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原　　著

Clinical and Experimental Studies of the Relationship Between Phasic Mitral Flow and Mitral Valve Echogram: Echocardiographic Evaluation of Annuloplasty for Mitral Regurgitation

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Introduction

Echocardiography, as a noninvasive method of diagnosis of all cardiac diseases, has become a very necessary test and is being used extensively. By this diagnostic technique, a great deal of information for the assessment of cardiac anatomy and function has become available. The qualitative assessment of mitral regurgitation (MR) is fairly accurate, but in the quantitative assessment of this disease, such as the degree of MR and the amount of mitral flow, there have been very few echocardiographic evalutions. Indeed, left ventricular angiographic findings are the most important aid in defining the clinical severity of MR. In most cases of MR due to non-rheumatic causes, such as congential factors, chordal rupture and papillary muscle dysfunction, mitral valve replacement must be avoided if possible and reconstructive surgery performed instead. In the evaluation of the effects of surgery, one must follow the clinical course and perform frequent clinical examinations. A decision to reoperate or to change to MVR must be made occasionally on the basis of the results of such observations. Left ventricular angiography, however, cannot be done frequently. Since echocardiography is noninvasive and frequent use is possible, the importance and effectiveness of this method are becoming more and more appreciated in the quantitative assessment of MR.

In an experiment with mongrel dogs with normal mitral valves, MR, or mitral annuloplasty, echocardiographically recorded mitral valve motion was compared with phasic transmitral flow which was recorded simultaneously by electromagnetic flowmetry.

In patients, the hemodynamic results of pre- and postoperative cardiac catheterizations were correlated with the echogram of mitral valve motion. The usefulness of echocardiography in

Key words: Phasicmitral flow, Mitral valve echogram, Mitral annuloplasty, Mitral regurgiation, Corrected E-F slope.
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the determination of the degree of MR and in the evaluation of mitral reconstructive surgery is discussed.

Materials and methods

Experiments were performed in 20 mongrel dogs weighing 16–30 kg. They were anesthetized with intravenous Nembutal (25–30 mg/kg). Each dog was ventilated with room air via an endotracheal tube attached to a Harvard pump respirator with 20–25 ml/kg of tidal volume. The chest was then opened by bilateral thoracotomy through the 4th intercostal space and transverse sternotomy. The pericardial sac was opened medianly and retracted with stay sutures. The preoperative electrocardiogram (ECG) and mitral echocardiogram (UCG: Toshiba 01A, Probe 5MHz Aerotec ϕ10 mm), obtained by placing the echo-probe on the surface of the right ventricle, were recorded. During cardiopulmonary bypass with the arterial infusion tube in the right femoral artery and the venous drainage tube in the right atrium, mitral annuloplasty was performed with a single U stay suture in the anterior commissure. Then a squarewave electromagnetic flow probe (model FR 080T-160T, NIHON KOHDEN) was sutured in the left atrium above the mitral ring. In order to obtain better operative results, cold potassium cardioplegia and topical myocardial cooling were used for myocardial protection. The dogs that were not treated with mitral annuloplasty served as controls. After the intracardiac procedures, the heart was resuscitated in the usual manner. ECG, left ventricular (LV) pressures obtained through the catheter which was inserted from the LV apex, left atrial (LA) pressures and flow waves of the mitral orifice were recorded continnuously, and the mitral UCG was recorded simultaneously. The electromagnetic flow meter was model MFV 1200 NIHON KOHDEN, and the transducers of the manometer were model P23 ID GOULD Statham. Next, MR was induced by a nerve hook inserted from the LV apex, and the chordae of the mitral anterior leaflet were plucked off. The onset of MR was recognized by the mitral flow pattern and elevated v wave in the LA pressure

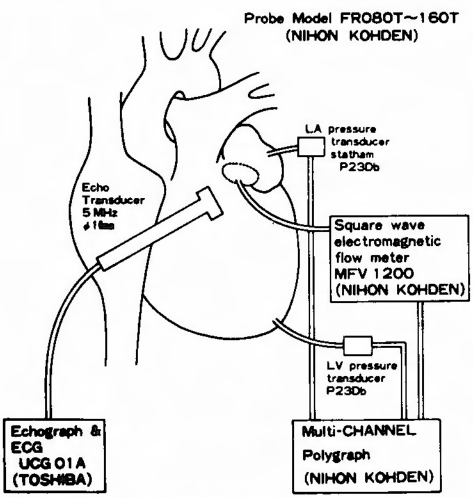

Fig. 1. Diagram of the Experiment

curve. In the same manner, ECG, LV pressure, LA pressure, mitral flow wave and mitral UCG were recorded simultaneously by a multichannel oscillographic recorder (NIHON KOHDEN polygraph system) at a paper speed of 50 or 100 mm/sec. Fig. 1 is a schematic representation of the experimental outlines.

Measurements and calculations

Fig. 2 is a schematic representation of the relationship between the mitral UCG and mitral flow with ECG, in which the measured parameters are defined.

Mitral filling volumes and closing volumes were calculated by planimetry of the area under the calibrated mitral flow curve. Cardiac output was obtained from aortic or mitral flow measurement and heart rate. UCG parameters such as C-E amplitude and E–F slope were calculated by OSCON cathlabo. system, automatically. Each value obtained was the mean measurement of several stabilized consecutive beats.

Results

The recorded tracings of ECG, mitral flow, LV pressure, LA pressure and mitral UCG are shown in Fig. 3. As shown in the diagram of Fig. 2, the mitral flow curve is strikingly similar in pattern to the mitral UCG curve, especially in diastole. The onset of mitral flow starts slightly after the mitral valve opening, and the peak flow is also delayed beyond the complete opening of the mitral valve. The reason for this delay is that the opening motion of the mitral valve may coincide with mitral annular movement. The negative component of the mitral flow curve, the dotted area in Fig. 2, is caused by bulging of the mitral leaflet in the systolic phase; an increase in this component indicates the presence of MR. In Fig. 4, hemodynamic parameters and mitral

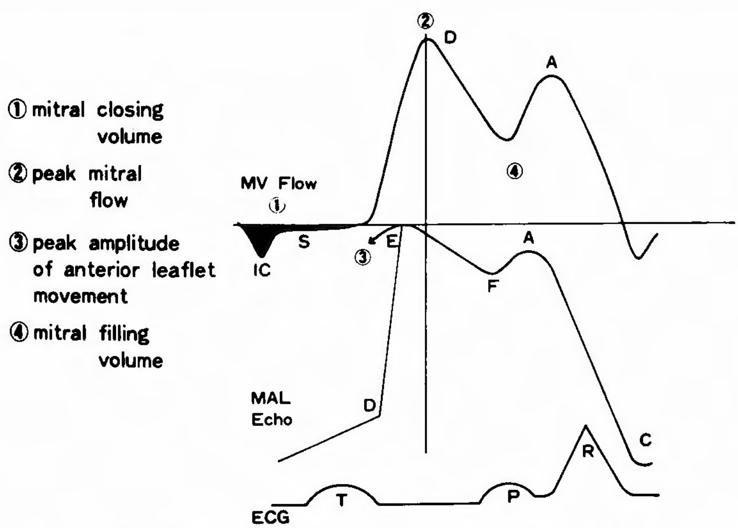

Fig. 2. REPRESENTATION of the NORMAL RELATIONSHIP between mitral flow and mitral valve echogram

