Surgical Correction of Mitral Insufficiency Under Direct Vision: Report of Clinical Cases

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Over 30 years ago Cutler and Beck attempted to relieve mitral stenosis by excising a small segment of the scarred valve with the rationale that a minimal degree of insufficiency was better tolerated than severe stenosis. Ten years ago Horace Smithy revived this concept and awakened interest in the surgical treatment of rheumatic valvular disease in general. From the large experience in surgical treatment of mitral stenosis in the last decade pioneered by the work of Brock, Harken, Bailey and others there has emerged an appreciation of the fact that significant mitral insufficiency may be of even more serious import than mitral stenosis. Severe mitral insufficiency of a “pure” type is apparently about as common as is “pure” mitral stenosis. Bland’s data on incidence of mitral disease indicates that neither lesion in the “pure” state is as common as is the combination of the two.

Numerous ingenious experimental technics have been devised in recent years for relief of mitral valvular leakage by closed methods and a few of these have been applied clinically. The concept of repair of the incompetent mitral valve by open methods under direct vision antedated the availability of satisfactory technics for maintenance of extracorporeal circulation, but clinical application of this idea has only been possible in the last two or three years. This report describes a method of operative repair of the insufficient mitral valve under direct vision and records our preliminary experience with the method.

Anatomic and Functional Pathology of Mitral Insufficiency

The normal mitral valve mechanism extends over a distance of about 5 cm. from the atrioventricular fibrous ring or annulus which lies within the left atrium to the two papillary muscles and their associated chordae tendineae which are located in the left ventricle. Stretching from the annulus above to the chordae tendineae below are the two sail-like leaflets—a large anteromedial leaflet and a smaller posterolateral one. Normally these leaflets are brought into apposition with ease at the time of valve closure at the beginning of ventricular systole (Fig. 1).

Pure mitral regurgitation may rarely be the result of acute trauma with the production of a hole or defect in a valve leaflet, or with rupture of a papillary muscle or its associated tendon. Infinitely more commonly, rheumatic valvulitis produces rigidity of the margins of the valve orifice with contracture of the leaflets and shortening of the musculotendinous mechanism. Secondary dilatation of the annular ring leads to a further increase in the degree of mitral regurgitation, producing a vicious cycle.
Certain forms of myocarditis may apparently also produce dilatation of the annulus primarily without concomitant disease of the leaflets. The pathologic conditions encountered may thus consist of (a) simple dilatation of the annulus with relatively normal valve leaflets and musculotendinous structures, and (b) secondary dilatation of the annulus associated with fibrous and even calcific changes in the leaflets and their musculotendinous structures. This latter form may be accompanied by actual reduction in leaflet area and is frequently associated with various degrees of fusion at the commissures.

The left ventricle is protected by pure mitral stenosis but with mitral insufficiency the work load of the left ventricle is increased and this chamber must undergo compensatory pathologic changes. As pointed out by Rodbard and Williams, when mitral insufficiency exists, dilatation of the left ventricle is an important factor in providing sufficient forward flow through the aortic orifice, since the first volume of blood to leave the left ventricle regurgitates through the mitral orifice into the atrium where relatively low pressure exists. The regurgitant volume serves as a kind of "overhead" cost, without which no forward flow can occur. If dilatation did not take place and the ventricular volume remained small, only mitral regurgitation would occur and there would be no outflow into the systemic circuit. A strong quick contraction of a distended ventricle is thus necessary to eject enough blood into the aorta to provide a relatively normal systemic output when simultaneous backward flow into the left atrium occurs. Therefore, when mitral insufficiency exists, the left ventricle must of necessity ultimately become hypertrophied and dilated. However, this compensatory dilatation unfortunately results in further increase in the size of the annulus of the mitral valve and a progressive increase in regurgitation develops.

A review of the complex anatomical and functional alterations in mitral insufficiency suggests several principles as a guide to surgical repair. First, in so far as possible the normal mobility of the leaflets must be restored by elimination of commissural and subvalvular fusion. Second, the dilated annulus must be reduced in size appropriately so as to permit coaptation of the leaflets at the time of ventricular contraction. The adaptation of pump-oxygenator circuits for left heart surgery has made it possible to follow these principles in the repair of the incompetent valve under direct vision.

