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Phonocardiographic Changes of Mitral Stenosis Before and After the Operation

ESPECIALLY IN REGARD TO Q-1 AND 2-OS INTERVALS

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Re-evaluation of Q-1 and 2-OS intervals and (Q-1)-(2-OS) index was attempted on preoperative phonocardiogram in mitral stenosis. Fibrosis of mitral valve relates to Q-1 interval and this disturbs the correlation between Q-1 interval and the size of mitral orifice and left atrial pressure. 2-OS interval showed good correlation to the size of mitral orifice and left atrial pressure. The effect of fibrosis of mitral valve on this interval seems little. (Q-1)-(2-OS) index showed rough correlation to the size of mitral orifice but less correlation to left atrial pressure, probably due to fibrosis of mitral valve.

Postoperative phonocardiograms reveal the clinical course of patient postoperatively and preoperative value of Q-1 and 2-OS intervals return toward normal value unless congestive failure or incomplete commissurotomy present.

THE CHARACTERISTIC feature of phonocardiogram in mitral stenosis is loud apical first sound, prolonged Q-1 interval, presence of opening snap followed by protodiastolic murmur. When the stenosis becomes tight the Q-1 interval becomes prolonged and 2-OS interval becomes shortened. When the rhythm is in sinus, usually protodiastolic murmur accompanies presystolic accentuation. When the rate becomes slow and the diastole becomes prolonged the presystolic accentuation disappears, and Q-1 and 2-OS intervals vary and false prediction of the size of mitral orifice ensues. When the rhythm changes to atrial fibrillation the Q-1 and 2-OS intervals vary with previous R-R cycle and presystolic accentuation of protodiastolic murmur disappears.

The size of mitral orifice and left atrial pressure are conjectured by the measurement

of Q-1 and 2-OS intervals. In fact we encountered cases which showed discrepancy between prediction of mitral orifice by phonocardiogram and actual findings in operation. Especially in cases with prolonged Q-1 interval and seemingly small mitral orifice the actual mitral orifice was found to be not so narrow. The aim of this investigation is to re-evaluate the Q-1, 2-OS intervals and (Q-1)-(2-OS) index to determine which most reliable for conjecture of the size of mitral orifice and left atrial pressure is and what the cause for false prediction is. Also postoperative clinical significance was examined with postoperative changes of these values.

METHOD

Among 1902 cases of cardiac operations performed at The Heart Institute, Tokyo Women's

Medical College until the end of February, 1960, mitral commissurotomy was performed in 800 cases. Among these cases adequate tracings of phonocardiograms in 150 cases were selected for this investigation. The operative findings were determined by index finger of Professor S. Sakakibara. Left atrial pressure was measured in 50 cases at the time of operation. Postoperative phonocardiograms were taken at 52 cases at the interval of one month to one year. Degree of thickening and hardening of mitral valve was estimated at the time of operation and was classified as mild, moderate and severe.

The mild degree was defined as valvulotomy was done with finger but thickening and hardening of valve was detected. The moderate degree is that certain portion of commissure was dilated by finger but valvulotomy was completed with dilator. Severe degree was defined as valvulotomy was impossible with finger at all and was completed with dilator and remarkable thickening and hardening of valve and calk were detected.

The phonocardiograms were taken by using crystal microphone and recorded at Yokokawa three elements oscillograph through own made amplifier. The phonocardiograms were taken at apex, Erb's point, and right and left second intercostal spaces. The speed of paper is 10 cm per second.

The measurement of Q-1 interval was done from Q in ECG to the beginning of main vibration of the first heart sound. 2-OS interval was determined from main vibration of aortic second heart sound to the main vibration of opening snap. When the rhythm is in sinus, at least 5 measurements of these intervals were done and mean value was calculated. When the rhythm is in atrial fibrillation at least 5 measurements of Q-1 and 2-OS intervals were done with previous R-R cycle of 0.60–0.90 second and mean value was calculated. Cases accompanied by arterial hypertension were excluded.

RESULTS

1) Relation between Q-1 interval and size of mitral orifice and left atrial pressure.

