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DETERMINATION OF SUCCESS AFTER MITRAL VALVOTOMY

ROLE OF CIRCULATORY OBSTRUCTION OF THE MYOCARDIUM AND OF OTHER FACTORS

BY

PATRICK MOUNSEY, M.D., M.R.C.P.

Sherbrook Research Fellow, Cardiac Department, London Hospital

The object of this paper is to describe the progress during two to six years of patients following mitral valvotomy for mitral stenosis at the London Hospital, and to emphasize the relative importance of circulatory obstruction, the state of the myocardium, and other factors in determining clinical improvement after operative treatment.

Description of the Material and the Investigation

One hundred patients, operated upon by Mr. Vernon Thompson and Mr. Geoffrey Flavell and under the care of the cardiac department, were followed before, during, and after operation by one observer. There were 71 women and 29 men in the series and their ages varied between 17 and 55 years. Fifty-six patients were in sinus rhythm before operation and the remainder in atrial fibrillation. In 68 patients the width of the heart was less than half that of the chest, measured in a postero-anterior radiograph, while in the remaining 32 patients it equalled or exceeded this measurement. Significant pulmonary hypertension was present in 47 patients. Associated valve defects, complicating dominant mitral stenosis, included mitral incompetence which was slight in 30 and considerable in 10 patients, aortic stenosis in 3, and aortic incompetence which was judged to be slight in 17 and moderate in 5. In addition 7 patients had pulmonary incompetence from pulmonary hypertension. No patient with tricuspid stenosis or organic incompetence before operation was included in this series. Severe emphysema and chronic bronchitis were present in four patients.

A detailed history was taken ; this not only provided a subjective account of the patient's exercise tolerance but also afforded an opportunity of getting to know the patients, and their reaction to the disease, which was thought to be an important factor in the selection of patients for mitral valvotomy. In addition, in 47 patients pre- and post-operative exercise tests were carried out, the patient being tested on his ability to climb the hospital stairs.

Clinical examination included an electrocardiogram, using the standard leads and CR leads 1, 4, and 7, with the addition of full circumferential V leads in patients with doubtful right ventricular hypertrophy. Teleradiograms were obtained in every patient and each patient was screened, special care being taken to recognize calcification of the mitral valve. Phonocardiograms were recorded before and after operation in 68 patients. Cardiac catheterization was carried out in 10 patients, and was reserved for those in whom some adverse complicating lesion was present or suspected.

While in hospital awaiting mitral valvotomy, patients, including those in sinus rhythm, were given full doses of digitalis in order to prevent a rapid heart rate, should atrial fibrillation occur during or shortly after operation. A mercurial diuretic was given where indicated. A strict low-salt diet was in general avoided before operation, in the belief that it predisposed to serious electrolyte disturbances during the immediate post-operative period.

At operation a careful appraisal was made of the valve aperture, the state of the valve, and the degree of mitral incompetence, if any. Valvotomy was performed by fracturing the valve commissures with the finger, but in 12 patients the use of a knife was found necessary. Two types of knife were used, that described by Vernon Thompson (1954) and that devised by Brock. After the valve had been split, the resultant relief of stenosis was immediately assessed and the presence of any mitral incompetence looked for.

After operation the patient was followed in the cardiac department, at first at three-monthly intervals and later at intervals of six months to a year. The data thus obtained were analysed on the Powers Samas sorting machine, for in this way it was hoped that the many variables in the clinical picture could be more readily integrated.

General Progress after Mitral Valvotomy

Before discussing individual factors which may have been responsible for success or failure, a description is given of the progress of the group of patients as a whole following mitral valvotomy. In addition there is a short account of the patients who died following operation.

General Note on Grading of Effort Tolerance.—Five grades of effort tolerance were recognized : very good, when the patient was able to lead an almost normal life, indulging in active sports ; good, when he could live a normal working life, avoiding strenuous exertion ; moderate, when activities were restricted to light household duties in the case of a woman or to light work in the case of a man ; poor, when the lightest duties, such as cooking and dusting, could be performed only with difficulty ; very poor, when the patient was either completely or partially confined to bed or was in chronic congestive failure.

The overall general improvement *during the first two years* after mitral valvotomy is shown in Table I, where the patient's exercise tolerance before and after operation is compared. Whereas before operation most patients could only do light work, such as cooking and dusting in the case of the housewife or relatively light work in the case of a man, after operation they were

TABLE I.—*Relationship Between Pre- and Post-operative Grades of Effort Tolerance in 92 Patients in First and Second Years After Operation; Also in 55 Patients in Third to Fifth Years*

Post-operative Grade	Pre-operative Grade				
	Very Good	Good	Moderate	Poor	Very Poor
3rd to 5th Years (55 Cases)					
Very poor ..	—	—	2	1	1
Poor	—	—	—	3	2
Moderate ..	—	—	5	7	4
Good	—	1	5	13	3
Very good ..	—	—	—	8	—
1st and 2nd Years (92 Cases)					
Very poor ..	—	—	—	—	2
Poor	—	—	1	2	4
Moderate ..	—	—	4	16	6
Good	—	—	8	27	7
Very good ..	—	2	3	9	1
Death within 3 months ..				6	2

able to resume full duties, provided they avoided heavy manual exertion. Relief of other symptoms closely paralleled the improvement in effort tolerance. Thus paroxysmal nocturnal dyspnoea which was present in 52 patients, haemoptysis which occurred in 50, and cardiac pain which was present on effort in 32 patients were completely abolished in every patient, whose effort tolerance was also satisfactorily improved.

