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COMPARISON OF ECHOCARDIOGRAPHIC AND ANATOMIC MEASUREMENTS OF THE LEFT VENTRICULAR WALL THICKNESS

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INDEXING WORDS

echocardiographic measurements of LV wall thickness, anatomic measurements, LV trabeculations

SYNOPSIS

The measurement of the left ventricular(LV) wall thickness by echocardiography(echo) is an important part of cardiologic routine. To evaluate the reliability of the LV wall thickness by echo, we compared echo measurements of LV wall thickness with anatomic measurements at autopsy, and assessed the influence of the development of LV trabeculations on these measurements. LV transverse sections at the papillary muscle level of 44 formalin-fixed hearts at autopsy were investigated : 18 with concentric hypertrophic heart diseases, 20 with dilated heart diseases, and 6 normal control hearts. B-mode echo images were obtained and echo

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measurements of the interventricular septum(IVS) and LV posterior wall thickness were made. Anatomic measurements of compact zone thickness and total wall thickness including trabeculae and areas of compact zone, trabeculae, and LV cavity were made. Echo measurements of LV wall thickness were significantly correlated with anatomic measurements of compact zone thickness and total wall thickness including trabeculae. Echo measurements correspond more closely to anatomic measurements of total wall thickness including trabeculae than compact zone thickness alone in normal and hypertrophic hearts($r=0.95$, $r=0.78$). The trabecular area correlated with compact zone area in normal and hypertrophic hearts, but it correlated with cavity area in normal and dilated hearts. Trabecular area was greater in the dilated hearts than in the normal and hypertrophic hearts, but trabecular thickness was greater in the hypertrophic hearts than in the normal and dilated hearts. From this study we found that some discrepancies between echo and anatomic measurements were caused by the development of the trabeculations. And to make echo measurements of wall thickness more reliable, we suggest that well developed and closely adjoining trabeculae should be measured as a part of LV wall thickness.

INTRODUCTION

The estimation of the absence or presence and degree of left ventricular hypertrophy is an important part of cardiologic routine. This estimation has both diagnostic and prognostic significance. Biplane angiocardiography was the most accurate method for the estimation of LV wall thickness before the

development of echocardiography. But this invasive procedure is not without hazard to the patient.

Echocardiography is a noninvasive repeatable technique and it has been used as a very useful method for measuring LV wall thickness. Previous studies showed a good correlation between measurements by echocardiography and angiography.[6)7)9)10)11)12)] But echo measurements have some limitations of artifacts and resolutions. And the identification of the endocardium is not always easy because of the existence of the trabeculations. To evaluate the reliability of echoc measurements of LV wall thickness, 44 hearts at necropsy were studied, and their echo measurements of LV wall thickness were compared with anatomic measurements.

MATERIAL AND METHOD

Forty-four human hearts at autopsy, weighing 300-830g, were obtained at Kobe Univ.hosp. Eighteen were concentric hypertrophic hearts, in which 9 were hypertrophic cardiomyopathy and 9 were secondary hypertrophic hearts, 20 were dilated hearts, in which 11 were dilated cardiomyopathy and 9 were secondary dilated hearts. Six were normal control hearts. Their mean age was 52 years, ranging from 11 to 86. These hearts were formalin-fixed and hand-sectioned along a transverse plane into 1cm-thick sections. LV transverse sections at the papillary muscle level were used for our investigation.

Echocardiographic measurements

The heart sections were suspended in a water filled tank and B-mode echocardiographic images were obtained using a TOSHIBA

SSH160A echocardiograph with a 3.75MHz transducer. The transducer was placed just below the water surface, and the beam was directed perpendicular to the IVS and the LV posterior wall. Gain, reject, damping and compression controls were adjusted to produce as complete an image as possible with the least gain. The sensitivity of the ultrasonoscope was adjusted to display the simultaneous echo of the IVS and the LV posterior wall. Measurements of wall thickness were made perpendicular to the endocardial surface.(Fig.1) Echocardiographic regional wall thickness of the IVS and the LV posterior wall were measured by 3 echocardiologists and the measurements were averaged for calculation. The value which is apart from other 2 values was excluded. All measurements were made before the anatomic measurements.