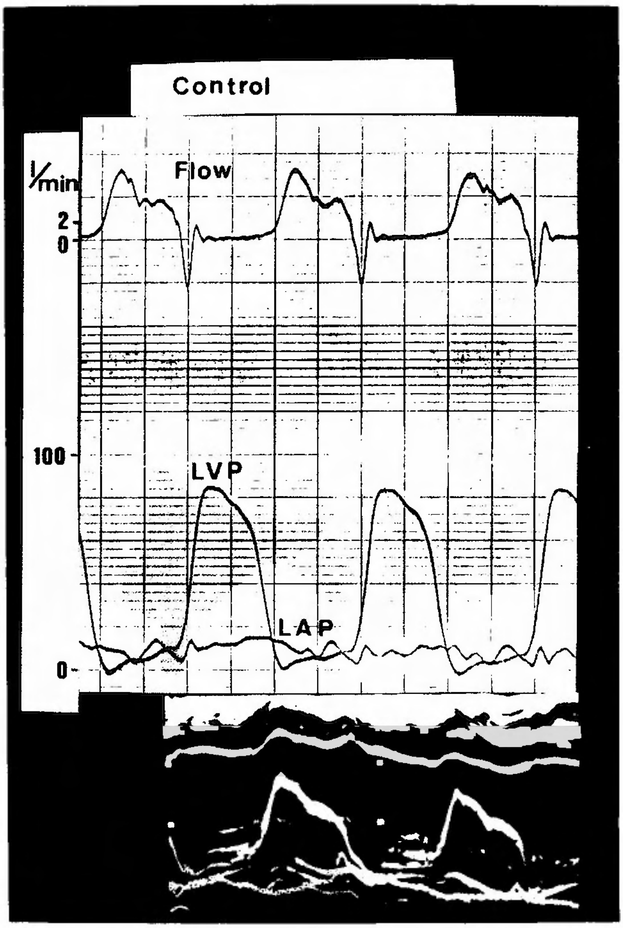

Fig. 3.

Table 1. Hemodynamic and Echocardiographic Data from 10 Dogs without mitral Regurgitation in Control group

Dog	Cardiac output (l/min)	Percent closing (%)	C-E Amplitude (mm)	E-F Slope (min/sec)
1	1.03±0.04	18.8±0.7	11.3±0.2	52.0±2.4
2	0.90±0.02	20.1±1.0	12.5±0.1	40.0±1.8
3	0.98±0.02	17.5±0.4	14.8±0.1	58.0±3.6
4	1.75±0.03	16.3±0.7	15.1±0.3	90.0±2.5
5	1.77±0.04	16.8±0.8	15.4±0.2	83.0±3.6
6	1.58±0.04	15.3±0.5	17.8±0.3	77.0±2.3
7	1.55±0.05	13.2±0.2	17.8±0.2	78.0±2.6
8	1.52±0.07	15.7±0.6	17.5±0.2	78.0±3.2
9	1.85±0.05	11.4±0.1	18.0±0.3	94.0±3.8
10	2.22±0.06	13.9±0.1	15.0±0.1	102.0±3.6
Mean±S.E.	1.52±0.43	15.9±2.61	15.5±2.3	75.2±19.5

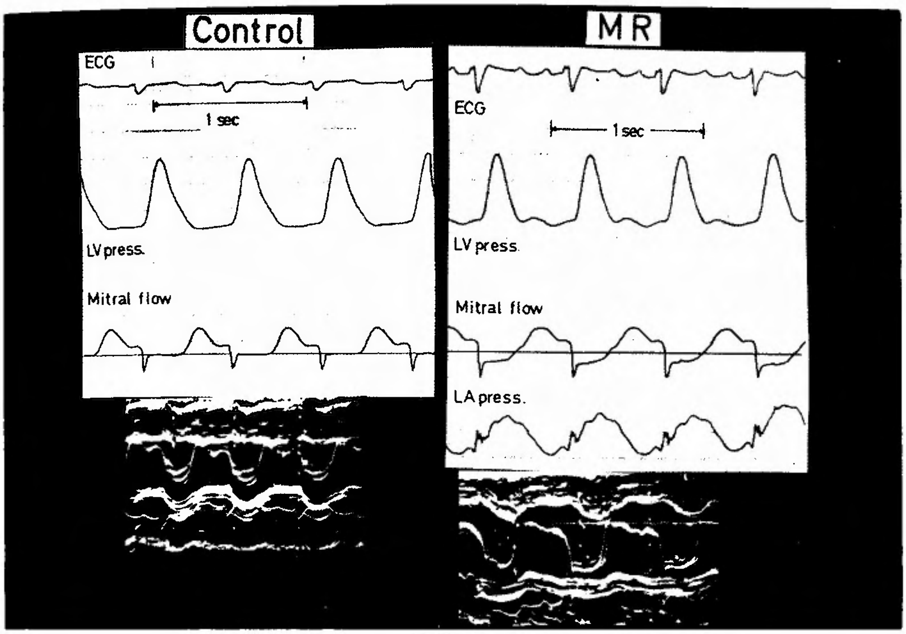

Fig. 4.

UCG are shown in which the mitral valve is induced to MR; an increased negative component with descent of the S-segment, elevation of the v wave in the LA pressure recording, and acceleration of the E–F slope in the mitral UCG are observed. Fig. 5 is a record of the hemodynamic factors and mitral UCG of a dog in the annuloplasty group in which the mitral UCG shows a pattern of mitral stenosis along with disappearance of the second peak. The flow curve shows a pattern similar to the UCG in its diastolic phase except for a slight decrease of the negative component due to reduction of the systolic bulging of the mitral leaflet into the LA and caused by

Table 2. Hemodynamic and Echocardiographic Data from 10 Dogs with mitral Regurgitation in Control group

Dog	Cardiac output (*l*/min)	Percent Closing (%)	C-E Amplitude (mm)	E-F Slope (mm/sec)	LA-v wave (mmHg)
1	0.83±0.07	36.0±0.2	14.2±0.1	72.8±3.2	21.9±1.6
2	0.94±0.05	40.0±0.3	17.1±0.5	82.1±3.6	23.2±2.1
3	0.99±0.06	43.2±0.3	19.4±0.3	94.7±4.1	22.8±1.8
4	1.17±0.04	31.2±0.1	20.0±0.4	87.7±3.5	24.2±1.8
5	1.18±0.08	44.0±0.3	17.2±0.4	105.0±4.3	25.7±2.2
6	1.37±0.03	27.4±0.4	16.2±0.3	93.6±3.7	26.2±2.1
7	1.42±0.05	40.0±0.4	18.3±0.5	104.8±3.8	27.8±2.0
8	1.63±0.07	37.7±0.2	18.0±0.2	118.3±4.3	32.4±2.4
9	1.45±0.03	37.0±0.3	15.7±0.1	106.9±4.0	33.7±1.9
10	1.97±0.05	35.4±0.4	20.0±0.2	117.8±3.8	38.4±2.3
Mean±S.E.	1.30±0.35	37.2±5.1	17.6±1.9	98.5±14.8	27.6±5.5

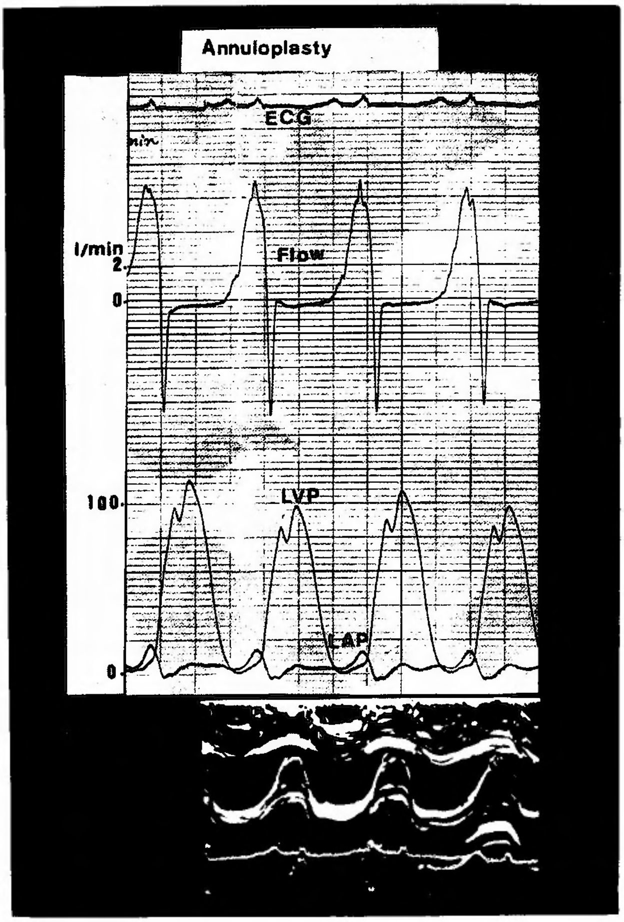

Fig. 5.

