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Diastolic left ventricular function in normal children: The maximal positive dD/dt compared with the E/A ratio of mitral flow pattern

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Summary

The normal values for left ventricular diastolic function in children are influenced by numerous factors. As an index of this function, the maximum velocity of left ventricular internal dimension expansion (+max dD/dt) was calculated from M-mode echocardiography for 33 normal persons who ranged in age from seven days to 18 years. This index showed a linear correlation with left ventricular end-diastolic dimension in the resting state. This index was compared with the E/A ratio which is ordinarily used as the diastolic functional index for children. Considering changes in physical development during childhood, both indices showed similar trends in relation to body surface area. The E/A ratio was strongly influenced by heart rate, but +max dD/dt was not. This was the major difference between two indices.

Key words

Left ventricular diastolic function　　+max dD/dt　　E/A ratio

Introduction

In children, normal left ventricular diastolic function is influenced by many factors[1~6]. Among them, the changes due to physical development are important and different from

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the situation in adults. To examine left ventricular diastolic function of normal children, we calculated the maximal velocity of left ventricular internal dimension expansion (+max dD/dt) using M-mode echocardiography, and it was postulated that the +max dD/dt correlated linearly with left ventricular end-diastolic dimension (LVDd). Previously, we reported that the value of +max dD/dt divided by LVDd, (+max dD/dt/D), is nearly constant (2.68±0.48 LVDd/sec) and relatively stable during right atrial pacing (heart rates up to 150/min) or by methoxamine loading (acute mild afterload changing)[7]. In the present study, we compared the +max dD/dt with the E/A ratio calculated from the pulsed Doppler echocardiogram of mitral flow (E: early diastolic rapid filling wave, A: atrial contraction wave) in the same individual without cardiac abnormalities or hypertension.

Materials and methods

Thirty-three children and adolescents (7 days to 18 years of age), who had no obvious cardiac abnormalities or hypertension, were examined using the ATL Mark V system or Aloka SSD 860 apparatus. All subjects were in the resting and recumbent position during the recordings. M-mode echocardiograms and Doppler shift frequencies were recorded at a paper speed of 100 mm/sec. Left ventricular (LV) wall motion was measured from the LV endocardial tracing on the M-mode echocardiogram using an X-Y digitizer and a Sony Tektronics 4051 microcomputer. The +mas dD/dt was calculated by differentiating the wave form processed by a digital filter (cut-off frequency was approximately 7.5 Hz). Analysis was performed according to a modified method of Papademetriou et al.[1] Doppler examination was performed immediately after the M-mode record-

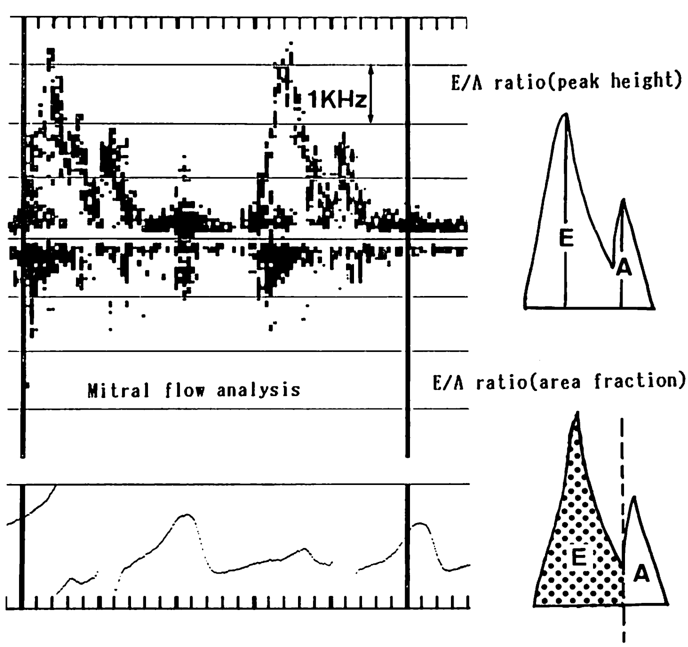

Fig. 1. Two methods of calculating the E/A ratio from the transmitral flow pattern analysis.
The E/A ratios are obtained by either the peak height ratio or area fraction.
E=early diastolic rapid filling; A=atrial contraction.