Anatomic measurements

Photographic images of the corresponding anatomic specimen were taken, compact zone thickness and trabecular thickness were measured in the IVS and the LV posterior wall at the same portions that the echo measurements were made, and the sum of the compact zone and trabeculae was calculated(Fig.1). The endocardium, the epicardium and the border of the compact zone and the trabeculae were outlined. Papillary muscles were excluded. Area of the compact zone and the trabeculae of the left ventricle was measured by image analyzer IBAS-1. The measurements were made by two pathologists. Intraobserver and Interobserver variability was below 5% for all measurements. All the measurements were averaged for calculation.

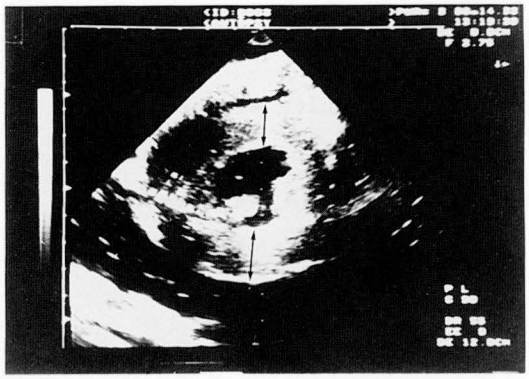
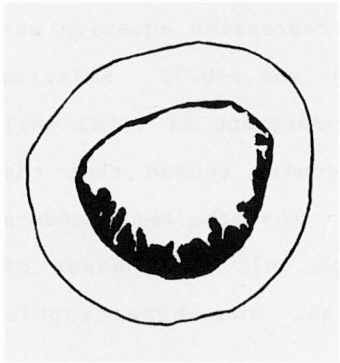


Fig.1
Method of echocardiographic and anatomic measurements:
upper: B mode echocardiogram of the left ventricular(LV) transverse section of the autopsy heart at papillary muscle level. Regional wall thickness of the interventricular septum and the LV posterior wall were measured(arrows).

middle: Photographic image of the same specimen. Compact zone thickness [T(CZ)] (black arrows) and trabeculae thickness [T(TR)](white arrows) were measured at the corresponding portions that echo measurements were performed.



lower: the epicardium, endocardium and the border of compact zone and trabeculae were outlined. The compact zone area, trabecular area, and cavity area were measured. Papillary muscles (arrow head on the photograph above) were excluded.

Statistical analysis

Data were presented as the mean±S.D. Results were analyzed statistically using paired or unpaired Student's t-test. Correlation and linear regression analysis were performed by standard statistical method. Probability less than 0.05 was considered significant.

RESULTS

1. Clinical characteristics and echo and anatomic measurements in normal, hypertrophic and dilated hearts

There was no significant difference in age and sex among these 3 groups. Echo and anatomic measurements of the LV wall thickness in hypertrophic hearts were significantly greater than in normal and dilated hearts. The cavity area of dilated hearts was significantly greater than that of normal and hypertrophic hearts(Table1).

2. The relationship between echo and anatomic measurements in normal and hypertrophic hearts.

Relation between echo measurement and anatomic measurement of compact zone thickness revealed that the regression equation was $y=-0.02+1.26x$. The correlation coefficient was $r=0.78$. Relation between echo measurement and anatomic measurement of total wall thickness of the compact zone and trabeculae showed that the regression was $y=-0.50+0.94x$ and $r=0.95$. The echo measurements corresponded more closely with the total wall thicknesses of compact zone and trabeculae in normal and hypertrophic hearts(Fig.2).

Table.1 Clinical characteristics and echocardiographic and anatomic measurements of each patient