There was poor correlation between the size of mitral orifice and Q-1 interval. Also in relation to left atrial pressure poor correlation was observed (Fig. 1). After the operation Q-1 interval becomes shortened with decrease in left atrial pressure, so that there seems to be kin relation between left atrial pressure and Q-1 interval. However the examination was focused on the thickening and hardening of mitral valve and its related structures which seemed to be related to Q-1 interval.

2) Relation between Q-1 interval and thickening and hardening of mitral valve and its related structures.

26 cases of left atrial pressure of 25 ± 2 mmHg

Fig. 1. Left Atrial Pressure and Q-1 Interval. The relation between left atrial pressure and Q-1 interval is not obvious.

● S. R.—Sinus Rhythm

△ A. F.—Atrial Fibrillation

were selected for this study. As shown in Fig. 2 there seems to be correlation between Q-1 interval and the thickening and hardening of mitral valve. When the relation between Q-1 interval and thickening and hardening of mitral valve was examined with the condition making left atrial pressure constant and excluding factor of left atrial pressure which seemed to be kinly related to Q-1 interval the more the thickening and hardening of mitral valve becomes severe, the more the Q-1 interval prolongs. The fibrosis of mitral valve can be understood to be related to Q-1 interval from this fact and the reason why the poor correlation between the size of mitral orifice, left atrial pressure and Q-1 interval can be explained by this fact.

3) The relation between 2-OS interval and size of mitral orifice and left atrial pressure.

Good correlation is seen between the size of mitral orifice, left atrial pressure and 2-OS interval. When 2-OS interval becomes short, the size of mitral orifice becomes narrow and left atrial pressure is elevated.

4) The relation between 2-OS interval and thickening and hardening of mitral valve.

2-OS interval was thought to be influenced by the fibrosis of mitral valve and related structures

as previously reported. Same material of 26 cases was employed as stated before and the relation between 2-OS interval and fibrosis of mitral valve was examined. As shown in Fig. 2, there seems not to be so kinly related to 2-OS interval as previously thought.

- 5) The relation between (Q-1)-(2-OS) index, the size of mitral orifice and left atrial pressure.

Rough correlation is seen between (Q-1)-(2-OS) index and the size of mitral orifice. The relation between (Q-1)-(2-OS) index and the left atrial pressure, as shown in Fig. 3, showed a correlation on the minus side but toward the plus the correlation becomes not clear. Wells invented unique method to eliminate the error of prediction based upon the fibrosis of mitral valve, however, in our series the fibrosis of mitral valve was found not to prolong 2-OS interval.

- 6) Postoperative phonocardiographic changes.

Q-1 interval becomes short and 2-OS interval becomes prolonged after the mitral commissurotomy generally when compared with the pre-operative phonocardiogram. As shown in Fig. 5, 5 cases of unchanged Q-1 and 2-OS intervals were noted after the operation and of three the left atrial pressure after the operation did not change markedly. Q-1 interval becomes short in good outcome cases, however, the shortening of Q-1 interval was not remarkable in cases with fibrosis of mitral valve (Table I). 2-OS interval lengthens in uneventful post-operative course. However there was no definite relation between the fibrosis of mitral valve and changes of 2-OS interval.

Fig. 2. Q-1 & 2-OS Intervals and Fibrosis of Mitral Valve. The relation between Q-1 interval and fibrosis of mitral valve is linear when left atrial pressure is 25 ± 2 mmHg and making it constant. However the relation between 2-OS interval and fibrosis is not clear.

2-OS Interval & LAP

Fig. 3. Left Atrial Pressure and 2-OS Interval. Left atrial pressure and 2-OS interval shows good correlation.
● S. R.—Sinus Rhythm
△ A. F.—Atrial Fibrillation

LAP and (Q-1)-(2-OS) INDEX

Fig. 4. Left Atrial Pressure and (Q-1)-(2-OS) Index. The relation between left atrial pressure and (Q-1)-(2-OS) index is linear at minus side but is not obvious at plus side.

Postoperative Changes of Q-1 & 2-OS Intervals

Fig. 5. Postoperative Change of Q-1 and 2-OS Intervals. Q-1 interval shortens and 2-OS interval lengthens after the operation. Arrow indicates the direction of changes after the operation. ○ indicates cases with unchanged Q-1 and 2-OS intervals.

