

The Repair of Mitral Insufficiency Associated with Ruptured Chordae Tendineae *

JEROME HAROLD KAY, M.D., WILLIAM S. EGERTON, M.B., B.S., F.R.A.C.S.

From the Department of Surgery of The University of Southern California School of Medicine, The Saint Vincent's Hospital and The Los Angeles County General Hospital

THE EXPERIENCE of a number of surgeons in application of open-heart technics to the correction of mitral incompetence has provided accumulative compilation of knowledge regarding the functional pathology of the insufficient valve. The pathologic states commonly encountered have been described by Lillehei, Gott, DeWall and Varco,⁶ Effler, Groves, Martinez and Kolff,¹ Merendino, Thomas, Joseph, Heron, Winterscheid, and Vetto,⁸ Kay, Nogueira, Head, Coenen and Zimmerman,² and Nichols, Blanco, Uricchio and Likoff.³ More recently, McGoon⁷ has drawn attention to a technic for the correction of insufficiency due to ruptured chordae tendineae. Osmundsen, Callahan and Edwards¹⁰ reported the clinical features and pathologic anatomy of 20 cases in which dissolution of continuity of chordae tendineae was observed at autopsy.

Kay, Egerton, and Zubiate⁴ have recently reported their experience with correction of mitral insufficiency by open heart surgery in a series of 34 cases. The latter group has encountered nine cases in which chordae tendineae had ruptured prior to surgery and had contributed significantly to the incompetence of the mitral valve. There was one further patient previously reported by Kay, *et al.*⁵ in which the resection of a left ventricular myxoma re-

quired removal of the attachment of chordae, causing acute mitral incompetence. This lesion was corrected before conclusion of the operation by suturing the involved leaflet to the papillary muscle nearest the resected chordae. Since nine of these patients out of ten survived and were improved by operation, it is considered that the treatment of this type of valvular insufficiency is attended with encouraging results.

The history, clinical features, pathologic anatomy and method of repair have been reviewed in each patient and preoperative and postoperative examinations have been carried out in an attempt to appraise the functional result of open heart surgery for this condition. Six cases were subjected to cardiac catheterization to obtain incontrovertible objective evidence of mitral insufficiency. All patients had a history of progressive clinical deterioration despite prolonged medical treatment.

At the time of operation the average age was 46 years. Cardiac murmurs had been detected on physical examination in all patients long before symptoms of cardiac decompensation appeared. The average duration of this physical sign was 20 years. Significant deterioration had occurred in all patients within the 18 months prior to operation and cardiac failure was controlled only by digitalis, diuretics and salt restriction. Two patients had observed progressive deterioration following undiagnosed febrile illnesses. Two patients had under-

* Submitted for publication April 10, 1962.

Aided by Grant H-5885(C1) from The United States Public Health Service.

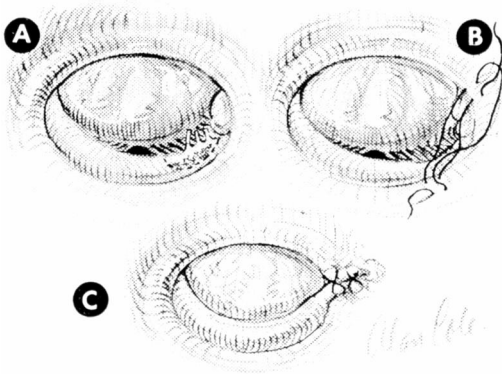


FIG. 1 (Case 1). a. Rigid area of mural leaflet excised. b. Closure of annulus at posteromedial commissure. Function of aortic leaflet of mitral valve unimpaired. c. Sutures tied, involved portion of mural leaflet excluded and annulus narrowed.

gone previous closed commissurotomy at other centers. One had shown an initial improvement, the other had marked left ventricular failure symptoms following a second closed commissurotomy. The preoperative course of five patients was marked by recurrent episodes of congestive cardiac failure. The remainder exhibited fatigue and exertional dyspnea as their principal complaints.

On admission for operation, cardiac enlargement was evident by the lateral displacement of the apical impulse in eight of ten cases. The left ventricular thrusting character of the apex beat was affirmed in four cases and an apical systolic thrill was present in an equal number. An apical systolic murmur was conspicuous in each patient except for Case 10. The average intensity was Grade III on a scale of I to VI. Radiation of the murmur was widespread in all cases and significant basal and cervical radiation raised the diagnostic possibility of aortic valve involvement in two patients. At surgery, no aortic valve lesion was evident in these patients. The confusion of mitral insufficiency with aortic valve lesions has been described previously by Osmundsen, Callahan and Edwards,¹¹ and Shapiro and Weiss.¹² A mitral diastolic

murmur was recorded in six of ten cases though the dominant lesion was mitral insufficiency.

Case Reports

Case 1. This white man, age 51 years, had suffered from progressive exertional dyspnea and fatigue for seven years. For two years he had experienced attacks of nocturnal dyspnea every two to three months. Two episodes of congestive failure had required hospitalization. In the intervals between episodes of failure, he had been able to work half time as a professor of dental plastics. Radiologic examination showed that the left atrium bulged strikingly towards the right and posteriorly. There was considerable left ventricular enlargement.

