PATHOLOGIC PHYSIOLOGY OF MITRAL STENOSIS AND ITS SURGICAL IMPLICATIONS*

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THE development of a direct surgical attack on narrowed mitral valves raises many questions as to its efficacy. Wilcox and Grace[1] have objected on theoretical grounds, believing that surgery could offer little or no benefit in the majority of patients with mitral stenosis. Harken and his associates[2, 3] Glover, O'Neill, and Bailey,[4] Baker, Brock, and Campbell,[5] and Prip Buus[6] have recently reported clinical improvement of their patients following direct valvular surgery. The evaluation of operative results by clinical impression alone leaves much to be desired, however, because spontaneous changes frequently occur in the clinical course of these individuals. The advent of pulmonary vascular changes and of right ventricular failure, for example, may result in symptomatic improvement by relieving pulmonary congestion, yet marks the onward progression of the disease. Objective evaluation of mitral valve surgery is therefore not only desirable but necessary. Baker, Brock, and Campbell[5] have studied the cardiac output and pulmonary arterial pressure in four cases after mitral valvulotomy and we[7] have reported the post-operative changes in circulatory dynamics in six cases.

This study reviews the pathological physiology of mitral stenosis as it relates to mitral valve surgery and analyzes the pre-operative and early post-operative changes in circulatory dynamics in twelve patients with incapacitating mitral stenosis on whom mitral valvuloplasty was performed at the Peter Bent Brigham Hospital by Dr. Dwight E. Harken.

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A diagram illustrating the pathological physiology of mitral stenosis is shown in Figure 1. A detailed description of the points that follow

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DIAGRAM OF PATHOLOGIC PHYSIOLOGY OF MITRAL STENOSIS

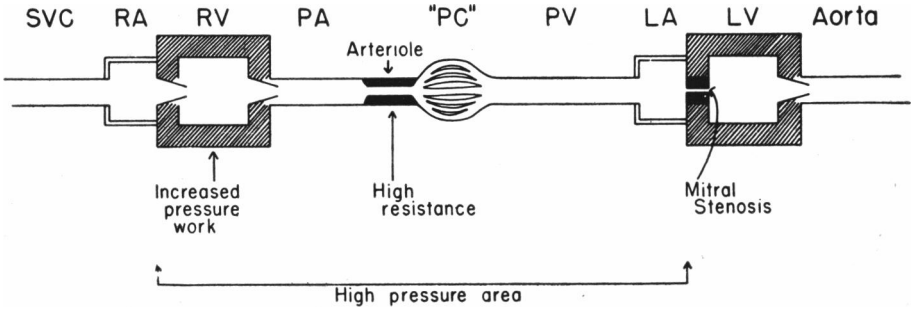

Fig. 1

have been published elsewhere.[8-12] It is to be emphasized at the outset that this discussion applies to mechanical mitral stenosis wherein there is no concomitant active rheumatic carditis.

The normal mitral valve has a cross-sectional area of 4 to 6 sq. cm. Methods have been developed by Gorlin and Gorlin[8] for accurately calculating the size of the orifice of the mitral valve during life in patients with mitral stenosis. In mitral stenosis, the orifice becomes narrowed and in the most advanced cases may be only 0.4 sq. cm. Narrowing of the mitral valve orifice produces an obstruction to the flow of blood at a critical point in the circulatory system, i.e., at a point just distal to the capillaries of the lung. Between these capillaries and the mitral valve there are no valves or other important buffering mechanisms. Indeed, in many ways the pulmonary capillaries, pulmonary veins, and left auricle can be thought of as a single vascular compartment with pressures in all parts not differing by more than a few mm. Hg. As the mitral valve orifice becomes narrower, it is obvious that if blood flow (cardiac output) is to be maintained at a normal level, pressure proximal to the mitral valve must increase. If pressure in the left auricle remains normal, blood flow must decrease. In mitral stenosis both occur, i.e., pressure in the left auricle and lung rises and cardiac output decreases. The pressure rise is predominant, however, and gives rise to the symptoms of dyspnea, orthopnea, paroxysmal nocturnal dyspnea, pulmonary edema, and hemoptysis, these being the prominent symptoms of mitral stenosis and the ultimate cause of disability. These symptoms are at-

tributable to a rise of pressure in the pulmonary capillaries to a level exceeding the osmotic pressure of plasma with the production of pulmonary edema. These two compensations – a rise of pressure proximal to the valve and a decrease in the amount of blood flowing through the valve – are the only two important compensations that take place during the time that the mitral valve is becoming narrower and narrower. Not until late in the course, when the valve becomes about 20 per cent of normal (about 1.0 sq. cm.) does the third compensation appear.