Table 3. Hemodynamic and Echocardiographic Data from 10 Dogs without mitral Regurgitation in Annuloplasty group

Dog	Cardiac output (*l*/min)	Percent closing (%)	C-E Amplitude (mm)	E-F Slope (mm/sec)
1	0.90±0.03	17.2±0.8	11.5±0.1	12.8±3.3
2	1.08±0.04	15.9±0.6	9.6±0.1	20.4±2.2
3	1.23±0.04	16.5±0.7	10.9±0.2	16.3±1.9
4	1.67±0.03	16.3±0.6	9.6±0.1	24.9±2.7
5	1.60±0.03	18.8±0.8	12.5±0.3	29.8±3.1
6	1.68±0.05	13.7±0.6	15.5±0.2	33.1±3.0
7	1.45±0.03	11.2±0.4	16.5±0.3	26.7±2.5
8	1.63±0.06	14.7±0.3	16.2±0.1	39.7±1.8
9	1.82±0.06	9.5±0.2	17.5±0.2	35.4±1.7
10	2.33±0.08	8.3±0.2	17.7±0.3	48.0±2.9
Mean±S.E.	1.54±0.40	14.2±3.5	13.8±0.3	28.7±10.8

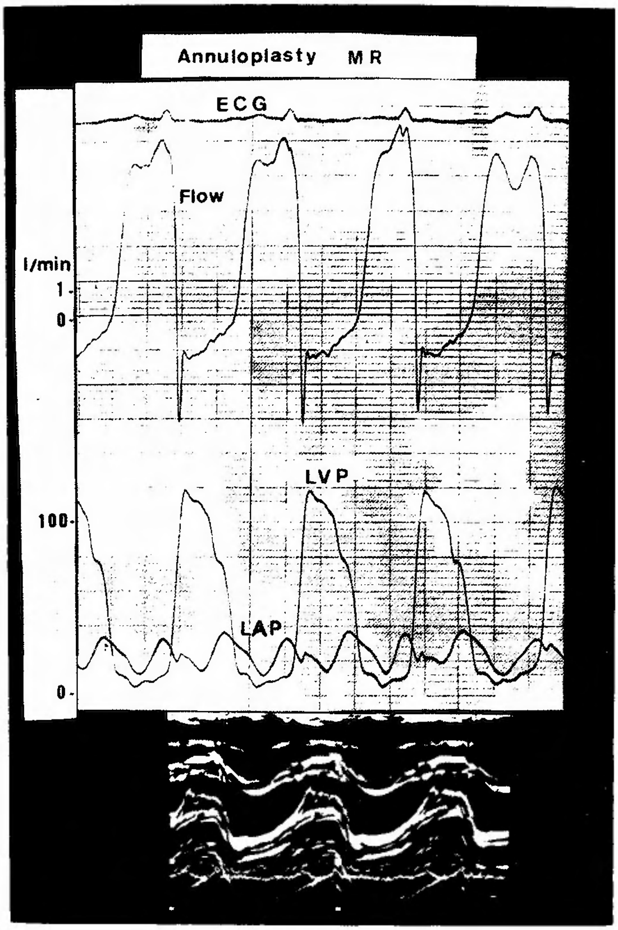

Fig. 6.

Table 4. Hemodynamic and Echocardiographic Data from 10 Dogs with mitral Regurgitation in Annuloplasty group

Dog	Cardiac output (l/min)	Percent Closing (%)	C-E Amplitude (mm)	E-F Slope (mm/sec)	LA·v wave (mmHg)
1	0.99±0.02	30.3±0.7	12.5±0.2	37.6±2.3	26.3±1.4
2	0.94±0.03	28.9±0.9	14.5±0.3	31.2±1.6	27.7±2.1
3	1.06±0.02	32.5±0.3	11.4±0.2	42.0±2.7	30.4±1.8
4	1.17±0.04	31.0±0.2	11.8±0.2	43.3±1.9	31.8±2.3
5	1.17±0.03	34.5±0.5	17.5±0.1	51.9±3.0	32.0±1.7
6	1.33±0.04	40.4±1.2	18.3±0.4	50.7±2.9	34.1±2.3
7	1.54±0.05	33.5±0.7	18.4±0.2	69.4±3.3	37.9±2.3
8	1.63±0.07	35.1±0.6	15.5±0.5	70.0±2.8	42.3±3.0
9	1.97±0.03	41.9±0.8	17.5±0.4	77.3±3.5	40.1±3.1
10	1.95±0.06	42.7±1.1	17.8±0.3	87.9±4.6	47.0±2.7
Mean±S.E.	1.38±0.38	35.1±4.9	15.5±2.8	56.1±18.8	34.96±6.7

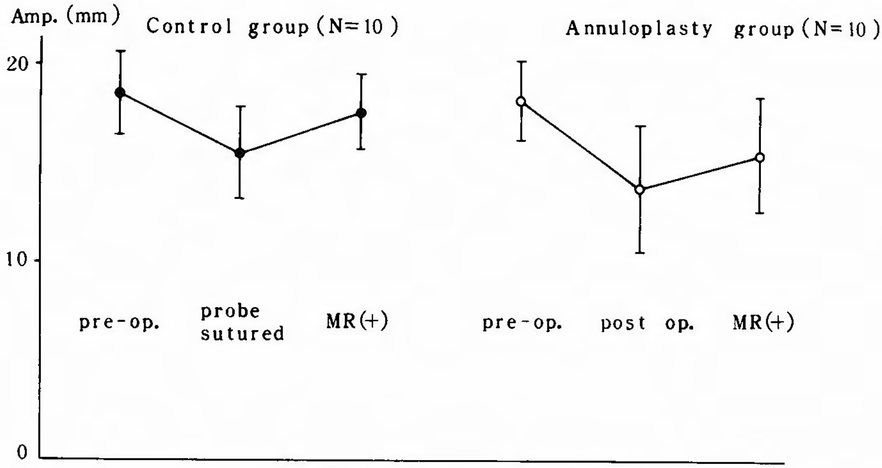

Fig. 7. Changes in Values of C-E Amplitude

annular narrowing after mitral annuloplasty.

When MR is induced in dogs with annuloplasty, the S-segment of the mitral flow wave is significantly lowered, indicating increased mitral closing volume, along with acceleration of the E–F slope and elevation of the v wave in the LA pressure curve (Fig. 6).