Those who were least incapacitated before operation obtained a higher proportion of very good and good results. Nevertheless, the relative improvement of some of the more severely handicapped was very impressive and the operation seemed equally worth while if it enabled bedridden patients to return to an ambulant fuller life, even though their effort tolerance remained relatively poor. Severe disablement before operation, however, did not necessarily mean that a good or even a very good result could not be looked for, and one patient, who was in congestive failure before operation with tight mitral stenosis, obtained a very good result, being able once again to follow his previous hobby of long country walks.

Fifty-five patients have been followed for *three to five years* since operation. In general the initial improvement seen in the first two years was maintained in the third to fifth years (Table I). Fourteen patients, however, deteriorated. No correlation was seen between this late deterioration and the degree of incapacity before operation, for those who had been most severely incapacitated before operation showed no greater tendency to regress than other groups.

Patients Who Have Died Since Operation

Four patients died *within three days* of operation. Cerebral embolism resulting from extensive intra-atrial clot was the cause of death in two of them: in one, recurrent emboli followed after the first 24 hours, whereas in the other the embolus occurred at the time of operation. Technical accidents contributed to a fatal outcome in the other two patients. In one the valve was approached through the left common pulmonary vein because of clot in the atrial appendage; the vein tore during the valvotomy and the patient died of ventricular fibrillation on the operating table; at necropsy she was also found to have a cerebral embolus. In the other the valvotome became impacted in the valve orifice and severe haemorrhage resulted.

Four patients died *within the first three months*. Technical anaesthetic difficulties were probably responsible for the death of one, who had a second operation for post-operative haemothorax. Associated aortic stenosis of severe degree caused progressive left ventricular failure in another patient, who was treated by mitral valvotomy alone. In the remaining two patients extreme rigidity of a heavily calcified valve and associated incompetence counteracted the functional improvement resulting from mitral valvotomy.

Seven more patients died *within the first five years* of operation—three with calcific mitral stenosis and incompetence, three with severe emphysema and bronchitis complicating mitral stenosis, and one from cerebral embolism. They are described below in greater detail in considering the influence of such lesions on progress after valvotomy.

Role of Obstruction, the Myocardium, and Other Factors

Mitral stenosis is by definition an obstructive lesion. The relative importance, however, of obstructive and myocardial factors in the development of symptoms in mitral stenosis has long been a matter of controversy. Sir Henry Souttar (1925) and Cutler and Beck (1929), in their pioneer work in the surgical treatment of mitral stenosis, believed that the obstruction at the mitral valve was of dominant importance; others, including Sir Thomas Lewis (1946), held that cardiac enlargement and the cardiac reserve were the most important factors. Although since the era of mitral valvotomy the importance of obstruction at the mitral valve is no longer questioned (Baker *et al.*, 1950), there remained to be decided the relative importance of the state of the myocardium (Harvey *et al.*, 1955) and of general factors, including age and rhythm, and of pulmonary hypertension, which is an additional obstructive factor. It is now proposed to describe each of these, to consider their influence on clinical improvement after mitral valvotomy, and to try to assess their relative importance.

The obstructive effects which are considered are the degree of mitral stenosis, the increased functional stenosis produced by rigidity of a heavily calcified mitral valve, the presence of associated aortic stenosis, and the presence of complicating pulmonary hypertension.

Degree of Mitral Stenosis

In the assessment of the degree of stenosis the most reliable clinical guide was found to be the amount of breathlessness on effort, although auscultatory and radiological signs provided valuable confirmatory evidence. Effort

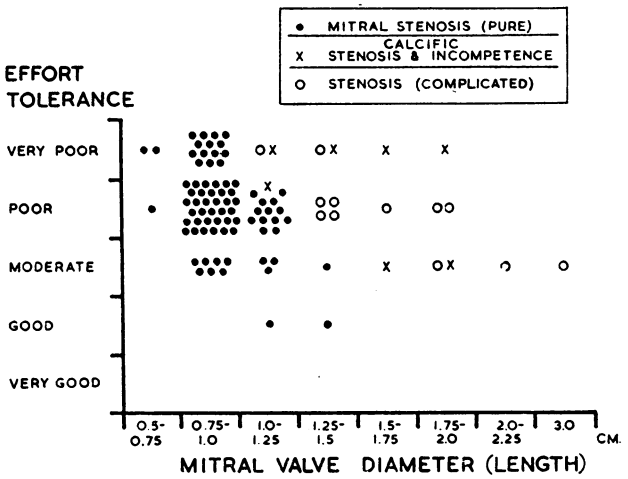

FIG. 1.—Correlation of the pre-operative effort tolerance with the length of the mitral valve diameter as estimated by the surgeon at operation (96 patients).

tolerance was assessed on a careful history, and a simple exercise test helped to distinguish functional from organic dyspnoea in nervous patients. The relationship between the long diameter of the mitral valve estimated at valvotomy and the effort tolerance is shown in Fig. 1.

In patients with pure mitral stenosis a definite correlation was found between the grade of exercise tolerance and the size of the mitral valve orifice. It will be seen that most of the patients with a poor or very poor exercise tolerance were found to have a mitral valve whose long diameter was between 0.75 and 1 cm. In seven patients, on the other hand, in whom rigid calcific stenosis with complicating incompetence was present, a more severe degree of breathlessness was met in relation to the length of the diameter of the mitral valve, for the measurement gave no index of the amount of functional stenosis from immobility of the valve cusps nor of the amount of incompetence. In the remaining 12 patients, complicating lesions were present which contributed to their breathlessness, and these included aortic stenosis, aortic incompetence of moderate degree, emphysema, and bronchitis and functional dyspnoea. No direct relationship, therefore, existed in this group between the degree of breathlessness and the size of the mitral valve.

In this selected series the heart sounds and murmurs were found to give qualitative rather than quantitative information about the state of the mitral valve, and detailed estimation of their characteristics and timing in the phonocardiogram did not afford accurate information about the size of the mitral valve orifice.

