Significance of Augmentation of Left ventricular Slow Filling in Pulsed Doppler Echocardiography in Patients with Hypertrophic Cardiomyopathy

Emoto, Ryuichi

Yokota, Yoshiyuki

(Citation)
Bulletin of allied medical sciences Kobe : BAMS (Kobe),11:65-74

(Issue Date)
1996-01-31

(Resource Type)
departmental bulletin paper

(Version)
Version of Record

(URL)
https://hdl.handle.net/20.500.14094/00182495

Significance of Augmentation of Left ventricular Slow Filling in Pulsed Doppler Echocardiography in Patients with Hypertrophic Cardiomyopathy.

Ryuichi Emoto[1] and Yoshiyuki Yokota[2]

To investigate the significance of augmentation of left ventricular slow filling in patients with hypertrohic cardiomyopathy (HCM), M-mode and pulsed Doppler echocardiograms were obtained with simultaneous recording of left ventricular pressure in patients with HCM. The large slow filling wave (LSFW) was defined as the slow filling wave whose peak velocity was more than a half of the peak velocity during the early filling phase (E). Patients with LSFW tended to have a longer isovolumic relaxation time and smaller E, and had a longer time constant T than patients without LSFW. Furthermore, in patients with LSFW, left ventricular pressure kept declining not only during the rapid filling phase, but also during the slow filling phase, but not in the patients without LSFW. Thus, the augmentation of left ventricular slow filling in patients with HCM might be caused by the delayed and incomplete relaxation of the left ventricle.

Key Words
Left ventricular slow filling,
Hypertrophic cardiomyophathy,
Pulsed Doppler echocardiography,
Left ventricular relaxation

INTRODUCTION

Hypertrophic cardiomyopathy is a primary myocardial disease characterized by an increase in left ventricular wall thickness and impairment of diastolic property. Abnormalities of left ventricular relaxation and compliance are common in patients with hypertrophic cardiomyopathy (1-7). Numerous studies, using noninvasive techniques including pulsed Doppler echocardiography, have shown impaired left ventricular filling in patients with hypertrophic cardiomyopathy (8-16). Pulsed Doppler studies have demostrated that transmitral left ventricular filling abnormalities are frequently observed during early and late diastolic phase in patients with hypertrophic cardiomyopathy (13,14). However, left ventricular filling during the mid-diastolic filling phase is little known. In our previous pulsed Doppler study (17), we found the presence of argmentation of the slow filling wave in some patients with hypertrophic cardiomyopathy, although the augmentation was not observed any healthy persons. We designed the

The Department of Internal Medicine, Miki City Hospitall, Miki, Faculty of Health Science, Kobe University School of Medicine[2], Kobe Japan.

Table I. Clnical data and M-mode echocardiographic parameters in patients with hypertrophic cardiomyopathy Echocardiographic findings

Table I. Clnical data and M-mode echocardiographic parameters in patients with hypertrophic cardiomyopathy

						Echocardiographic findings						
Case	Age	Sex	FH	NYHA	Rhythm	IVST (mm)	PWT (mm)	LVDd (mm)	%FS	IRT (m/sec)	SAM	LSFW
1	53	F	+	II	SR	16	7	49	38.0	118	-	+
2	69	M	-	II	SR	15	10	42	40.5	105	-	+
3	59	F	+	III	AF	14	11	67	25.4	120	-	+
4	54	M	-	I	SR	17	13	47	52.2	95	-	-
5	55	M	-	II	SR	21	15	50	40.0	90	-	-
6	61	M	+	II	SR	20	9	53	28.3	100	-	-
7	38	M	-	I	SR	16	8	40	42.5	60	-	-
8	42	M	-	II	SR	25	14	40	47.5	105	-	-
9	49	M	+	I	SR	20	11	51	45.1	100	-	-
10	51	M	-	I	SR	16	10	50	40.0	100	-	-

FH-family history of hypertrophic cardiomyopathy, NYHA-classification of cardiac functional capacity, IVST-interventricular septal thickness, PWT-left ventricular posterior thickness, LVDd-left ventricular diameter at end-diastole, %FS-percent fractional shortening, IRT-isovolumic relaxation time, SAM-systolic anterior movement of mitral valve with septal contact, LSFW-large slow filling wave, SR-sinus rhythm, AF-atrial fibrillation, F:female, M:male.

present study to clarify the clinical significance of the augmentation of left ventricular slow filling by simultaneous recording of transmitral flow velocity by pulsed Doppler echocardiography and left ventricular pressure.

