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Left Ventricular Wall Motion Dynamics of Asymmetric Septal Hypertrophy : Assessment by Intramyocardial Pulsed Doppler Echocardiography

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Abstract

Apical pulsed Doppler tissue imaging can be used to assess the function of regional myocardium. We hypothesized that septal dysfunction might be clarified in the hypertrophic cardiomyopathy (asymmetric septal hypertrophy) by this method.

Twenty-one patients with asymmetric septal hypertrophy (mean age 54.8±11 years) and age-matched 24 normal subjects (52.4±8 years) were studied. The E/A ratio measured by mitral inflow Doppler was not different between the groups (1.1 vs 1.2). E wave velocities of the septum were significantly decreased in the hypertrophy group compared to the control group (4.0±1.5 vs 8.1±2.2 cm/sec), and A wave velocities were increased in the hypertrophic septum, resulting in a significantly lower E/A ratio (0.5±0.3) compared to the E/A ratio (0.9±0.3) of the normal septum. Deceleration time of the E wave and isovolumic relaxation time were significantly prolonged in the thick septum compared to the normal septum (136±51 vs 107±28 msec, 91±36 vs 63±19 msec, respectively).

In conclusion, asymmetric septal hypertrophy was characterized by diastolic dysfunction of the thickened septum. Intramyocardial pulsed Doppler echocardiography can detect regional myocardial dysfunction earlier than the mitral inflow Doppler method.

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Key Words

Doppler ultrasound (Doppler tissue imaging, intramyocardial pulsed Doppler), Diastole (diastolic dysfunction), Cardiomyopathies (asymmetric septal hypertrophy)

INTRODUCTION

Doppler tissue imaging has recently emerged as a new modality for the recording of myocardial velocities[1-4]. The major advantage of modified pulsed Doppler tissue imaging, or intramyocardial pulsed Doppler echocardiography, is that myocardial wall motion velocities can be recorded continuously in any area throughout the cardiac cycle. We previously recorded the biphasic, early diastolic "E" and presystolic "A", pattern of left ventricular wall motion similar to mitral inflow Doppler signals in normal subjects, and observed that the E/A ratio was lower in the septal than the posterior walls[5,6]. Based on those studies, we proposed that Doppler tissue imaging-guided technique from the apical approach (apical pulsed Doppler tissue imaging) could become a standard method for recording wall motion velocities

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and possibly a new modality to evaluate regional myocardial function. Recently, a similar new method applied to normal myocardial wall motion was described[7]. Although this approach was from the parasternal area, the results validated the use of pulsed Doppler tissue imaging for studying myocardial function.

To assess mitral annular dynamics in patients with normal, left ventricular hypertrophy, and constrictive pericarditis, two recent studies used this new pulsed Doppler tissue imaging[8,9]. The motion of the left ventricular posterior wall was first evaluated by the conventional pulsed Doppler method by Isaaz *et al*[10]. However, wall motion velocities in patients with cardiomyopathy have not been well investigated.

The present study investigated wall motion velocities in patients with hypertrophic cardiomyopathy to characterize the wall motion dynamics, and to study whether intramyocardial pulsed Doppler echocardiography is useful for the assessment of ventricular function.

SUBJECTS AND METHODS

We performed conventional Doppler and echocardiography in 21 patients with asymmetric septal hypertrophy aged 54.8±11 (mean±SD) years old in whom adequate images and tracings were obtained. The diagnosis of asymmetric septal hypertrophy was based on standard echocardiographic criteria: unexplained hypertrophy of the interventricular septum of 15 mm or more, and ratio of septal to left ventricular posterior wall thickness of 1.3 or more. Patients with significant mitral regurgitant signals (more than 1/4 relative to the regurgitant jet in the left atrium) were excluded from the study. Eleven of 24 patients had trivial or mild Doppler mitral regurgitation. No patients had evidence of clinical mitral insufficiency, and all were in sinus rhythm. None had evidence of conduction disturbances. No patient had significant left ventricular obstruction, or significant systolic anterior motion of the mitral valve. Peak velocities were 2 m/sec or less at the outflow tract of the left ventricle in all patients. All patients had no or minimal cardiac symptoms, although 13 patients were taking β-blockers, verapamil, dysopiramide, or combinations at the time of echocardiographic examinations.