Operative Technic

Anesthesia is induced with cyclopropane and after tracheal intubation light anesthesia is maintained throughout the remainder of the procedure with nitrous oxide, oxygen and ether. Preparations are made for continuous recording of EKG, EEG, arterial and venous pressures and temperature.

The patient is placed in supine position with left chest elevated about 30 degrees. After skin preparation and draping the femoral vessels are exposed in both groins through small oblique incisions. Catheters for continuous pressure recordings are inserted into the left femoral artery and through the left saphenous vein into the inferior vena cava.

The chest is entered anteriorly in the fourth intercostal space through a curved submammary incision extending from the right anterior axillary line across the sternum to the left anterior axillary line. The in-
ternal mammary vessels are ligated and divided and the sternum is transected. A catheter is inserted into each hemithorax and attached to continuous suction to facilitate measurement of blood loss during the procedure. The thoracic viscera are inspected with particular care to exclude anomalies of pulmonary venous drainage, aberrant left vena cava and patent ductus arteriosus.

The pericardium is opened widely over the base of the heart and systematic examination of the heart and great vessels is made. The site of maximal intensity of the systolic thrill over the left atrium is determined. Pressure tracings are recorded in the left atrium, left ventricle and pulmonary artery. The left atrium and mitral valve are then carefully explored digitally by inserting a finger through the left atrial appendage. The character of the valvular deformity is assessed with particular reference to the intensity and location of the regurgitant jet, the degree of mobility of valve leaflets, the extent of annular dilatation, the presence of calcification, associated commissural fusion and thrombi. The atrial septum is palpated to exclude co-existing atrial defects.

At this point the decision is made to proceed with open atriotomy if the status of the valve indicates an attempt at repair under direct vision. The pump-oxygenator circuit is primed with compatible heparinized blood and preparations for its attachment to the venous and arterial systems of the patient are completed (Fig. 2).

The ascending aorta is dissected free from the adjacent pulmonary artery and a small purse-string suture of 5-0 arterial silk is placed near the base of the aorta on its anterior aspect. Another purse-string suture of 2-0 silk is placed at the base of the right atrial appendage. Heparin in dosage of 3 mg./kilo of body weight is given intravenously. A thin-walled stainless steel cannula of large caliber is inserted into the right common femoral artery via a transverse arteriotomy and connected to the arterial line of the pump-oxygenator. After digital exploration of the right atrium through its appendage to assess the status of the tricuspid valve, a single, large flanged cannula is inserted through the same incision, secured with the purse-string suture and connected to the venous reservoir of the pump-oxygenator. Perfusion is started and flows are adjusted to maintain circulatory equilibration as evidenced by EEG, arterial pressure and venous oxygen saturation. This usually requires flows in the range of 2.0 to 2.4 liters per square meter of body surface per minute.

The ascending aorta is cross clamped and a 15 gauge needle is inserted through the previously placed purse-string suture into the aortic lumen. Cardiac asystole is induced by the rapid injection of a solution of 2.5 per cent potassium citrate in oxygenated blood. Retained blood in the left side of the heart is aspirated by an atraumatic suction device inserted through the left atrial appendage. The left atrium is then opened widely by an incision extending from the base of the appendage towards the point of entry of the left pul-

**Fig. 2.** Diagram to illustrate thoracotomy incision and type of cannulation employed for open left atriotomy with extracorporeal circulation.
monary veins. Bronchial venous return is continuously aspirated from the opened atrium and returned to the pump-oxygenator circuit. A malleable retractor elevates the anterior atrial wall and facilitates exposure of the mitral valve. A careful appraisal of the valve is now made under direct vision (Fig. 3).