SUBJECTS and METHODS

Subjects

The subjects were ten patients with hypertrophic cardiomyopathy (2 females and 8 males) between 38 and 69 years old with a mean age of 53 years (Table I). The diagnosis of hypertrophic cardiomyopathy was established by echocardiographic demonstration of a hypertrophied left ventricle in the absence of any other candiac or systemic disease which by itself could have produced left ventricular hypertrophy. Nine of the 10 patients had a non-dilated left ventricle, but one (case 3) had a dilated left ventricle. Case 3 was diagnosed as having hypertrophic cardiomyopathy because a familial study demonstrated typical hypertrophic cardiomypathy in her three relatives. Coronary arteriography did not show any significant narrowing of the extramural coronary anteries in any of the 10 patients. Normal sinus rhythm was shown in nine patients and atrial fibrillation in one. Systolic anterior motion of the mitral valve on M-mode echocardiogram was not observed in any of them.

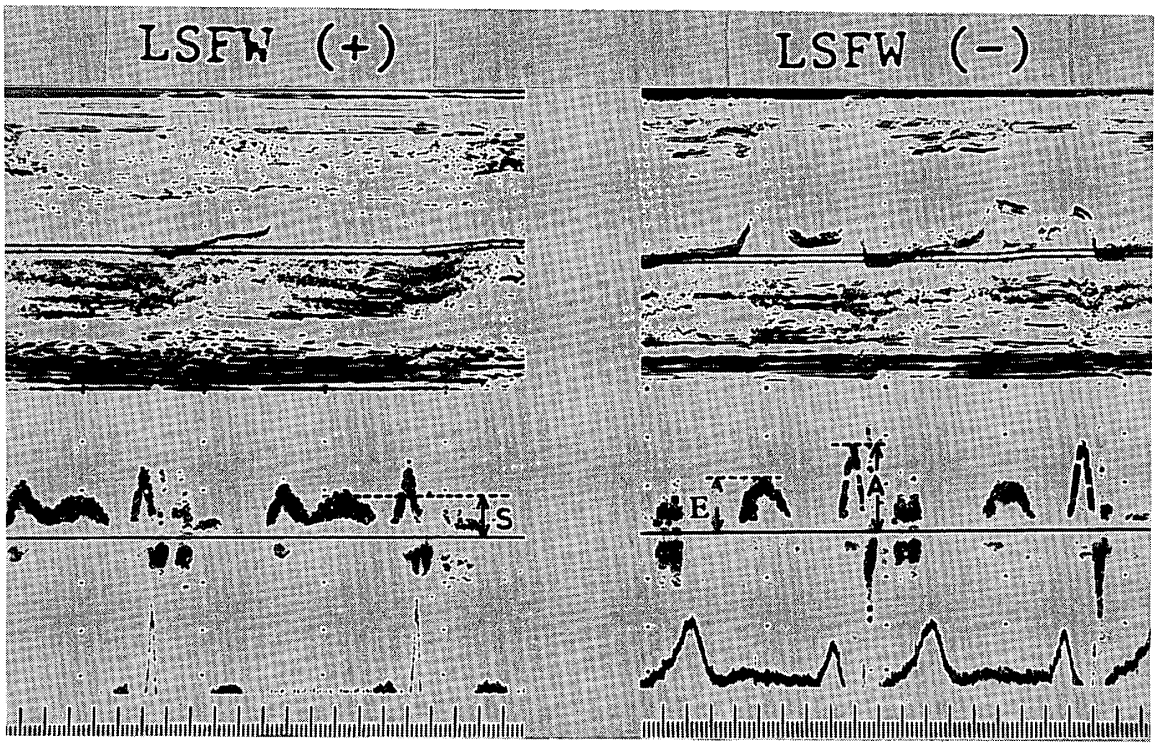

Figure 1. Transmitral flow velocity patterns obtained by pulsed Doppler echocardiography. The left panel shows the transmitral flow velocity pattern with a large slow filling wave (LSFW) and the right panel shows one without any LSFW. E: peak velocity during early filling phase, A: peak velocity during atrial contraction phase, S: peak velocity during slow filling phase.