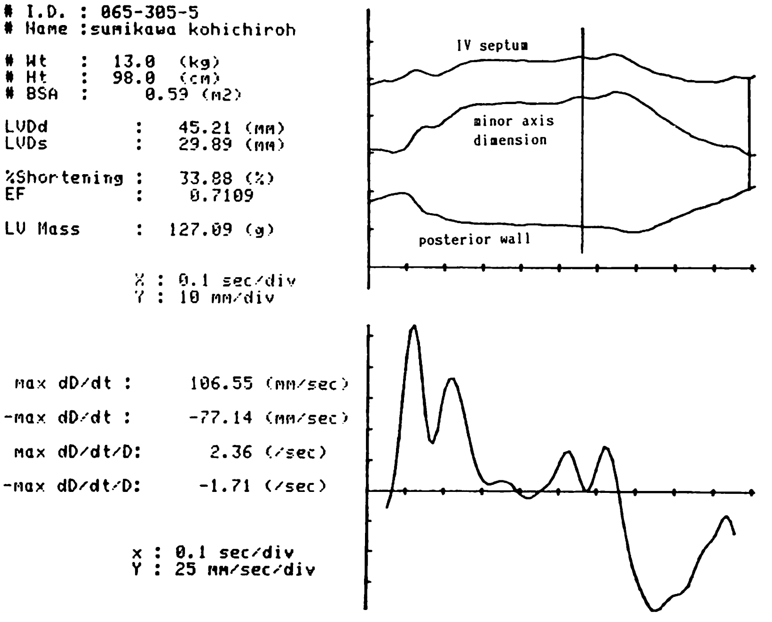

Fig. 2. The actual output of the +max dD/dt calculation.
max dD/dt/D = max dD/dt divided by left ventricular end-diastolic dimension.

ing. The sampling point was set in the inflow portion of the LV, approximately at the center of the mitral annulus as determined from the apical long-axis view or apical 4-chamber view. The E/A ratio was calculated using two methods as to an early diastolic left ventricular filling (E) wave and an atrial contraction (A) wave; i) the peak heights of the recorded Doppler shift frequency pattern, and ii) areas calculated from the integration of each wave (**Fig. 1**). The area ratio of both waves was determined using the above digitizer system. The data obtained during at least three cardiac cycles were averaged to minimize the influence of respiration.

Fig. 2 shows the actual output of +max dD/dt and dD/dt/D. Left ventricular internal dimension at end-diastole was obtained at the initiation of the Q wave of a simultaneously-recorded electrocardiogram.

Results

The E/A ratios calculated using different methods correlated well with each other (**Fig. 3**). Therefore, the E/A ratios obtained from the peak heights of the two waves were used in the following analysis.

The E/A ratio correlated linearly with LVDd as well as the +max dD/dt (**Fig. 4**). It also correlated well with body surface area in ascending order of power (**Fig. 5**). From the standpoint of physical development during childhood, the E/A ratio and the +max dD/dt showed a similar change. The +max dD/dt showed a weak positive linear correlation with the E/A ratio (**Fig. 6**). To analyze the effect of heart rate, which changes with physical development, we studied the relationship between the cardiac cycle length and the two indices (**Figs. 7, 8**). The E/A ratio strongly correlated positively with the cardiac cycle length (correlation coefficient of the E/A ratio was 0.80). The correlation was weak in the +max dD/dt (correlation coefficient was 0.41). This was the major difference between the two indices.

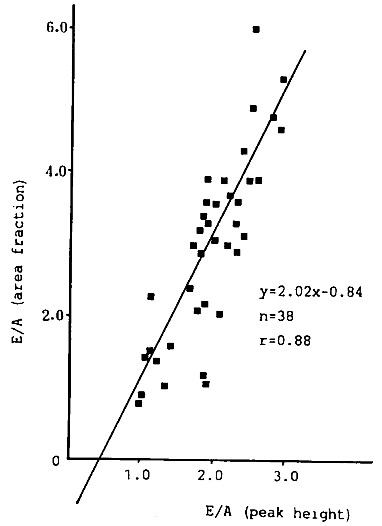

Fig. 3. Relation of the E/A ratio calculated by the two methods.

Vertical axis: E/A ratio calculated from area; horizontal axis: E/A ratio calculated from the peak height.

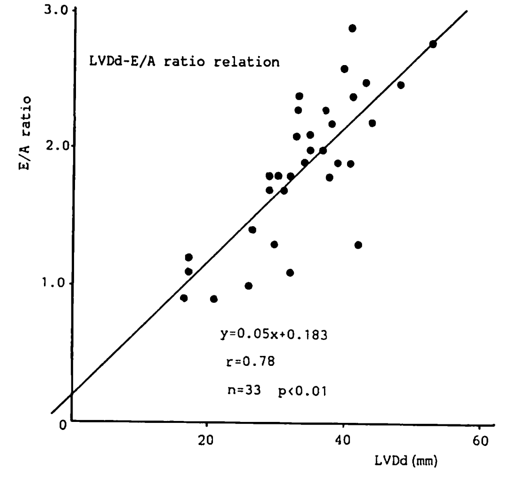

Fig. 4. Relation of the E/A ratio and LVDd.