This compensation consists of narrowing of the arterioles and small arteries in the lung. Histologically there is intimal proliferation and medial hypertrophy.[13, 14] Physiologically, there is an increased resistance to blood flow through this segment of the lung which can easily be measured with the cardiac catheter.[9, 15] There is considerable variation in patients with mitral stenosis of the same severity in the extent of this vascular resistance in the lung. Some with tight mitral stenosis never develop important increases in resistance and these are the patients who have severe exertional dyspnea, orthopnea, hemoptysis, and attacks of acute pulmonary edema. These patients have hearts which are usually little if any enlarged and there is no venous distension, hepatomegaly, or other manifestations of right ventricular failure.[12] There are others who develop a moderate degree of pulmonary vascular resistance wherein there is a delicate balance between the resistances in the lung and at the mitral valve. These patients have few respiratory complaints because the right ventricle, due to the increased pulmonary resistance, cannot pump blood into the lung any faster than it can comfortably escape through the mitral valve. These two areas of increased resistance – the lung and the mitral valve – result in a low fixed cardiac output so that the predominant symptoms are fatigue, exhaustion, weakness, tiredness, ennui. At this point, the heart is enlarged, but the right ventricle is usually still competent. In some individuals, the pulmonary vascular resistance becomes excessive, i.e., 15 to 20 times the normal. The resistance to blood flow through the lung may become greater than that at the mitral valve. These individuals do not in our experience have episodes of pulmonary edema, but as in patients with severe cor pulmonale, there is excessive exertional dyspnea and orthopnea, the right ventricle becomes greatly enlarged and fails, with the appearance of venous distension, hepatomegaly, and edema.

The only clue to the mode of production of these pulmonary vascular lesions in mitral stenosis is that they make their appearance only late

in the course of mitral stenosis when the size of the mitral valve is about 1.0 sq. cm. or less, at which point even at rest pulmonary edema impends. It has been postulated[15] that this chronic threat of pulmonary edema in some unknown fashion leads to the appearance of the vascular changes. We have considered it to be a compensatory mechanism successfully preventing the right ventricle from sudden surges of output, thereby preventing the flooding of the pulmonary capillaries with blood.

The importance of this pulmonary vascular resistance cannot be over-estimated in modifying and influencing the clinical course of patients with mitral stenosis. Before its appearance, respiratory symptoms become increasingly prominent as the valve becomes narrower. It is not until the pulmonary resistance becomes five to ten times the normal level that the transverse diameter of the heart by x-ray becomes increased and respiratory symptoms decrease, and ten to fifteen times the normal that the right ventricle fails grossly.

Evaluation of Surgery

With these points in mind, it is obvious that relief of the stenosis itself may not necessarily result in clinical improvement of the patient unless the secondary changes in the lungs revert toward normal. As an amplification of an earlier report,[7] an attempt will be made to answer the following questions based on the findings shortly after operation in twelve patients on whom mitral valvuloplasty for severe, incapacitating mitral stenosis has been performed.

1. Can the mitral valve orifice really be widened?
2. Is mitral insufficiency necessarily produced?
3. Does the cardiac output increase?
4. Do pressures in the pulmonary circuit fall?
5. Does the increased pulmonary arteriolar resistance return to or towards normal?
6. Does right ventricular function, as indicated by its filling pressure, return to or towards normal?

Material

Twelve patients with mitral stenosis subjected to mitral valvuloplasty[16] in the Peter Bent Brigham Hospital were all incapacitated, many leading a bed and chair existence, and were graded as Class III or IV according to the New York Heart Association Classification. Studies were carried out a few days before operation and again between two

TABLE 1—CIRCULATORY DYNAMICS IN PATIENTS BEFORE AND AFTER MITRAL VALVULOPLASTY

Patient	Mitral Valve Stenotic Area cm.²		Cardiac Index l/min./sq.m.		Pulmonary "Capillary" Pressure mm. Hg.		Pulmonary Arteriolar Resistance dynes sec. cm.⁻⁵		Right Ventricular Filling Pressure mm. Hg.		Mitral Regurgitation Present	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
M.McG.	0.4	0.7	1.8	1.9	25	17	770	889	4	4	0	0
W.F.	0.5	0.9	1.8	2.8	23	20	1139	332	8	6	0	0
R.W.	0.6	1.2	2.7	2.2	34	11	274	441	9	4	0	0
E.D.	0.6	1.5	2.4	1.9	36	21	411	600	12	4	0	++
J.G.	0.6	1.5	2.1	2.9	34	17	400	200	10	2	0	0
L.L.	0.7	1.3	2.5	2.6	27	24	632	554	5	13	0	0
T.C.	0.7	1.7	2.9	3.3	32	14	488	254	7	7	0	0
C.E.	0.8	1.7	2.2	2.8	18	11	292	173	5	3	0	0
B.A.	0.9	1.6	3.6	3.8	32	19	569	364	0	5	0	0
N.W.	1.0	1.6	3.2	3.6	33	19	204	280	2	4	0	0
E.L.	1.1	2.3	1.4	1.9	24	10	1480	523	5	4	++	++
A.D.	1.3	1.9	2.0	2.3	37	26	103	178	8	4	++	++

and six weeks after operation. Mitral insufficiency was detected qualitatively from the contour of the pulmonary "capillary" pulse tracing and estimated semi-quantitatively by means of hydraulic formulae.[17, 18]

METHODS

The methods have been described in detail elsewhere.[9] In general, they consisted of measuring cardiac output by the direct Fick principle and recording pressures with Sanborn electromanometers in the pulmonary "capillaries," pulmonary artery, right ventricle, right atrium, and brachial artery. From these pressure and flow measurements, calculations by the formulae described elsewhere[8] have been made of the size of the mitral valve orifice, and the pulmonary arteriolar and total pulmonary resistances. Estimates of the degree of mitral insufficiency, graded from one to four plus, have been based on the height of the v-wave in relation to the mean pulmonary "capillary" pressure.[17, 18]

Results

Pertinent data will be found in Table I and Figures 2 through 6.