The heart was exposed by a median sternotomy incision and the left atrium was observed to be greatly enlarged. The mitral orifice was at least 6.0 cm. in diameter. At the posteromedial third of the mural leaflet, the chordae tendineae had become detached. This segment of the valve was rolled, hard and calcified and projected into the cavity of the left atrium beyond the plane of the rest of the mural leaflet. The absence of support with resultant rigidity of this prolapsed segment was the primary cause for insufficiency of the mitral valve. There was secondary dilatation of the mitral annulus also contributing to the insufficiency. The 1.5 cm. in length sclerotic segment was excised and the posterior commissure was obliterated by suturing the annulus at the apex of the aortic leaflet at the posteromedial commissure to the annulus at the line of resection of the mural cusp. The residual opening of the mitral valve was 3.0 cm. in diameter. This completely corrected the insufficiency (Fig. 1).

A postoperative review 2½ years after surgery showed that the Grade IV systolic murmur which had been present on preoperative examination was completely absent. This man had returned to full physical activity and was unhampered by fatigue or dyspnea (Fig. 2).

Case 2. This 38-year-old woman had been disabled by fatigue and dyspnea on exertion for one year following a febrile episode possibly due to endocarditis. However, there had been a past history of rheumatic fever at the age of 12 and 18 years. The left atrium was greatly enlarged on x-ray examination. There was questionable enlargement of the left ventricle. Transbronchial left atrial puncture revealed a left atrial pressure of 31/5 mm. Hg. There was a well marked late

positive V-wave. The mean diastolic gradient between left atrium and left ventricle was 10 mm. Hg.

At operation marked dilatation of both the left atrial and left ventricular chambers was evident. The regurgitant stream from the left ventricle emerged through an opening in the posteromedial one-third of the valve orifice where apposition of the leaflets was impossible because of projection of the medial one-third of the mural leaflet. The chordae tendineae to this region of the valve had ruptured from the posteromedial papillary muscle. This patient was operated upon before we conceived the idea to reattach the involved portion of the valve to the nearer papillary muscle. An attempt was made to control the insufficiency by a posteromedial annular plication with No. 2 silk sutures. The residual orifice admitted two fingers.

At follow up examination two years after operation, comparison of chest radiographs with those taken preoperative illustrated a small decrease in size of the cardiac silhouette. There had been little significant diminution of the intensity of the Grade III, harsh, widely radiated systolic murmur which was present before surgery. Functional improvement was, however, sufficient to allow her normal activity working eight hours a day.

Case 3. (Previously reported.⁴) This 49-year-old woman had been symptomatic for six years and was confined to bed for one year prior to operation. Slight enlargement of both right and left ventricles was seen on x-ray. Moderate enlargement of the left atrial chamber was present. Examination of the mitral valve revealed combined stenosis and insufficiency. The former was caused principally by fusion of the two leaflets at the anterolateral commissure, the latter by a combination of contraction and thickening of the posterior third of the mural leaflet and by the rupture of two chordae tendinae of this part of the valve. The aortic leaflet was sutured to the mural leaflet at the site of the ruptured chordae tendineae and the mural annulus was shortened by heavy silk sutures. The increased opening obtained by anterolateral commissurotomy prevented residual stenosis.

At the end of 20 months, a Grade I apical systolic murmur was audible and radiographic examination revealed no change in over-all cardiac size. However, this housewife was now able to perform all her household duties without fatigue. Prior to operation, she had been confined to bed.

Case 4. (Previously reported.⁴) Although this 50-year-old man was able to work for eight hours a day prior to operation, he had suffered four episodes of congestive cardiac failure in the pre-