Radiological evidence of hilar clouding and of interlobular lines (Kerley, 1933; Short, 1955) provided confirmatory evidence of significant stenosis, but in this series were not found to correlate directly with the valve size at operation.

Neither the volume of the pulse nor the level of the blood pressure was found to be a reliable indication of the degree of mitral stenosis, although in general the pulse was small and the systemic pressure low or normal in the presence of tight stenosis.

In assessing the degree of splitting and surgical enlargement of the mitral valve, the subjective nature of the impressions of the operator makes it difficult to compare directly the findings of one operator with those of another. In this connexion, therefore, only the findings in the 60 patients operated upon by one surgeon (V. C. T.) are discussed. The size of the mitral valve orifice pre-operatively was not found to influence the ultimate size obtained by valvotomy. The amount of valvular distortion, however, including shortening of the chordae tendineae, fusion of the musculi papillares to the valve cusps, and of calcification of the valve, must predetermine to a large extent the success obtainable by valvotomy. Surgical technique, on the other hand, and in particular the degree of splitting aimed at, varied during this series, and, whereas enlargement of the valve to a length of 2 cm. was considered adequate initially, later every effort was made to attain a length of at least 2.5 to 3 cm. For this reason a knife was used more frequently in the later patients in this series.

During the first two years after valvotomy patients appeared to do equally well, irrespective of the amount of enlargement of the orifice obtained at valvotomy. The initial improvement, however, was not maintained in those patients whose valve had been less fully split, in the third, fourth, and fifth years after operation (Table II) (Baker *et al.*, 1955). It is probable that there is a critical size of the mitral valve orifice, when the length is about 1 cm., and below this a marked increase in the left atrial pressure results and symptoms develop. Even a small increase in size of the valve above this critical measurement will relieve symptoms by reducing left atrial pressure. The deterioration seen in the group with an incomplete valvotomy probably indicated some re-stenosis, whether from refusion of the commissures or from increasing rigidity of the valve due to fibrosis or calcification. It is possible that the same process may have taken place in some of those in whom a more complete valvotomy was obtained and who have remained symptomatically well, the valve orifice being still above the critical measurement. Apart from one patient with a heavily calcified mitral valve, with some complicating incompetence, no patient whose mitral valve had been enlarged to a length of 2.5 cm. or more deteriorated during the first three to five years after operation.

TABLE II.—*Correlation of Length of Mitral Valve Diameter Achieved After Valvotomy With the Post-operative Grade of Effort Tolerance in Short- and Long-term Follow-up Periods. 33 Patients Operated Upon by One Surgeon (V. C. T.) and Followed for at Least Three Years After Operation*

Post-operative Grade	Length of Mitral Valve After Valvotomy (cm.)				
	1·5	2	2·5	3	3·5
	3rd to 5th Years				
Very poor ..	1	1	—	—	1
Poor	—	2	—	—	—
Moderate ..	1	4	2	—	—
Good	—	6	7	1	—
Very good ..	—	3	2	2	—
	1st and 2nd Years				
Very poor ..	—	—	—	—	—
Poor	—	3	—	—	—
Moderate ..	1	2	2	—	—
Good	1	5	7	1	1
Very good ..	—	6	2	2	—

Two patients treated by a second valvotomy had deteriorated after initial conspicuous success following the first valvotomy. One had the second operation four years after the first, and a good split of the anterolateral commissure was obtained. Once again the patient was greatly benefited, and, although in pulmonary oedema before operation, was able to return to a normal quiet life. The second patient had a second valvotomy two years after the first operation and was again improved. The repeated improvement following two valvotomies in these patients suggested that obstruction at the mitral valve contributed materially to their symptoms, although each in addition had severe pulmonary hypertension, which was an additional cause of breathlessness.

Calcification and Rigidity of Mitral Valve

Calcification of the mitral valve, when extensive, could always be recognized on screening or on a penetrating radiograph, but lesser degrees could only be diagnosed on palpation of the valve at operation. Auscultation added further confirmatory evidence of the extent of the calcification, a soft or absent opening snap and soft or normal first heart sound being related to extensive calcification of the valve, as estimated at operation (Fig. 2).

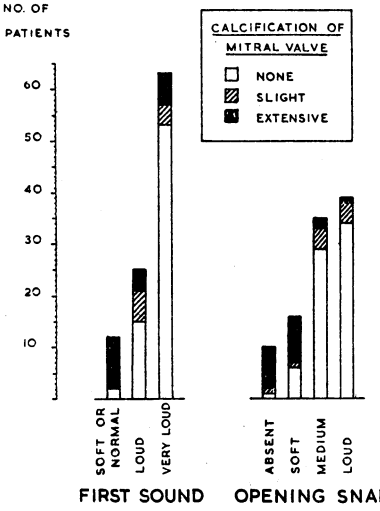

FIG. 2.—Correlation of the loudness of the first heart sound and of the opening snap with calcification of the mitral valve as estimated at operation (100 patients).

Extensive calcification was commoner in men in this series, 12 of the 29 men showing it, but only 8 of the 71 women. Calcification, on the other hand, was not related to the length of valve diameter, the age of the patient, a history of rheumatic fever, or the duration of symptoms.

Mitral incompetence of considerable degree was a more frequent complication of dominant stenosis where extensive

calcification was present (Fig. 3) (Wood, 1954; Belcher, 1956). There were seven patients with calcific, stenotic, and incompetent valves. In the three patients in this group who have come to necropsy it was seen that incompetence resulted from irregularity of the margins of the heavily calcified cusps, which could not therefore close during ventricular systole (Fig. 4). It was not due to shortening and retraction of the cusps, as in isolated mitral incompetence, and in only one of the three patients was the incompetence of sufficient degree to give rise to left ventricular hypertrophy. All these patients had an apical pansystolic murmur, which proved to be the only reliable sign of mitral incompetence complicating dominant stenosis in this series (Mounsey and Brigden, 1954).