All experimental values in each group are shown in Tables 1 to 4. The % closing volume is the ratio of mitral closing volume to mitral filling volume, that is, regurgitant ratio from the LV to the LA. The correlations between these parameters are as follows:

1. Changes in values of C–E amplitude (Fig. 7)

In the control group, in which the electromagnetic probe was sutured to the mitral annulus, the preoperative value averaged 18.5±2.1 mm (average±S.E), and this decreased to 15.5±2.3

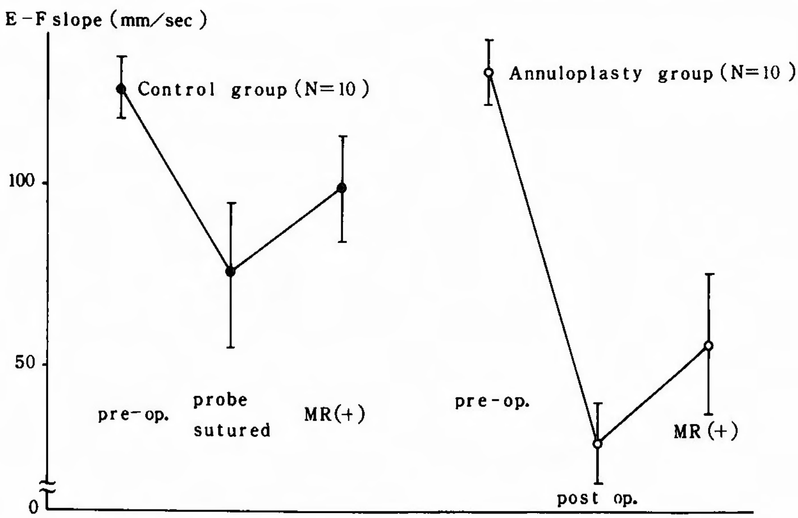

Fig. 8. Changes in Values of E-F slope

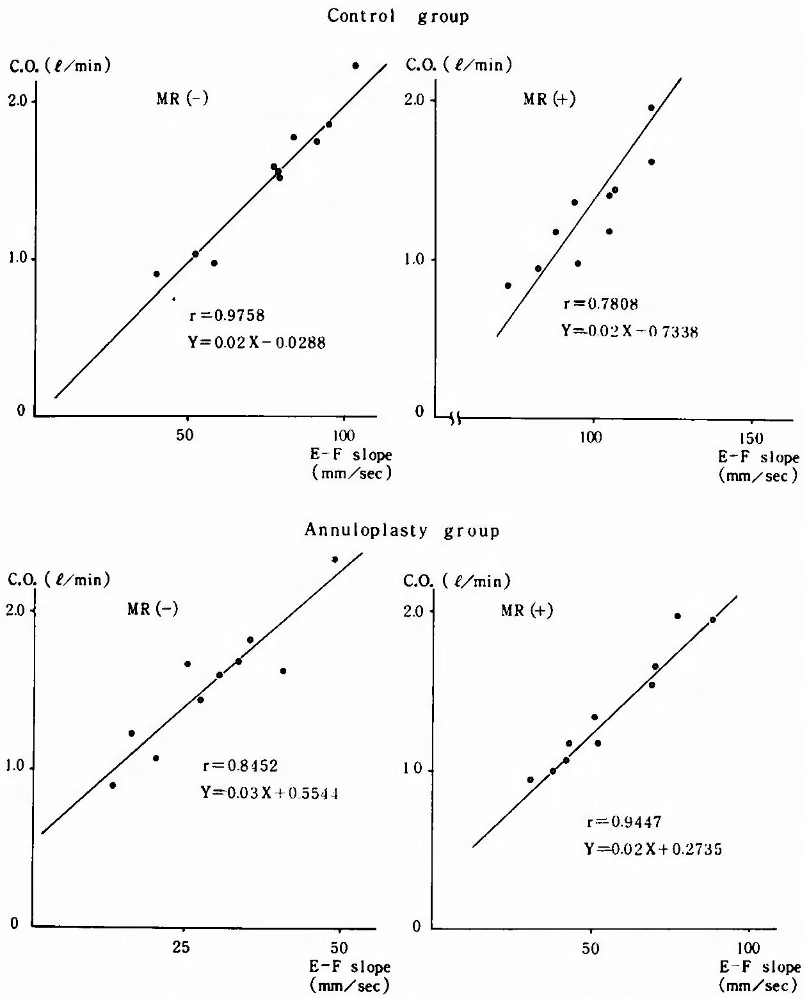

Fig. 9. Relationship between E–F slope and C.O.

mm after operation. However, after experimental regurgitation was produced, the average increased to 17.6±1.9 mm again.

In the annuloplasty group, these averages were 18.2±2.0 mm preoperatively and 13.8±0.3 mm postoperatively, and increased again to 15.5±2.8 mm after the creation of MR.

2. Changes in values of E–F slope (Fig. 8)

In the control group, the preoperative average (126.4±8.5 mm/sec) decreased to 75.2±19.5 mm/sec with the attachment of the flow probe, but increased again to 98.5±14.8 mm/sec with the creation of experimental MR.

In the annuloplasty group, the preoperative average (130.8±9.2 mm /sec)diminished significantly to 28.7±10.8 mm/sec after annuloplasty and attachment of the flow probe. However, after experimental MR, it increased to 56.1±18.8 mm/sec.

3. Relationship between E–F slope and cardiac output (C.O.)

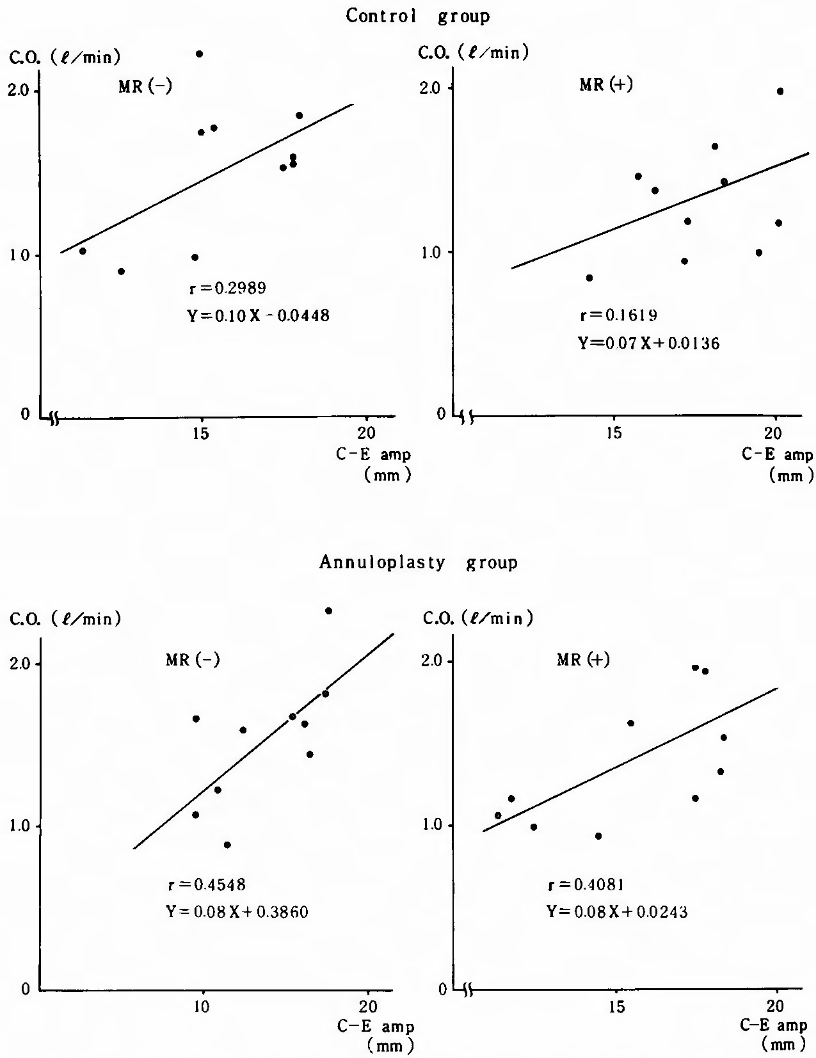

Fig. 10. Relationship between C−E amplitude and C.O.

As shown in Fig. 9, mitral valve E−F slope varied in a close and positive linear relationship to the cardiac output in both groups, with or without MR.