Fig. 6. Postoperative Changes of Q-1 Interval in Months. Changes of Q-1 interval in postoperative course revealed shortening of Q-1 interval in one month in general, but in cases with congestive failure or incomplete dilation of mitral orifice this interval remains unchanged.

TABLE I POSTOPERATIVE CHANGE OF Q-1 INTERVAL

		Postop. Q-1 Interval						
		0.06	0.07	0.08	0.09	0.10	0.11	0.12
Preop. Q-1 Interval	0.06							
	0.07	2	(3)*					
	0.08	7 (2)	7 (5)	(4)*				
	0.09	1	2 (1)	3*(9)	(3)			
	0.10	1 (1)	3	7	1	(1)		
	0.11			1	1			
	0.12							

() Fibrosis, moderate & severe

* Including a case of incomplete commissurotomy

Q-1 interval shortens after the operation but in cases with moderate or severe fibrosis of mitral valve, this interval changed a little or remained unchanged.

(Q-1)-(2-OS) index changed toward minus direction after the operation, but in cases with the fibrosis of mitral valve the index changed a little.

Q-1 interval becomes short in one month following operation in uneventful cases. When careful attention is given to cases of unchanged Q-1 interval in one and four months after operation, these two revealed congestive failure in one month after the operation and incomplete commissurotomy in four months with severe degree of thickening and hardening of mitral valve (Fig. 6). 2-OS interval lengthened in one month after the operation but in two cases of congestive failure which occurred in one month following operation and in a case with incomplete commissurotomy 2-OS interval did not change.

COMMENTS

When the mitral stenosis is tight, the Q-1 interval is prolonged¹²⁾, 2-OS interval is shortened⁸⁾ and (Q-1)-(2-OS) index moves toward plus side²⁾¹⁰⁾¹⁶⁾¹⁷⁾. The normal Q-1 interval is from 0.02 sec to 0.06 sec⁷⁾ and mean value of 0.055 sec¹¹⁾. In the study among Japanese the mean value is 0.047 sec¹⁶⁾. Among patients with mitral stenosis the mean value of Q-1 interval is 0.075 sec¹⁶⁾ and we encountered cases with prolongation of 0.12 sec. The closure of mitral valve is accomplished until the left ventricular pressure exceeds left atrial pressure and in cases with severe mitral stenosis the left atrial pressure reached to 35 to 40 mmHg occasionally, and the closure of mitral valve is delayed after the beginning of left ventricular contraction¹²⁾. Therefore the Q-1 interval is prolonged.

Wells¹²⁾ found rough correlation between

valvular area and Q-1 and 2-OS intervals. His unique corrected (Q-1)-(2-OS) index also showed further excellent correlation to diastolic pressure gradient. Bayer, Wolter et al.⁵⁾⁴⁾⁵⁾ stated 2-OS interval showed good correlation to pulmonary capillary pressure and little effect of fibrosis of mitral valve was found on this interval and concluded that 2-OS interval is determined by pressure gradient between left atrium and ventricle. Julian et al.⁶⁾ recognized that poor correlation was found between left atrial pressure and Q-1 interval and also stated that the good correlation exists between 2-OS interval and left atrial pressure. He mentioned the reason of poor correlation between Q-1 interval and left atrial pressure as the wide range of normal Q-1 interval⁷⁾.

Factors relating the prolongation of Q-1 interval in mitral stenosis are elevated left atrial pressure, hardening and thickening of the mitral valve and its related structures and rise of the left ventricular pressure. When the diastole is short the rise of left ventricular pressure is slow when compared with the long diastole without delay of electrical-mechanical interval²⁾. In case of tight mitral stenosis with severe fibrosis of mitral valve the closure of the mitral valve occurs with the delay after the crosspoint of left atrial and ventricular pressure¹⁸⁾. Accordingly the mitral closure is delayed and Q-1 interval is prolonged. In our series Q-1 interval and thickening and hardening of mitral valve showed correlation and the fibrosis of mitral valve influences on the relation between Q-1 interval and the size of mitral orifice obscuring the correlation.