Vertical axis: E/A ratio; horizontal axis: LV end-diastolic dimension.

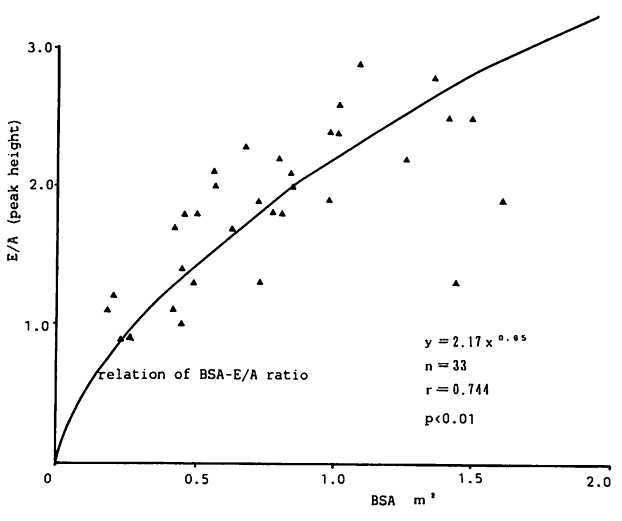

Fig. 5. Relation of the E/A ratio and the body surface area.

Vertical axis: E/A ratio; horizontal axis: BSA (body surface area).

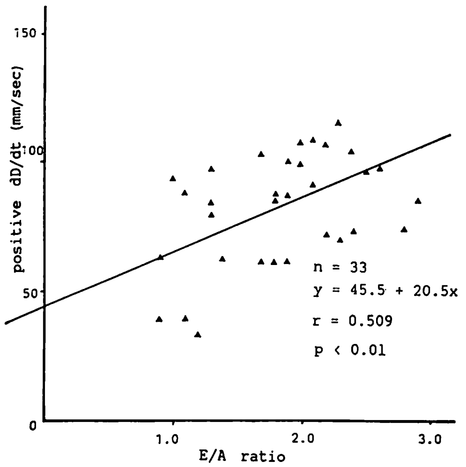

Fig. 6. Relation of the E/A ratio and the +max dD/dt.

Vertical axis: +max dD/dt; horizontal axis: E/A ratio.

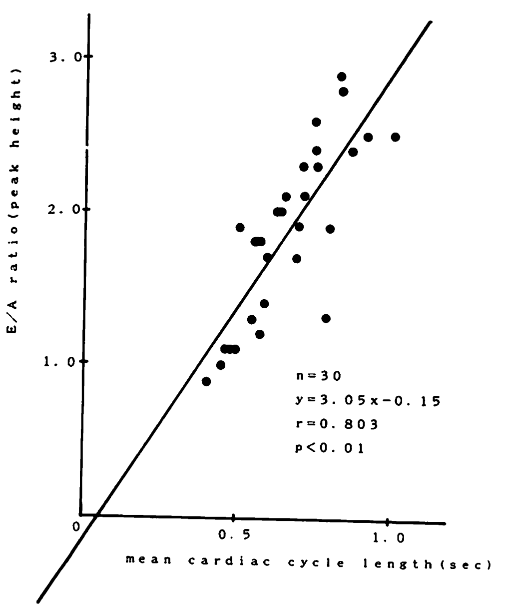

Fig. 7. Relation of mean cardiac cycle length and +max dD/dt.

Vertical axis: +max dD/dt; horizontal axis: mean cardiac cycle length.

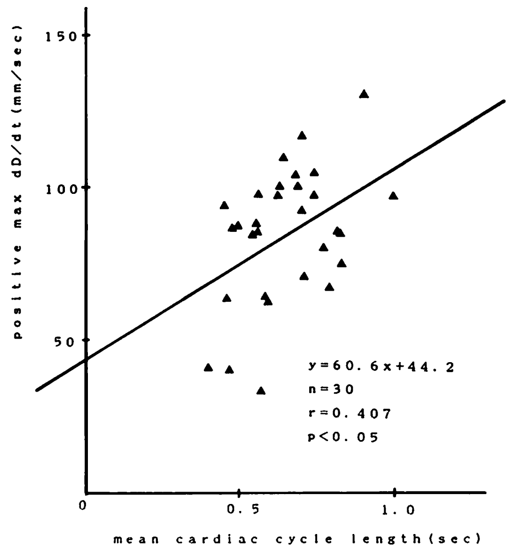

Fig. 8. Relation of mean cardiac cycle length and the E/A ratio.