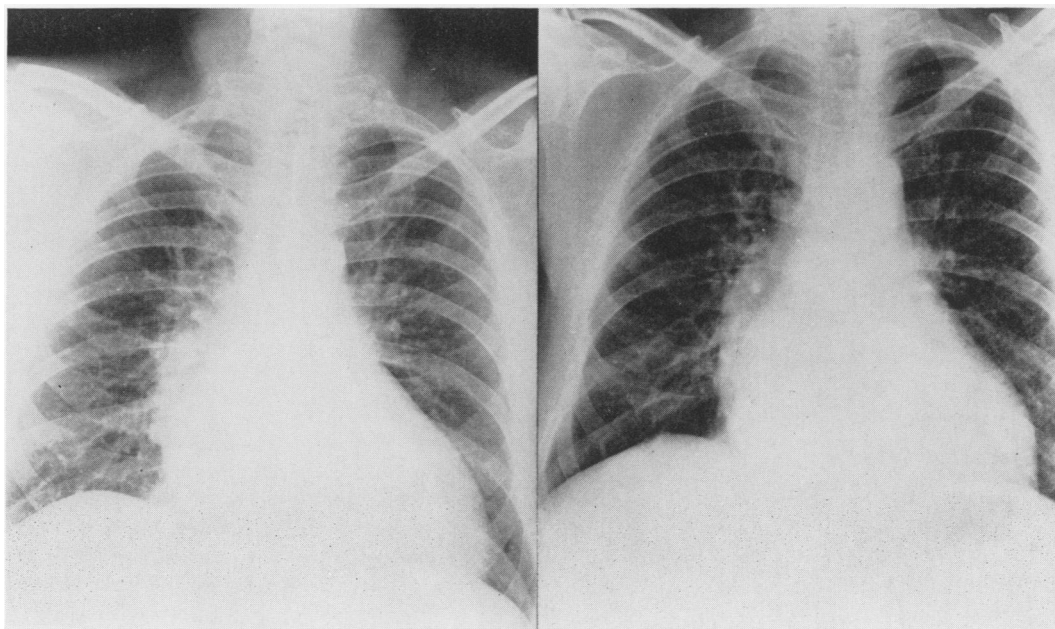


FIG. 2 (Case 1). Preoperative film and postoperative film 2½ years later. Despite little change in heart size, patient is asymptomatic and without heart murmurs.

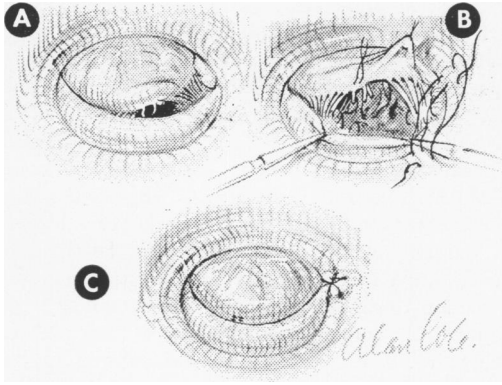


FIG. 3 (Case 4). Area of aortic leaflet of mitral valve with ruptured chordae tendineae sewed to nearer papillary muscle with figure-of-eight sutures of 3-0 silk. Annulus narrowed with No. 2 silk at posteromedial commissure to correct secondary annular dilatation. (Reprinted from *Surgery* 50:67, 1961.)

vious four years. Radiologic examination of the chest revealed moderate enlargement of the left atrium and gross enlargement of the left ventricle. Pulmonary artery pressure measured at right heart catheterization was 35/20 and selective left ventriculography demonstrated continued re-opacification of the left atrium.

At the time of operation all chambers of the heart were considerably enlarged. A Grade IV

systolic thrill was palpable over the left atrium and the atrial wall was tense. On opening the atrium the mitral annulus was so dilated that five fingers could be passed through the mitral valve. A group of chordae controlling the medial portion of the aortic leaflet had disrupted from the medial papillary muscle. Four interrupted 3-0 and 4-0 sutures were used to reattach the involved portion of the aortic leaflet to the papillary muscle. The correction of this incompetent valve was completed by posteromedial annuloplasty (Fig. 3).

Sixteen months following operation no murmur was audible on clinical examination. The patient was working full time and had been relieved of exertional dyspnea. There had been no recurrence of the episodes of congestive cardiac failure which had periodically incapacitated him prior to operation (Fig. 4).

Case 5. This 46-year-old patient had considerable subjective improvement following a closed commissurotomy in 1955. Six months prior to open heart surgery, fatigue, palpitation and dyspnea had forced her to resume a life of considerable restriction. Moderate enlargement of the left atrium, right ventricle and left ventricle was evident on x-ray examination of the chest. Mean pulmonary arterial pressure at rest was 36 mm. Hg; on exercise mean pressure rose to 60 mm Hg and the systolic-diastolic to 104/38.