4. Relationship between C−E amplitude and C.O. (Fig. 10)

In no group, was there a correlation between these two parameters.

5. Relationship between % C.V. (regurgitation ratio) and E−F slope (Fig. 11).

In the control group, before the creation of MR there was a negative linear relationship between %C.V. and E−F slope, but in the presence of MR, there was no such relationship.

In the annuloplasty group without MR, the %C.V showed a negative linear relationship to the E−F slope, while with MR there was a positive linear relationship.

6. Relationship between %C.V. and C−E amplitude (Fig. 12)

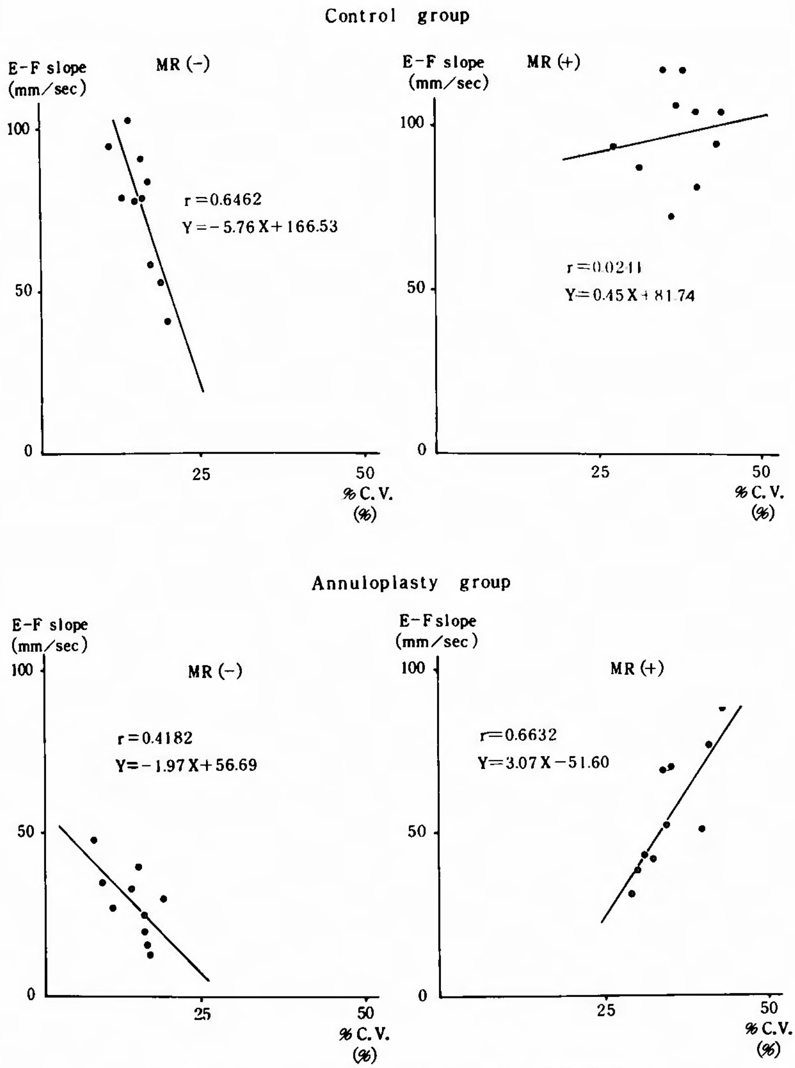

Fig. 11. Relationship between % C.V. and E-F slope

In the control group without MR, there was negative linear relationship between these two parameters, but with MR there was no relationship.

In the annuloplasty group with MR, %C.V. varied in a slightly positive linear relationship to C-E amplitude, but without MR there was a negative linear relationship.

7. Relationship between E-F slope and LA v wave (Fig. 13)

In both groups with MR, the E-F slope varied in positive linear relationship to the pressure of the LA v wave.

8. Relationship between LA v wave and C-E amplitude (Fig. 14)

In both groups with experimental MR, LA v wave pressure showed no relationship to C-E amplitude.

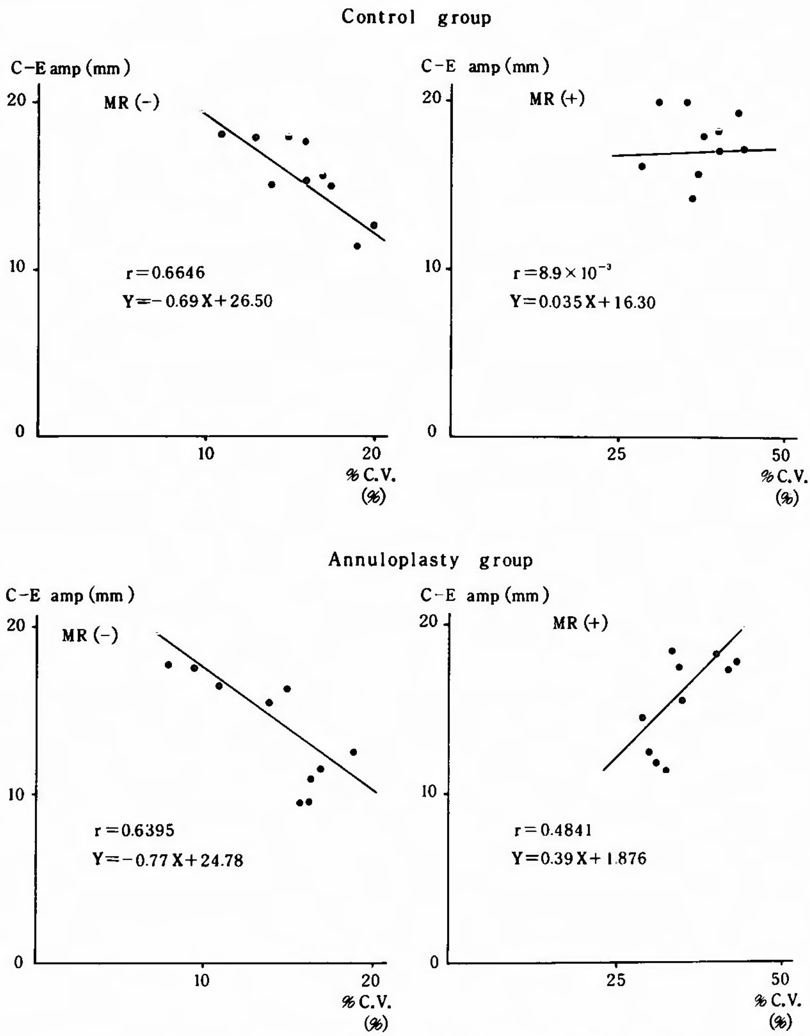

Fig. 12. Relationship between % C.V. and C-E amplitude

9. Relationship between corrected E-F slope and %C.V. (Fig. 15)

As it was found that the E-F slope was closely related to the C.O., a corrected E-F slope derived from the expected value of the E-F slope with a cardiac output of 100 ml/kg/min, was correlated with the %C.V. In both groups the corrected E-F slope showed a positive linear relationship to the %C.V.

Clinical applications and results

In order to put these findings to practical use, an echocardiographic study was done on nine patients with MR due to ruptured chordae tendineae of the anterior mitral leaflet. All patients were treated with reconstructive surgery; no thickness or vegetation of their mitral leaflets was found at the time of operation. The patients' pre- and postoperative data are shown in table 5.