1. *Size of the orifice of the mitral valve*: In each patient, the mitral orifice was significantly increased in size by operation (Figure 2). In eight, the size of the orifice post-operatively was considered to be satisfactory, i.e., greater than 1.5 sq. cm. If the size of the valve orifice were the only problem in mitral stenosis, these eight patients could be expected to return to almost normal activity. In R.W. and L.L., an adequate size of the valve orifice was obtained, i.e., 1.2 and 1.3 sq. cm. respectively. W.F. had an extremely elastic valve orifice which made finger fracture of the commissures difficult so that the resulting valve orifice measured post-operatively was only 0.9 sq. cm. The problem in her case was similar to that of trying to fracture a rubber band. Now that this problem is recognized, an appropriate surgical maneuver has been devised to overcome this difficulty. In M. McG., the anatomical nature of the stenosis made enlargement of the orifice technically almost impossible.

2. *Mitral insufficiency*: Nine patients had mitral stenosis without insufficiency before operation. None had mitral insufficiency post-operatively (Figure 2). Patients A.D. and E.L. had mitral stenosis and insufficiency before operation and, as nearly as could be judged, no definite change in their regurgitation either for better or for worse was produced by operation. In one patient, E.D., fracture of the valve commissure was carried forward unintentionally into the aortic leaflet so that some mitral regurgitation was produced. The dissection should have been carried to the annulus and no further or else into the minor leaflet. This must be regarded as a technical error incident to efforts at improving leaflet mobilization. Despite this one case, it is apparent that mitral valvuloplasty can relieve stenosis without producing regurgitation.

3. *Cardiac output*: Cardiac output was not significantly different two to three weeks post-operatively in the majority of patients (Figure 3). In W.F. and E.L. the cardiac output had increased appreciably, presumably due to the striking decrease of pulmonary arteriolar resistance. In J.G. and C.E., cardiac output rose significantly though not markedly. Baker, Brock and Campbell[5] found little change in cardiac output in four cases studied two to three months after surgery. The failure of cardiac output to increase shortly after operation may be due to the "disuse atrophy" of the left ventricle which occurs in mitral

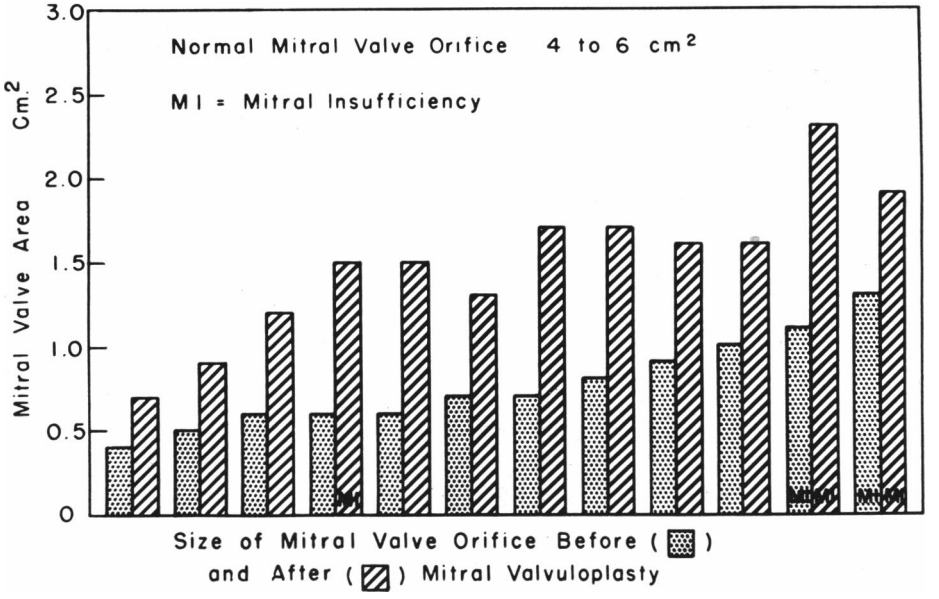
Normal Mitral Valve Orifice 4 to 6 cm²
MI = Mitral Insufficiency
Mitral Valve Area Cm.²
3.0
2.5
2.0
1.5
1.0
0.5
0
MI
Size of Mitral Valve Orifice Before ( ) and After ( ) Mitral Valvuloplasty