On exposure of the left atrial cavity, the mitral

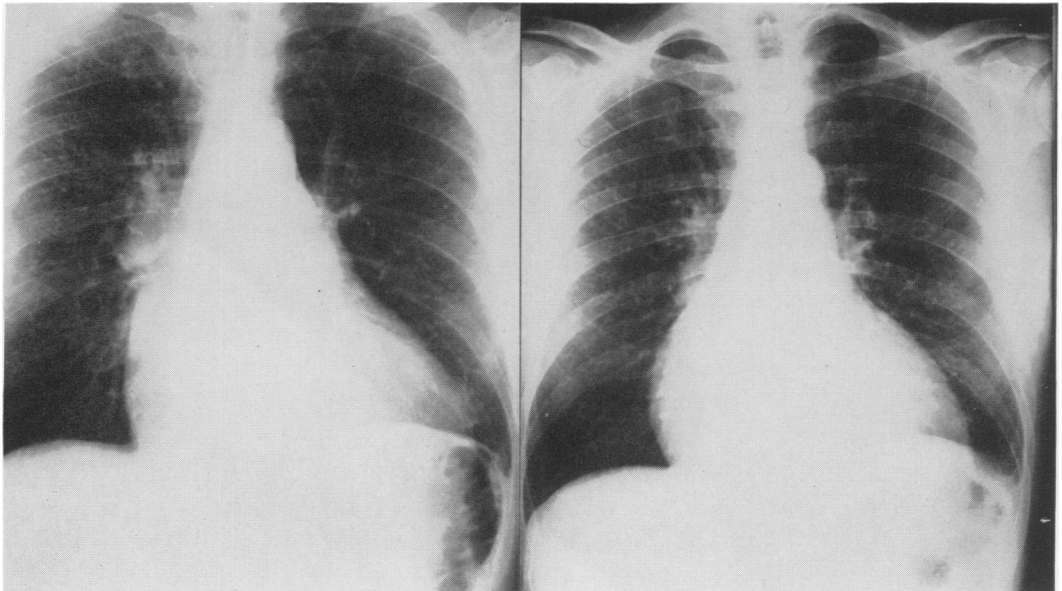


FIG. 4 (Case 4). Preoperative x-ray and x-ray 20 months following surgery. This patient is asymptomatic and has no murmur.

valve readily admitted three and one-half fingers. There was a small posteriorly directed tear in the mural leaflet adjacent to the anterolateral commissure. This was repaired with interrupted sutures. The central part of the aortic leaflet everted freely into the left atrium as a consequence of rupture of the chordae which normally prevent eversion of the valve at this region. Partial competence of the valve was obtained by anchoring the chordae to the anterolateral papillary muscle with interrupted silk sutures which transfixed the detached chordae. The annulus was narrowed by suturing the area of the posteromedial commissure thereby further correcting the insufficiency (Fig. 5).

Sixteen months following operation, the systolic murmur of mitral insufficiency had been decreased from Grade III to Grade I intensity and the cardiac silhouette on x-ray had shown a decrease of 17 mm. in the transverse diameter. There had been a corresponding improvement in physical activity to normal (Fig. 6).

Case 6. This 48-year-old white man had a known heart murmur for 21 years. In the 18 months prior to operation, he had multiple episodes of congestive cardiac failure. In the interludes between failure he could be controlled only by a rigid medical program of rest, digitalis and diuretics. On examination there was a Grade VI apical systolic murmur and also a Grade IV basal

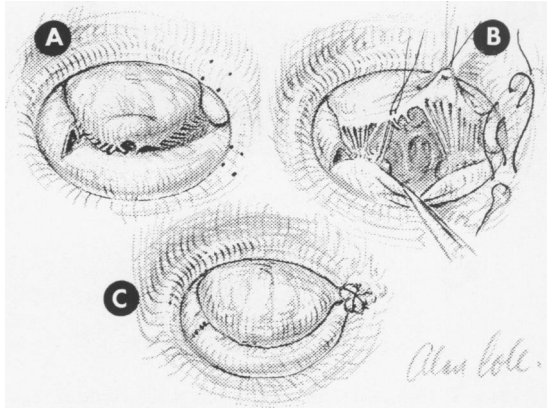


FIG. 5 (Case 5). a. Previous commissurotomy performed. At open heart surgery cut of mural leaflet noted at anterolateral commissure. Chordae tendinae at central portion of aortic leaflet found to be detached. b. Involved area of aortic leaflet sutured to nearer papillary muscle. Tear in mural leaflet to be repaired and then annulus narrowed at posteromedial commissure. c. Repair completed and valve competent. (Reprinted from *Surgery* 50:67, 1961.)

systolic murmur heard loudest at the right second intercostal space. Left heart catheterization failed to reveal any evidence of aortic valve disease. Pulmonary artery pressure at rest was 85/25 and left atrial pressure was determined to be 20/4.

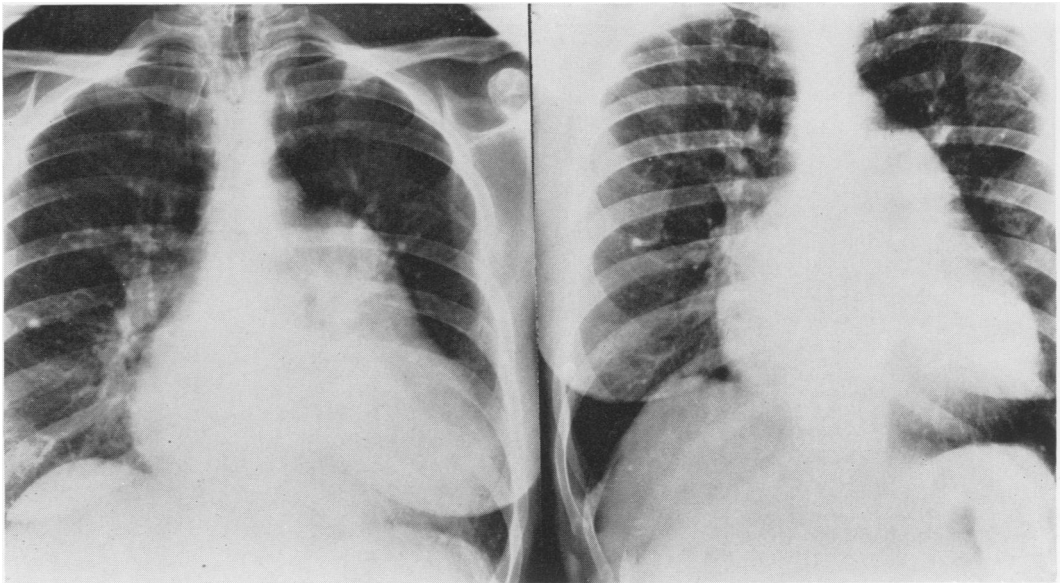


FIG. 6 (Case 5). Preoperative chest film and x-ray 16 months after surgery showing decrease in heart size. Grade I systolic murmur present following surgery.