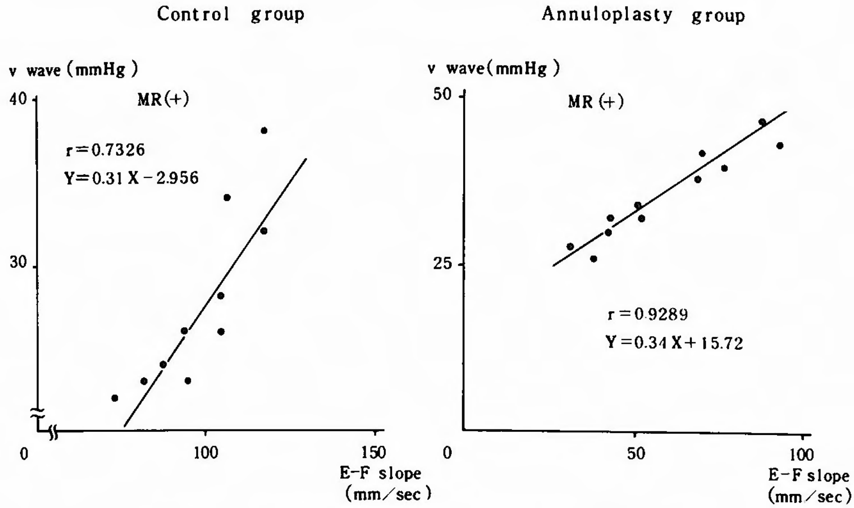

Fig. 13. Relationship between E-F slope and LA·v wave

Cardiac output and echocardiographic parameters were not determined simultaneously but were recorded when the patients were in a stable condition. MR was graded 1–4 by LV angiography according to SELLER's[31] classification. The surgical procedures were cuneiform resection or plication of the anterior mitral leaflet where chordal support was absent. Then annuloplasty was performed by the method of KAY[13] or REED[28] or with CARPENTIER's[4] artificial mitral ring.

Fig. 16 shows the pre- and postoperative C–E amplitude. Although in all patients C–E amplitude decreased following annuloplasty, there was no correlation between C–E amplitude and the grade of MR. The pre- and post-operative E–F slope values are shown in Fig. 17. After annuloplasty, E–F slopes decreased significantly, and some of them showed the pattern of

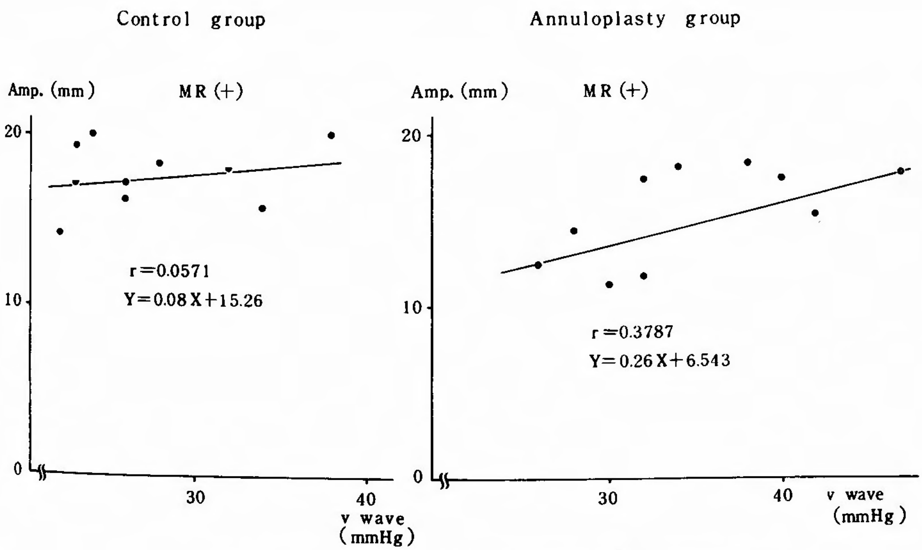

Fig. 14. Relationship between LA·v wave and C-E amplitude

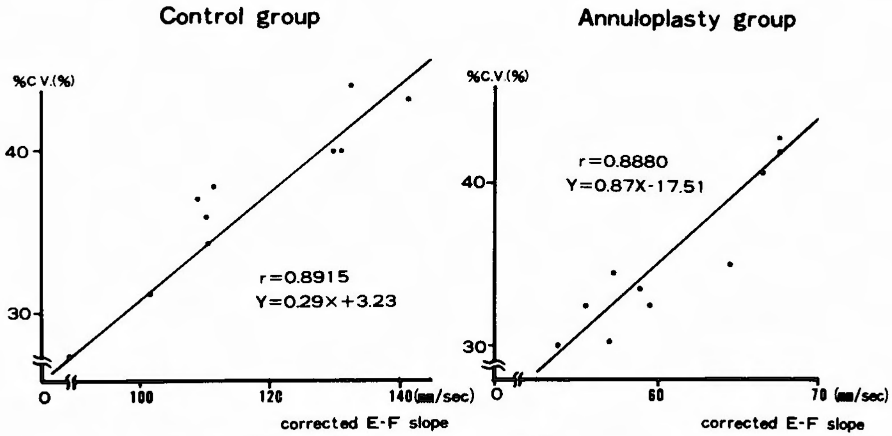

Fig. 15. Relationship between corrected E-F slope and % C.V.

Table 5. Hemodynamic and Echocardiographic Data from 9 Patients

Patient	Age	Sex	grade of MR		C.I (l/min/m²)		C-E amp. (mm)		E-F slope (mm/sec)	
			pre	post	pre	post	pre	post	pre	post
1. F.R	55	F	4°	none	2.28	3.35	30	20	85	40
2. H.M	38	F	3°	2°	2.97	2.99	28	24	77	75
3. U.A	37	M	4°	1°	2.92	3.20	44	29	70	46
4. K.M	31	F	4°	none	2.13	3.10	43	22	120	42
5. U.H	33	M	4°	1°	2.86	3.05	44	25	116	45
6. M.Y	58	M	3°	none	2.88	5.34	29	27	105	40
7. Y.H	23	M	4°	none	2.57	3.07	31	29	115	35
8. M.S	35	M	4°	none	3.44	3.61	28	23	100	33
9. O.S	31	M	3°	none	3.75	4.32	38	26	85	30

mitral stenosis. Patients with residual MR postoperatively showed greater E–F slope values than with no residual MR. When the real value of the E–F slope was corrected in compliance with cardiac output, the corrected E–F slope derived on the assumption that the patient had a cardiac output of 2.0 $l/min/m^2$ showed a more significant change than the uncorrected E–F slope.

Discussion

Although one should recognize some limitations[29] in the study of phasic transmitral flow with electromagnetic flowmetry, this method is already well established[15] and has aided in the research on the hemodynamics of the mitral orifice by many investigators. NOLAN[25] and his colleagues have described the influence of atrial contraction and mitral valve mechanics on ventricular filling by conjugating the heart rates by this method. The phasic flow through normal and prosthetic mitral valves has been studied in unanesthetized dogs by placing electromagnetic flowmeter probes in the left atrium[8]. LANIADO[16,17] and his colleagues studied the dynamic relationship between the mitral valve echogram and phasic mitral flow in dogs. In experimental