Fig. 2

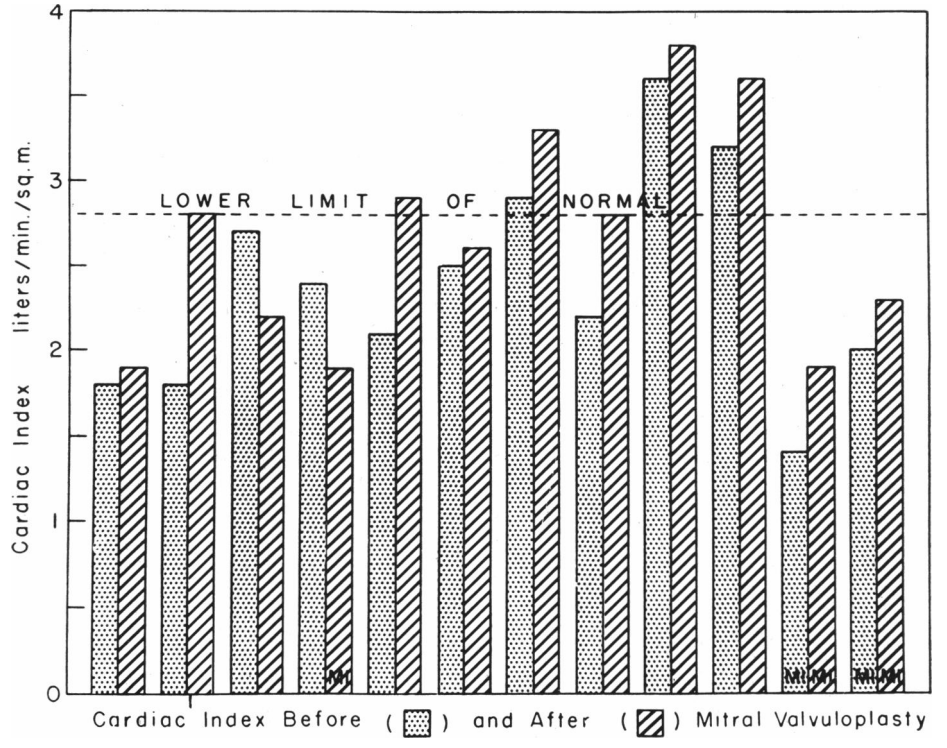
Cardiac Index liters/min./sq.m.
4
3
2
1
0
LOWER LIMIT OF NORMAL
MI
Cardiac Index Before ( ) and After ( ) Mitral Valvuloplasty

Fig. 3

stenosis and to the increased resistance in the arterioles of the lung, which tends to keep the output of the right ventricle depressed in mitral stenosis as well as in cor pulmonale.[19, 20] The relative role of these two factors and the eventual level at which cardiac output will stabilize must await subsequent follow-up. Follow-up reports indicate clinically a progressive increase in exertional tolerance over the course of one to eight months at this writing, from which it is anticipated that the cardiac output gradually increases over the course of weeks and months.

4. *Pulmonary "capillary" pressure*: Since the valve orifice was enlarged and blood flow through it relatively unchanged, a striking fall of pulmonary "capillary" pressure occurred in eleven of the twelve patients (Figure 4). Baker, Brock, and Campbell[5] noted a fall of pulmonary arterial pressure post-operatively in three cases. The fall of pulmonary "capillary" pressure in our patients resulted in a relief of their pulmonary congestive symptoms which were their major cause of disability. In all but two cases, this pressure was well below the pulmonary edema level post-operatively. In W.F., pulmonary "capillary" pressure was little changed, but instead the cardiac output and blood flow through the valve had increased considerably. In A.D., severe mitral regurgitation was considered to be the cause of the failure of the pulmonary "capillary" pressure to fall to more normal levels. The dramatic fall of pulmonary "capillary" pressure post-operatively was reflected clinically by the impressive absence of dyspnea, orthopnea, and other signs and symptoms of pulmonary congestion in the post-operative period.

5. *Pulmonary arteriolar resistance*: In eight patients there was no significant change in pulmonary arteriolar resistance two to three weeks post-operatively (Figure 5). In E.L. and W.F., the decrease of resistance was striking and was in excess of any possible error in the methods. In T.C. and J.G., less striking but significant reductions of the resistance were observed. The marked fall of resistance in E.L. and W.F. so early in the post-operative period strongly suggests that part of the elevated arteriolar resistance pre-operatively was due to functional vasoconstrictor activity and that the post-operative values for resistance represented the residual obstruction due to organic narrowing of the arterioles which is known to be present in severe mitral stenosis.[13, 14] In two patients (B.A. and T.C.), values for resistance returned almost to normal (160 and 131 dynes second cm.-5 respectively) seven months post-operatively. Whether organic narrowing of pulmonary arterioles