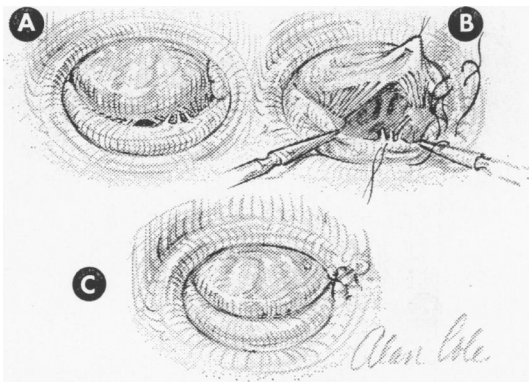


FIG. 7 (Case 6). a. Torn chordae tendinae present at posteromedial aspect of mural annulus. b. Involved area of mural annulus sutured to nearer papillary muscle and sutures placed at posteromedial commissure to narrow annulus. c. Valve repaired.

Left ventriculography confirmed reflux of blood from the left ventricle into the left atrium during systole. At the time of operation the aortic systolic murmur was determined to be due to referral from the left atrium. The left atrium was so large that its uppermost portion pressed against the posterior portion of the root of the aorta. The atrial systolic murmur was referred to the base of the aorta. After repairing the mitral insufficiency the aortic thrill and murmur completely disappeared. This referred murmur to the aortic

area has been found in other patients with mitral insufficiency.

The pathologic changes and technic of repair can be seen in Figure 7. His follow up period has been short—only nine months. However, in this time the cardiac size has decreased and there has been a complete disappearance of murmurs and relief of symptoms (Fig. 8).

Case 7. This woman, age 36 years, had mitral heart disease diagnosed eight years prior to admission for open heart surgery. She had been subjected to two previous commissurotomies by a closed technic and had deteriorated rapidly following the second commissurotomy. Symptoms of left ventricular failure and marked mitral insufficiency had appeared at that time. The systolic regurgitant murmur was widely distributed over the whole of the left chest and radiated towards the base of the heart and to the lower cervical region. Moderate enlargement of the left atrium and the left and right ventricle was seen on the cardiac x-ray studies.

The x-ray findings were confirmed at operation. On examination of the mitral leaflets, gross regurgitation was apparent and was due to three separate lesions. There were two tears, one in the posterior leaflet adjacent to the anterolateral commissure, the other in the aortic leaflet about 1.5 cm. from the posteromedial commissure and this extended from the margin of the aortic leaflet to the annulus. In addition, the chordae which nor-

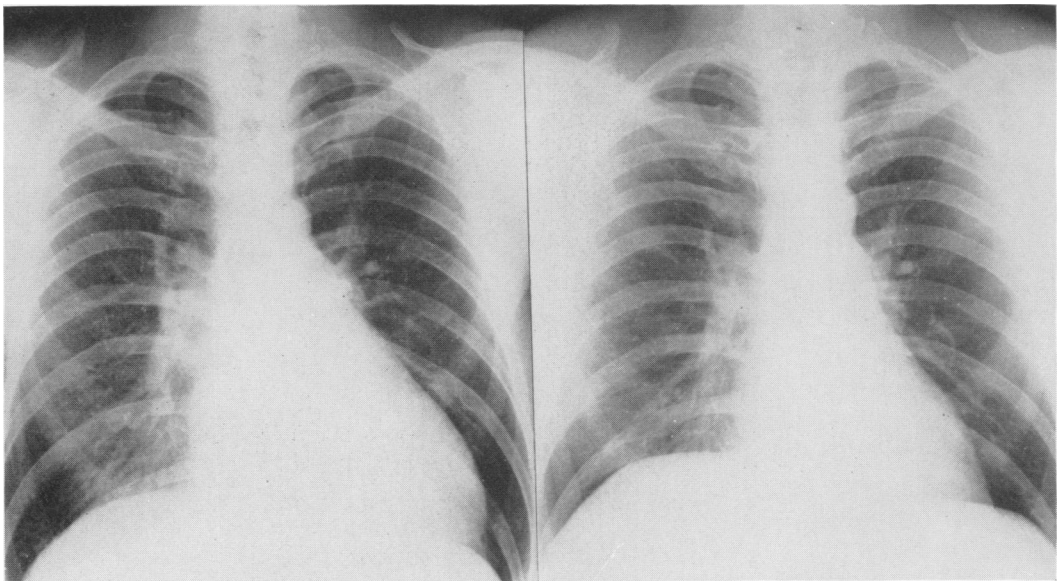


FIG. 8 (Case 6). Chest film one year after surgery reveals striking decrease in heart size.

mally supported the larger segment of the aortic leaflet had been separated from the posterior papillary muscle. There was also stenosis of the anterolateral commissure. An anterolateral commissurotomy was performed. The aortic leaflet where the chordae had been torn was firmly anchored to the posterior papillary muscle and both tears were repaired by interrupted silk sutures. Following this repair, there was still a small jet of insufficiency at the posterior one-third of the mitral opening where imperfect closure of the aortic and mural leaflets occurred. Following a posteromedial annuloplasty, the insufficiency was judged to have been reduced by at least 90 per cent (Fig. 9).