If fusion at the commissures is present the leaflets of the valve are separated accurately in the line of fusion to the annulus by sharp dissection with knife or scissors. The annulus is then grasped with Babcock forceps at either commissure and with traction the atrioventricular fibrous ring or annulus is clearly defined. The operator’s index finger is passed through the mitral orifice into the outflow tract of the left ventricle to define the exact position of the aortic valve and to assess its status. While this finger protects the aortic valve, a suture of 2-0 braided silk is placed and tied to approximate the annulus at the postero-medial commissure. Additional interrupted sutures are placed in the annulus to approximate the posteromedial portion of the dilated valve ring for a distance of about one half of the orificial diameter. The sutures are tied snugly so as to leave as little exposed silk as possible. Bronchial venous blood is then allowed to fill the left heart while closure of the atrial incision is carried out. Prior to occluding the appendage with an auricular clamp any residual air is carefully displaced from the left heart. The base of the aorta is aspirated for air prior to removing the aortic clamp and terminating arrest.

After cardiac activity is restored and satisfactory rhythm established, the venous intake of the pump-oxygenator is gradually occluded, the work load of the heart gradually increased and extracorporeal circulation is discontinued.

Final assessment of the function of the repaired mitral valve is made by digital palpation through the left atrial appendage and by measurements of pressure in the left atrium and ventricle prior to removal of the venous cannula from the right atrial appendage. Any measured deficit in blood volume is corrected before removal of the femoral arterial cannula and closure of the femoral arteriotomy.

A slow drip of protamine sulfate is started to neutralize heparin effect while closure of the pericardium and thoracotomy wound is carried out in the usual manner.

Case Reports

During the last six months five patients with severe rheumatic deformity of the mitral valve have been submitted to open left atriotomy with induced cardiac arrest and cardiopulmonary bypass. One of these had recurrent mitral stenosis following a digital commissurotomy done four years previously and had no mitral insufficiency. The heavily calcified commissures were completely opened with heavy scissors and no suturing of the annulus was required.
Now six months postoperative he has an excellent result. Four other patients with severe mitral insufficiency have had direct visual repair of the mitral valve following the technic outlined above.

Case 1. B. J. C. (VUH #169411). This 22-year-old white woman had a history of several attacks of acute rheumatic fever in childhood and had been followed in the Cardiac Clinic at Vanderbilt University Hospital since age 12 with a diagnosis of rheumatic heart disease and mitral insufficiency. She had had admissions to the Vanderbilt Hospital in 1953 and 1956, because of chronic congestive failure which had been controlled with difficulty by digitoxin, salt free diet and diuretics.

At the time of admission for operation in June 1957, she was greatly incapacitated. Although not totally bed-ridden she was unable to carry on her duties as a housewife and could walk for only short distances. There was great cardiac enlargement with a grade IV systolic murmur over the apex. At operation on June 27, 1957, severe mitral regurgitation and annular dilatation were demonstrated with no associated stenosis. There was contracture of the posterior leaflet and its chordae tendineae but both leaflets were pliable and contained no calcification. Maximal regurgitation occurred at the posteromedial commissure. The incompetent valve was repaired under direct vision via a left atrial incision using the pump-oxygenator and induced cardiac arrest in the manner described above. Five sutures of 2-0 silk were used to approximate the annulus postero-medially, but after cardiac rhythm was restored persistence of a localized regurgitant jet at the lateral aspect of the suture line necessitated a second brief period of induced arrest and the placement of three additional sutures in the annulus. The annulus was thus reduced to about 50% of its original dilated state and the residual mitral orifice would accept two fingers (Fig. 4). The regurgitant jet was completely abolished when cardiac rhythm was restored. In the postoperative period the patient's course was one of gradual improvement. Evidence of co-existing tricuspid insufficiency which had been masked in part by the mitral lesion was prominent in the first 2 weeks but thereafter diminished progressively. Six weeks after operation she was able to make a 3,500 mile drive to Alaska with her husband. Her reported continued improvement is encouraging.

Comment

This patient had a "pure" mitral insufficiency with great dilatation of the mitral annulus and minimal deformity of the leaflets of the valve. Posteromedial plication of the annulus has apparently eliminated the mitral regurgitation. It is possible that the co-existing tricuspid insufficiency is a secondary phenomenon which may gradually disappear. Her over-all early improvement is most gratifying.