Study protocol

M-mode, two dimensional and Doppler echocardiograms were obtained just before hemodynamic examination in all patients. In the hemodynamic study, the left ventricular pressure was recorded simultaneously with M mode and transmitral pulsed Doppler echocardiograms in all patients.

Echocardiographic study

An echo-Doppler study was performed with a commercially available instrument (Toshiba SSH 40A and SDS 21A sonolayer system) using A 2.4MHz transducer. A complete standard M-mode echocardiogram was recorded on a strip chart with the electrocardiogram and phonocardiogram. From the M-mode echocardiogram at the chorda tendon level, left ventricular diameters at end-diastole and end-systole (LVDd, LVDs), interventricular septal thickness (IVST) and left ventricular posterior wall thickness (PWT) at end-diastole were obtained. Percent fractional shortening (%FS) was calculated by the following formula: %FS = (LVDd-

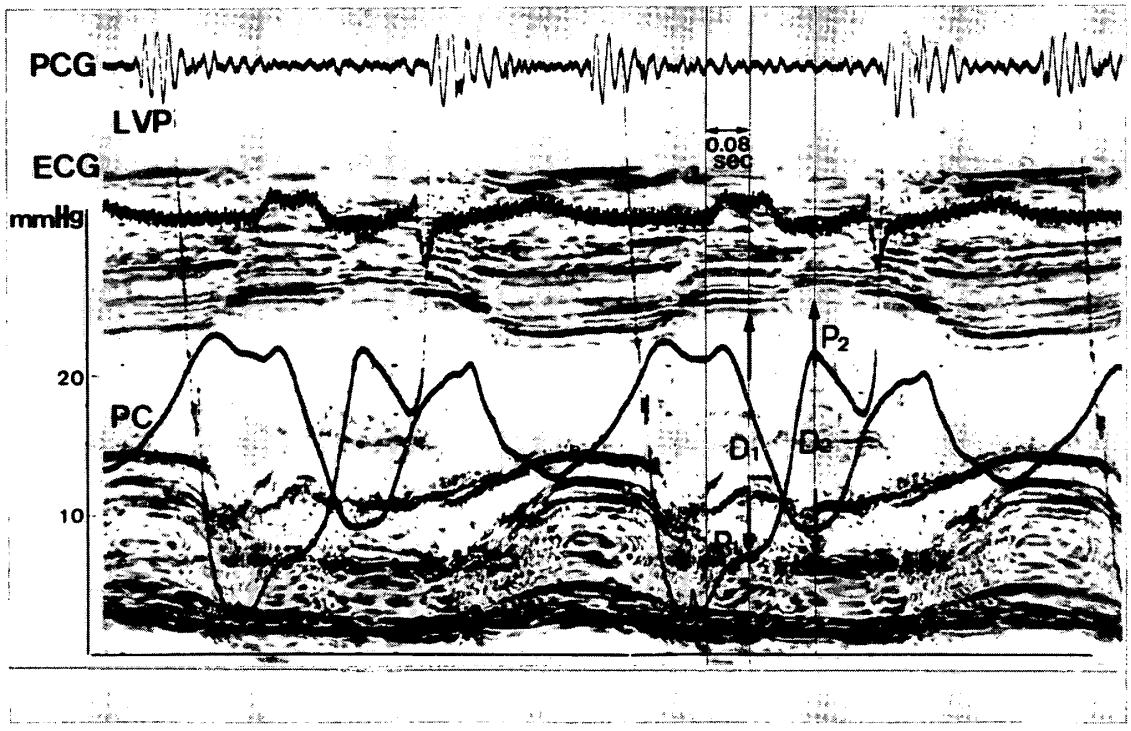

Figure 2. Simultaneous M-mode echocardiogram, left ventricular pressure and electrocardiogram for a representative patient showing the calculation of left ventricular diastolic stiffness during contraction ($\Delta P/\Delta V$). D1 and D2 are left ventricular internal diameters at the onset and the peak of left atrial systole. Corresponding LV pressures at the onset and the peak of left atrial systole are shown as P1 and P2. The onset of left atrial systole was defined as occurring 80 msec after the onset of P wave of ECG and the peak of left atrial systole was defined as the peak of the atrial wave in the LV pressure. $\Delta P/\Delta V = P2 - P1/V2 - V1$. $V = 7D3/(2.4 + D)$ according to the method of Teichholz (24).