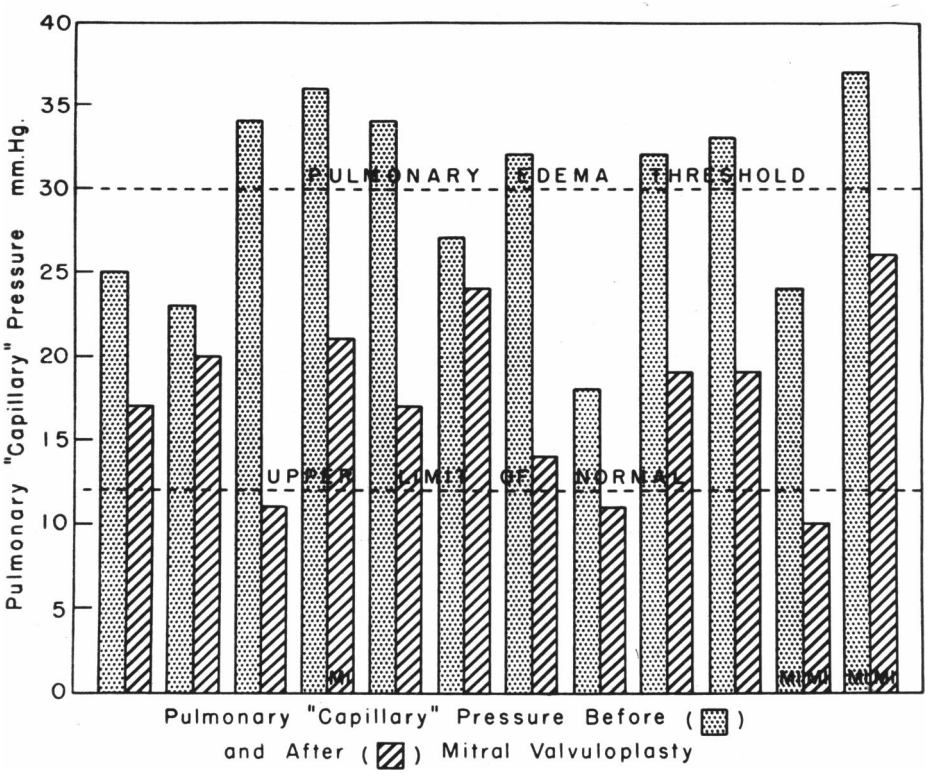
Pulmonary "Capillary" Pressure mm.Hg.
40
35
30
25
20
15
10
5
0
PULMONARY EDEMA THRESHOLD
UPPER LIMIT OF NORMAL
M
M(M)
M(M)
Pulmonary "Capillary" Pressure Before ( ) and After ( ) Mitral Valvuloplasty

Fig. 4

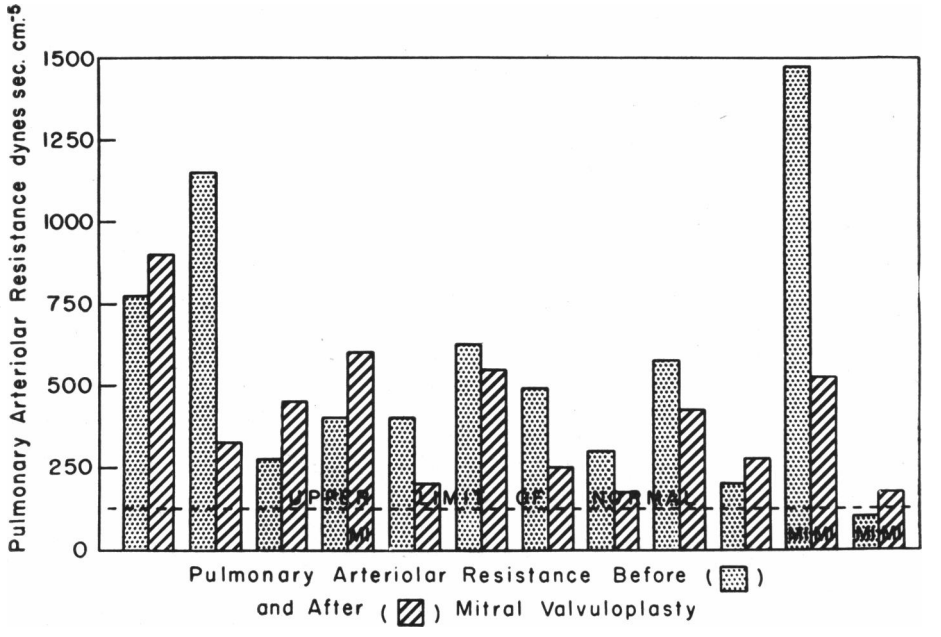
Pulmonary Arteriolar Resistance dynes sec. cm.-5
1500
1250
1000
750
500
250
0
UPPER LIMIT OF NORMAL
M
M(M)
M(M)
Pulmonary Arteriolar Resistance Before ( ) and After ( ) Mitral Valvuloplasty

Fig. 5

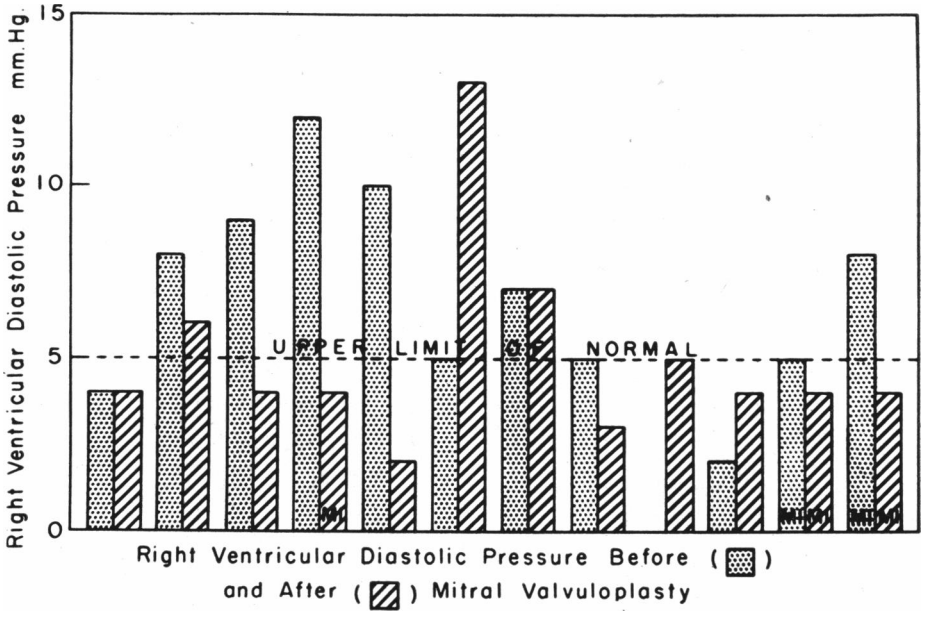

Fig. 6

is reversible in all patients is not known and must await study of more cases.