Case 2. I. M. S. (VUH #262200). This 45-year-old Negro female had an attack of rheumatic fever 34 years before admission and 10 years later she first noted exertional dyspnea. This progressed in severity and for three years she had noted orthopnea, paroxysmal nocturnal dyspnea, hemoptyses, easy fatigability, peripheral edema, and substernal pain relieved by nitroglycerin. During this latter period she had required constant digitals and diuretics, and at the time of admission she was confined almost completely to bed. Physical examination revealed a prominent apical systolic thrill and murmur with a soft apical diastolic murmur. X-ray and electrocardiographic examination demonstrated marked hypertrophy of the left ventricle. At operation on July 16, 1957, the left atrium was markedly distended. The pump-oxygenator and the described technic were used. Examination revealed minimal fusion at the anterolateral commissure and a powerful regurgitant jet. The most intensive fusion at the posteromedial commissure. There was little calcification of the leaflets and leaflet mobility was readily restored. The dilated annulus was plicated with three interrupted mattress sutures of 2-0 silk leaving a residual valvular orifice of 22 mm. diameter. Upon resumption of cardiac activity, there was no evidence of residual systolic thrill or regurgitant jet. Her postoperative course was complicated by recurrent episodes of digitalis intoxication. She temporarily became ambulatory and was able to perform some light household activities. On
October 10, 1957 she was re-admitted with a temperature of 102°F, cough, weakness, and malaise. All studies failed to localize the source of infection and there was no response to an intensive course of antibiotics. The patient expired suddenly on October 27, 1957. Postmortem examination of the heart revealed a large organized thrombus in the left atrium which originated from the most lateral suture in the annulus. This thrombus almost completely occluded the mitral orifice. Microscopic examination of this area revealed a fungus endocarditis probably due to Histoplasma capsulatum. There was no evidence of engorgement of the pulmonary vascular bed.

**Comment**

This patient also had a relatively “pure” mitral insufficiency but with more rigidity of leaflets than was found in Case 1. The thrombus which occluded the mitral orifice at autopsy had formed around the most lateral suture in the annulus. This particular suture had been tied rather loosely and therefore it tended to bridge the edge of the mitral orifice. This demonstrates the necessity of tying the sutures securely so as to leave as little foreign body exposed as is possible. The remainder of the sutured annulus was solidly healed and the suture line was otherwise endothelialized. This is clearly one of the hazards of the procedure and is preventable.

**Case 3.** J. S. (VUH #224197). This 47-year-old white farmer had a history of congestive heart failure and atrial fibrillation of seven years duration. There was no definite history of rheumatic fever. Despite digitalis, diet and diuretics his course had been one of progressive limitation with severe exertional dyspnea, orthopnea and hemoptysis prior to hospitalization in August 1957. His heart was greatly enlarged with a loud rumbling diastolic murmur and a loud systolic murmur at the apex. After cardiac evaluation a diagnosis of mitral stenosis and insufficiency and tricuspid insufficiency was made. At operation on September 4, 1957, the mitral valve was exposed directly using the pump-oxygenator and the technique as described above. There was heavy calcific fusion of both commissures and a fixed, rigid, contracted valve orifice with a powerful regurgitant jet about the size of the operator's index finger. Both commissures were divided to the annulus and four sutures were placed to approximate the annulus posteromedially leaving a two finger residual orifice with fairly pliable and mobile leaflets (Fig. 5). After closure of the atriotomy and restoration of cardiac rhythm the regurgitant jet was completely eliminated. The diagnosis of tricuspid regurgitation was confirmed by digital appraisal through the right atrium but no repair of this lesion was attempted. There was gradual improvement in the early postoperative period with disappearance of the signs of congestive failure and reduction in the manifestations of tricuspid insufficiency, but persistence of atrial fibrillation. He was discharged much improved three weeks after operation.

He continued to make steady progress and could walk long distances without limitation or dyspnea until 6 weeks later when he developed a severe prostrating febrile illness diagnosed as influenza but with some elements suggesting recurrent rheumatic carditis. His convalescence following this episode was slow but improvement in general health and cardiac status has occurred in the last month although he has not yet been able to return to his work as a farmer.

