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FUNCTIONAL DOPPLER ECHOCARDIOGRAPHY IN EVALUATING DEGREE AND TENSION OF ADAPTATION

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Abstract. To reveal hemodynamic peculiarities in apparently healthy children with cuspid valvular dysfunctions or pulmonary arterial regurgitation, 76 children and juveniles, aged 6-18, were examined by Doppler echocardiography in supine and upright position. Whereas an optimal coordination of intracardiac hemodynamic parameters at supine position and minimum pronounced orthostatic response was observed in children with normal valvular kinesis, the most tense orthostatic response occured in combined prolapse of mitral, tricuspid and pulmonary arterial valves. We suppose, that certain characteristics of valvular kinesis reflect tension of adaptation and can be used by pediatricians and juvenile therapists in their clinical experience.

Key words: valvular dysfunctions, tension of adaptation, orthostatic response, apparently healthy children

Introduction

Although Doppler echocardiography is now a routine investigation technique, its diagnostic potentialities, based on new approaches to obtaining and interpreting some parameters characteristics of intracardiac hemodynamics, are far from being exhausted. The most popular cardiological diagnosis in children and juveniles - mitral valve prolapse (MVP) - is commonly associated with congenital or acquired connective tissue defects [1] , and no clinical significance is usually attached to pulmonary arterial regurgitation (PAR), revealed by color mapping in 98% of healthy individuals [2].

Cases of vasoneurosis accompanied by syncope, which are frequently encountered by pediatricians and juvenile therapists, required clinical and prognostic assessment of regulation mechanisms at postural changes, being a natural disturbance factor for circulation. Mathematical analysis of cardiac rhythm, commonly used for this purpose, despite of its obvious merits [3], gives no idea which specific autoregulation mechanisms are involved during orthostatic response.

Since studies, investigating peculiarities of hemodynamics in children and juveniles with cuspid valve prolapse, are not numerous [4-6], and, actually, no data is available concerning changes in intracardiac flows during postural response, the main concern of the present work was to study intracardiac hemodynamics in children and juveniles with various valvular dysfunctions, both at rest and postural changes.

Materials and Methods

Using Doppler echocardiographic findings (Hewlett - Packard 77020A, Acuson 128XP) of 76 apparently healthy children and juveniles, aged from 6 to 18, without organic

heart diseases and congenital/acquired connective tissue defects, 8 groups were distinguished according to kinesis of cuspid valves and presence of PAR.

The following parameters were evaluated:

– atrial and ventricular dimensions at diastole, including the relative ones (by sq. m of body surface area);
– left ventricular posterior wall thickness (LVPWT) and intraventricular septal thickness (IVST) at diastole;
– relative dimensions of the aorta (Ao) and pulmonary artery (PA).

And some hemodynamic parameters, too:

– aortic and pulmonary arterial systolic flow velocities (including acceleration period, AP);
– left and right transatrioventricular flow velocities (V) and time (T) at early diastole (Ve) and atrial systole (Va), and their ratio (Ve/Va);
– ejection period (E);
– isovolumic relaxation time (IVRT) of the left and right ventricles.

Atrial filling was estimated by trans-thoracic Doppler echocardiography on the basis of forward flow velocities measured in ostia of the pulmonary vein and vena cava at systole (Svp and Svc) and ventricular diastole (Dvp and Dvc), as well as a reverse flow velocities in these veins at atrial systole (Vreg) obtained by placing a sample (volume 1-2 cm) proximal to the junction of the veins into atrium [7, 8].

Immediately after changing to upright position (right and left chamber hemodynamic parameters being previously evaluated) we measured peak atrial and ventricular filling velocities, and PA and Ao flow velocities, noting whether regurgitation through cuspid valves persists or emerges.

Along with determining the reliability of distinction using Student's t-test, correlational analysis was made.

Results and Discussion

Since morphometric dimensions of ventricles and atriums, Ao and PA diameters, and LVPW and IVS thickness in all examined children were consistent with commonly accepted age standards, and cardiac cycle duration in distinguished groups had no reliable distinction, only Doppler echocardiographic findings were analysed. The efficiency of cardiac output activity was estimated on the basis of flow velocity in the ascending Ao, which was the highest (102.0±3.3 cm/s) in children with normal valvular kinesis.