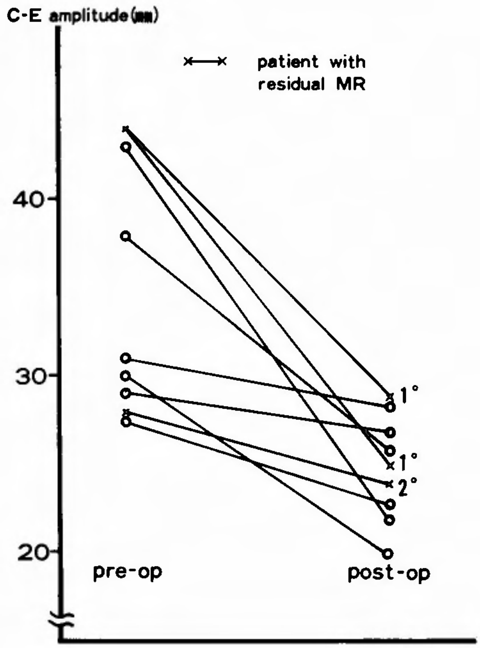

Fig. 16. Changes in values of C–E amplitude

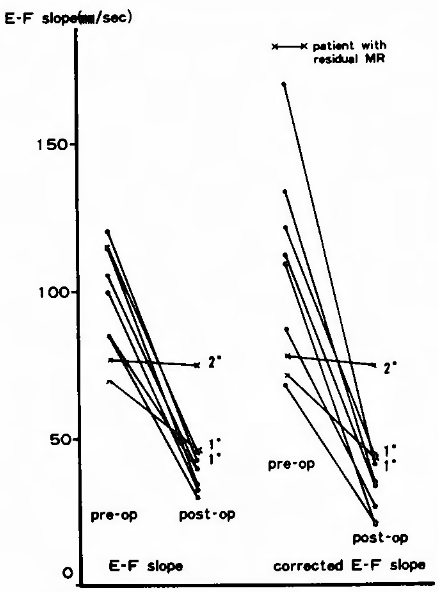

Fig. 17. Changes in values of E–F slope and corrected E–F slope

studies of MR, Nolan[26] et al, Yellin[42] et al and Yoshimura[43,44] et al have investigated the hemodynamics of MR with the use of electromagnetic flowmetry. Echocardiography of the mitral valve has also helped to explain the mechanism of the hemodynamics[2]. According to Laiken[14] and his colleagues, the echocardiographic pattern of the anterior mitral leaflet in diastole accurately reflects the phasic transmitral flow measured by the numerical differentiation of left ventricular volume as a function of time. RASMUSSEN[27] et al derived a formula for calculating mitral valve stroke volume from the mitral valve echogram. FISCHER[6] et al have determined mitral valve flow and left ventricular stroke volume by echocardiography.

MR is generally produced by severing the chordae with a nerve hook inserted into the LV cavity from the LV apex[43,44], or by inserting a plastic basket catheter into the mitral orifice[42], or by applying tension to a string which restricts the motion of the posterior cusp[2]. Since MR due to ruptured chordae of the anterior mitral leaflet is very important clinically[22], we produced acute MR by the serial division of the chordae tendineae of the anterior mitral leaflet[10,11].

There are many reports of the echocardiographic findings in MR[37,39,40], and the usefulness of UCG is now widely recognized. In the differentiation among the causes of MR, i.e. non-rheumatic vs rheumatic[3], UCG can provide helpful information. In regard to MR due to RCT numerous reports of echocardiographic findings have been published[5,12,21,34,36], so that accurate diagnosis and evaluation of the results of surgery are now possible. RCT is now known to be the cause of 60–70% of cases of acute MR[30,32], and in these cases there is almost no organic change in the mitral valves. Our estimation of the grade of MR quantitatively by a noninvasive method pre- and postoperatively should have great value, because in such cases reconstructive surgery is required[19]. In the evaluation of congenital MR by UCG, many problems remain to be solved [7,9,23,24], such as changes of the mitral valve itself, the physical development of the patients, and the definition of the normal UCG values in childhood.

It is already known that in normal subjects there is a striking similarity between the configuration of the recorded mitral flow and the anterior cusp echogram, that the E–F slope of the normal valve is closely related to cardiac output, and that the C–E amp. does not reflect the amount of mitral flow[17,44]. The present studies confirm these results. It appears to be certain that C–E amp. and E–F slope are increased in both experimental and clinical MR. However, no reference has been made to the relationship between the regurgitation ratio (% closing volume) and various parameters of the MV echogram. The reason may be, as descirbed before, that the E–F slope is closely affected by the cardiac output; therefore, if the E–F slope is corrected by a certain value of the cardiac output a positive correlation should be found between the E–F slope and the % closing volume.

The reason that the LA v wave showed a close linear relationship to the E–F slope may be that the data were recorded in the acute stage of MR when the wall of the LA reflected the direct impact of the MR. Some discrepancy would be expected, therefore, between experimental results and the findings in clinical patients who have had the disease for some time.

In experimental acute MR, there is echocardiographic evidence of LV dilatation, probably due to the increased mitral valve flow after the production of MR[18].

When mitral annuloplasty is performed, the similarity in the configuration of the recorded mitral flow and the anterior cusp echogram remains unchanged, and shows a nearly stenotic pattern of the mitral echogram[10,11]. Although annuloplasty makes the mitral orifice stenotic and reduces mitral flow[35,38], the close relationship between phasic transmitral flow and the mitral valve echogram is maintained.

In cases of only slight organic change in the mitral leaflet, such as congenital MR or MR due to RCT, mitral annuloplasty is a valuable reconstructive technique, as well as valvuloplasty. The methods of KAY[13], REED[28] and WOOLER[41] are most frequently used. When the chordal rupture occurs in the anterior leaflet, however, surgical treatment be cuneiform resection[20] or plication of the anterior leaflet which has lost its chordal support together with annuloplasty. It has been pointed out, however, that suturing the mitral leaflet may have poor results[33]. CARPENTIER's[4] ring is useful because with it annuloplasty can be done uniformly, there is less fear of organic destruction by annular sutures.

In clinical subjects, both C–E amp. and E–F slope decreased, as reported by others[35,38] after surgery[1] as in experimental MR[10,11]. Although the number of patients who have residual regurgitation is too small to assert that echocardiography can provide quantitative data to substantiate the degree of regurgitation, the relationship between the regurgitation ratio and the E-F slope or corrected E–F slope suggests the same tendency as the results of the experimental study.

In MINAMI's[24] long-term follow up echocardiographic study of congenital MR there was no significant correlation between echographic parameters and regurgitation ratio, perhaps because of the influence of the cardiac output, physical development of the patients, etc.

Summary

Echocardiographically recorded mitral valve motion was compared with phasic transmitral flow in 20 open chest dogs with normal valves and after annuloplasty and MR.

1) After annuloplasty both C–E amplitude and E–F slope tended to decrease and then to increase after the production of MR. E–F slope changed more than C–E amplitude.

2) E–F slope changes correlated well with mitral flow.

3) E–F slope did not necessarily reflect the mitral regurgitation ratio. The corrected E–F slope, derived by modifying the E–F slope by the cardiac output, varied in a close positive linear relationship with the mitral regurgitation ratio.

4) In acute MR, the E–F slope showed a close relationship with the LA v wave.

5) C–E amplitude did not reflect the hemodynamic state more faithfully, than the corrected E–F slope.

Nine patients treated with mitral reconstructive surgery because of MR due to ruptured chordae tendineae were studied clinically.

1) Both E–F slope and corrected E–F slope did not decrease postoperatively in patients with residual MR, but the change in the corrected E–F slope was more significant than in the uncorrected E–F slope.

2) It is useful to follow patients with MR with no organic lesion of their valves by their E-F slope and corrected E–F slope postoperatively.