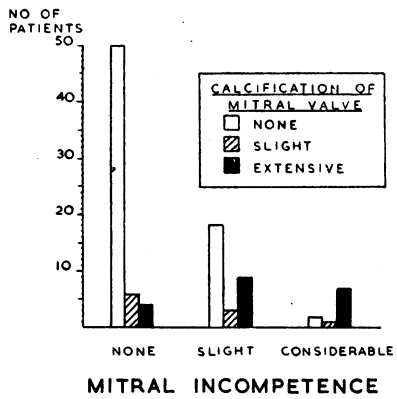

FIG. 3.—Correlation of mitral incompetence estimated at operation with calcification of the mitral valve (100 patients).

A minor degree of calcification was not found to be an adverse factor after mitral valvotomy. In fact, splitting of the valve was sometimes easier when it was brittle from calcification than when it was tough from fibrosis.

In patients with extensive calcification, rigidity of the valve cusps prevented the full separation in diastole which freeing of the commissure at valvotomy would otherwise have allowed, stenosis being due as much to the rigidity of the cusps as to their fusion (Sellors *et al.*, 1953). The long-term results of operation in this group have been poor, although some patients obtained considerable temporary improvement for one or two years (Table III). Those with complicating mitral incompetence had the worst results, and five of the seven patients with this combined lesion have now died in congestive heart failure, two within the first three months, one within two years, and two within four years of operation. In one of these patients a second valvotomy effected a second period of temporary improvement, which was again followed by deterioration a year and a half later. At necropsy the valve orifice was seen to be 3 cm. in length and crescentic in shape, but the cusps were so rigid, especially the anterior, that no effective opening or closure of the valve could take place and extreme functional stenosis as well as moderate incompetence was present. Of the 13 patients with a heavily calcified mitral valve but no incompetence, four have maintained their original degree of improvement, a further seven patients have deteriorated, and two died within three years of the operation, death being due mainly to emphysema and bronchitis, which complicated mitral and aortic valve disease.

TABLE III.—*Correlation of Extensive Calcification of Mitral Valve With the Post-operative Grade of Effort Tolerance in Short- and Long-term Follow-up Periods*

Post-operative Grade	Calcification	
	None or Slight	Extensive
3rd to 5th Years (55 Cases)		
Very poor	3	1
Poor	3	2
Moderate	11	5
Good	19	3
Very good	8	—
1st and 2nd Years (92 Cases)		
Very poor	1	1
Poor	4	3
Moderate	21	5
Good	34	8
Very good	14	1
Death within 3 months	6	2
Death within 2 years	1	2
Death within 3 to 5 years	1	3

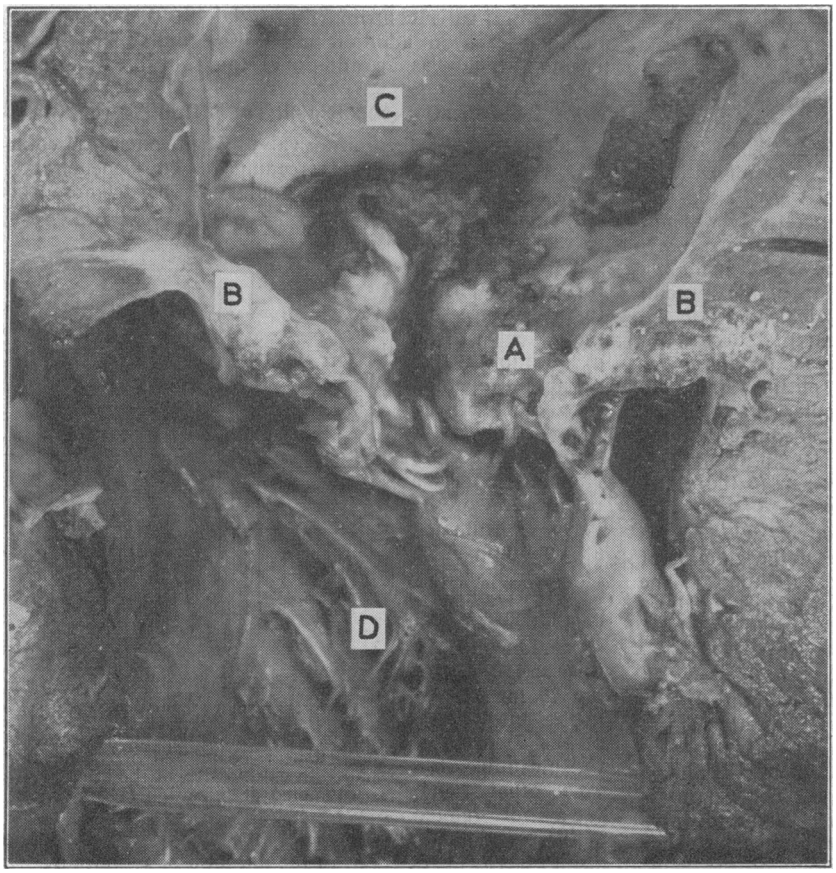

FIG. 4.—Calcific mitral stenosis with considerable incompetence. A=Semilunar deficiency in margin of posterior valve cusp, through which incompetence arose. B=Grossly thickened and calcified valve cusps, seen in cross-section. C=Left atrium. D=Left ventricle.

Aortic Stenosis

Severe aortic stenosis complicating mitral stenosis is generally accepted as a contraindication to mitral valvotomy, unless a simultaneous aortic valvotomy is considered (Turner and Frazer, 1956). Relief of the obstruction at the mitral valve causes increased filling of the hypertrophied left ventricle; the ventricle is unable to increase its output through the stenosed aortic valve, and consequently fails.