Good correlation was seen between 2-OS interval and the size of mitral orifice and left atrial pressure⁶⁾. Factors related to the 2-OS interval are left atrial pressure or pressure gradient between the left atrium and ventricle at the end of systole²⁾⁶⁾. When the left atrial pressure rises, the crosspoint at left atrial and ventricular pressure comes earlier and in turn 2-OS interval becomes short. When the pressure gradient of left atrium and ventricle at the end of systole becomes larger, the interval between the crosspoint at left atrium and ventricle and opening snap becomes short. Therefore 2-OS interval becomes short. 2-OS interval

is thought to express well the degree of elevation of left atrial pressure⁶⁾ and in our series its relation is linear. It was thought that the fibrosis of mitral valve and its related structures prolongs 2-OS interval²⁾¹⁶⁾, however, in our series its relation is not clear. Conjecturing the left atrial pressure and the size of mitral orifice, 2-OS interval is thought to be most reliable index.

Graige⁶⁾ reported that when (Q-1)-(2-OS) index is plus 2 or more the mitral area is 1.2 cm² or less. In our series the rough correlation was seen between (Q-1)-(2-OS) index and the size of mitral orifice. In relation to left atrial pressure and (Q-1)-(2-OS) index, there is rough correlation was seen at minus portion but the correlation was obscured at plus portion. (Q-1)-(2-OS) index was invented to minimize the error of conjecturing the left atrial pressure or the size of mitral orifice based upon the thinking to mislead the conjecture of left atrial pressure or the size of the mitral orifice due to the fibrosis of mitral valve¹⁾²⁾. It is thought the prolongation of Q-1 interval due to fibrosis of mitral valve relates to its index at the plus portion and obscuring the correlation at plus portion. At minus portion of its index a little effect of fibrosis of mitral valve to Q-1 interval was seen.

In postoperative phonocardiographic changes the Q-1 interval becomes short and 2-OS interval prolongs generally¹³⁾¹⁴⁾ and in only three cases the opening snap disappeared. Postoperatively Q-1 interval becomes short in general, but in cases with severely fibrosed mitral valve its change was a little or remained unchanged. In spite of decrease in left atrial pressure after the operation, the fact that the Q-1 interval did not become short is explained by the delay of mitral closure due to fibrosis of mitral valve.

2-OS interval generally becomes prolonged postoperatively and the clear cut correlation to the fibrosis of mitral valve was not observed.

(Q-1)-(2-OS) index moved toward minus side generally postoperatively but in cases with severe fibrosis of mitral valve, the change was a little.

In postoperative changes of Q-1 and 2-OS intervals in a postoperative course, these intervals did not change in cases with congestive failure. This will be ascribed to the decreased cardiac output or elevation of diastolic pressure. In case with incomplete commissurotomy Q-1 and 2-OS intervals did not change and it is reasonable that the left atrial pressure did not change before and after the operation.

Postoperative phonocardiogram is a good mirror reflecting clinical picture and will be a good index to judge the clinical course of patient postoperatively.

SUMMARY

1) In our series of mitral commissurotomy preoperative Q-1 interval and the size of mitral orifice and left atrial pressure did not show correlation. It is not denied that a kin relation between left atrial pressure and Q-1 interval exists from the fact that postoperative decrease in left atrial pressure and shortening of Q-1 interval are seen and also in cases with unchanged postoperative left atrial pressure Q-1 interval does not change. It is thought that poor correlation of preoperative Q-1 interval and the size of mitral orifice and left atrial pressure was due to the thickening and hardening of the mitral valve.

2) Good correlation was observed between 2-OS interval and the size of mitral orifice and left atrial pressure and it is useful to conjecture the size of the mitral orifice and left atrial pressure. The effect of fibrosis of mitral valve is little.

3) Regarding to (Q-1)-(2-OS) index, it has certain reliability to guess the mitral size and left atrial pressure at minus portion but less reliable at plus portion of (Q-1)-(2-OS) index. It is ascribed that the fibrosis of mitral valve relates to the plus portion of (Q-1)-(2-OS) index.