Although in isolated PAR Ao flow velocity did not decrease, contribution of the right atrium in RV filling was reliably higher (RV late diastolic filling velocities are 45.2±3.0 and 34.3±3.5 cm/s, respectively), PA flow acceleration period was longer, the ratio of systolic to diastolic flow velocities in pulmonary veins was less, and LV filling velocity at early diastole was higher, - all these can be regarded as a result of systemic autoregulation, essentially relevant to diastole.

Efficiency of LV output activity in MVP, MVP+PAR, tricuspid valve prolapse TVP+PAR and MVP+TVP does not decrease either, being ensured by various autoregulation mechanisms: the increase in LV Ve in MVP, MVP+PAR and TVP+PAR, and PA V in TVP+MVP; the increase in time parameters: late diastolic filling flow acceleration and PA flow acceleration periods in TVP+PAR, as well as the decrease in RV Ve/Va ratio in MVP+TVP. The increase in RV isovolumic relaxation time in children with MVP+TVP may manifest the presence of a moderate pulmonary hypertension in this group.

In TVP the decrease in LV activity effectiveness is observed: Ao flow velocity is lower (88.3±2.3 cm/s), as well as Dvp (35.3±2.3 cm/s vs 44.3±2.4 cm/s), RV Ve (57.6± 3.0 cm/s vs 68.4 ±2.6 cm/s) and LV Va (40.1±2.6 cm/s vs 53.3±3.8 cm/s). The decrease in Ao

flow velocity (88.5±2.5) and absence of compensation is indicative of a significant reduction of functional reserves in children and juveniles with MVP+TVP+PAR.

It should be noted, that, whereas RV Ve/Va ratio in children without valvular dysfunctions was 2.04±0.20, in children with PAR and MVP+TVP it was reliably lower (1.50±0.13 and 1.50±0.15) due to the increase in Va, that indicates RV diastolic dysfunction. Values of LV ve/Va ratio had no differences in all groups.

Correlational analyses revealed different density and direction of correlations between systemic elements at rest in different groups. Thus, the greatest quantity of correlations (121) was observed in children without valvular dysfunctions, 45 - in PAR, 32 - in MVP, 36 - in MVP+PAR, 13 - TVP, 64 - in TVP+PAR, 21 - in MVP+TVP and 38 - in MVP+TVP+PAR. Although a large quantity of positive correlations may reduce a number of degrees of freedom in the system, close interrelations between venous returns (RA filling velocity at diastole) and RV Ve, and temporal and velocity parameters of the left chambers (both atrium and ventricle) probably suggest, that optimal regulation of intracardiac hemodynamics does exist.

In children with PAR, which causes some changes in RV filling, RV Ve is not connected with left chamber hemodynamic parameters, though RV Va positively relates to diastolic flow velocity in pulmonary veins and LV Va. The higher systolic flow velocity in vena cava in children with MVP, the lower Ao flow velocity; on the contrary, the higher RV Va (as in TVP+PAR), the higher Ao flow velocity. However, in MVP+PAR, TVP and MVP+TVP+PAR venous returns and RV filling velocities have no effect on left chamber hemodynamics. Probably hemodynamic mechanisms of pulmonary circulation appear to take more significant part in cardiac output autoregulation.

The best regulation at orthostasis was observed in children without valvular dysfunctions: cardiac cycle was moderately reduced from 83.1±6.2 s to 74.8±5.1 s, and hemodynamic parameters, which have changed (decreasing Ve of both ventricles, Dvp and Ve/Va, and increasing S/Dvp), was less in number, compared with other groups (Tables 1 and 2). In this group 161 correlations between different hemodynamic parameters at orthostasis were revealed, in PAR - 74, in MVP - 68, MVP+PAR - 76, TVP - 55, TVP+PAR - 72, MVP+TVP - 46 and MVP+TVP+PAR - 100.

Table 1. Right chamber hemodynamic parameters in children and juveniles with various valvular dysfunctions (M±m).