Selected abbreviations and acronyms

IRT = isovolumic relaxation time

Our previous study[5] found a correlation between early and late diastolic velocities and A/E ratio and age. Therefore, the current study used age-matched 24 normal subjects (52.4±8 years in age) as the control group. These individuals were 15 patients who were referred for a variety of cardiac symptoms but were found to be normal, and 9 healthy volunteers, in all of whom physical and Doppler echocardiographic examinations were normal.

Images were taken with the subjects in the left lateral position. After performing routine Doppler echocardiography, we changed the mode from the conventional Doppler method to the Doppler tissue imaging system. Color images of the left anterior oblique-equivalent view of the left ventricle were obtained using the apical approach, then the sampling positions for recording velocities at the level of mitral valve tip of the septal and posterior walls were selected after confirming normal color-coded wall motion in all subjects. Doppler echocardiograms were obtained using an Acuson 128XP/10ART (USA). The carrier frequency for Doppler tissue imaging was 2.5 MHz and the depth of sample volume was 1.5 mm at minimum. All Doppler findings were stored on S-VHS video tape and flow velocity signals were recorded simultaneously with a phonocardiogram using a stripchart recorder for subsequent analysis. Recordings were made at a paper speed of 10 cm/sec during expiratory apnea after observing insignificant respiratory changes. The values of three velocity components were measured: S, E, and A waves, and E/A ratio. Isovolumic relaxation time (IRT) and deceleration time of the E wave (**Fig. 1**) were also determined in both walls of all subjects. IRT was defined as the time interval from the second heart sound on the phonocardiogram to the onset of the E wave in each wall. E wave deceleration time was calculated as the interval from the peak E wave to the zero intercept of the extrapolated deceleration slope. Three or more cycles were measured and averaged to obtain each value. These parameters

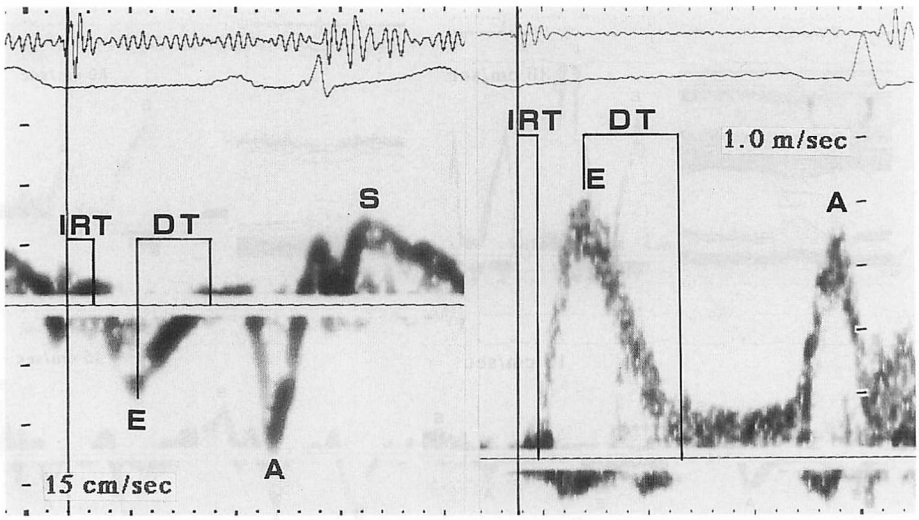

Fig. 1 Measurement techniques in intramyocardial pulsed Doppler (*left*) and transmitral Doppler (*right*)

In the left panel, the left ventricular walls move upward or toward the apex during systole and move downward or toward the annulus during diastole.

IRT = isovolumic relaxation time determined as the interval from the second heart sound to the onset of early diastolic rapid motion or transmitral inflow ; DT = deceleration time from the peak of E wave to the zero intercept of the deceleration slope of wall motion or transmitral inflow.

were compared between septal and posterior walls, and between the cardiomyopathy and normal groups.

The Doppler sample volume was also positioned in the left ventricular inflow between the tips of the mitral valve leaflets, where the maximal flow velocity during diastole was obtained with standard pulsed wave Doppler echocardiography. The transmitral inflow Doppler variables were obtained in both groups. Peak E and A wave velocities, A/E ratio, the time interval from the second heart sound to the onset of the E wave (IRT) and the deceleration time of the E wave were measured. These data were correlated with velocity components and time intervals in both walls of the two groups.