LVDs) $\times 100$/LVDd. By the M-mode echocardiogram at the mitral valve level, isovolumic relaxation time was obtained as the interval of the onset of the second heart sound to mitral valve opening. Transmitral flow velocity pattern using pulsed Doppler echocardiography was obstained by the apical long axis view with a 400Hz filter and the sampling volume located at the center of the mitral annulus, aligned nearly parallel to the expected transmitral blood flow. The following indices were obtained from the pulsed Doppler transmitral flow velocity tracing; peak flow velocity during early filling phase (E), peak flow velocity during atrial contraction phase (A), and their ratio (A/E). When the slow filling wave in mid-diastole was obviously observed, peak flow velocity during slow filling phase

(S) was also measured (Fig 1). The large slow filling wave (LSFW) was defined as the slow filling wave whose peak velocity (S) was more than a half of the peak flow velocity during the early filling phase (E) as we previosly reported (17). LSFW was observed in 3 patients in this study (Table I).

Hemodynamic study

Simultaneous recordings of pulsed Doppler echocardiogram and intracardiac pressures were obstained in all ten patients. Pulmonary capillary wedge pressure and cardiac index were measured by a Swan-Gantz catheter, and left ventricular pressure by a Millar micromanometer-tipped catheter. The indices calculated were time constant of left ventricular pressure decay (T) according to the method of Weiss et al (19), and the ratio of pressure change to volume change during atrial contraction ($\Delta P \Delta V$) according to the method of Grossman et al (20) (Fig2).

Statistical methods

The results of this study were expressed as the mean ± 1 standard deviation. Differences between the two groups were tested by Student,s t test, where appropriate. A probability value < 0.05 was considered significant.

RESULTS

Three patients had LSFW in this study, and the other seven patients had no LSFW. M-mode echocardiographic indices (IVST + PWT, LVDd and %FS) were not different between the two groups with and without LSFW, but isovolumic relaxation time tended to be longer in the group with LSFW than in the group without LSFW (114.3 ± 8.1 vs 92.9 ± 15.2 msec). In pulsed Doppler echocardiographic indices, E and A tended to be smaller in the group with LSFW than in the group without LSFW (E: 27.3 ± 3.8 vs 39.1 ± 15.4 cm/s, A: 27.5 ± 17.7 vs 42.1 ± 10.0 cm/s), and A/E yere not different between the two groups (1.09 ± 0.98 vs 1.20 ± 0.47). Hemodynamic indices of pulmonary capillary wedge pressure, left ventricular end-diastolic pressure and cardiac indices were not different between the two groups (Table II). Time constant (T) was significantly longer in the group with LSFW than in the group without LSFW (62.9 ± 9.3 vs 51.9 ± 4.7 msec, $p < 0.05$), but $\Delta P/\Delta V$ was not different between the two groups (0.37 ± 0.08 vs 0.43 ± 0.18 mmhg/ml) (Table II, Fig3). Moreover, in all three patients with LSFW, left ventricular pressure kept declining during not only the rapid filling phase but also the slow filling phase, which was not observed in seven patients without LSFW (Fig4, 5).

DISCUSSION

Impairment of left ventricular filling in patients with hypertrophic cardiomyopathy has been demonstrated using pulsed Doppler echocardiography by serveral investigators, and the indices during the rapid filling phase have been thought to be closely related with the abnormality of left ventricular relaxation. Maron et al. (14)

Table II. Pulsed Doppler echocardiograhic and hemodynamic indices

CASE	E (cm/s)	A (cm/s)	A/E	S (cm/s)	PCWP (mmHg)	LVEDP (mmHg)	CI (l/min/m^2)	T (msec)	ΔP/ΔV (mmHg/ΔC)
1	22.5	40.0	1.78	25.0	16	17	3.70	56.3	0.31
2	37.5	15.0	0.40	22.5	18	27	2.38	58.8	0.42
3	21.9	-	-	18.3	15	11	2.55	73.5	-
4	41.3	27.8	0.67	-	11	13	2.09	57.0	0.39
5	25.5	42.0	1.65	-	22	28	2.58	55.7	0.76
6	28.0	37.5	1.43	-	14	20	3.30	55.1	0.57
7	70.0	32.5	0.46	-	12	9	3.27	50.0	0.26
8	40.0	53.8	1.34	-	11	20	4.10	43.2	0.26
9	43.8	51.3	1.17	-	11	11	3.61	51.8	0.35
10	30.0	50.0	1.67	-	5	15	2.59	50.6	0.42

E: peak flow velocity during early filling phase, A: peak flow velocity during atrial contraction phase,.