	Age (years)	Sex	Diagnosis	HW (g)	CZ area (cm2)	TR area (cm2)	T(CZ)vs (mm)	T(CZ+TR)vs (mm)	Evs (mm)	T(CZ)pw (mm)	T(CZ+TR)pw (mm)	E pw (mm)	Cav (cm2)
1	86	M	CNT	360	17.30	5.90	15	16	15	13	18	16	4.02
2	52	F	CNT	340	15.40	3.80	12	13	13	14	18	18	2.08
3	23	F	CNT	340	14.60	1.20	14	15	15	15	16	15	2.04
4	42	F	CNT	300	14.70	1.20	12	13	13	13	15	14	3.51
5	71	M	CNT	350	16.90	2.90	13	17	17	16	18	18	1.72
6	50	M	CNT	355	25.10	5.10	18	25	22	18	21	20	3.87
mean	*58*			*341*	*17.30*	*3.35*	*14*	*16.5*	*15.8*	*14.8*	*17.7*	*16.8*	*2.87*
SD.	*27*			*22*	*4.00*	*2.00*	*2.3*	*4.5*	*3.4*	*1.9*	*2.1*	*2.2*	*1.00*
7	44	M	HT	680	26.5	8.21	14.5	22	18	13	24	18	5.19
8	76	M	HT	460	24.1	4.03	14	22	19	19.5	21.5	20	2.33
9	65	F	HT	430	21.5	5.74	15	22	20	15	23	20	1.83
10	59	M	HT	370	19.3	5.37	14	15	15	14	18	18	2.99
11	77	F	HT	450	21.1	6.72	19	21	19	13	22	20	2.47
12	68	F	HT	450	22.1	5.1	16	20	17	19	27	27	2.75
13	67	M	HT	440	25.6	3.56	18	22	16	11.5	19	15	2.96
14	74	M	HT	370	21	4.9	15	23	18	15	22	18	3.80
15	31	M	HT	710	34	6.15	20	24	24	20	27	26	6.75
16	57	M	HCM	550	25.35	5.7	16	28	23	17	27	23	6.30
17	79	F	HCM	340	18.9	4	17	20	19	15	17	16	4.30
18	34	M	HCM	520	31.1	4.3	26	32	28	13	20	18	7.20
19	47	F	HCM	730	42.3	6.66	23	39	40	21	36	35	3.24
20	51	M	HCM	430	27.3	8.06	16	25	20	14	24	23	4.84
21	47	F	HCM	440	17	6.36	16	21	20	14	18	16	2.44
22	48	M	HCM	500	28.5	6.75	27	32	30	22	27	26	4.45
23	61	F	HCM	735	37.6	6.28	15	27	30	23	35	32	3.92
24	48	F	HCM	531	30.8	11.5	23	33	30	15	24	22	2.63
mean	*57*			*510*	*26.3*	*6.07*	*18*	*24.9*	*22.6*	*16.3*	*24*	*21.8*	*3.91*
SD.	*15*			*129*	*6.8*	*1.88*	*4.1*	*5.9*	*6.6*	*3.5*	*5.3*	*5.6*	*1.61*
25	35	M	SD	700	21.8	7.57	12	16	14	13	17	13	16.13
26	11	M	SD	480	17	7.51	10	16	12	11	18	13	9.19
27	60	F	SD	630	26.8	8.9	10	14	11	14	20	14	12.60
28	44	M	SD	587	21.8	6.35	13	20	15	16	20	16	6.05
29	67	M	SD	565	28.1	4.74	17	18	18	16	18	17	6.14
30	62	M	SD	560	22.9	4.92	17	21	18	15	21	17	6.46
31	46	M	SD	440	16.1	2.11	14	17	16	11	13	12	5.88
32	59	M	SD	640	23	10.5	13	21	15	15	17	15	14.20
33	26	M	SD	700	15.2	7.8	8	8	8	8	10	10	17.70
34	48	M	DCM	620	15.7	7.96	12	13	12	10	12	11	21.07
35	57	M	DCM	780	21.9	7.98	11.5	14	12	8	12	12	28.55
36	54	F	DCM	700	27.3	5.08	15	16	16	15	20	17	16.23
37	56	M	DCM	800	20.8	7.03	8	11	9	7	13	8	23.10
38	16	F	DCM	600	17.1	5.09	8	8	8	8	13	9	18.81
39	42	M	DCM	500	19.7	11	10	15	13	8	13	9	17.90
40	42	F	DCM	500	17.5	11.3	10	11	11	11	14	11	16.80
41	44	M	DCM	590	22.1	7.68	10	15	10	9	15	10	12.02
42	52	M	DCM	830	28.3	9.344	11	18	14	14	21	15	12.16
43	66	F	DCM	540	20.1	6.63	8	8	8	10	12	11	13.97
44	26	F	DCM	640	12.6	7.04	8	14	10	7	13	7	15.16
mean	*47*			*620*	*20.8*	*7.33*	*11.3*	*14.7*	*12.5*	*11.3*	*15.6*	*12.4*	*14.5*
SD.	*17*			*185*	*4.41*	*2.22*	*2.8*	*3.9*	*3.1*	*3.1*	*3.5*	*3*	*5.9*