Results are expressed as mean values ± SD. The paired Student's *t*-test was used for comparison within the group and the unpaired Student's *t*-test was used to compare the two groups. Statistical significance was defined as $p < 0.05$.

RESULTS

Clinical and echocardiographic findings (Table 1)

Heart rate was not significantly different between the two groups. The left ventricular end-diastolic and end-systolic dimensions were significantly smaller in the patients with hypertrophic cardiomyopathy. There was a significant difference in the ejection fraction between the two groups (68 % vs 76 %).

Table 1 Clinical and echocardiographic findings in patients and normal subjects

	Patients ($n=21$)	Normal subjects ($n=24$)	p value
Age (yr)	54.8±11	52.4±8	NS
Male (n)	19	16	
Heart rate (beat/min)	64±8	63±10	NS
IVS (mm)	21±5	10±1	<0.01
PW (mm)	11±1	11±1	NS
LVDd (mm)	43±5	48±4	<0.01
LVDs (mm)	24±4	30±4	<0.01
EF (%)	76±7	68±6	<0.01

IVS = interventricular septum ; PW = posterior wall ; LVDd = left ventricular end-diastolic dimension ; LVDs = left ventricular end-systolic dimension ; EF = ejection fraction.

Transmitral and intramyocardial pulsed Doppler findings

Results are shown in **Table 2**, and representative pulsed Doppler recordings of the two

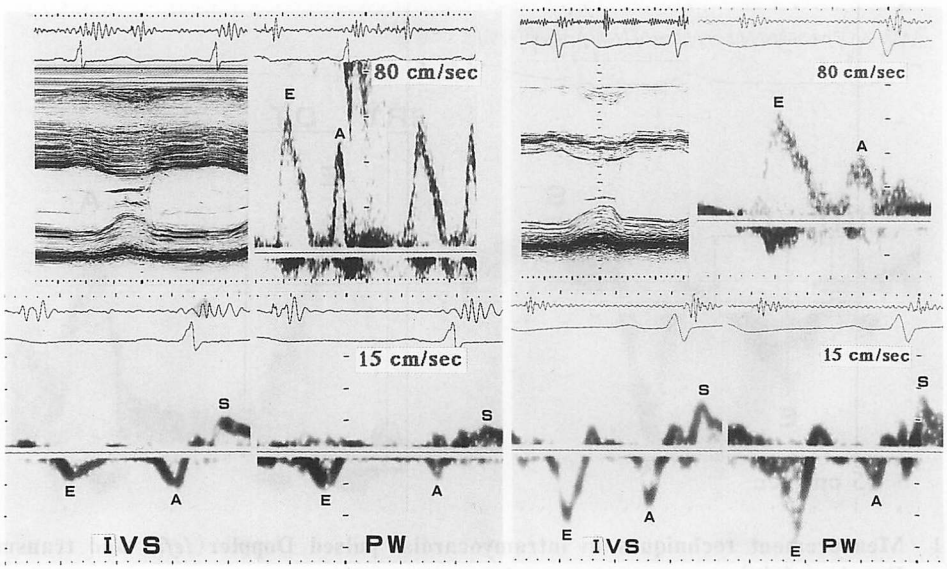

Fig. 2 Representative cases with asymmetric septal hypertrophy (*left*) and normal subject (*right*)
Left : 48-year-old. *Right* : 40-year-old.
Lower panels show intramyocardial pulsed Doppler findings.
Abbreviations as in Table 1.

Table 2 Doppler findings in patients and normal subjects

	Patients	Normal subjects	*p* value
Transmitral flow			
E wave (cm/sec)	55±11	59±17	NS
A wave (cm/sec)	57±14	54±13	NS
E/A	1.1±0.5	1.2±0.4	NS
IRT (msec)	69±22	60±19	NS
E wave DT (msec)	206±52	169±26	<0.01
Interventricular septum			
S wave (cm/sec)	6.0±1.3	6.6±1.1	NS
E wave (cm/sec)	4.0±1.5	8.1±2.2	<0.01
A wave (cm/sec)	7.3±1.7	8.7±1.8	<0.05
E/A	0.57±0.3	0.96±0.3	<0.01
IRT (msec)	91±36	63±19	<0.01
E wave DT (msec)	136±51	107±28	<0.05
Posterior wall			
S wave (cm/sec)	6.1±1.6	9.0±2.4**	<0.01
E wave (cm/sec)	7.3±2.7**	11.0±3.0**	<0.01
A wave (cm/sec)	5.2±2.8**	7.7±1.8*	<0.01
E/A	1.4±1.0**	1.5±0.5**	NS
IRT (msec)	60±19**	48±22**	NS
E wave DT (msec)	111±58	92±36*	NS