6. *Right ventricular function*: Six patients had elevations of right ventricular diastolic filling pressure (Figure 6). In four of these patients, values were normal post-operatively, in one (W.F.) it had fallen slightly, and in one (T.C.) it was unchanged. In one patient (L.L.) there was a rise from 5 mm. Hg pre-operatively to 13 post-operatively. Active rheumatic carditis was suspected as the cause, although there were no other confirmatory manifestations. The general trend was clearly a reversion toward but not necessarily to normal values early in the post-operative course.

Discussion

From these early post-operative observations, it is apparent that the surgical relief of mitral stenosis entails an evaluation not only of the stenotic valve itself, but also of mitral regurgitation, pressure and flow relations across the valve, arteriolar resistance in the lung, and right ventricular function.

The post-operative size of the mitral valve was increased in all cases

but was only 30 to 50 per cent of the normal size. By the surgical technique used, it seems unlikely to this author that the size can be made greater. As described in detail elsewhere,[11] a valve area of 1.5 sq. cm. or more should result in restoration to almost normal activity, assuming a regression of pulmonary vascular changes and return of right ventricular function to normal. If the valve is 2.0 sq. cm. or more, the patient has symptoms only on excessive exertion. A certain and appreciable number of such patients may never progress to symptomatic disease.[21] Surgery has certainly not been sufficiently perfected as yet to justify its use in patients with valve areas greater than 1.5 sq. cm.

A general concept in the past has been that relief of stenosis must be at the expense of producing mitral regurgitation. Harken[2] was the first to recognize that it was possible to relieve stenosis without producing regurgitation. The data reported here amply confirm him in demonstrating that the valve orifice can often be increased to a size which enables the patient to live a life of all but truly excessive activity without the concomitant production of regurgitation.

The early as well as later return of pulmonary arteriolar resistance toward normal in some of our patients is extremely encouraging and indeed surprising because authoritative pathological opinion has been that this would probably not occur.[14] Although relief of mitral valve obstruction would relieve pulmonary congestive symptoms, the patient might still remain relatively incapacitated if such elevated resistances persisted after operation.

The presence of auricular fibrillation in itself has no bearing on the decision to operate or not to operate. The incidence of embolism can be anticipated to be higher in fibrillators, but it is these very patients who stand to receive the greatest benefit from surgery. The eventual effect of the operation on cardiac rhythm remains to be determined. At this writing, there is no evidence that chronic auricular fibrillation spontaneously reverts to normal sinus rhythm post-operatively.

The only five absolute contraindications to operation at this stage of evolution of the surgical procedure, in our opinion, are: 1) that the mitral stenosis is too mild, i.e., symptoms are not severe enough to keep the patient from a useful and productive life; 2) that there is a serious associated disease, e.g., tuberculosis, nephritis, etc.; 3) that bacterial endocarditis is present; 4) that active rheumatic fever is present; and 5) that other valve lesions are present in serious degree. The recognition of rheumatic carditis is difficult when it is smouldering and often defies

all of the usual tests. If there are no clinical manifestations of rheumatic activity, however, it is assumed that rheumatic activity is either absent or so minimal as to be of little importance as regards the decision to operate.

Indications: In our opinion, tight mitral stenosis is *the* indication for mitral valvuloplasty. By tight is meant a valve area of 1.0 sq. cm. or less. This can usually be recognized accurately in patients with pure mitral stenosis without resorting to cardiac catheterization.

Mechanical narrowing of a mitral valve is well tolerated to a point. When it is but 20 per cent of its normal size, i.e., about 1.0 sq. cm., symptoms are present at rest or on the slightest exertion.[12, 22] We have encountered considerable difficulty in estimating larger valve sizes on clinical grounds alone, but have seldom had difficulty in recognizing "tight" mitral valves. In order to do this, aggravating factors must be eliminated such as thyrotoxicosis, pregnancy, active rheumatic carditis, subacute bacterial endocarditis, uncontrolled tachycardia, and other complicating episodes such as arterial or pulmonary embolism. In short, the patient is under good medical management without aggravating influences. The symptoms and signs derive from the mechanically obstructing mitral valve.

Nothing is so important as a careful history with one's attention focused on symptoms during the periods when these complicating events are *absent*, a careful physical examination, an x-ray and fluoroscopy of the heart, and an electrocardiogram. If the patient with pure mitral stenosis has any four of the following eight manifestations, he can be confidently assumed to have a mitral valve area of 1.0 sq. cm. or less, i.e., a tight mitral stenosis.[12]

1. Severe exertional dyspnea on one flight of stairs.
2. Left auricle moderately or markedly enlarged by fluoroscopy.
3. Pulmonary artery moderately or markedly enlarged by fluoroscopy.
4. Right ventricular hypertrophy by electrocardiogram.
5. Auricular fibrillation.
6. Heart 20 per cent or more enlarged by roentgenogram.
7. Hepatomegaly (4 cm. or more below the costal margin).
8. Three to four plus edema.

