Russian Journal of Biomechanics, № 1: 47-52, 1999

LEFT AND RIGHT HEART CHAMBERS INTERACTION IN HEALTHY YOUTH

Yu.L. Venyovtseva, A.Ch. Melnikov, V.V. Revyakina, T.A. Gomova, N.A. Pukhanova

Scientific Research Institute of New Medical Technologies, Clinical and Diagnostic Centre of Tula Regional Hospital, 140, Engels street, 300008, Tula, Russia

Abstract. To reveal correlations between functional parameters of the right and left heart chambers and their clinical value in Doppler echocardiographic findings 80 children of 7-9, 10-12 and 13-15 years without organic heart diseases were examined. The study demonstrated the significant role of the right chambers in left ventricular pumping function efficiency, as well as the importance of measuring right atrium and pulmonary artery dimensions and flow velocities in venae cavae and pulmonary veins for assessment of hemodynamic tension, both in healthy people and cardiac patients, especially during dynamic investigations.

Key words: Doppler echocardiography, right atrium, pulmonary artery, left chambers, correlation

Introduction

Modern methods of clinical physiology, and Doppler echocardiography in particular, give the opportunity to obtain numerous morphologic and functional parameters, characteristic of the cardiac activity [1,2]. Both in previous and recent studies [3,4] the attention is mainly focused on estimating left ventricle (LV) parameters, perhaps due to limitations of one-dimensional scanning in visualization of the right chambers. In any case, a close interaction of the left and right chambers, vividly demonstrated by invasive experiments on animals [5], is not taken into account in clinical interpretation of obtained findings.

Last clinical investigations revealed some morphologic and functional peculiarities of the cardiac activity in children and juveniles adapted to exercise (i.e. young sportsmen), dimensions of the pulmonary artery and the right atrium being obviously larger in young sportsmen than in untrained children of the same age, and similarly the occurence of tricuspid valve prolapse appeared to be higher [6,7].

However, the problem of interconnections of the right and left heart chambers and complex clinical assessment of Doppler echocardiografic findings in healthy individuals doesn't seem to be adequately investigated.

Materials and Methods

Doppler echocardiography was performed by means of Hewlett Packard 77020 A and Acuson 128 XP/10 equipment in 80 children without organic heart diseases: 15 children aged 7-9 (11 boys and 4 girls), 21 aged 10-12 (9 boys and 12 girls) and 44 aged 13-15 (24 boys and 20 girls).

The following parameters were evaluated:

- dimensions of left and right atriums (LA and RA) and ventricles (LV and RV) at diastole, including the relative ones (by m^2 of body surface area);
- the thickness of the left ventricular posterior wall (LVPWT) and the ventricular septum (IVS) at end diastole;

- relative dimensions of the aorta (Ao) and the pulmonary artery (PA).

And some hemodynamic parameters, too:

- peak aorta and pulmonary artery systolic flow velocities and duration (including acceleration period, AP);
- transmitral and transtricuspidal flow velocities and duration at early diastole (Ve, Te) and atrial systole (Va, Ta), and their ratio (Ve/Va);
- ejection period (E);
- isovolumic relaxation time (IVRT) of the left and right ventricle.

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 reversal flow velocities in these veins at atrial systole (Vrev) obtained by placing a sample volume 1-2 cm proximal to the junction of the veins into atrium [8,9].

Statistical processing of the results included determining the reliability of distinctions using Student's t-test and correlational analysis (only reliable correlations were taken into account).

Results and Discussion

Peak intracardiac flow velocities in children of different age groups are presented in Table 1, duration of cardiac periods - in Table 2. There are no differences in early-diastolic filling velocities of both ventricles and end-diastolic filling velocities of LV in children of all age groups. But in boys of 13-15 RV Va is reliably higher than in children of 7-9 and 10-12. The ratio of transmitral to transtricuspidal flow velocities is the same in all age groups and in agreement with those mentioned in the literature [1]. However, whereas RA filling velocity at right ventricular systole does not differ, Dvc is reliably higher in girls of 13-15 than in younger children. PA flow velocity is the same in children of all age groups. In boys of 13-15 Ao flow velocity is higher, that conforms to increased contractility of LV and diastolic pulmonary venous flow velocity. It is interesting to note, that no reliable differences in the pulmonary venous flow velocities at systole are observed in children of different ages.

Table 2 presents durations of some ventricular periods, which demonstrate no reliable distinctions in age groups of 7-9 and 10-12, as well as in boys and girls of 13-15 (there was no difference in cardiac cycle duration, too). In boys of 13-15, comparing to children of 7-9, RR is reliably higher, RV rapid filling period is larger and it is shorter at RA systole, IVRT of both ventricles being independent on children's age.