*$p<0.05$, **$p<0.01$ vs interventricular septum.
Abbreviations as in Fig. 1.

groups are shown in **Fig. 2.** The E/A ratio in transmitral inflow was not significantly different between the hypertrophic cardiomyopathy and control groups. However, the deceleration time in mitral inflow velocities was slightly prolonged in the former. There was no difference in septal S wave velocities between the two groups, but the peak velocity of the posterior S wave was higher in the control subjects. The E wave velocities of septal and posterior walls were significantly decreased in the hypertrophic cardiomyopathy group. The septal E wave velocities were significantly lower than the posterior E wave velocities in both groups ($p<0.01$ by paired *t*-test ; **Fig. 3**). The A wave velocities were increased in the interventricular septum in the hypertrophic cardiomyopathy group. Therefore, the E/A ratio in the ventricular septum was smaller in the patients with cardiomyopathy than in the normal subjects (**Table 2**). Deceleration time was prolonged in the septal compared to the posterior wall in both groups, and the deceleration time of septal E wave velocity was much more prolonged in the hypertrophic cardiomyopathy group compared to the control group. The E/A ratio in mitral inflow velocity was larger than that of the posterior wall and smaller than that

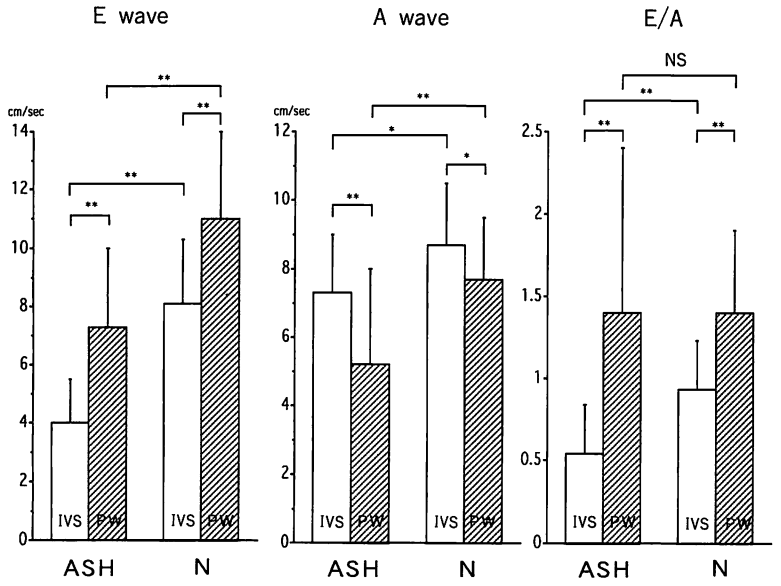

Fig. 3 Velocity components and E/A ratio of each wall in both groups
$*p<0.05$, $**p<0.01$.
ASH=asymmetric septal hypertrophy; N=normal subjects. Other abbreviations as in Table 1.

of the septal wall in both groups.

Although the isovolumic relaxation time in mitral inflow velocities was not different between the groups (69 vs 60 msec), the wall motion-derived isovolumic relaxation time was prolonged in the septal compared to the posterior wall in both groups, and the hypertrophic septum had a much more prolonged relaxation time than the normal septum (91 vs 63 msec; **Fig. 4**).