Three patients in this series had aortic stenosis in addition to tight mitral stenosis. In two it was of only moderate degree and only slight left ventricular hypertrophy was found at necropsy, both patients dying from other lesions—cerebral embolus in one and emphysema and bronchitis in the other.

Clinically the lesion presented as aortic incompetence rather than stenosis, since the basal systolic murmur was soft, owing to the low stroke-output from associated tight mitral stenosis.

One patient had severe aortic stenosis in addition to mitral stenosis, with evidence of left ventricular preponderance in the electrocardiogram. After successful mitral valvotomy she went into progressive left ventricular failure and died six weeks after operation. Necropsy confirmed the presence of severe aortic stenosis in addition to mitral stenosis.

Pulmonary Hypertension

The presence of pulmonary hypertension was assessed in this series on clinical, electrocardiographic, and radiological evidence. Cardiac catherization was also carried out in 10 patients. Forty-one patients had severe pulmonary hypertension, judged by a parasternal tap and heave, a loud pulmonary component of the second sound, right ventricular preponderance in the electrocardiogram, with a dominant R wave and T wave inversion in right chest leads, radiographic evidence of great enlargement of the pulmonary artery, and in 16 patients a sound in early systole (Leatham and Vogelpoel, 1954). A further six patients were thought to have pulmonary hypertension, because of their clinical signs and the great enlargement of the pulmonary artery, although the electrocardiogram showed only early right ventricular preponderance. In the remaining 53 patients the resting pulmonary arterial pressure was judged to be normal or only moderately raised.

Pulmonary hypertension was met with in this series only in the presence of severe mitral valve disease, either tight mitral stenosis or calcific stenosis with incompetence. Normal resting pulmonary arterial pressures, however, were also met with in the presence of stenosis of equal severity.

In comparing the post-operative course of patients with and without pulmonary hypertension, allowance was made for other variables, including the amount of splitting of the valve at operation, the presence of calcific mitral stenosis with incompetence, aortic valve disease, and severe emphysema and bronchitis, where this appeared to be an independent disease. When due allowance was made for these, which accounted for most instances of deterioration and death in the pulmonary hypertensive group, there appeared to be little difference in clinical improvement between those with and without pulmonary hypertension during the first two to five years after operation (Table IV). The signs of pulmonary hypertension persisted after operation in all patients,

TABLE IV.—*Correlation of Pulmonary Hypertension With the Post-operative Grade of Effort Tolerance in Short- and Long-term Follow-up Periods. Of the Five Patients with Pulmonary Hypertension Dying more than Three Months After Operation None had Simple Mitral Stenosis, Three Having Calcific Stenosis with Incompetence and Two Severe Emphysema and Bronchitis*

Post-operative Grade	Normal or Slightly Raised Resting Pressure	Pulmonary Hypertension
3rd to 5th Years (55 Cases)		
Very poor	1	3*
Poor	1	4*
Moderate	9	7
Good	12	10
Very good	4	4
1st and 2nd Years (92 Cases)		
Very poor	2	—
Poor	1	6
Moderate	16	10
Good	24	18
Very good	7	8
Death within 3 months	3	5
Death within 2 years	2	1
Death within 3 to 5 years		4

* Of these 7 patients, 1 had emphysema and bronchitis, 3 had heavily calcified mitral valves, and 1 had considerable aortic incompetence.

although in 13 the electrocardiogram suggested that this was of diminishing severity, which was confirmed by modification in the clinical signs. No patient developed right heart failure with oedema from pulmonary hypertension after successful valvotomy, although six had been in gross congestive failure before operation.

Role of the Myocardium

In attempting to determine the role of the ventricular myocardium in clinical improvement after mitral valvotomy two main factors will be considered: first, the possibility of active rheumatic carditis; and, secondly, enlargement and failure of the right ventricle in response to circulatory obstruction.

It is unlikely that *active rheumatic carditis* played any part in determining the post-operative course of the patients in this series. In only two patients was there clinical evidence of rheumatic fever immediately before the operation, and both have done outstandingly well since valvotomy, which was undertaken as soon as rheumatic activity had subsided. No patient has had a recurrence of rheumatic fever since operation. It should be emphasized, however, that only three patients between the ages of 17 and 20 and six between the ages of 21 and 25 were included in the series, and that, if younger patients were submitted to valvotomy, the possibility of active rheumatic carditis might play a part in determining their post-operative progress.

Left atrial biopsies were taken from 69 patients at valvotomy, but, in these, no correlation was seen between histological evidence of round-cell infiltration or Aschoff's nodules and the post-operative course of the patients. Forty-two patients were shown to have round-cell infiltration in the atrial wall, involving especially the subendocardium, and in five Aschoff's nodules were also present. None of these patients, however, had clinical signs of rheumatic activity and the erythrocyte sedimentation rate was normal in every case. The exact significance of these histological findings therefore remains in doubt.

Generalized cardiac enlargement affords an indication of the reaction of the right ventricle to circulatory obstruction. The generalized enlargement in mitral stenosis in the postero-anterior view is due primarily to right ventricular and right atrial enlargement. No patient with great enlargement of the heart or with a giant left atrium was included in the series. The best overall results from valvotomy were obtained in patients with smaller hearts. Good results, however, were also seen in patients with larger hearts, although only one patient with considerable enlargement achieved the best grade of post-operative result, and she was under 21 at the time of operation (Table V).