The postoperative course followed to seven months had been uneventful and a considerable decrease in the intensity and the area of radiation of the systolic murmur had been observed.

Case 8. This 50-year-old white woman had suffered intermittent bouts of congestive cardiac failure for 29 years. There had been a progressive and marked deterioration in her exercise tolerance in the past two years prior to operation. Pulmonary artery pressure at right heart catheterization was recorded as 40-50/18. Reflected V-waves were observed in the wedge pressure tracing, the peak pressure being 32 mm. Hg.

At operation, the left atrium was tense and a pronounced systolic thrill was palpable at the cephalic border of that chamber. Palpation of the atrial septum from the right side confirmed the presence of a systolic jet impinging on the atrial

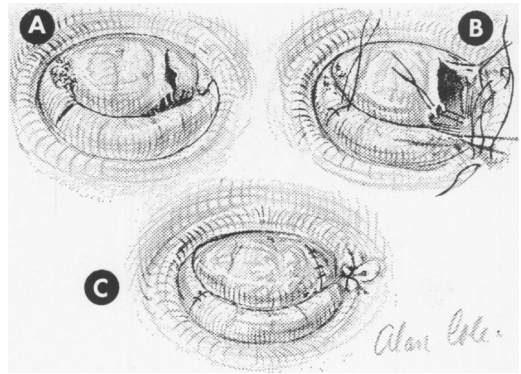


FIG. 9 (Case 7). a. Stenosis of anterolateral commissure. Tears of aortic leaflet and mural leaflet of mitral valve. Torn chordae tendineae of aortic leaflet. b. Anterolateral commissurotomy performed. Area of rupture of chordae tendineae sutured to papillary muscle. Tears in leaflets repaired. Annulus at posteromedial commissure repaired. c. Completed repair.

septum. The mitral orifice admitted two and one-half fingers. Gross mitral insufficiency was due to prolapse of the unsupported medial two-fifths of the mural leaflet where at least three chordae were discontinuous with their origin. Because of the apparent loss of substance of these chordae, three separate 2-0 silk sutures were each tied around the midportion of three separate groups of chordae and these sutures were passed through the involved portion of the valve and the sutures were tied. The valve then appeared competent (Fig. 10).

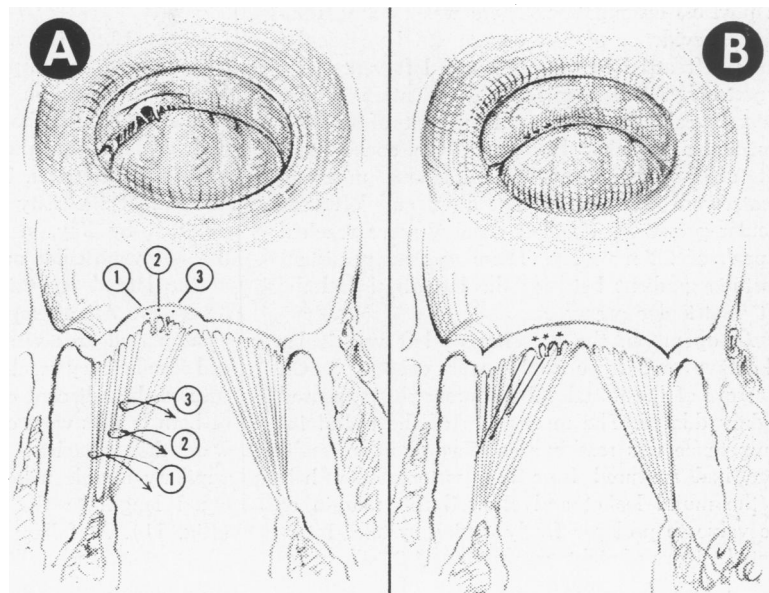


FIG. 10 (Case 8). Area of involved portion of mural leaflet sutured to nearby chordae tendineae with correction of mitral insufficiency.