Abbreviations are M: male, F: female, CNT: control, SH: secondary hypertrophic hearts, HCM: hypertrophic cardiomyopathy, SD: secondary dilated hearts, DCM: dilated cardiomyopathy, HW: heart weight, CZ area: compact zone area, TR area:trabecular area, vs: interventricular septum, pw: LV posterior wall, T(CZ): compact zone thickness at autopsy, T(CZ+TR): compact zone and trabecular thickness at autopsy, E: echo measurements of wall thickness, cav: cavity area,

3. The relation between echo and anatomic measurements of wall thickness in normal and dilated hearts.

Relation of echo measurement to compact zone thickness showed that the regression was y=0.72+1.05x and r=0.94. For total thickness of the compact zone and trabeculae, the regression was y=1.23+0.78x and r=0.84. All correlations were statistically significant ($p<0.001$). The echo measurements corresponded closely with both of the anatomic measurements(Fig.3).

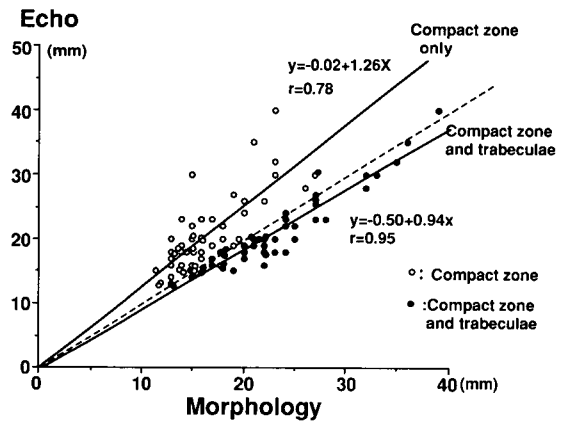


Fig.2
Correlation between echo and anatomic measurements(morphology) of LV wall thickness in normal and hypertrophic hearts The LV wall thickness by echo correlated significantly with the compact zone thickness and the total wall thickness including trabeculae and compact zone. The echo measurements corresponded more closely with anatomic measurements of total wall thickness.

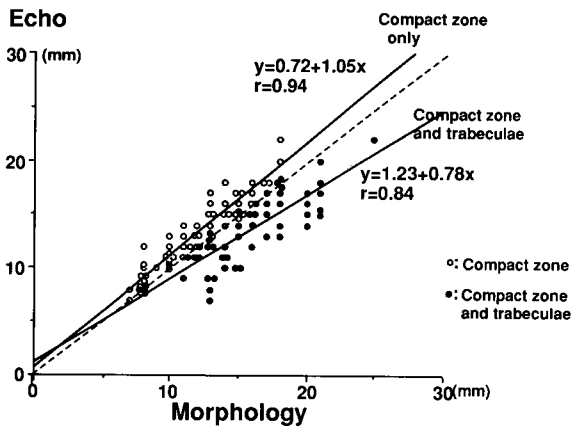
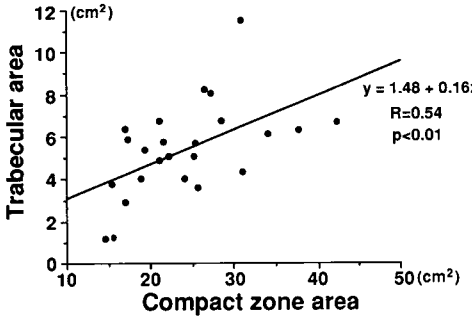
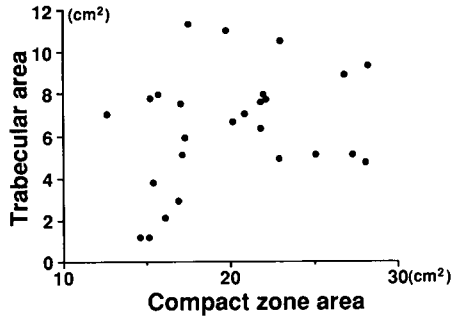


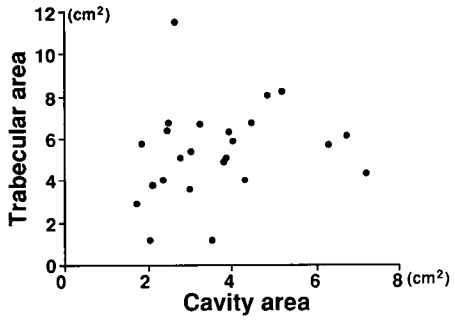
Fig.3
Correlation between echo and anatomic measurements(morphology) of LV wall thickness in normal and dilated hearts The LV wall thickness by echocardiography correlated significantly with the compact zone thickness and the total wall thickness including the compact zone and trabeculae.