4) Predicting the size of mitral orifice and left atrial pressure 2-OS interval is thought to be most reliable. Q-1 interval is less reliable because the fibrosis of mitral valve relates to its prolongation. With same reason (Q-1)-(2-OS) index is less reliable.

5) In uneventful cases of mitral commissurotomy, shortening of Q-1 and lengthen-

ing of 2-OS intervals and decrease in (Q-1)-(2-OS) index were observed. In cases with congestive failure or incomplete commissurotomy these values were changed a little or remained unchanged. It is thought to be a good index for evaluation of clinical course.

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REFERENCES

- 1) Wells, B. G., The assessment of mitral stenosis by phonocardiography. *British Heart J.* **16**: 261, 1954.
- 2) Wells, B. G., Prediction of mitral pressure gradient from heart sounds. *British Med. J.* **1**: 551, 1957.
- 3) Bayer, O., Loogan, F. and Wolter, H. H., The mitral opening snap in the quantitative diagnosis of mitral stenosis. *Am Heart J.* **51**: 234, 1956.
- 4) Bayer, O., Wolter, H. H., Teige, I. and Rippert, R., Die Berechnung der Oeffnungsflaeche stenoser Herzklappen demonstriert am Beispiel der Stenose der Mitralis und Pulmonalis. *Ztschr. Kreislaufforsch.* **41**: 976, 1952.
- 5) Wolter, H. H., Bayey, O. and Queerman, I., Zur Beurteilung des Schwergrades von Mitral-stenosen. *Ztschr. Kreislaufforsch.* **44**: 177, 1955.
- 6) Julian, D. and Davies, L. G., Heart sounds and intracardiac pressure in mitral stenosis. *British Heart J.* **19**: 486, 1957.
- 7) Kelly, J. J. Jr., Diagnostic value of phonocardiography in mitral stenosis. Mode of production of first heart sound. *Am. J. Med.* **19**: 862, 1955.
- 8) Mounsey, P., The opening snap of mitral stenosis. *British Heart J.* **15**: 135, 1953.
- 9) Messer, A. L., Counihan, T. B., Rappaport, M. B., and Sprague, H. B., The effect of cycle length on the time of occurrence of the first heart sound and the opening snap of mitral stenosis. *Circulation* **4**: 576, 1951.
- 10) Craige, E., Phonocardiographic studies in mitral stenosis. *New Engl. J. Med.* **257**: 650, 1957.
- 11) Leonard, J. J., Weissler, A. M. and Warren, J. V., Observations on the significance of the delayed appearance of the first heart sound in mitral stenosis. *Abstract Circulation* **16**: 906, 1957.
- 12) Braunwald, E., Moscovitz, H. L., Amram, S. S., Lasser, R. P., Sapin, S. O., Himmelstein, A., Ravitch, M. M. and Gordon, A. J., The hemodynamics of the left side of the heart as studied by simultaneous left atrial, left ventricular, and aortic pressure; particular reference to mitral stenosis. *Circulation* **12**: 69, 1955.
- 13) Comberiati, L. and Collicelli, A., Modifications du phonocardiogramme après commissurotomie pour sténose mitrale. *Arch. mal coeur.* **3**: 268, 1954.
- 14) Gallavardin, L. and Delahaye, J. P., La phonocardiographie pré- et post-opératoire dans la sténose mitrale. *Cardiologia* **30**: 90, 1957.
- 15) Margolies, A. and Wolferth, C. C., Opening snap ("claquement d'ouverture de la mitrale") in mitral stenosis. Its characteristics, mechanism of production and diagnostic importance. *Am Heart J.* **7**: 443, 1932.
- 16) Ota, R., Clinical significance of Q-1 and 2-OS intervals in mitral stenosis. *Japanese Society for Int. Med.* **46**: 739, 1957.
- 17) Furuta, S., Watanabe, H., Sato, F., Saegusa, M., Phonocardiographic changes of mitral stenosis before and after the operation. *Japanese Circulation J.* **21**: 47, 1957.
- 18) Nichols, H. T., Likoff, W., Goldberg, H. and Lisan, P., The relation of valve function to the genesis of the sharp first sound in mitral stenosis. *Am. Heart J.* **50**: 577, 1955.