Since clinical cardiology considers the decrease in the ratio of early to late ventricular filling velocities one of the most popular parameters characteristic of diastolic function, impairing of which typically heralds some disturbances in pumping function of LV [3,4], the correlation analysis was performed in order to reveal the influence of various intraventricular hemodynamic factors on early and late diastolic filling velocities of both ventricles, and on their ratio, too.

In children of 7-9 the less Ao diameter, the higher RV Ve ($r=0.57$); in children of 10-12 the more left ventricular enddiastolic volume (LVEDV) /m^2, the higher RV Ve ($r=0.45$); in boys of 13-15 RV Ve is higher when LV filling velocity at early diastole is higher ($r=0.41$), LV ejection period is longer ($r=0.54$, $P<0.01$) , Ao is wider ($r=0.57$, $P<0.01$) and IVS is thicker ($r=0.49$). In this group we revealed positive correlations between RV Ve and reversal flow velocity both in venae cavae and pulmonary veins. In girls of 13-15 there were positive correlations between RV Ve and LV Va and Spv.

Table 1.
Peak flow velocities in healthy children of different age groups obtained by Doppler echocardiography, cm/s (M ± m)

	Age group			
Velocity values	7-9 years (n=15)	10-12 years (n=21)	13-15 years boys (n=24)	13-15 years girls (n=20)
RV Ve	64.3±3.2	63.2±2.4	67.3±2.7	67.4±2.9
RV Va	28.4±1.3	29.7±1.9	33.5±1.6*	31.2±1.9
RV Ve/Va	1.90±0.09	1.81±0.11	1.76±0.08	1.80±0.11
Venae cavae systolic flow	45.3±2.3	46.0±2.6	51.4±2.8	52.7±2.1
Venae cavae diastolic flow	38.9±3.2	44.3±3.5	45.8±2.2	49.0±3.3*
Pulmonary arterial flow	72.4±2.7	78.0±1.8	80.0±2.5	75.4±2.5
LV Ve	90.6±4.3	92.1±2.1	92.0±4.8	99.8±3.1
LV Va	40.6±3.3	45.5±2.4	39.0±2.3	41.8±4.8
LV Ve/Va	2.27±0.16	2.04±0.10	2.35±0.16	2.25±0.17
Pulmonary venous systolic flow	42.2±4.1	43.4±2.4	45.7±2.6	45.6±2.8
Pulmonary venous diastolic flow	58.3±2.1	54.3±2.1	64.2±2.6**	53.4±3.1
Aortic flow	92.1±2.6	95.3±2.6	109.6±3.0**	99.4±3.6

Reliability of distinction: * $P < 0.05$, ** $P < 0.01$.

In children of 7-9 RV late diastolic filling velocity is higher, when PA diameter (r=0.59) and LVED diameter (r=0.59) are larger. In age group of 10-12 this filling velocity value determines Ao flow velocity (r=0.58), stroke index (SI) (r=0.44) and ΔS (r=0.48), i.e. parameters characteristic of the LV pumping function.

In boys of 13-15 RV Va positively correlates to PA flow velocity (r=0.50) and to some morphologic and functional parameters of the left chamber: Ao flow velocity (r=0.56, P<0.01), LV PW thickness (r=0.43), pulmonary venous reversal flow velocity (r=0.47); and negatively - to RR (r=0.43). All these correlations confirm the fact, determined in adults: when cardiac cycle shortens, late diastolic filling velocities increase [1].

In girls of 13-15 correlations are a bit different. Thus, there are positive correlations between RV Va and systolic flow velocity in venae cavae (r=0.48) and LV IVRT (r=0.49), and negative ones between RV Va and LV SI (r=0.51).

Whereas in children of 7-9, 10-12 and in girls of 13-15 no interconnections between RV Ve/Va and left chamber parameters are detected, in boys of 13-15 this ratio positively correlates to LV E duration and LV Ve/Va.

Table 2.