**Comment**

This patient had a severely deformed and calcified valve with combined mitral insufficiency and stenosis. There was also severe tricuspid regurgitation. His early general improvement with alleviation of congestive failure and increase in exercise tolerance is encouraging evidence of the improved status of the combined mitral lesions. The recent febrile illness which may have been a flare-up of rheumatic carditis has marred
the convalescence and thwarted attempts at conversion of persisting atrial fibrillation.

Case 4. N. A. K. (VUH #167755). This 19-year-old white female presented a history of recurrent acute attacks of rheumatic fever in childhood associated with rheumatic myocarditis and mitral valvulitis with resulting evidence of mitral stenosis and mitral insufficiency. In the six months prior to admission she had developed irreversible auricular fibrillation. Cardiac compensation was maintained only by the use of daily digitalis. Cardiac catheterization on July 30, 1957 revealed the pulmonary arterial pressure to be 66/35 mm. Hg. Digital exploration of the mitral valve on August 2, 1957 demonstrated fusion of the leaflets at each commissure but the orifice measured two finger-breathths in diameter and there was severe regurgitation without functional stenosis. Accordingly on September 12, 1957 re-exploration of the mitral valve was carried out under direct vision with the pump-oxygenator. Examination revealed the previously noted commissural fusion, definite curling of the anterior and posterior leaflets, and marked dilatation of the annulus. The leaflets were pliable without evidence of calcification. The anterolateral commissure was first opened to the annulus. The posteromedial portion of the dilated annulus was then approximated with five interrupted silk sutures to leave a residual mitral orifice with a diameter of 20 mm. After resumption of cardiac activity a definite but markedly diminished systolic thrill persisted posteriorly but it was felt that additional constriction of the annulus should not be performed. Postoperatively the patient did well for 24 hours, but then developed respiratory depression and became unresponsive. Despite vigorous therapy, progressive cyanosis developed and death ensued on the 4th postoperative day. Postmortem examination revealed diffuse red hepatization of all lobes of the lungs. Inspection of the mitral valve revealed that additional regurgitation was probably due to inaccurate division of the fused anterolateral commissure with inadvertent incision of the lateral segment of the distorted posterior leaflet. There was microscopic evidence of active rheumatic myocarditis.

Comment

This patient had the pathologic changes of mitral insufficiency combined with fusion of the commissures, scarring of the leaflets and retraction at the line of coaptation. There was less dilatation of the annulus than in some of the other patients. The residual regurgitation was probably secondary to the misplaced incision at the anterolateral commissure which had divided the posterior leaflet. This is a clearly preventable error.

Discussion

This preliminary experience with open surgical repair of mitral insufficiency has demonstrated to us that considerable alleviation of valvular incompetency may be obtained by the application of simple surgical techniques without reliance on elaborate prosthetic devices. It is clear that accurate appraisal and optimal correction of the complex valvular deformities which result in mitral insufficiency can best be accomplished under direct vision. It is possible by simple plication of the dilated annulus, especially in its posteromedial portion where the maximal degree of regurgitation most often occurs, to restore a remarkably normal degree of coaptation of the valvular leaflets. At the same time a solid buttress is established which adds support to the “aortic baffle” at the outflow tract of the left ventricle.

Although two of our patients have died subsequent to operation, the cardiac findings at postmortem examination have shown that preventable technical errors were responsible for these failures. The early improvement in the survivors has closely paralleled the excellent early results which have been recently reported by Merendino and Bruce and by Gott and his associates in similar small series of patients with mitral insufficiency treated by open “annuloplasty.” While the basic principles of valvular repair are identical, the technic of operation employed by both of these groups has differed from that which we have used in several respects. By approaching the left atrium through a right posterolateral thoracotomy they have been able to avoid the added trauma of sternal transection and bilateral thoracotomy. In addition direct visual repair of the valve has been
accomplished by the use of heavy (#2) mattress sutures of silk with a beating heart which they have felt permits greater accuracy in determining the extent of annular plication needed to correct regurgitation. These are technical points which appear to have considerable merit and may ultimately prove to be more advantageous than the approach which we have employed.