S: peak flow velocity during slow filling phase, PCWP: pulmonary capillary wedge pressure,

LVEDP: left ventricular end-diastolic pressure, CI: cardiac index,

T:time constant of left ventricular pressure decay, ΔP/ΔV: the ratio of pressure change to volume change during atrial contraction according to the method of Grossman et al.

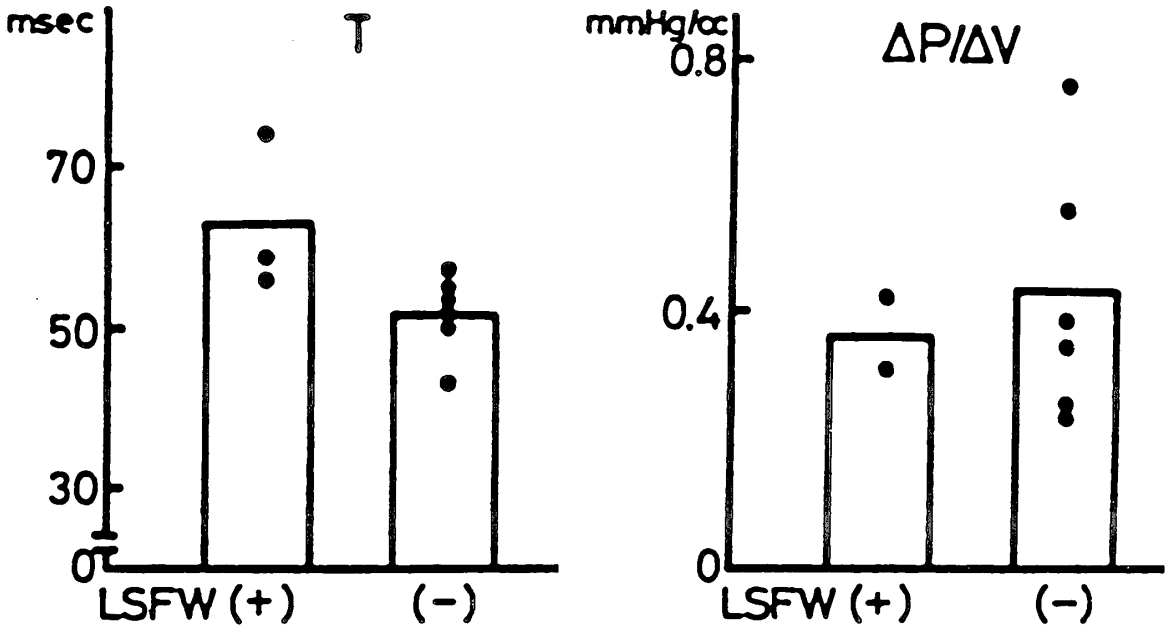

Figure 3. Comparison of indices of LV relaxation and stiffness between patients with and without LSFW. Abbreviations are the same as in table II.

