2%) (Fig. 1). Figures 2 and 3 demonstrate physiologic mitral and aortic regurgitation respectively.

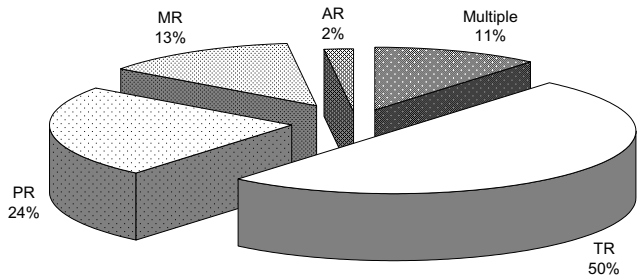

Fig. 1. The frequencies of valvular regurgitation in the study population.
TR: tricuspid regurgitation. PR: pulmonary regurgitation.
MR: mitral regurgitation. AR: aortic regurgitation.
Multiple: regurgitation in multiple valves.

Fig. 2. Physiologic mitral regurgitation.
LA: left atrium.
LV: left ventricle.

Fig. 3. Physiologic aortic regurgitation. The arrow depicts the regurgitant flow (AR).
LV: left ventricle.
LA: left atrium.
Ao: aorta.

Table I. Peak Velocities of Regurgitant Flow Measured by Continuous-and Pulsed-wave Doppler Techniques

	Continuous-wave doppler (m/sec)	Pulsed-wave doppler (m/sec)	p
Tricuspid regurgitation	1.78±0.94	1.81±0.58	>0.05
	range 0.99-2.54	range 1.06-2.22	
Pulmonary regurgitation	1.13±0.32	1.11±0.30	>0.05
	range 0.50-1.80	range 0.50-1.76	
Mitral regurgitation	1.51±0.60	1.70±0.70	

The peak velocities of regurgitant flow in different valves are depicted in Table I. The difference in velocities measured by CW and PW Doppler was not statistically significant ($p>0.05$). Maximum velocity of the regurgitant flow was ≤2.54 m/sec in all the valves with PW or CW Doppler. The length of the regurgitant flow with color Doppler was less than 1 cm beyond the mitral and aortic valves. It reached up to 1.8 cm behind the pulmonary and 1.83 cm behind the tricuspid valves.

Discussion

Most previous studies of valvular regurgitation in structurally normal hearts have been limited to adults, and the prevalence of valvular regurgitation detected by Doppler echocardiography markedly varies in normal individuals[1,11,13,15]. Comparison of these studies is not possible due to differences in the technique used, the definition of regurgitation and the caharacteristics of the study population. For instance, Yoshida et al.[7] defined valvular regurgitation when its duration was more than 100 msec with M-mode color flow mapping, whereas the regurgitant flow had to have a duration of more than 200 msec and a velocity exceeding 1.2 m/sec in studies of Brand et al.[6] and Choong et al.[16].In the present study, we based our definition of regurgitation on the presence of typical flow disturbance visualized with color Doppler, rather than the duration of the regurgitant flow. Van Dijk et al.[14] similarly used color-Doppler while detecting right-sided valvular regurgitation in children. Using unguided PW or CW Doppler may be very time consuming and it may be difficult to demonstrate the eccentric or trivial regurgitation[14]. Still, the artifacts caused by valve closure, which have a very short duration, should be carefully ruled out[14,16].

The present study reveals that physiological valvular regurgitation is most commonly observed in the tricuspid valve among children (32.8%), followed by pulmonary regurgitation (17.2%). Although the frequencies vary, this is concordant with some of the pervious studies[6,16,17]. It is likely that no single factor is responsible for the marked variability in the reported prevalence of right-sided regurgitation in normal subjects. The frequency of right-sided regurgitation may be related to the degree of physical conditioning[18]. Body habitus may also affect the ability to detect right-sided regurgitation. In individuals with a narrow chest, the transducer can be positioned closer to the right side of the heart, thereby increasing the likelihood of detection of the regurgitation[1].

Most studies have shown a preponderance of right-sided regurgitant flow in normal subjects[1,6,11,17]. The lower frequency of mitral and aortic regurgitation seems to indicate better preservation of the left-sided valvular integrity during childhood[6]. Physiological aortic regurgitation is an unusual finding and was only reported in studies concerning normal adult subjects[1,11]. Our results suggest that left-sided regurgitation in children should be carefully sought. The presence of aortic regurgitation especially should always raise the suspicion of valvular disease.

The peak velocity of the regurgitant jet is related to the pressure difference between the two chambers. Normal systolic pressure in the left ventricle is generally >100 mmHg, whereas left atrial pressure is <12 mmHg. In mitral regurgitation, based on the modified Bernoulli equation, this pressure difference should result in a peak regurgitant velocity >4 m/sec. Berger et al.[1] offered two possible explanations for this. One is that the highest velocities were recorded because of a weak Doppler signal. The second is that the modified Bernoulli equation may not apply to the small regurgitant orifices present in normal subjects. The second theory is more likely, since Holen et al.[19] have demonstrated that when the orifice diameter is <1.5 mm, viscous friction may result in a peak velocity that is lower than expected.

There is agreement among color, pulsed-, and continuous-wave Doppler imaging techniques in evaluating regurgitant flow patterns. In children, however, color Doppler imaging is the method of choice for diagnosis of valvular regurgitation. In insignificant or mild degrees of regurgitation, neither PW nor CW Doppler contributes much to the diagnosis[6]. In the present study PW and CW Doppler contributed in determining the characteristics of the regurgitant flow. Maximum velocity of the regurgitant flow was ≤2.54 m/sec in all the valves with PW or CW Doppler. The length of the regurgitant flow with color Doppler was less than 1 cm beyond the mitral and aortic valves. It reached up to 1.8 cm behind the pulmonary and 1.83 cm behind the tricuspid valves, which corresponded

to "first-degree regurgitant flow" in all the valves according to the studies by Miyatake et al.[20] (mitral regurgitation) and Takamoto et al.[21] (tricuspid and aortic valve regurgitations). These findings are extensively in agreement with previous studies. Therefore, Doppler-detected mitral, tricuspid and pulmonary regurgitation with these characteristics can be a normal or physiologic finding.

Although there is evidence that valvular regurgitation increases with age[13], in the present study, frequency of valvular regurgitation was unchanged with age ($p>0.05$). Tricuspid regurgitation was more frequent in males ($p=0.016$). This result differed from other studies where no gender preference was observed for valve regurgitation.

Since our study population was mostly comprised of children with innocent murmur, the absence of a control group may be a limitation of this study. We do not believe this is a major limitation, however, since Van Dijk et al.[14] demonstrated in a controlled study that in children having innocent murmur, the prevalence of valvular regurgitation was not increased. The present study is one of the rare studies concerning a large group of pediatric patients with a wide spectrum of age (from birth to 18 years old).

We conclude that valvular regurgitation occurs commonly in children with structurally normal hearts. The low velocity (≤1.5 m/sec) of the regurgitant flow measured by PW or CW Doppler within the vicinity of the valve (not beyond 1 cm in left-sided valves, reaching up to 1.83 cm in right-sided valves) is the characteristic of a physiological valve regurgitation. Aortic regeurgitation is rarely found in a normal individual and its presence should always raise suspicion of valvular heart disease. It is important that no clinical decision be based on detection of regurgitant flow by Doppler examination, but rather should be correlated with clinical findings. The questions of whether the frequency of valvular regurgitation increases with age, and of the outcome of mild physiologic regurgitation can best be addressed with longitudinal follow-up studies.

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