It is convenient to consider the associated effects of *atrial fibrillation* and the patient's *age* when discussing cardiac enlargement in relation to post-operative progress. Atrial

TABLE V.—*Correlation of Cardiac Enlargement with the Post-operative Grade of Effort Tolerance in First and Second Years After Operation*

Post-operative Grade	Generalized Cardiac Enlargement		
	Slight	Moderate	Considerable
Very poor	—	1	1
Poor	1	1	5
Moderate	8	9	9
Good	14	18	10
Very good	6	8	1
Death within 3 months		2	6

TABLE VI.—*Correlation of Age of Patient with the Post-operative Grade of Effort Tolerance in First and Second Years After Operation*

Post-operative Grade	Age in Years								
	16	21	26	31	36	41	46	51	56
Very poor	—	—	—	1	—	—	—	1	—
Poor	—	—	—	—	1	3	3	—	—
Moderate	—	1	2	6	8	3	5	1	—
Good	2	2	5	13	7	9	4	—	—
Very good	1	3	5	5	—	1	—	—	—
Death within 3 months				1	2	2	3		

TABLE VII.—*Correlation of Pre-operative Rhythm With the Post-operative Grade of Effort Tolerance in First and Second Years After Operation*

Post-operative Grade	Sinus Rhythm	Long-standing Atrial Fibrillation	Recent Atrial Fibrillation
Very poor ..	—	1	1
Poor	2	4	1
Moderate ..	13	10	3
Good	27	10	5
Very good ..	12	2	1
Death within 3 months ..	2	6	

fibrillation before operation was almost confined to patients over the age of 30. It was more often associated with larger hearts, half the patients who were fibrillating having considerable cardiac enlargement, compared with less than a fifth of the patients in sinus rhythm. In Tables VI and VII and in Fig. 5 the interrelationship between age, heart size, and pre-operative cardiac rhythm and its effect on post-operative progress is shown. It will be seen that the group of patients with small hearts under the age of 35 and in sinus rhythm formed the great majority of those obtaining a very good result from valvotomy, both

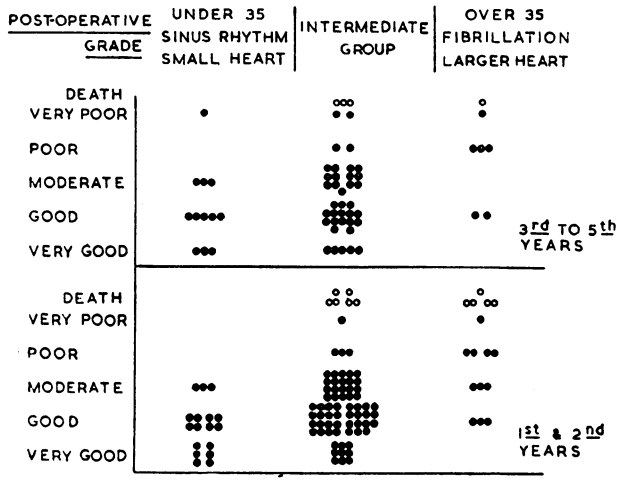

FIG. 5.—Interrelationship between age, pre-operative rhythm, heart size, and post-operative grade of effort tolerance, in short- and long-term follow-up periods.

in the short- and long-term follow-up periods (Evans, 1956). Good results, however, were none the less obtained in older patients with larger hearts and in atrial fibrillation. The better results in the younger age group reflect in part the greater exercise tolerance which would be expected in normal subjects of this age, whereas the poorer results in the older age group suggest that the length of time during which rheumatic disease had been present affects the final outcome. As might be expected, very good results, in which the patient was able to indulge in sports, were rare among patients who were in atrial fibrillation, for their heart rate is often unstable on exercise, even with adequate digitalization.

Post-operative atrial fibrillation, coming on within the first fortnight of operation, occurred in 25 patients. In 14 no attempt was made to restore sinus rhythm with quinidine, and fibrillation persisted. Of the remaining 11, quinidine was used successfully to restore sinus rhythm in nine and two reverted spontaneously. The rhythm of this group of 11 patients has on the whole proved unstable (Goodwin *et al.*, 1955) and only six have remained in sinus rhythm in the longer-term follow-up period. In only one patient fibrillating before operation was an attempt made to restore sinus rhythm after operation, and this was unsuccessful.

Recurrent attacks of *right heart failure* with oedema occurred in 22 of the patients before operation. In 14 of these severe pulmonary hypertension appeared to be the precipitating cause, but in the remaining eight patients electrocardiographic and clinical signs did not suggest that this was the dominant lesion. As a group, patients with a history of recurrent attacks of right heart failure did less well after mitral valvotomy than the remaining patients, who had never been in failure or had had one episode of failure only, but considerable benefit was none the less obtained in many individual patients (Table VIII). Only two

TABLE VIII.—*Correlation of Recurrent Right Heart Failure With the Post-operative Grade of Effort Tolerance in First and Second Years After Operation*

Post-operative Grade	No R.H.F. or Once Only	Recurrent R.H.F.
Very poor	—	2
Poor	5	2
Moderate	17	9
Good	36	6
Very good	14	1
Death within 3 months ..	6	2

remained in right heart failure after operation, in each of whom some complicating lesion was present—calcific mitral stenosis in one, and severe tricuspid incompetence developing after operation in the other.

Other Factors Determining Success After Mitral Valvotomy

A *functional overlay* to organic symptoms was seen in six patients before operation. In general this consisted in exaggerating their disability or drawing attention to real incapacity in such a way as to attract attention to themselves and thus remain the centre of interest and attention in the home. Two of these patients were found to have only moderate mitral stenosis at operation, from which the physical disability cannot have been great. It is significant that in five patients the functional symptoms became temporarily worse after the operation, and in two hallucinations and delusions developed in the immediate post-operative period. In only one did functional symptoms improve after operation.