Group/parameter	RV Ve, supine position	RV Ve, upright position	RV Va, supine position	RV Va, upright
Withouth valvular dysfunction, (n=6)	68.4±1.6	49. 4±2.8*	71.2±5.8	67.1±4.3
PAR (n=9)	66.4±6.2	57.5±3.5	78.9±5.5	63.8±2.8*
MVP (n=7)	65.0±5.8	54.5±3.5	75.8±3.1	65.1±3.2*
MVP+PAR (n=7)	74.5±5.3	50.5±5.1**	76.8±4.9	79.7±6.2
TVP(n=10)	62.4±4.4	59.9±6.0	69.8±2.0	61.4±2.6*
TPV+PAR (n=11)	66.7±3.7	57.2±3.6	80.2±4.8	71.3±2.8
MVP+TVP (n=10)	61.2±2.3	49.8±2.5*	77.6±3.9	71.6±4.7
MVP+TVP+PAR (n=15)	63.3±3.3	52.1±2.4*	76.1±3.3	69.4±1.9

Reliability of distinction compared to supine position: ∗-P < 0.05; ** - P<0.01.

Table2. Left chamber hemodynamic parameters in children and juveniles with various valvular dysfunctions (M±m).

Group/parameter	LV Ve, supine position	LV Ve, upright position	LV Va, supine position	LV Va, upright
Withouth valvular dysfunction, (n=6)	87.4±6.2	69.4±4.1*	47.7±6.3	44.8±2.9
PAR (n=9)	102.0±3.6	71.1±7.3**	46.5±4.8	57.0±4.8
MVP (n=7)	101.7±7.3	70.9±2.7**	50.0±2.9	50.1±4.0
MVP+PAR (n=7)	106.0±4.5	74.6±1.9***	46.0±4.7	48.8±5.2
TVP(n=10)	93.1±2.1	64.2±4.2***	44.2±1.8	52.3±2.8*
TPV+PAR (n=11)	104.4±5.1	78.7±2.9***	50.0±3.0	60.8±2.8*
MVP+TVP (n=10)	90.4±3.5	67.8±3.2***	50.7±4.2	55.5±4.1
MVP+TVP+PAR (n=15)	94.0±5.2	74.7±4.5**	45.7±3.8	58.5±3.0*

Reliability of distinction compared to supine position: *-P < 0.05; ** - P<0.01; *** - P<0.001.

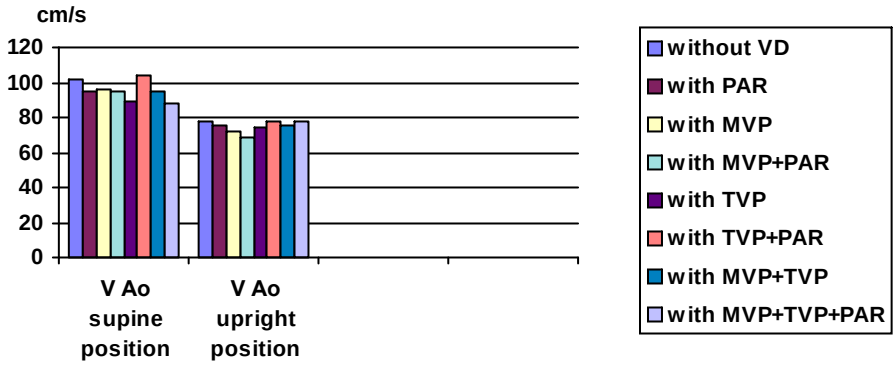

Fig. 1. Dynamics of aortic flow velocity in upright and supine position in children with various valvular dysfunctions.

In children and juveniles with TVP and TVP+PAR an excessive vegetal responsiveness, accompanied by further shortening of RR at orthostasis and deceleration of Svp (venous return), was observed, and Dvp and LV Va reduction was highly reliable (P<0.001), as well as AP and Ao V shortening. These can form a pathophysiologic basis for syncope and indicate poor regulation.