We have felt that the more complete appraisal of the heart and great vessels permitted by bilateral thoracotomy outweighs the disadvantages of this incision. An obvious advantage is the availability of the left atrial appendage which facilitates digital examination of the mitral valve before and after repair. Certainly an excellent view of the valve is afforded through a long left sided atriotomy with the heart in arrest and a perfectly dry field. Other possible advantages includes the ease of digital assessment of the aortic valve while the atrium is open and the protection of the aortic valve by the operator's index finger during placement of the most medial suture in the mitral annulus. With the heart in arrest the annular sutures may be placed with great accuracy and there is less danger of coronary and cerebral air embolism. An obvious disadvantage of this method is the lack of functional appraisal of the repair during the period of arrest. It is apparent that further experience is required to assess fully the relative merits of these technical considerations.

Two points in the application of extracorporeal circulation to the surgery of the left heart deserve further emphasis. As long as no septal defects are present, the use of a single cannula of large caliber inserted into the right atrial appendage appears to have certain advantages over the employment of two vena caval cannulae for the drainage of venous blood to the pump-oxygenator. These include ease of insertion; avoidance of the hypotension which may accompany the use of occlusive cannulae in the cavae prior to and after cardiopulmonary bypass; prevention of distention of the right heart by coronary venous return; and greater ease of grading the work load of the heart after terminating a period of induced arrest. The second point concerns the appreciation of the large volume of blood which may be contained in the left side of the heart and the pulmonary circuit in patients with mitral valvular disease. Since only the systemic vascular bed is actually perfused during cardiopulmonary bypass, the large volume of blood which must be aspirated from the left atrium prior to exposure of the mitral valve should not be immediately returned to the patient's systemic arterial bed but instead it is held in a reservoir for subsequent re-infusion upon completion of bypass. This volume of blood has measured as much as 1,500 cc. in some patients.

At the present time there is inadequate experience to permit conclusions as to precise indications and contraindications for direct surgical methods in correction of mitral insufficiency. There are many major and minor technical problems in application of these methods which must be solved. The basic principles, however, seem sound enough and the preliminary results of their application in an heretofore intractable disease certainly indicate that further clinical trial is in order. If encouraging results persist after additional experience and long range observation of patients, it seems highly likely that a direct surgical technic of repair with a pump-oxygenator will be the method of choice for the optimal management of mitral valvular disease.

Summary

This report describes a method of repair of the incompetent mitral valve by open left atriotomy and suture of the dilated annulus fibrosus under direct vision with the aid of extracorporeal circulation and induced cardiac arrest.
Preliminary experience with the method in four patients is described.

References

Discussion

Dr. Frank Glenn: These two papers are very timely. One summarized briefly the results of mitral commissurotomy by the indirect method. As has been mentioned, several thousand patients have been operated upon and the results in general are parallel with those reported. We have been at some pains to evaluate our first 300 patients, of which we have been able to follow some 255. I shall not go into the figures but they are very close to these.

I would like to mention briefly where we consider the great difficulty rests at the present time. It is in the Group 4 patients. Where, as has been pointed out, there is not only calcification and deterioration of the myocardium but there is also this very important problem of insufficiency and whether or not you can evaluate this beforehand sufficiently to proceed properly. I say proceed properly because in these individuals who are very ill, as has been mentioned before this morning, if you do not help them they may not sustain the burden of operation. The procedure that has been outlined here by Dr. Scott is a distinct step forward and I think tends to establish the feasibility of sewing the defective valve together. Some work that has been done both experimentally and clinically has not been successful; we hope it will be in the future.

My congratulations to the essayists on these articles.

Dr. J. Warner Duckett: It is very interesting to note how uniform the reports have been in mitral commissurotomy for mitral stenosis, in cases of pure stenosis or those in which the insufficiency is relatively light. The results as far as re habilitation is concerned are strikingly parallel; as far as mortality is concerned they also have been relatively well standardized now and are exceptionally low. Most of the series reported have been from large university hospitals where operations are performed, to some extent at least, by residents, and I think it might be of interest to report a series of 120 private cases with a hospital mortality of less than 1%. These patients were operated on under relatively ideal conditions with a standardized safeguarding procedure including careful preoperative preparation and evaluation by competent cardiologists; operation by an experienced senior