A history of *recurrent bronchitis* was given by 71 patients. In 67 of these bronchitis was thought to be a secondary manifestation of mitral stenosis, the high pulmonary venous pressure dilating pulmono-bronchial venous anastomoses, and these in turn giving rise to congestion in the bronchial mucosa and predisposing to bronchial infection. In four patients, however, all of whom were men over the age of 30, severe emphysema was present in addition to chronic bronchitis, and in these the chest disease was thought to be an independent primary lesion. Bronchitis was usually worse in the winter, but many of the patients described themselves as " chesty " all the year round. Bronchospasm was a prominent symptom in many, and 14 noticed purulent sputum during bad attacks of bronchitis. Bronchitis was commoner in patients with pulmonary hypertension, being present in 40 out of 47 patients.

After successful mitral valvotomy, 29 patients with secondary bronchitis noticed a marked improvement in the frequency and severity of attacks of bronchitis, and in 12 these ceased altogether. In the long-term follow-up period, however, bronchitis returned in six of the patients and developed for the first time in 17 ; these patients have lost much time off work, especially during the winter, and their breathing has remained embarrassed by bronchospasm most of the year round. In the four male patients with severe emphysema the symptoms of bronchitis were completely unrelieved by valvotomy : three have now died, and in each the respiratory disease was the major cause of death.

Cerebral embolism occurred in three of the four patients dying at or immediately after the operation. In two calcification in the wall of the left atrium had been seen in the radiograph and in all three thrombosis within the left atrium was extensive. Although temporary carotid occlusion with tapes and digital pressure may lessen the danger of this catastrophe, it cannot completely remove it, and where

thrombosis in the left atrium is found to be extensive an open method of operation with interruption of the circulation will probably prove more successful.

A history of recent systemic embolism, on the other hand, is sometimes an indication for mitral valvotomy, provided extensive atrial clot is not present, since valvotomy diminishes stasis in the left atrium and thus helps to prevent clot formation. Of 10 such patients in this series, in only five of whom intra-atrial clot was found at operation, only one had a recurrence of systemic embolism after valvotomy.

In three patients without atrial clot at operation, systemic embolism occurred for the first time in the immediate post-operative period, possibly from detachment of a small thrombus at the site of incision or of a piece of calcium from the mitral valve in one of them. The arteries affected were the posterior inferior cerebellar, a branch of the retinal, and the popliteal in the third; all three patients have made good functional recovery in the area involved.

Valvular incompetence seldom played an important part in influencing post-operative progress in this selected series of patients with dominant mitral stenosis. Although some *mitral incompetence* was judged to be present at operation in 40 patients, it was only of slight degree in 30 of these, and appeared to detract from the success of the operation in only the seven patients whose mitral valve was heavily calcified. Mitral incompetence created during splitting of the valve commissures was felt by the surgeon in four patients and confirmed by the development of an apical pansystolic murmur; the incompetence was slight in all and has not affected post-operative progress. *Aortic incompetence,* which was slight in 17 and moderate in five patients, was never accompanied by left ventricular preponderance in the electrocardiogram. In only one patient, who also had pulmonary hypertension (Table IV), did aortic incompetence appear to modify the success of mitral valvotomy, the signs of incompetence becoming more marked after operation.

Tricuspid incompetence developed for the first time after operation in six patients. All except one have remained well in spite of this complication, reporting a marked improvement in their breathing since valvotomy; in the remaining patient the tricuspid incompetence has been of sufficient degree to cause gross oedema and symptoms of a low cardiac output. Four of the patients did not show this complication until their first attendance in the out-patient department after valvotomy, but the other two developed signs of tricuspid incompetence during the second week after operation. None had pulmonary hypertension, and hence right heart failure secondary to this was not the explanation of the incompetence. All had fibrillation after operation, although three had been in sinus rhythm pre-operatively. There was no evidence of active rheumatic carditis in this group of patients at the time of operation. One developed a pericardial and pleural effusion with pain, pyrexia, and a raised erythrocyte sedimentation rate in the immediate post-operative period—a syndrome which was met with in 21 other patients in this series and which was thought to be a simple post-operative pericardial effusion (Papp and Zion, 1956).

In each case valvotomy was successful and no special difficulty was encountered in splitting the commissures of the valve.

A possible explanation of the syndrome of post-operative tricuspid incompetence without right heart failure is old rheumatic scarring of the tricuspid valve, which becomes incompetent when the right ventricle is called on to increase its output after removal of the obstruction at the mitral valve. The prognosis appears generally to be good, and patients have not been unduly troubled by the slight ankle oedema which has been present in some of them.

Summary and Conclusions

The progress of 100 patients during two to six years after mitral valvotomy has been examined and an attempt made to assess the relative importance of circulatory obstruction, the state of the myocardium, and other factors in determining clinical improvement.

Success after mitral valvotomy, maintained in the long-term follow-up period, was related to the degree of surgical success in *removing obstruction to blood flow through the mitral valve.* A short-term remission of symptoms was often obtained in patients in whom only a small amount of enlargement of the valve had been effected, but in the third and fourth years many of these patients began to deteriorate.

Calcification of the mitral valve, when extensive, presents an added obstructive factor in mitral stenosis, the stenosis being due as much to rigidity of the cusps as to fusion of their commissures. In the long-term follow-up period most of these patients have had disappointing results, and this was especially so in patients in whom extensive calcification of the stenosed valve was associated with moderate incompetence.

Associated aortic stenosis of severe degree was present in one patient treated by mitral valvotomy alone. Relief of circulatory obstruction at the mitral valve precipitated left ventricular failure and death. Special care should therefore be given to the recognition of this lesion, the physical signs of which may be partly masked by the associated mitral stenosis.

Pulmonary hypertension presents another form of obstruction to the circulation in mitral stenosis. During the two to six years over which patients have so far been observed since operation, the clinical improvement of those with and without pulmonary hypertension has differed little when allowance has been made for other causes of deterioration. Although a proportion have shown electrocardiographic evidence of regression of hypertension, in none has the electrocardiogram returned to normal.