For children and juveniles with MVP+TVP+PAR changing from supine to upright position (“getting up”) is a stressful disturbance, resulting in marked changes in intracardiac parameters: the decrease in Ve of both ventricles and drastic intensification of hemodynamic activity of right and left atriums, followed by the reduction of cardiac output.

The fact, that in 3 of 7 children with MVP regurgitation through the tricuspid valve emerged in upright position at rest, seems to be rather important: this may indicate locus minoris resistentiae in autoregulation at rest. In 4 of 11 children withTVP+PAR regurgitation through the tricuspid valve persisted also at orthostasis, in 2 - through PA. This phenomenon with similar frequency (in 4 of 10 children) occured in MVP+TVP and in MVP+TVP+PAR (in 7 of 15). In children with persisted regurgitation through the tricuspid valve more

pronounced changes in all parameters of both right and left chambers were observed, that can be treated as a reduction of functional reserves.

Orthotest gave the opportunity to get an exact idea of the significance of isolated PAR in children without any signs of organic heart deseases. A marked disturbance of left ventricular hemodynamics (pronounced diastolic dysfunction) and the decrease in aortic flow velocity from 100.0±0.8 to 75.4±2.7 cm/s ($P<0.01$) at upright position manifest reduction of adaptation reserves and necesitate recuperative measures.

Thus, kinesis of cuspid valves and PAR not only characterizes a certain hemodynamic status, but also reflects the function of systemic autoregulation mechanisms, and Doppler echocardiographic assessment of orthotest can give pediatricians, juvenile and sport therapists valuable clinical information.

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ФУНКЦИОНАЛЬНАЯ ДОППЛЕРЭХОКАРДИОГРАФИЯ В ОЦЕНКЕ УРОВНЯ И НАПРЯЖЕННОСТИ АДАПТАЦИИ

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В настоящее время допплерэхокардиография широко применяется для изучения параметров, характеризующих внутрисердечную гемодинамику. Однако можно утверждать, что диагностические возможности этого метода далеко не исчерпаны, возможно использование новых подходов к получению и интерпретации ряда параметров сердечной деятельности. Самый популярный кардиологический диагноз в детском и подростковом возрасте – пролапс митрального клапана (т.е. избыточное

прогибание его створок в полость левого предсердия с их размыканием в определенный момент систолы) обычно связывается с врожденным или приобретенным поражением соединительной ткани, а выявляемой у 98% здоровых лиц регургитации (выраженному обратному течению крови) на легочной артерии обычно не придается клинического значения. В ряде случаев для клинической и прогностической оценки качества регулирования кровообращения требуется рассмотреть изменение положения тела в пространстве, что для системы кровообращения является естественным возмущением. Целью настоящего исследования являлось применение метода допплерэхокардиографии для изучения внутрисердечной гемодинамики у детей и подростков с различными клапанными дисфункциями как в покое, так и при изменении положения тела.

Были обследованы 76 практически здоровых детей и подростков в возрасте от 6 до 18 лет без признаков органического поражения сердца, а также наследственной или приобретенной неполноценности соединительной ткани.

Определялись диагностические размеры предсердий и желудочков, в том числе относительные (на $м^2$ площади поверхности тела) толщина задней стенки левого желудочка и межжелудочковой перегородки в диастоле, относительные размеры аорты и легочной артерии, а также скорости систолических потоков в этих сосудах, скорость и длительность потоков через левый и правый атриовентрикулярный клапаны в ранней диастоле и т.д.

Сразу после перехода из горизонтального в вертикальное положение измеряли пиковые скорости наполнения предсердий и желудочков, а также скорости потоков в легочную артерию и аорту, при этом обращали особое внимание на сохранение или возникновение регургитации на створчатых клапанах.

Исследование в положении лежа и стоя показало, что оптимальная согласованность параметров внутрисердечной гемодинамики и менее напряженная реакция адаптации наблюдались у детей с нормальной кинетикой клапанов, в то время как наиболее напряженная – у детей с сочетанным поражением створок митрального, трикуспидального и клапана легочной артерии. Получены количественные закономерности указанных наблюдений. Библ. 8.

Ключевые слова: допплерэхокардиография, внутрисердечное кровообращение, адаптация системы кровообращения, клапанные дисфункции

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