Duration of ventricular periods in healthy children of different age groups, s (M ± m)

Parameters	Age group			
	7-9 years (n=15)	10-12 years (n=21)	13-15 years boys (n=24)	13-14 years girls (n=20)
RR	0.74±0.03	0.80±0.03	0.89±0.04*	0.83±0.03
RV rapid filling	0.21±0.008	0.23±0.01	0.24±0.008*	0.23±0.009
Filling at RA systole	0.20±0.01	0.18±0.008	0.16±0.006*	0.18±0.009
Pulmonary arterial flow	0.29±0.007	0.29±0.007	0.30±0.005	0.29±0.006
Flow acceleration period in PA	0.12±0.005	0.13±0.006	0.14±0.005	0.14±0.005
LV rapid filling	0.19±0.008	0.21±0.007	0.24±0.01*	0.23±0.01*
Filling at LA systole	0.17±0.008	0.18±0.007	0.16±0.01	0.15±0.007
Aortic flow	0.27±0.006	0.27±0.005	0.28±0.005	0.27±0.006
Flow acceleration period in Ao	0.10±0.004	0.10±0.004	0.09±0.004	0.09±0.004
RV isovolumic relaxation time	0.06±0.004	0.06±0.006	0.06±0.005	0.055±0.004
LV isovolumic relaxation time	0.07±0.006	0.07±0.004	0.07±0.004	0.07±0.04

Reliability of distinction: * $P<0.05$.

Peak velocity of LV early diastolic filling in age group of 7-9 is appeared to be positively correlated only to left chamber parameters: Ao dimension ($r=0.73$, $P<0.01$), Dvp ($r=0.88$, $P<0.01$) and LV PW thickness ($r=0.58$). In children of 10-12 positive correlations of LV Ve to RV Te ($r=0.42$) and to Dvc velocity ($r=0.41$) are observed. In boys of 13-15 the higher LV Ve, the less LVEDV/m^2 ($r=0.40$), the shorter LV IVRT ($r=0.40$) and the higher RV Va ($r=0.40$). In girls of 13-15, as in children of 7-9, no correlations between LV Ve and the right chambers are revealed.

In children of 7-9 LV Va, as well as LV Ve, correlates only to functional parameters of the left chamber (positively - to Ao dimension and Ao flow acceleration time, and negatively - to LV IVRT). In children of 10-12, along with the positive correlation with Ao dimension ($r=0.69$, $P<0,01$) and the negative one with LA dimension ($r=0.43$), LV filling velocity at LV systole positively relates to RA dimension ($r=0.58$) and reversal flow velocity in venae cavae ($r=0.47$).

In boys of 13-15 LV Va is higher, when SI ($r=-0.48$) and LVEDV/m^2 ($r=-0.44$) are lower and Ao is wider ($r=0.42$). Moreover, positive correlations between this parameter and RV Ve ($r=0.41$) and RV Ta ($r=0.40$) are revealed. In girls of 13-15, as well as in boys of this age, there is a positive correlation between LV Va and RV Ve ($r=0.46$) and PA flow velocity ($r=0.66$).

LV Va/Ve ratio depends on many hemodynamic factors. Thus, in children of 7-9 this

ratio is higher, when relative dimensions of RA (r=0.61, P<0.01) and PA (r=0.65, P<0.01) are larger, and it is lower, when LA/m^2 (r=-0.65, P<0.01) and Ao dimension (r =0.49) are lower and Ao acceleration period is shorter (r=-0.57).

In children of 10-12 LV Ve/Va ratio has positive connections with RR duration (r=0.54), RV E (r=0.50), Ao AP (r=0.44), and negative ones - with Ao dimension (r=-0.49) and V rev in venae cavae (r=-0.43). In children of this age with signs of vasoneurosis the latter correlation can explain frequent incidence of hepatalgia in pathogenesis of which venous stagnation takes a certain part.

In boys of 13-15 this ratio, as in children of 10-12, is positively related with RV E duration (r=0.45) and, as in children of 7-9, - with RA dimension (r=0.44). Interaction of both ventricles is also confirmed by the positive relation with transmitral to transtricuspid flow velocities ratio (r=0.45).

Six correlations of LV Ve/Va ratio are observed in girls of 13-15. Thus, this ratio is higher, when RV E (r=0.43) and RV late diastolic filling time (r=0.60) are longer (as well as in children of other age groups), RR is higher (r=0.63), PA dimension (r=-0.52) and LV PW thickness (r=-0.48) are less and pulmonary venous flow velocity at systole is lower (r=-0.44).

Analysis of quantity and manifestation levels of intrasystemic connections between the right and left chambers in children and juveniles of different age groups demonstrated, that in children of 7-9 95 correlations are revealed, in children of 10-12 - 134, in boys of 13-15 - 124, in girls of 13-15 - 109. As is generally known, increasing number of interconnections between systemic elements indicates tension of adaptation mechanism. We can suppose, that it is the highest in age group of 10-12 (prepuberscent in boys and puberscent in girls).

Proceeding from the above-stated we can conclude, that revealed correlations between right and left chamber functional parameters take an important part in LV systolic function, both in healthy individuals and patients with various pathologies. Moreover, changes in RV parameters are the earliest signs of dysadaptation, which become apparent at the time when diastolic and systolic functions of the left ventricle still can be considered normal.