Four or more of these manifestations are, in our opinion, indications for mitral valvuloplasty.

The presence of mitral insufficiency or involvement of other valves in the rheumatic process complicates the decision regarding surgery.

It must be remembered that mitral valvuloplasty is designed specifically for relief of severe mitral stenosis. If other valves are involved, the degree of improvement from mitral valvuloplasty will not be so great as in pure mitral stenosis.

In patients with mitral stenosis, the estimation of the severity of other valve lesions is not easy. In our experience, the best clue to the *severity* of *aortic insufficiency* is the diastolic blood pressure; of *aortic stenosis*, the duration of systole on a brachial arterial pressure tracing; of *mitral insufficiency* the presence of left ventricular hypertrophy, combined ventricular hypertrophy, or even the absence of right ventricular hypertrophy in a patient with both systolic and diastolic murmurs at the apex whose symptoms and signs would lead one to expect that right ventricular hypertrophy ought to be present; of *tricuspid insufficiency* an enlarged pulsating liver; and of *tricuspid stenosis*, pronounced edema and ascites and an elevated venous pressure not responding well to the usual forms of cardiac therapy. Cardiac catheterization is now reserved for those cases which remain doubtful using the usual clinical measures. If one or more valves other than the mitral have serious disease, it is not in the best interest of the patient to operate. If one or more valves are minimally involved and the mitral valve is severely stenosed, a good but not excellent result from successful mitral valvuloplasty may be anticipated.

One of the pressing questions is whether the valve orifice will continue to remain patent for a prolonged period of time or whether it will become sealed off again in the course of weeks or months. Since the orifice is continually opening and closing, the only obvious ways in which it can become reduced in size again is by a recurrence of active rheumatic valvulitis or by thrombus formation on the fractured commissure at or shortly after operation, before endothelium has grown over the denuded areas. Sufficient objective data are as yet unavailable as regards the size of the mitral orifice six months or more after operation, but clinical follow-up on these patients indicates progressive improvement in their exercise tolerance over the course of the succeeding four to six months, which is possibly attributable to the regression of the secondary vascular changes in the lungs. After six months, their activity stabilizes and their capacity to exert themselves has shown no tendency to diminish. It would seem likely, then, that the valve orifice has remained unchanged in size for periods up to three years, which is the longest that any patients have been followed.

To date, 115 patients have had a finger fracture valvuloplasty performed by Dwight E. Harken. Sixty-five have been in his group 3[23] (corresponding with certain modifications to the same grouping of the New York Heart Association). There have been four operative deaths, a 6 per cent mortality – all in the earlier part of the series. Among fifty patients in group 4, there have been eighteen operative deaths, a mortality of 36 per cent. With experience and with the development of suitable instruments, there have been no technical deaths in the last eighty or more operations. Arterial embolism has accounted for seven deaths, cardiac standstill, ventricular fibrillation, and shock have accounted for about ten deaths, and the remainder have been from miscellaneous causes. Much of this mortality occurred during the developmental period of this type of surgery. Details of the surgical technique and anesthesia will be found in the publications of Harken.[16]

It is apparent that the operative risk is low in those patients who have pure mitral stenosis and who are incapacitated by exertional dyspnea, orthopnea, hemoptysis, and paroxysmal nocturnal dyspnea but whose hearts and livers are not greatly enlarged and who have little or no edema. In those who do have big hearts and signs of right ventricular failure, i.e., in those who are completely incapacitated, the risk is considerable, and the results are not so marked or so sure, but in some the benefit has been dramatic.

From this study, some of the problems of the effectiveness of mitral valvuloplasty have been answered, but many remain to be solved. The results are so encouraging, however, that this surgical approach seems to rest on solid ground.

Summary

1. The salient points of the pathological physiology and clinical manifestations of mitral stenosis and of surgical objectives are discussed.

2. Twelve patients with mitral stenosis on whom valvuloplasty was performed by Dr. D. E. Harken at the Peter Bent Brigham Hospital have been studied before and two to six weeks after operation in order to obtain objective information regarding the effectiveness of the surgical procedure.

3. The orifice of the mitral valve was increased in size in each case, but in none was it brought back to normal. In the majority, the postoperative size was such that normal but not excessive activity should be and actually was regained.

4. Mitral regurgitation was not produced in eleven of these twelve cases.

5. The immediate effect of operation in ten of twelve cases was to lower the pressure in the pulmonary circuit rather than to increase cardiac output.

6. In two patients, there was a dramatic decrease and in two others a significant decrease of pulmonary arteriolar resistance shortly after operation. In two, this resistance had returned to practically normal values seven months after operation. Whether changes in the arterioles of the lung will regress completely with the passage of time in all cases cannot be answered as yet.

7. There was a general tendency for the diastolic filling pressure of the right ventricle to decrease post-operatively to or towards normal.

8. Operative indications and risks are discussed.

The author is merely the spokesman for a team at the Peter Bent Brigham Hospital who have recently been concerned in the study of mitral stenosis.

Dr. Dwight E. Harken has performed the surgery, with the able assistance of Drs. R. E. Farrand, H. L. Black, and J. E. Dickson, III.