4. The relation of wall hypertrophy and cavity dilatation of the left ventricle.

In the normal and hypertrophic hearts, the trabecular area significantly correlated with the compact zone area, but did not correlate with the cavity area (Fig.4). On the contrary, in the normal and dilated hearts, the trabecular area did not correlate with the compact zone area, but did correlate significantly with the cavity area(Fig.5).







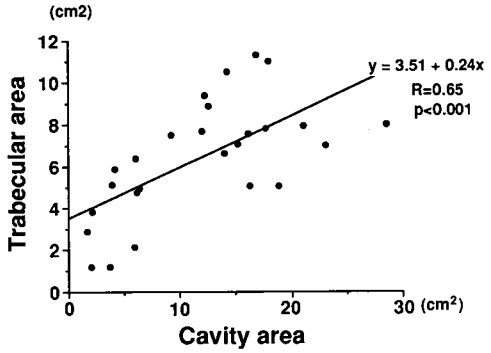


Fig.4
Relationship of trabecular area to compact zone area and to cavity area in the normal and hypertrophic hearts:
Upper: Trabecular area correrlated significantly with compact zone area.
Lower: Trabeculae area showed no correlation with cavity area.

Fig.5
Relationship of trabecular area to compact zone area and to cavity area in normal and dilated hearts:
Upper: Trabecular area showed no correlation with compact zone area.
Lower: Trabeculae area correlated significantly with cavity area.

The trabecular area was significantly greater in the dilated hearts than in the normal and hypertrophic hearts($p<0.001$, both). The trabecular thickness was, however, significantly greater in the hypertrophic hearts than in the normal and dilated hearts(Fig.6).

The compact zone area had no correlation with cavity area.

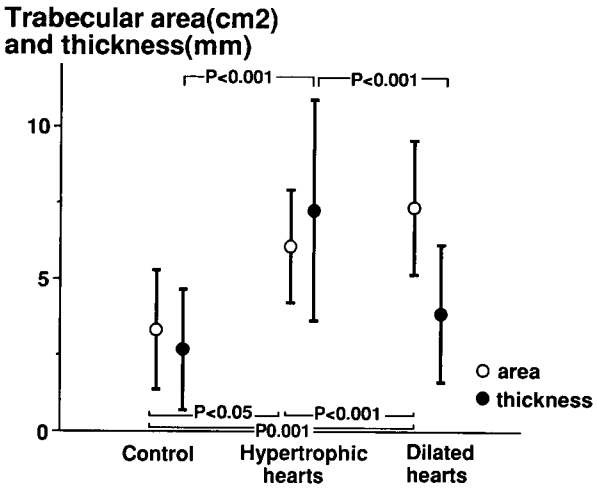


Fig.6 Area and thickness of trabeculae in normal, hypertrophic and dilated hearts: Note that trabeculae of dilated hearts were larger in area, but smaller in thickness than that of hypertrophic hearts.

DISCUSSION

Many publications evaluated the reliability of echo measurements of the LV wall thickness in comparison with angiographic measurements in vivo.[6)7)9)10)11)12)] There are some studies about comparison of echo during life and autopsy measurements of the LV wall thickness. These studies showed the close correlation between autopsy and echo measurements of the LV wall thickness at systole.[1)2)5)8)] Our present study also showed