According to the literature [5], left ventricular geometry and end-diastolic pressure greatly depend on the right chamber activity. It could be attributed to the important role of venous returns and also to participation of various (hetero- and homeometric) mechanisms in controlling cardiac pumping function. Our study data obtained in healthy children reveals some age peculiarities of hemodynamics, and also confirms the results of previous experimental investigations.

Therefore, connections between functional parameters of both heart chambers should be taken into account while interpreting Doppler echocardiographic findings, that significantly enhances diagnostic capabilities of the technique.

Acknowledgements

The authors thank Yessipova E.L. for translating and preparing the article for publishing.

References

1. SHILLER H., OSIPOV M.A. **Clinical echocardiography**. Mir, Moscow, 1993 (in Russian).
2. MITKOV V.V., SANDRIKOV V.A. **Ultrasound diagnosis**. Vol.5. Vidar, Moscow, 1998 (in Russian).
3. COHEN G.I., PIETROLUNGO J.F., KLEIN A.L. A practical guide to assessment of ventricular diastolic function using Doppler echocardiography. **J Am Coll Cardiol**, 7: 1753-1760, 1996.
4. YAMAMOTO K., REDFIELD M.M., NISHIMURA R.A. Analysis of left ventricular diastolic function. **Heart** (Suppl. 2), 75:27-35, 1996.
5. BEMIS C., SERUR J., BORKENHAGEN D., SONNENBLICK E., URSCHELL C. Influence of right

ventricular filling pressure on left ventricular pressure and dimension. **Circul Res**, 1: 498-504, 1974.
6. KHRUSCHOV S.V., VENYOVTSEVA YU.L., MELNIKOV A.CH. Important problems of cardiac biomechanics of young sportsmen. **Russian Journal of Biomechanics**, 1-2: 74-83, 1997.
7. VENYOVTSEVA YU.L., KHRUSCHOV S.V., MELNIKOV A.CH. Valve disfunctions in young sportsmen. **Physician**, 10: 16-17, 1996 (in Russian).
8. APPLETON G.P., HATLE L.K., POPP R.L. Superior vena cava and hepatic vein Doppler echocardiography in healthy adults. **J Am Coll Cardiol**, 10: 652-659, 1987.
9. KEREN G., SHEREZ J., MEGIDISH R., LEVITT B., LANIADO S. Pulmonary venous pattern - its relationship to cardiac dynamics. A pulsed Doppler echocardiographic study. **Circulation**, 71: 1105-1112, 1985.

Взаимодействие правых и левых отделов сердца у здоровых молодых людей

Ю.Л.Веневцева, А.Х.Мельников, В.В.Ревякина, Т.А.Гомова,
Н.А.Пуханова (Тула, Россия)

Современные методы клинической физиологии, в частности, допплерэхокардиография, представляют возможности получения многочисленных морфофункциональных показателей, характеризующих работу сердца. Как в предыдущих , так и в современных работах основное внимание уделяется оценке параметров левого желудочка сердца, что, возможно, связано с трудностями определения параметров правых отделов сердца. В клинической практике не учитывается тесное взаимодействие правых и левых отделов сердца, отмеченное в инвазивных опытах на животных. Последние клинические наблюдения свидетельствуют о том, что у детей и подростков, адаптированных к выполнению физических нагрузок (юных спортсменов), наблюдаются характерные морфофункциональные особенности работы сердца, при этом размеры легочной артерии и правого предсердия у юных спортсменов оказались достоверно выше, чем у их нетренированных сверстников, так же как и частота выявления пролапса правого предсердно-желудочкового трехстворчатого клапана. Однако вопрос о взаимообусловленности и комплексной клинической оценке показателей правых и левых отделов сердца у здоровых людей представляется недостаточно изученным.

Для выявления взаимозависимости допплерэхокардиографических показателей функционирования правых и левых отделов сердца обследовано 80 детей 7-9, 10-13 и 13-15 лет без признаков органического поражения сердца. Показана роль правых отделов в эффективности насосной функции левого желудочка, а также важность определения размеров правого предсердия, легочной артерии и скоростей потоков крови в полых и легочных венах для оценки гемодинамики как у здоровых лиц, так и у кардиологических пациентов, особенно при динамических наблюдениях. Описанные результаты являются весьма важными для биомеханического описания деятельности сердца. Библ. 9.

Ключевые слова: допплерэхокардиография, сердце, правое предсердие, легочная артерия, корреляция параметров деятельности сердца

Received 10 November 1998