Vertical axis: E/A ratio; horizontal axis: mean cardiac cycle length.

Discussion

This report indicated that the +max dD/dt and E/A ratios changed corresponding to the child's physical development, and that the former was not as greatly influenced by the cardiac cycle length. In another expression, the +max dD/dt and E/A ratios are functions of left ventricular end-diastolic dimension and the cardiac cycle length, respectively.

This LV function index, dD/dt, was intended for evaluating cardiac function of early hypertension in childhood, since we have been studying the primary prevention of hypertensive cardiovascular disease from childhood in the Shimane Heart Study[3,6]. In that longitudinal field study, M-mode echocardiograms of the left ventricle were recorded every three years in the same cohort. The children in the hypertensive group showed higher left ventricular muscle volume than those in the normotensive group[3,6]. The Shimane Heart Study permits comparison of the LV function index obtained from M-mode echocardiography longitudinally in the same subject, and facilitates comparison of its data with other data from the same individual; for example, blood pressure.

The E/A or A/E ratio calculated from pulsed Doppler echocardiography is usually used as the left ventricular diastolic function index. Using Doppler echocardiography, Snider et al.[4] reported that the abnormal patterns of LV diastolic filling appeared in children with mild systemic hypertension. Papademetriou et al.[1] reported subtle abnormalities of diastolic LV function in mildly hypertensive adults when their LV systolic function is still normal. Dianzumba et al.[5] reported similar results. Therefore, we investigated the role of the max+dD/dt as the diastolic LV function index, comparing it with the E/A ratio.

Transmitral blood flow during diastole is proportional to the rate of left ventricular volume change (dV/dt); therefore, it reflects directly the diastolic behavior of the ventricle[2]. Both in animals and in normal human subjects, the volume of the LV correlates closely with the diameter of the transverse dimension or the minor axis of the ventricle, so the dD/dt correlates closely with the dV/dt. The left ventricular time-volume curve can be estimated approximately from the time-dimension curve. Consequently, the +max dD/dt calculated from M-mode echocardiography is assumed to be parallel to transmitral blood flow, especially the E wave, which corresponds to the peak flow velocity of early ventricular filling. The peak flow velocity of normal children with the heart of various sizes showed nearly the same value; about 60 cm/sec. This is comparable to the constant value of the +max dD/dt/D from M-mode echocardiography. In children, calculating the actual peak flow velocity of early ventricular filling is complicated because of the difficulty in setting the angle of the ultrasonic beam at nearly 0 degrees in respect to the direction of blood flow. Consequently, the predicted +max dD/dt calculated from body surface area (+max $dD/dt = 106 \times BSA^{0.4}$) is presumed to be the normal value for the LV diastolic function index, and proportional to the value calculated from the actual recording. Although the +max dD/dt cannot be evaluated in cases of cardiac malformations and LV deformities, it can be adopted as the index of LV diastolic function in cardiomyopathy with no cardiac deformity, or in hypertensive cardiopathy, regardless of moderate heart rate changes or mildly acute afterload changes.[7]

Conclusion

It is concluded that the +max dD/dt exhibited nearly the same trends as the E/A ratio in normal children, considering their physical development. However, the E/A ratio was strongly influenced by the cardiac cycle length as compared to the +max dD/dt. Therefore, the dD/dt, or dD/dt/D was regarded as the better index of LV diastolic function for conventional examinaions.

要　　約

小児左心機能指標の比較：Positive max dD/dt と Doppler 法による E/A 比

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小児の拡張期左室機能は種々の要因により影響をうける．拡張期左室機能の指標の一つとして，我々は左室内径最大拡張速度（+max dD/dt）をMモード心エコー図から求めた．この指標は安静時において左室拡張末期径と直線相関を示した．我々はこの指標を，小児において一般的に使われている拡張期左室機能の指標であるE/A比と比較した．対象は生後7日から18歳までの健常者33名である．小児の身体発育という観点からすれば，これら2つの指標はどちらも体表面積と線相関を示した．E/A比は心拍数により強く影響されたが，+max dD/dt は影響されなかった．これはこの2つの指標の間の大きな相違と考えられた．

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