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References

1) Asada K, Kondo K, et al.. Pre- and postoperative echocardiographic studies on mitral annuloplasty. Proceedings of JSUM **34**: 43-44, 1978.
2) Borgenhagen D, Serur J, et al: The effects of left ventricular load and contractility on mitral regurgitant orifice size and flow in the dog. Circulation **56**: 106-113, 1977.
3) Burgess J, Clark R, et al: Echocardiographic findings in different types of mitral regurgitation. Circulation **48**: 97-106, 1973.
4) Carpentier A, Deloche A, et al: A new reconstructive operation for correction of mitral and tricuspid insufficiency. J Thrac Cardiovasc Surg **61**: 1-7, 1971.
5) Cosby R, Giddings J, et al: The echocardiogram in nonrheumatic mitral insufficiency. Chest **66**: 642-646, 1974.
6) Fischer J, Chang S, et al: Echocardiographic determination of mitral valve flow. Amer J Cardiol **262**. (ABSTRACTS) 1972.
7) Flege J, Vlad P, et al: Congenital mitral incompetence. J Thorac Cardiovasc Surg **53**: 138-144, 1967.
8) Folts J, Young W, et al: Phasic flow through normal and prosthetic mitral valves in unanesthetized dogs. J Thorac Cardiovasc Surg **61**: 235-241, 1971.
9) Henry W, Ware J. et al: Echocardiographic measurements in normal subjects. Circulation **57**: 278-284, 1978.
10) Ishihara H, Minami K, et al: The relations between the mitral valve echogram and phasic mitral flow. Proceedings of JSUM **36**: 329-330, 1980.
11) Ishihara H, Muraguchi T, et al: The relations between the mitral valve echogram and phasic mitral flow. (PART 2) Proceedings of JSUM **37**: 183-184, 1980.
12) Johnson M. Holmes H, et al: Usefullness of echocardiography in patients undergoing mitral valve surgery. J Thorac Cardiovasc Surg **64**: 922-934, 1972.
13) Kay J, Zubiate P, et al: Mitral valve repair for significant mitral insufficiency. Amer Heart J **96**: 253-262, 1978.
14) Laiken S, Johnson A, et al: Instantaneous transmitral flow and anterior mitral leaflet motion in man. Circulation **59**: 476-482, 1979.
15) Laniado S, Yellin, E, et al: Simultaneous recording of mitral valve echogram and transmitral flow. In The Mitral Valve, edited by Kalmanson D. Acton, Mass, Publishing Sciences Group: 155-162, 1976.
16) Laniado S, Yellin E, et al: Temporal relation of the first sound to closure of the mitral valve. Circulation **47**: 1006-1014, 1973.
17) Laniado S, Yellin E, et al: A study of the dynamic relations between the mitral valve echogram and phasic mitral flow. Circulation **51**: 104-113, 1975.
18) Maeda M. Sasaki S, et al: Experimental acute mitral regurgitation; Echocardiographic and hemodynamic observations. Proceedings of JSUM **35**: 17-18, 1979.
19) Manhas D, Rittenhouse E, et al: Reconstructive surgery for the treatment of mitral incompetence. J Thorac Cardiovasc Srug **62**: 781-787, 1971.
20) McGoon D: Repair of mitral insufficiency due to ruptured chordae tendineae. J Thorac Cardiovasc Surg **39**: 357-362, 1960.
21) Meyer J, Frank M, et al: Systolic mitral flutter, an echocardiographic clue to the diagnosis of ruptured chordae tendineae. Amer Heart J **93**: 3-8, 1977.
22) Miki S, Tatsuta N, et al: Reconstruction of mitral valve with regurgitation due to ruptured chordae tendineae of anterior leaflet. Arch Jpn Chir **48**: 289-296, 1979.
23) Minami K, Koie H, et al: Echocardiographic evaluation for mitral incompetence after mitral annuloplasty—especially a study on the cases brought on poor postoperative results. Proceedings of JSUM **33**: 21-22, 1978.

24) Minami K: Echocardiographic follow-up study on congenital mitral incompetence after mitral annuloplasty. Arch Jpn Chir **48**: 311–332, 1979.
25) Nolan S, Dixon S, et al: The influence of atrial contraction and mitral valve mechanics on ventricular filling. Amer Heart J **77**: 784–791, 1969.
26) Nolan S, Botero L, et al: Flow dynamics in mitral regurgitation . InThe Mitral Valve, edited by Kalmanson D. Acton, Mass, Publishing Sciences Group: 207–211, 1976.
27) Rasmussen S, Corya B, et al: Stroke volume calculated from mitral valve echogram in patients with and without ventricular dyssynergy. Circulation **58**: 125–133, 1978.
28) Reed E: A symmetric exaggerated mitral annluoplasty: Repair of mitral insufficiency with hemodynamic predictability. J Thorac Cardiovasc Surg **49**: 752–761, 1965.
29) Reneman R: The use of electromagnetic flowprobes in the mitral valve position-principle, advantages and limitations. In The Mitral Valve, edited by Kalmanson D. Acton, Mass, Publishing Sciences Group: 117–125, 1976.
30) Ronan J, Steelman R, et al: The clinical diagnosis of acute severe mitral insufficiency. Amer J Cardiol **27**: 284–290, 1971.
31) Sellers D, Levy T, et al: Left retrograde cardiography in acquired cardiac disease—Technic, indications and interpretations in 700 cases. Amer J Cardiol **14**: 437–447, 1964.
32) Selzer A, Kelly J, et al: The syndrome of mitral insufficiency due to isolated rupture of the chordae tendineae. Amer J Med **43**: 822–836, 1967.
33) Shimakura T, Imai Y, et al: Reconstructive methods of congenital mitral regurgitation. J Jap Associate Thorac Surg **26**: 702–713, 1978.
34) Shimizu Y, Miyamoto T, et al: Reconstructive surgery for mitral insufficiency due to ruptured chordae tendineae. J Jap Associate Thprac Surg **25**: 862–879, 1977.
35) Sugi K, Senoo T, et al: Mechanisms of decrease in diastolic descent rate after plastic valvular surgery in mitral regurgitation. Proceedings of JSUM **33**: 19–20, 1978.
36) Sweatman T, Selzer A, et al: Echocardiographic diagnosis of mitral regurgitation due to ruptured chordae. Circulation **46**: 580–586, 1972.
37) Sze, K Nanda N, et al: Systolic flutter of the mitral valve. Amer Heart J **96**: 157–162, 1978.
38) Tanimoto M, Yamamoto T, et al: Study with echocardiography of 3 patients with mitral annuloplasty. Proceedings of JSUM **31**: 87–88, 1977.
39) Tatemichi K, Miki S, et al: The UCG of congenital mitral insufficiency; Diagnosis and its problems. Proceedings of JSUM **22**: 163–164, 1972.
40) Tatemichi K, Miki S, et al: The UCG of congenital mitral insufficiency; Comparison of its pre- and postoperative states. Proceedings of JSUM **23**: 149–150, 1973.
41) Wooler H: Experiences with the repair of the mitral valve in mitral incompetence. Thorax **17**: 49–57, 1962.
42) Yellin, E, Laniado S, et al: Flow studies of experimental mitral stenosis and regurgitation. In The Mitral Valve, edited by Kalmanson D. Acton, Mass, Publishing Sciences Group: 195–206, 1976.
43) Yoshimura H, Tanaka H, et al: An experimental study on the echocardiographic finding in mitral regurgitation due to chordal rupture; Echocardiographic patterns and correlation to the severity of mitral regurgitation. Jap J Med Ultrasonics **6**: 159–167, 1979.
44) Yoshimura H, Tanaka H, et al: An experimental study of acute mitral regurgitation due to rupture of chordae tendineae; Relation between mitral valve echogram and phasic mitral flow. Jap Circ J **44** supplement: 393–399, 1980.

和文抄録

僧帽弁エコー図と弁口血流波形の関係からみた僧帽弁輪縫縮術の評価法に関する実験的ならびに臨床的研究

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雑種成犬を用いて実験を行い，僧帽弁の正常・閉鎖不全および弁輪縫縮施行の各条件下で，弁尖の心エコー図および電磁流量計による弁口血流を同時に記録し両者の関係を検討した．

前尖の腱索断裂による僧帽閉鎖不全症9例について，術前後の心カテーテル検査より求めた血行動態成績と心エコー図を比較検討した．

以上の結果次の結論を得た．1）僧帽弁輪縫縮術の施行により C–E Amplitude, E–F slope は減少する．2）Corrected E–F slope により弁輪縫縮術の評価をするのが有用である．3）C–E Amplitude は僧帽弁口の血行動態を忠実に反映する指標とはならない．