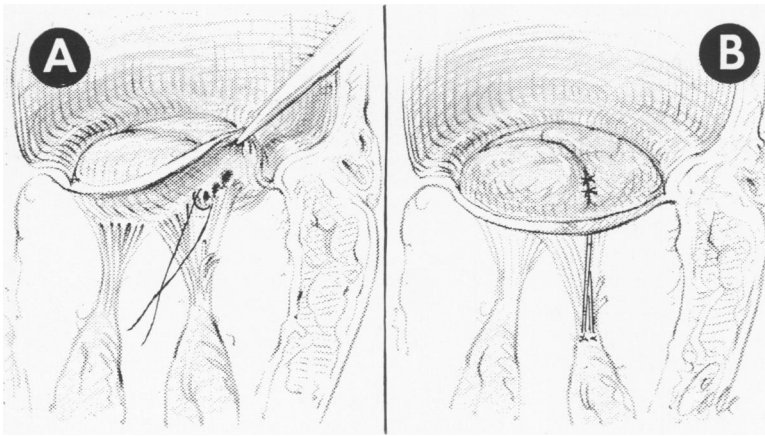


FIG. 11. Technic of suturing involved aortic leaflet to uninvolved mural leaflet and suturing this combined area to the papillary muscle.

Nine months later there was marked symptomatic improvement and the systolic murmur had disappeared.

Case 9. This 41-year-old white woman recalled a past history of childhood rheumatic fever and subacute bacterial endocarditis. Six months prior to admission to the hospital she suffered the sudden onset of left ventricular failure requiring bed rest and oxygen therapy. Since then she had suffered from paroxysmal nocturnal dyspnea despite digitalis therapy and restriction of activity. She complained of a continual sense of fatigue and walking up one flight of stairs was the limit of her physical activity. A marked degree of pectus excavatum complicated the clinical picture. A Grade IV mitral systolic murmur was present on physical examination. There was electrocardiographic evidence of first degree atrial ventricular block, left atrial hypertrophy and left ventricular hypertrophy. Roentgenologic examination of the chest revealed moderate enlargement of the left ventricular chamber but very little concomitant left atrial enlargement. Simultaneous measurements were made of the left atrial and left ventricular pressures. The left atrial V-wave reached a peak of 22 mm. Hg. There was no persistent diastolic gradient between the left atrial and the left ventricular pressures.

At operation, the presence of left ventricular dilatation and hypertrophy was confirmed. On exposure of the mitral valve the annulus appeared slightly dilated. The mechanism of the mitral incompetence was readily seen. Two chordae tendineae had ruptured from the posteromedial half of the mural leaflet and allowed this margin of the valve to prolapse freely during systole. Interrupted figure-of-eight sutures of 4-0 silk were placed passing through the edge of the mural

leaflet at the site of the torn chordae and through the apex of the papillary muscle nearer to the divided chordae. After these sutures were tied the insufficiency appeared well controlled. A posteromedial annuloplasty was then used to provide additional support for the medial portion of the mural leaflet.

The period of cardiopulmonary bypass was well tolerated and the heart beat strongly maintaining a good pressure during closure of the chest.

The postoperative course was complicated by a hemorrhagic diathesis and extensive mesenteric infarction which occurred on the second postoperative day. Autopsy revealed that the mitral valve had remained sufficient. There was extensive obliterative arteriosclerosis in the mesenteric arteries.

Case 10. This young woman presented at the Saint Vincent's Hospital with a long history of arterial embolization. Previous histologic examination of arterial emboli and left atrial exploration had confirmed a preoperative diagnosis of left ventricular myxoma. The complete and successful removal of the sixty gram tumor was previously reported by Kay, *et al.*³ During the removal of the left ventricular mass, excision of the chordae of the lateral one-third of the aortic leaflet was necessary. An attempt at direct plication of the unsupported area was unsuccessful and gross mitral insufficiency resulted. By means of interrupted sutures the adjacent edges of the lateral one-third of both leaflets were coapted. The conjoined edges were then attached to the base of the severed papillary muscle using interrupted silk sutures of equal length to the adjacent chordae tendineae (Fig. 11). At follow up examination, three years after operation, no murmur is audible and no recurrence of the tumor is evident.

Discussion

In considering the preoperative diagnosis of ruptured chordae tendineae, one should give account to the fact that acceleration of the progressive down-hill course of the disease of these patients had occurred within a year prior to operation. In Cases 7 and 9 one is believed to be justified in dating the time of rupture of chordae. In Case 7 the postoperative course of the second commissurotomy was characterized by symptoms and signs of left ventricular failure which had not previously been present. In Case 9 a slowly down-hill course was punctuated by the sudden onset of pulmonary edema. One is tempted to ascribe the exacerbation of symptoms and the increased difficulty of control of congestive failure to the additional burden imposed by increased incompetence caused by rupture of chordae. Nevertheless, this clinical course is not distinguishable from that of severe mitral insufficiency due to other causes. Increase in heart size continued as progressive decompensation occurred. One cannot confirm, in this series, the hypothesis that the dissolution of the chordae is commonly due to bacterial endocarditis. If one excludes the iatrogenic cases, then no definite exciting cause of rupture has been discovered in the remainder.