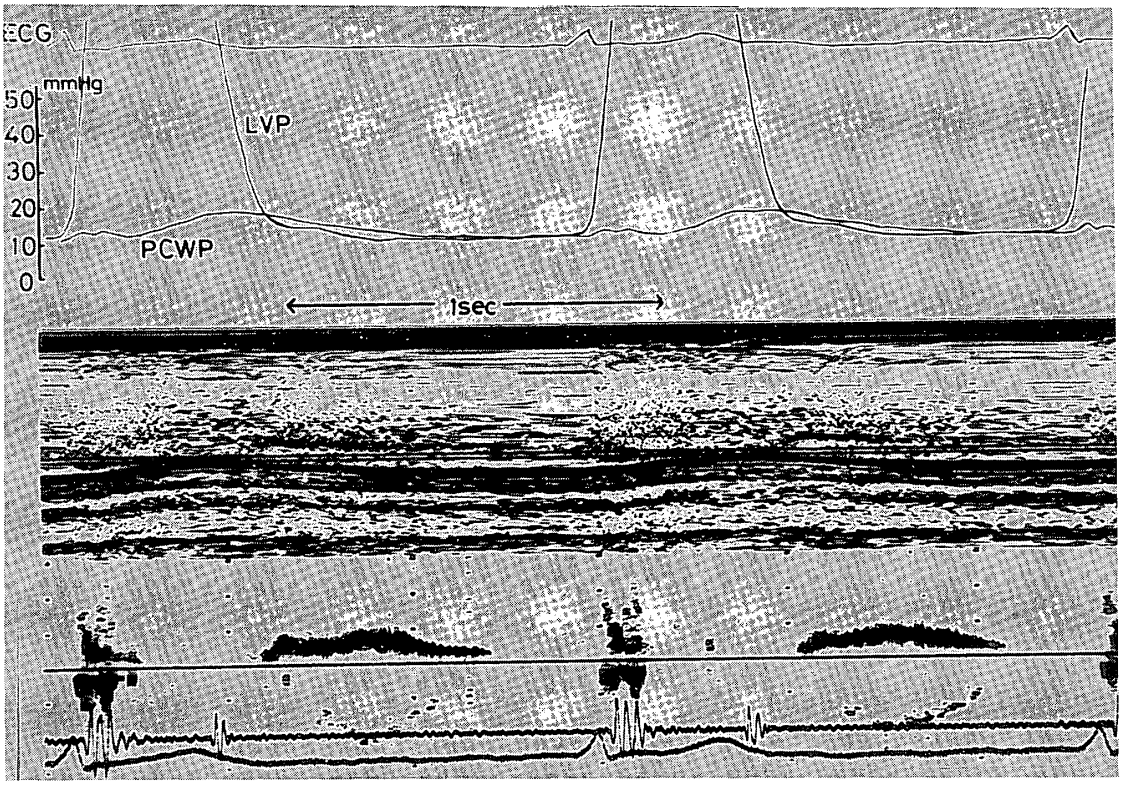

Figure 4. Simultaneous recording of ECG, PCWP, LV pressure and transmitral flow velocity pattern in patient of case 3 with atrial fibrillation. Large slow filling wave was recorded and LV pressure kept declining after the rapid filling phase.

reported that in the majority of patients with hypertrophic cardiomyopathy, isovolumic relaxation and rapid filling time prolonged and peak velocity and deceleration of rapid filling flow was reduced. However, they did not mention about the left ventricular filling velocity wave during the mid-diastolic mitral flow velocity wave on the pulsed Doppler echocardiogram in 50% of normal subjects. They suggested that the wave was caused by the reduction of of left atrial pressure accompanied with rapid filling and subsequent augmentation of left atrial filling via the pulmonary veins. However, the peak velocity of this mid-diastolic mitral flow wave in normal subjects in thier paper was not so large and was smaller than half of the peak velocity during the rapid filling phase. Courtois et al. (22) observed a distinct mid-diastolic deflection in the pulsed Doppler transmitral flow signal in dogs accompanied by a forward transmitral pressure gradient and Nishimura et al. (23) described it in patients with a high filling pressure and high afterload.