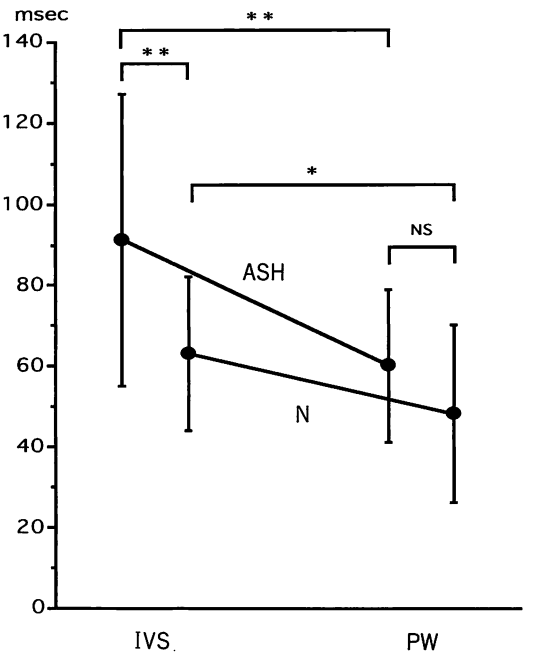

Fig. 4 Isovolumic relaxation time of each wall in both groups
IRT of the septum in patients with ASH was significantly prolonged compared to that of the posterior wall in patients with ASH and that of the septum in normal subjects.
$*p<0.05$, $**p<0.01$.
Abbreviations as in Table 1, Fig. 3.

DISCUSSION

Pulsed Doppler echocardiographic transmitral inflow velocity has been extensively used for the noninvasive assessment of left ventricular diastolic function[11–15]. Our previous studies[5,6] using intramyocardial pulsed Doppler echocardiography also showed biphasic patterns in wall motion velocities similar to those of mitral flow velocity in normal subjects, so we concluded that this technique is a new modality to assess regional left myocardial function. We also proposed that the apical approach be used as the standard position.

Hypertrophic cardiomyopathy is a unique cardiac disease characterized by diastolic dysfunction. The present study used intramyocardial pulsed Doppler echocardiography to characterize diastolic function, and to determine whether the method can differentiate septal from posterior wall dynamics in asymmetric septal hypertrophy.

Dynamics of annular motion versus myocardial wall motion

Mitral annular displacement or descent of the atrioventricular plane shown by two-dimensional, M-mode echocardiography or conventional pulsed Doppler echocardiography has been proposed as an indicator for left ventricular systolic[16–20] or diastolic[20,21] functions. Reduced excursion of the mitral ring is correlated with reduced systolic function in a variety of cardiac conditions, and there is a good correlation between the atrial contribution to diastolic atrioventricular plane displacement and the transmitral E/A ratio. Recently, lateral annular velocities have been evaluated as new parameters for left ventricular diastolic function with the new Doppler tissue imaging-guided pulsed Doppler method, but myocardial wall velocities were not evaluated[8,9].

Our previous[5,6] and present studies evaluated mid-wall motion velocities in the septal and posterior walls with the intramyocardial pulsed method, because we consider that wall motion velocities directly and sensitively reflect regional myocardial function. We previously showed the close correlation between the dynamics of septal and posterior walls, and aging and mitral inflow velocities. Myocardial wall motion will be parallel or equivalent to mitral annular motion, although the amplitude of its excursion is not identical, as long as the left ventricle has no myocardial wall abnormalities.

The present study showed that this method is ideal to differentiate the function of septal and posterior walls in patients with hypertrophic cardiomyopathy.

Left ventricular diastolic function in hypertrophic cardiomyopathy

The majority of patients with hypertrophic cardiomyopathy are found to have abnormal left ventricular diastolic function by the catheterization technique[22,23], M-mode echocardiography[24,25], pulsed Doppler echocardiography[26,27], or the radioisotope method[28,29], which demonstrate prolonged relaxation or impairment in early diastolic filling and elevated late diastolic pressure or augmented atrial systolic filling. This disturbed diastolic function is attributed to increased muscle mass and stiffness, and decreased volume of the left ventricle. Characteristic findings based on mitral inflow patterns are low E wave velocity, delayed E wave deceleration, higher A wave velocity and small E/A ratio[26,27,30], which are clearly differentiated from normal inflow patterns in normal subjects. However, the overlap is considerable[27]. Normal mitral inflow patterns are expected to occur in mild cardiomyopathy and in severe hypertrophic cardiomyopathy with an increased filling pressure in the left atrium, which increases the early diastolic E wave velocity, resulting in a higher E/A ratio or pseudonormalization[15]. Our patients had the milder form, so that transmitral inflow patterns were not significantly different between the cardiomyopathy and normal groups in the present study except for the prolonged deceleration time in the former. Pseudonormalization in mitral inflow is unlikely because our patients with no or minimal symptoms had normal systolic function and had no or mild degree of mitral regurgitation. Another possibility is that medications may have produced beneficial effects on otherwise disturbed diastolic function[29,30].