a close correlation between the echo and autopsy measurements of the LV wall thickness. These results confirmed that echocardiography is a useful and reliable diagnostic method for measuring the LV wall thickness. However, the echo measurements were not always consistent with autopsy measurements. This inconsistency arises in part from a fundamental problem, which is the inherent limitation of echocardiographic image resolution, and results in limited accuracy of boundary identification of the endocardium. The hypertrophied trabeculations make it more difficult. Few publications have discussed these problems of echo measurements in terms of the left ventricular structures.[2)5)12)] In our present study B-mode echo images of the hearts at autopsy were taken, and echo measurements of the LV wall thickness were compared with direct anatomic measurements of the photographic image. We examined the accuracy of echo measurement of LV wall thickness in relation to the anatomic identification of the endocardium. The echo measurements correlate very well with the anatomic measurements of the compact zone thickness and the total wall thickness of compact zone and trabeculae, but of our interest, the echo wall thickness in hypertrophic hearts corresponded more closely with the anatomic measurements of the total wall thickness of compact zone and trabeculae rather than the compact zone thickness alone. This reason may be explained as follows: In concentric hypertrophic hearts, the LV cavity is small and the trabeculae, which develop with the augmentation of compact zone [4)], are closely adjoining to each other in the small LV cavity. It is therefore impossible to distinguish the trabeculae from the compact zone by echocardiography, and trabeculae might be measured as a part of the LV wall thickness .

On the other hand, in the dilated hearts, trabeculae augment their area with the dilation of the LV cavity, but the trabecular thickness is not large, and trabeculae are not closely adjacent to each other in the dilated LV cavity. Consequently, in many cases with LV dilatation, trabeculae can be distinguished from compact zone.[8] From these results, we concluded that some discrepancies between echo and anatomic measurements exist in the presence of the trabeculations. To make echo measurements of wall thickness more reliable, we suggest that well developed and closely adjoining trabeculae should be measured as a part of LV wall thickness.

Limitations

In clinical echocardiographic examinations, LV wall thickness is measured in late diastole by convention. This study is an autopsy examination and hearts at autopsy are compatible with the systolic phase of cardiac cycle.[5]

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REFERENCE

1. Feigenbaum, H., Popp, R.L., Chip, J.N., et al : Arch Intern Med 1968.121.391/395. Left ventricular wall thickness measured by ultrasound.
2. Helak, J.W., Reichek, N.: Circulation 1981.63.1398/1407. Quantitation of human left ventricular mass and volume by

two-dimensional echocardiography : In vitro anatomic validation.

3. Keren, A., Billingham, M.E., Popp, R.L.: Circulation 1984. 70.836/842. Echocardiographic recognition and implications of ventricular hypertrophictrabeculations and aberrant bands.
4. Keren, A., Billingham, M.E., Popp, R.L.: Am J Cardiov Path 1988.1.369/378. Ventricular aberrant bands and hypertrophic trabeculations. A clinical pathological correlation.
5. Maron, B.J., Henry, W.L., Roberts, W.C., et al: Circulation 1977.55.341/346. Comparison of echocardiographic and necropsy measurements of ventricular wall thickness in patients with and without disproportionate septal thickening.
6. Murrary, J.A., Johnston, W., Reid, J.M.: Am J Cardiol 1977.30.252/257. Echocardiographic determination of left ventricular dimensions, volumes and performance.
7. Pombo, J.F., Troy, B.L., Russel, R.O.Jr.: Circulation 1971.43.480/490. Left ventricular volume and ejection fraction by echocardiography.
8. Prakashi, R., Umali, S.A.: Am J Cardiol 1984.53.838/841. Comparison of echocardiographic and necropsy measurement of left ventricular wall thickness in patients with coronary artery disease.
9. Sjogren, A.L., Hytonen ,I,. Frick, M.H.: Chest 1970.57.37/40. Ultrasound measurements of left ventricular thickness.
10. Sjogren, A.L.: Chest 1971.60.341/346. Left ventricular wall thickness determined by ultrasound in 100 subjects without heart disease.
11. Teichiholz, L.E., Kreulen, T., Herman, M.V. : Am J Cardiol 1976.37.7/11. Problems in echocardiographic volume

determinations. Echocardiographic angiographic correlations in the presence and absence of asynergy.

12. Troy, B.L., Pombo, J.F., Packley, C.E.: Circulation 1972. 45.602/611. Measurement of left ventricular wall thickness and mass by echocardiography.

13. Wakafuji, S., Shirai, T., Okada, R.: Jpn Cir J 1987.51. 527/534. Histopathological study of the papillary muscle and 2wapex cordis of the hypertrophied left venticle.