In our previous study (17, 18), we

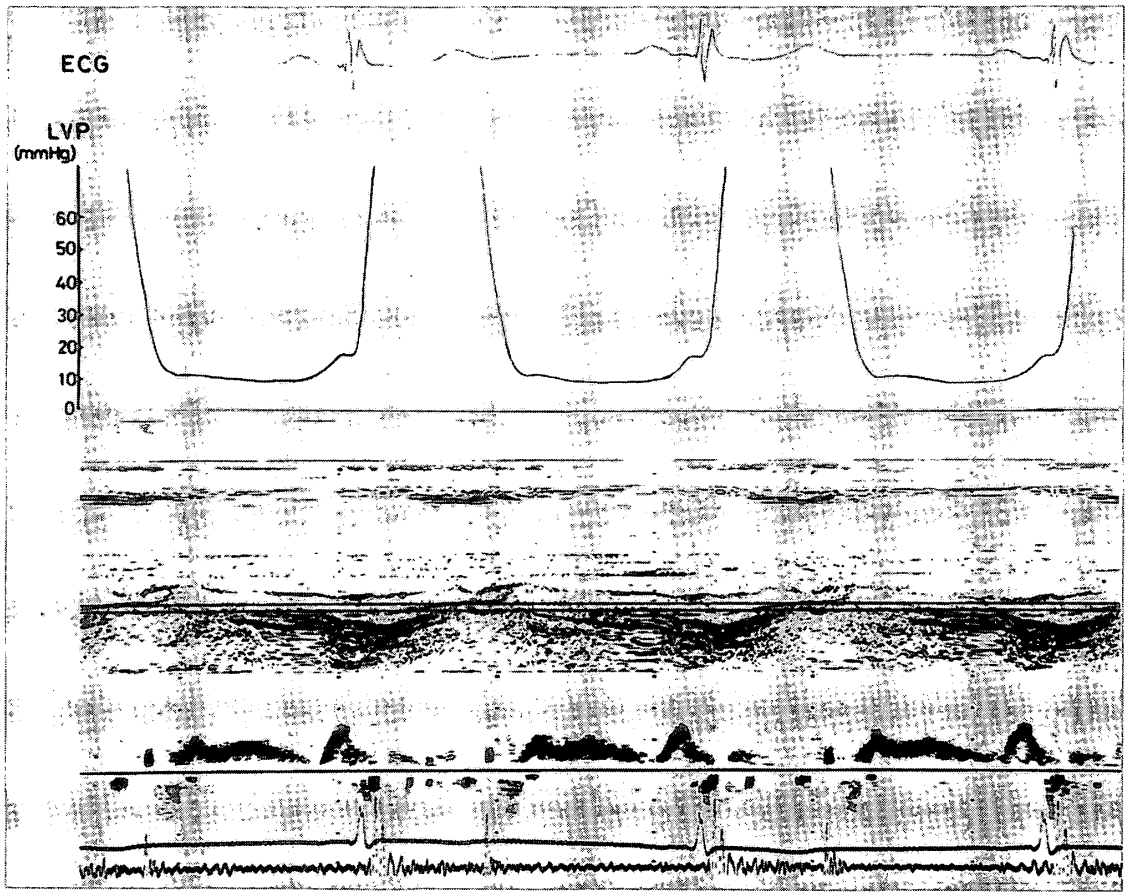

Figure 5. Simultaneous recording of ECG, LV pressure and transmitral flow velocity pattern in patient of case 1. Large slow filling wave was recorded and LV pressure Kept declining after the rapid filling phase.

found that the LSFW was observed in 14% of the patients with hypertrophic cardiomyopathy, but it was very rarely observed in normal subjects or patients with other cardiac disease. In this study, we showed that patients with LSFW had a more prolonged time constant T and tended to have a smaller peak rapid filling velocity and longer isovolumic relaxation period than patients without LSFW. Moreover in all three patients with LSFW, left ventricular pressure kept decreasing during not only the rapid filling but also the slow filling phase. These finding suggest that the presence of LSFW in hypertrophic cardiomyopathy may be related with the markedly delayed and incomplete relaxation of the left ventricle. This mechanism is much different from that of the appearance of the small mid-diastolic wave in normal subjects (21). Lorell et al. (13,14) also reported cases with hypertrophic cardiomyopathy whose left ventricular pressure

showed a continuous decrease during early to mid diastole. In such patients with the continuous decrease of left ventricular pressure, the LSFW may be observed on pulsed Doppler transmitral flow velocity pattern.