Wall motion velocities and cardiac function in asymmetric septal hypertrophy

Left ventricular systolic function in hypertrophic cardiomyopathy is usually normal to supernormal. In the present study, the peak of the S wave velocity of the posterior wall was decreased more in patients than in normal subjects, regardless of the increased ejection fraction of 76 % in the former. Intramyocardial S wave velocities in the long-axis direction are not directly related to the total amplitude of systolic excursion of the endocardium in the short-axis direction. Thus, we conclude that the peak of the S wave velocity is not an indicator of so-called systolic function.

Many studies of hypertrophic cardiomyopathy have focused on global left ventricular diastolic dysfunction, and only a few have investigated regional left ventricular asynchrony with radionuclide angiography[31] or computer-analyzed left ventricular echocardiography[32,33]. The latter study included a subgroup of patients with obstructive cardio-

myopathy in whom both normalized peak rate of septal thickening and thinning were significantly lower compared to increased systolic thickening and normal diastolic thinning of the posterior wall. Our study of hypertrophic cardiomyopathy demonstrated significantly diminished E wave velocity, prolonged isovolumic and deceleration times, and increased A wave velocity in the hypertrophic septum compared to the non-hypertrophic posterior wall, resulting in a small E/A ratio, *i.e.* impaired septal diastolic function. Hypertrophic ventricular septum is likely to have diminished elasticity due to the disorganized myocardium, in addition to myocardial fibrosis or ischemia, which is characteristic of hypertrophic cardiomyopathy[33]. The effects of the right ventricle on the septal wall motion are unlikely to be the genesis of septal diastolic dysfunction in hypertrophic cardiomyopathy, because diastolic abnormalities were much more distinct in the hypertrophic than the normal septum.

Recently, Wallbridge *et al.*[34] also reported diastolic dysfunction of the hypertrophied septum using M-mode tissue Doppler echocardiography without pulsed mode from the parasternal window. Our previous study[6] found it was difficult to determine wall motion velocities of the septum parasternally in all subjects because of its decreased motion. Additionally, on-line quantification is time consuming and has limitations for common clinical applications. The current method of pulsed Doppler tissue imaging offers a much better resolution.

Clearly, intramyocardial pulsed Doppler echocardiography has great advantages over previous noninvasive methods in evaluating regional wall motion dynamics in regard to simplicity, accuracy and easy repeatability.

Comparison of wall motion velocities to transmitral inflow

The transmitral inflow velocity, an indicator for global diastolic function, is dependent on pressure-volume interactions. This inflow responds directly to instantaneous change in left ventricular filling and volume, and the latter is closely related to left ventricular wall dynamics. The present data showed that the E/A ratio of transmitral flow was intermediate between those of the velocities of both ventricular walls, as already found in normal subjects[4,5]. Therefore, there was no difference in the E/A ratio of transmitral inflow velocity between the hypertrophic and normal groups, despite the lower E/A ratio in the wall motion velocity of the hypertrophic septum. The smaller E/A ratio of the septum may be counterbalanced by the relatively larger E/A ratio of the posterior wall.

Regional or septal impairment in diastolic function may precede global diastolic dysfunction in asymmetric septal hypertrophy. Intramyocardial Doppler E/A ratio will be an earlier indicator of regional diastolic function than transmitral Doppler E/A ratio.