Without the collaboration and fundamental contributions to the pathological physiology and clinical and physiological correlations by Drs. R. Gorlin, B. M. Lewis, and F. W. Haynes, this work would not have been possible.

REFERENCES

1. Wilcox, L. D. and Grace, A. J. Barriers to surgery in mitral stenosis, *Congrès* (1) *Mondial de Chardiologie,* Paris 1950. Abstracts of papers, pp. 183-84.
2. Harken, D. E., Ellis, L. B., Ware, P. F. and Norman, L. R. Surgical treatment of mitral stenosis, *New Engl. J. Med. 239*:801-09, 1948.
3. Harken, D. E., Ellis, L. B. and Norman, L. R. Surgical treatment of mitral stenosis; progress in developing a controlled valvuloplastic technique, *J. Thorac. Surg. 19*:1-15, 1950.
4. Glover, R. P., O'Neill, T. J. E. and Bailey, C. P. Commissurotomy for mitral stenosis, *Circulation 1*:329-42, 1950.
5. Baker, C., Brock, R. C. and Campbell, M. Valvulotomy for mitral stenosis; report of six successful cases, *Brit. Med. J. 1*:1283-93, 1950.
6. Prip Buus, C. E. Traitement chirurgical des stenoses mitrales, 5 cas; film de l'operation. *Congrès* (1) *Mondial de Cardiologie,* Paris, 1950. Abstracts of papers, p. 187.
7. Dexter, L., Gorlin, R., Lewis, B. M., Haynes, F. W. and Harken, D. E. Physiological evaluation of patients with mitral stenosis before and after mitral valvuloplasty, *Trans. Amer. Clin. Climatol. Assoc. 62*:170-80, 1950.
8. Gorlin, R. and Gorlin, S. G. Hydraulic formula for calculation of the area of

the stenotic mitral valve, other cardiac valves, and central circulatory shunts, *Amer. Heart J. 41:*1-29, 1951.

9. Gorlin, R., Haynes, F. W., Goodale, W. T., Sawyer, C. G., Dow, J. W. and Dexter, L. Studies of the circulatory dynamics in mitral stenosis; altered dynamics at rest, *Amer. Heart J. 41:*30-45, 1951.
10. Gorlin, R., Sawyer, C. G., Haynes, F. W., Goodale, W. T. and Dexter, L. Effects of exercise on circulatory dynamics in mitral stenosis, *Amer. Heart J. 41:*192-203, 1951.
11. Gorlin, R., Lewis, B. M., Haynes, F. W., Spiegl, R. J. and Dexter, L. Factors regulating pulmonary "capillary" pressure in mitral stenosis, *Amer. Heart J. 41:*834-54, 1951.
12. Lewis, B. M., Gorlin, R., Houssay, H. E. J., Haynes, F. W. and Dexter, L. Clinical and physiological correlations in patients with mitral stenosis. *Amer. Heart J., in press.*
13. Parker, F., Jr. and Weiss, S. Nature and significance of the structural changes in the lungs in mitral stenosis, *Amer. J. Path. 12:*573-98, 1936.
14. Larrabee, W. F., Parker, R. L. and Edwards, J. E. Pathology of intrapulmonary arteries and arterioles in mitral stenosis. *Proc. Staff Meet. Mayo Clin. 24:*316-26, 1949.
15. Dexter, L., Dow, J. W., Haynes, F. W., Whittenberger, J. L., Ferris, B. G., Goodale, W. T. and Hellems, H. K. Studies of the pulmonary circulation in man at rest. Normal variations and the interrelations between increased pulmonary blood flow, elevated pulmonary arterial pressure, and high pulmonary "capillary" pressures, *J. Clin. Invest. 29:*602-13, 1950.
16. Harken, D. E., Dexter, L., Ellis, L. E., Farrand, R. E. and Dickson, J. L., III. Surgical treatment of mitral stenosis. Finger fracture valvuloplasty, *Ann. Surg. 134:*722-41, 1951.
17. Gorlin, R. and Dexter, L. Hydraulic formula for the calculation of the cross-sectional area of the mitral valve during regurgitation. *Amer. Heart J., in press.*
18. Gorlin, R., Lewis, B. M., Haynes, F. W. and Dexter, L. Studies of the circulatory dynamics at rest in mitral valvular regurgitation with and without stenosis. *Amer. Heart J., in press.*
19. Dexter, L.: Pulmonary circulatory dynamics in health and disease at rest, *Bull. New Engl. Med. Center 11:*240-46, 1949.
20. Dexter, L., Whittenberger, J. L., Gorlin, R., Lewis, B. M., Haynes, F. W. and Spiegl, R. J. The effect of chronic pulmonary disease (Cor Pulmonale and Hypoxia) on the dynamics of the circulation in man, *Trans. Assoc. Amer. Phys., 64:*226-35, 1951.
21. Sprague, H. B. and Carmichael, D. B., Jr. Rheumatic valvular disease in the aged, *Geriatrics 5:*239-51, 1950.
22. Gorlin, R. Physiologic and clinical correlations in mitral stenosis, *Bull. New Engl. Med. Center 13:*20-30, 1951.
23. Harken, D. E., Ellis, L. E., Dexter, L., Farrand, R. E. and Dickson, J. L., III. Responsibility of the physician in the selection of patients with mitral stenosis for surgical treatment, *Circulation, in press.*