With regard to the myocardium, acute rheumatic carditis has not been seen in any of the patients after operation, and it is therefore unlikely that active rheumatism played any part in influencing the response of the myocardium to circulatory obstruction.

The degree of cardiac enlargement is one index of the state of the myocardium. The best results after valvotomy were seen in patients with smaller hearts, especially where they were young and in sinus rhythm. Satisfactory progress, on the other hand, was often seen in older patients in atrial fibrillation and with larger hearts.

Recurrent right heart failure suggests considerable myocardial damage, and such patients did less well after valvotomy when considered as a group, although some individual patients were improved.

Certain specific factors affected the outcome of surgical treatment directly. A *functional reaction* to the pre-operative symptoms usually tended to hinder and delay improvement. *Bronchitis,* although often alleviated by successful valvotomy, has tended to recur in some patients in the long-term follow-up period. Where severe emphysema was present in addition to bronchitis, patients have followed a uniformly downhill course.

Mitral valvotomy in the presence of massive *intra-atrial thrombosis* was followed by fatal cerebral embolism in three patients, in two of whom calcification in the wall of the left atrium was seen in the radiograph: such patients probably require open operation. A recent history of systemic emboli was considered an indication for valvotomy, since removal of obstruction to the circulation diminishes the likelihood of clot formation, and in only one of 10 such patients did embolism recur after valvotomy.

Associated mitral incompetence did not appear to influence post-operative progress in this series, except in the presence of a heavily calcified mitral valve. With one exception *aortic incompetence* was not of sufficient degree to modify the success of the operation. *Tricuspid incompetence* developed for the first time after operation in six patients; except in one case, it did not seriously detract from clinical improvement.

In conclusion, relief of circulatory obstruction at the mitral valve has been shown to be a dominant factor in determining clinical improvement after mitral valvotomy, but enlargement and failure of the right heart consequent on this obstruction, and other factors, including particularly intercurrent emphysema and bronchitis, affect adversely the degree of success achieved by surgical treatment of mitral stenosis.

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TEETH OF 5-YEAR-OLD LONDON SCHOOLCHILDREN (1955)

WITH A COMPARISON OF RESULTS OBTAINED FROM 1929 TO 1955

BY

MAY MELLANBY, M.A., Sc.D.

HELEN COUMOULOS, Ph.D., D.D.S.

AND

MARION KELLEY

With the Assistance of GWENNETH NEAL

(From the Medical Research Council, Hampstead, London)

A survey of the dental condition of 5-year-old children attending London County Council day schools in 1955 was made in continuation of a series begun in 1929 at the request of the Board of Education, and from 1943 until 1951 carried out at two-yearly intervals. As it proved impossible to undertake one in 1953, the latest survey was made only after an interval of four years. References to papers on the earlier work are given at the end of this report.

The schools were scattered throughout the Metropolitan area, and those visited in 1929 were, so far as possible, used for the succeeding surveys. The same probe-and-mirror methods of examination and the same criteria for structure and caries were employed in all cases. These were developed by one of the authors (Mellanby, 1934), who took a prominent part in all the inspections.

A tooth was said to be hypoplasia-free (Hy_0) when its surface was smooth and shiny. Any roughness was graded according to type and degree, differentiation being made between gross hypoplasia (G-Hy) and M-hypoplasia (M-Hy) (King, 1940). The gross type, which is found in relatively few teeth, is the only one recognized by some dental surgeons; M-hypoplasia, on the other hand, is found in the majority of teeth. A tooth was regarded as caries-free when no disease could be diagnosed by the method of examination employed, and a child was considered to be free from caries only if all its teeth (with the exception of the few naturally shed incisors) conformed to this standard. Any history or evidence of extractions or fillings automatically barred it from this category. When the earliest inspections were made in 1929, very few of the children were free from dental disease, and it was decided by the Board of Education (1931), which was responsible for publishing the results, to bracket with such children any who had up to three teeth which were carious to a very slight degree. Even with this addition, however, only 4.7% could be brought into the so-called caries-free category, now referred to as "caries-free and almost caries-free," a classification which has been perpetuated for the other years in order to make comparison with the 1929 findings possible.

In presenting the results of the various investigations, the surface structure of the teeth is expressed both as the percentage incidence of the different grades of hypoplasia and as the average hypoplasia figure (A.H.F.). The latter, which relates only to M-hypoplasia and gives a rough computation of the extent of this type of defect, is obtained by allotting a number to every tooth in each grade (1 for $M\text{-}Hy_1$, 2 for $M\text{-}Hy_2$, and 3 for $M\text{-}Hy_3$) and dividing the sum of the numbers—that is, the total M-hypoplasia figure for any group—by the number of teeth in the group, excluding those showing gross hypoplasia. Caries is expressed as a percentage incidence and as the average caries figure (A.C.F.), which is estimated in a similar way to the A.H.F. The numbers 1, 2, and 3 are allotted to the carious teeth according to their grading, and the total caries figure is divided by the number of teeth in the group. For both A.H.F. and A.C.F. the maximum possible value is 3; therefore the greater the number of teeth with the more severe grades of M-hypoplasia and caries, the nearer the figures approach to this number.

1955 Survey

In this survey the teeth of 1,205 children were inspected. The tables of results are self-explanatory and need little comment.

Surface Structure

The 21,627 teeth which it was possible to examine for surface texture, amounting to about 90% of the full complement, were graded according to type and degree of roughness. The remainder, which could not be graded, consisted of shed incisors, extracted teeth (mainly molars), and teeth which were too carious or too extensively filled for an estimation of their structure to be made.

In Table I are shown the incidence and extent of M-hypoplasia and the incidence of G-hypoplasia in each type of tooth and in all types taken together. The "pattern" approximates to that found in the previous surveys of the series and in others made in residential homes (institutions)