REFERENCES

1. Goodwin JF, Oakley CM: The cardiomypathies. Br Heart J 34: 545-52, 1972
2. Gaasch WH, Levine HJ, Qunones MA, et al: Left ventricular compliance: mechanism and clinical implications. Am J Cardiol 38: 645-53, 1976
3. Samderson JE, Traill TA, St John Sutton MG, et al: Left ventricular relaxation and filling in hypertrophic cardiomyopathy: an echocardiographic study. Br Heart J 40: 596-601, 1978
4. Hanrath P, Mathey DG, Kremer P, et al: Effect of verapamil on left ventricular isovolumic relaxation time and regional left ventricular filling in hypertrophic cardiomyopathy. Am J Cardiol 45: 1258-64, 1980
5. Hirota Y: A clinical study of left ventricular relaxation. Circulation 62: 756-63, 1980
6. Ten Cate FJ, Serruys PW, Simon M et al: Effect of short-term administration of verapamil on left ventricular relaxation and filling dynamics measured by a combined hemodynamics-ultrasonic technique in patients with hypertrophic cardiomypathy. Circulation 68: 1274-9, 1983
7. Spirito P, Maron BJ, Chiarella F, et al: Diastolic abnormalities in patients with hypertrophic cardiomyopathy. Circulation 72: 310-316, 1985
8. St John Sutton MG, Tajik AJ, Gibson DG, et al: Echocardiographic assessment of left ventricular filling and septal and posterior wall dynamics in idiopathic hypertrophic subaortic stenosis. Circulation 57: 512-20, 1978
9. Hanrath P, Mathey DG, Siegest g,et al: Left ventricular filling pattern in different forms of left ventricular hypertrophy: an echocardiographic study. Am J Cardiol 45: 15-23, 1980
10. Bonow RO, Rosing DR, Backarach SL, et al: Effect of verapamil on left ventricular systolic function and diastolic filling in patients with hypertrophic cardiomyopathy. Circulation 64: 787-96, 1981
11. Lorell BH, Paulus WJ, Irossman W, et al: Improved diastolic function and systolic performance in hypertrophic cardiomyopathy. N Engl J Med 303:801, 1980
12. Lorell BH, Paulus WJ, Grossman W, et al: Modification of abnormal left ventricular diastolic properties by nifedipine in patients with hypertrophic cardiomyopathy. Circulation 65: 499-506, 1982
13. Gakenaka K, Dabestani A, Gardin JM, et al: Left ventricular filling in hypertrophic cardiomyopathy: A pulsed Doppler echocardiographic study. J Am Coll Cardiol 7: 1263-71, 1986
14. Maron BJ, Spirito P: Green KJ, et al: Noninvasive assessment of left ventricular diastolic function by pulsed Doppler echocardiography in patients with hypertrophic cardiomyopathy. J Am Coll Cardiol 10: 733-742, 1987
15. Shapiro LM, Iibson DG: Patternsof diastolic function in left ventricular hypertrophy. Br Heart J 59: 438-45, 1988
16. Emoto R, Yokota Y, Fukuzaki H: Prognosis in hypertrophic cardiomyopathy: echocardiographic follow-up and histopathological study. Jpn Cric J 53:1031-1044, 1989
17. Emoto R, Yokota Y, Miki T, et al: Augmentation of left ventricular slow filling in hypertrophic cardiomyopathy. Kokyu to Junkan 40: 903-909, 1992
18. Emoto R, Yokota Y, Takeuchi M: Augmentation of left ventricular slow filling in hypertrophic cardiomyopathy (abstract). Circulation 78: Öt-538, 1998
19. Weiss JL, Fredriksen JW, Weisfeldt ML: Hemodynamic deverminants of the time course of fall in canine left ventricular pressure. J Clin Invest 58: 751-760, 1976
20. Grossman W, Stefadouros MA, McLaurin LP, et al: Quantitative assessment of left ventricular diastolic stiffness in man. Circulation 47: 567-574, 1973
21. Keren G, Mecsner JS, Sherez J, et al: Interrelationship of mid-diastolic mitral valve motion, pulmonary venous flow, and transmitral flow. Circulation 74: 36-44, 1986

22. Courotois M, Kovacs SJ, Ludbrook PA, et al: Transmitral pressure-flow velocity relation: importance of regional pressure gradients in the left ventricle during diastole. Criculation 78: 661-671, 1988
23. Nishimura RA, Abel MD, Hatle LK, et al: Relation of pulmonary vein to mitral flow velocities by transesophageal Doppler echocardiography: effect of different loading conditions. Circulation 81: 1488-1497, 1990
24. Teichholz LE, Kreulen T, Herman MV, et al: Problems in echocardiographic determinations: echocardiographic-angiographic correlations in the presence or absence of asynergy. Am J Cardiol 37:7, 1976