Following rupture of the chordae tendineae there would appear to be secondary dilatation of the annulus with further accentuation of the insufficiency. The hemodynamic sequelae of insufficiency due to ruptured chordae do not differ from those described for incompetence with other types of pathology. The loud systolic murmur in Case 7 was audible to the patient and was described by her as reminiscent of the cooing of doves. A musical high pitched pansystolic murmur widely radiating from the apex should alert the examiner to the possibility of ruptured chordae as the anatomic basis for mitral insufficiency. Pulmo-

nary hypertension may result as in Case 6 as it may with other types of mitral insufficiency. Immediate postoperative tracheostomy, heavy sedation with morphine, barbiturates, continuous positive pressure breathing, rigid fluid restriction and digitalization were regarded as life saving measures in the presence of severe pulmonary hypertension. Though immediate symptomatic improvement occurred in most patients, all patients described progressive increase in well-being for the six months following operation.

In *no* instance, has there been any sign of late deterioration.

The technic of repair has depended on the individual circumstances. Synthetic reinforcing material has not been utilized because direct suture technics have appeared adequate. It was necessary to clamp the aorta for three to five minutes at a time in order to have a relatively quiet heart to suture the involved portion of the mitral valve to the nearer papillary muscle or to the neighboring chordae tendineae. The use of everting stay sutures on the mitral valve was also found to be helpful in obtaining adequate exposure for this part of the procedure. The problem of arterial air embolism has been avoided by left ventricular venting in all cases as described by Kay, Magidson, and Meihaus.⁵ After closing the left atrial incision the heart was allowed to fill with blood and the air permitted to escape from the left ventricle by elevating the heart. The left ventricular vent was then removed and the small hole in the left ventricle was closed with interrupted sutures of No. 2 silk placed in a figure-of-eight fashion.

One cannot provide unequivocal evidence of complete relief of insufficiency in all patients. However, in most cases freedom from symptoms, marked diminution in the intensity of radiation of murmurs and decrease in heart size all suggest considerable relief of the mitral insufficiency present at the time of operation.

Summary

The mode of presentation, clinical history and relevant ancillary investigation of ten cases of mitral insufficiency have been presented. The technic of surgical repair is described in detail. One patient died following repair of the incompetent mitral valve. The remaining patients are free of symptoms with either marked diminution of the intensity of the murmurs or complete absence of the murmurs. The mode of treatment was considered to be a good one and there was no indication for prosthetic valve replacement in this series of patients.

Bibliography

1. Effler, D. B., L. B. Groves, W. V. Martinez and W. J. Kolff: Open Heart Surgery for Mitral Insufficiency. *J. Thorac. Surg.*, **36**: 665, 1958.
2. Kay, E. B., C. Noguera, L. R. Head, J. P. Coenen and H. A. Zimmerman: Surgical Treatment of Mitral Insufficiency. *J. Thorac. Surg.* **36**: 677, 1958.
3. Kay, J. H., R. Anderson, J. Meihaus, R. Lewis, O. Magidson, S. Bernstein and G. Griffith: Surgical Removal of an Intracavitary Left Ventricular Myxoma. *Circulation*, **20**:881, 1959.
4. Kay, J. H., W. S. Egerton and P. Zubiato: The Surgical Treatment of Mitral Insufficiency with Use of the Heart-Lung Machine. *Surgery*, **50**:67, 1961.
5. Kay, J. H., O. Magidson and J. E. Meihaus: The Surgical Treatment of Mitral Insufficiency and Combined Mitral Stenosis and Insufficiency Using the Heart-Lung Machine. *Amer. J. Cardiol.* **IX**:300, 1962.
6. Lillehei, C. W., V. L. Gott, R. A. DeWall and R. L. Varco: The Surgical Treatment of Stenotic or Regurgitant Lesions of the Mitral and Aortic Valves by Direct Vision Utilizing a Pump Oxygenator. *J. of Thoracic Surgery*, **35**:154, 1958.
7. McGoon, D. C.: Repair of Mitral Insufficiency Due to Ruptured Chordae Tendineae. *J. Thorac. Surg.*, **39**:357, 1960.
8. Merendino, K. A., G. I. Thomas, J. E. Joseph, P. W. Herron, L. Winterscheid and R. R. Vetto: Open Correction of Rheumatic Mitral Regurgitation and/or Stenosis. *Ann. Surg.*, **150**:5, 1959.
9. Nichols, H. T., G. Blanco, J. F. Uricchio and W. Likoff: Open Heart Surgery for Mitral Regurgitation and Stenosis. *Arch. Surg.* **82**: 128, 1961.
10. Osmundsen, P. J., J. A. Callahan and J. E. Edwards: Ruptured Mitral Chordae Tendineae. *Circulation*, **XXIII**:42, 1961.
11. Osmundsen, P. J., J. A. Callahan and J. E. Edwards: Mitral Insufficiency from Ruptured Chordae Tendineae Simulating Aortic Stenosis. *Proceedings of the Staff Meetings of the Mayo Clinic*, **33**:235, 1958.
12. Shapiro, H. A. and D. R. Weiss: Mitral Insufficiency Due to Ruptured Chordae Tendineae Simulating Aortic Stenosis. *New England J. Med.*, **261**:727, 1959.