Isovolumic relaxation time assessed with wall motion velocities

Isovolumic relaxation time is a good noninvasive index of global ventricular relaxation. Reduction in ventricular relaxation induces a prolongation of IRT and a decrease in the early diastolic transmitral pressure gradient, resulting in diminished E wave velocity as long as filling pressures are not elevated. However, IRT is affected by multiple factors and has a wide range that is not significantly different from that in normal subjects[35] as also found in the present study. IRT is usually determined as the interval from minimal left ventricular dimension, the end of ejection or the second heart sound, to the onset of mitral opening or mitral inflow[24–27,35]. In the present study, we defined IRT as the interval from the second heart sound to the onset of expansion, or the beginning of the E wave velocity in each wall motion. This regional IRT is possibly dependent on the sampling position from the cardiac base to the apex, and thus is not equivalent to global IRT. This myocardial IRT was significantly prolonged in the hypertrophic septum compared to the posterior wall (91 vs 60 msec) in the hypertrophic cardiomyopathy group and to the normal septum (91 vs 63 msec) in age-matched controls, which is suggestive of impaired septal relaxation. We conclude that myocardial IRT is more sensitive than mitral inflow-derived IRT for detecting regional delayed relaxation.

Limitations of the study

We previously found that wall motion veloc-

ities became decreased as the sampling position moved toward the apex, although the E/A ratio did not change basically[5]. Positioning of the Doppler sample volume requires care. Almost half of the patients in the present study were taking medicine, and we could not neglect such influences on the Doppler findings. The inherent disadvantage of the present intramyocardial Doppler technology is that measured velocities are averaged values of the myocardium moving within the sample volume and dependent on the incidence angle of the ultrasonic beam, and are neither transmyocardial nor absolute measurements. Thus, there is an effect of translation of the whole heart on the measured velocities.

Clinical implications

Despite these limitations, the present intramyocardial pulsed Doppler method has potential for clinical investigation of wall motion velocities or myocardial function in a longitudinal direction. From the apical approach, we can possibly evaluate other areas of the myocardium by rotating the transducer around 360 degrees. Further assessment of wall motion velocities in other types of hypertrophic cardiomyopathy will provide new information about the pathophysiology of cardiomyopathy. This technique can be applied for both evaluation of left ventricular function and assessment of beneficial effects of treatment in various cardiac diseases including ischemic heart disease, hypertensive heart disease, dilated cardiomyopathy, pericardial disease, and valvular heart disease.

The E/A ratio of regional wall motion velocities provides an earlier indicator of diastolic dysfunction than that of the transmitral inflow velocity.

Recently, Doppler tissue imaging derived IRT of the posterior wall was reported to correspond well with the time constant[36], although the definition of the IRT was somewhat different from that in our present study. However, we think that the regional IRT is more sensitive than an index of global diastolic relaxation.

CONCLUSIONS

Diastolic function was impaired in the hypertrophic septum of asymmetric septal hypertrophy without global left ventricular dysfunction. Apical pulsed Doppler tissue imaging is a valuable and simple modality which can evaluate septal and posterior myocardial function separately. Analysis of wall motion velocities and time intervals with the present system is an additional method for assessing regional left ventricular diastolic function.

Part of this paper was presented at the 7th Annual Meeting of Japanese Society of Echocardiography in June, 1996.

要　約

非対称性心室中隔肥大の左室壁動態：心尖部心筋内パルス・ドップラー法による検討

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池ノ内　浩　田宮　栄治　桐谷　博巳

心尖部アプローチによる心筋内パルス・ドップラー法によれば局所心筋の機能評価が可能である．我々は本法を用いて肥大型心筋症(非対称性心室中隔肥大)における中隔の拡張障害を明らかにしようと試みた．

対象は肥大型心筋症21例(平均年齢54.8±11歳)で，対照群は年齢をマッチさせた(52.4±8歳)24例の健常者である．中隔，後壁の運動速度より求めた拡張期指標と僧帽弁流入波形からの拡張期指標を比較検討した．僧帽弁流入血E/Aは肥大型心筋症・対照群で有意差をみなかった(平均1.1 vs 1.2)．肥大型心筋症における中隔のE波は対照群の中隔に比べて有意に小で(4.0±1.5 vs 8.1±2.2)，中隔のA波は後壁よりも有意に大，したがって，中隔のE/Aは0.57±0.3と低値を示した．肥厚した中隔のE波減速時間と等容拡張期(II音より壁運動拡張開始までの時間)は正常中隔より有意に延長していた(それぞれ，136±51 vs 107±28 msec，91±36 vs 63±19 msec)．

非対称性心室中隔肥大では中隔の拡張障害がみられた．心筋内パルス・ドップラー法は局所心筋の拡張障害を僧帽弁流入血より早期に検出することが出来る検査法である．

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