# Cusp Replacement and Coronary Artery Perfusion in Open Operations on the Aortic Valve *

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ADEQUATE treatment of stenosis or insufficiency of the aortic valve may require replacement if the valve tissue is either fibrotic and contracted or, in more damaged valves, replaced by a calcified residuum of the original structure. In patients with aortic insufficiency fibrosis and contraction of the cusps may prevent their approximation even if the aortic ring is surgically reduced to a size commensurate with the smaller cusps, or if a portion of the aorta is removed and the valve made bicuspid.[3] Cusps may be rendered pliable and stenosis relieved in the stenotic aortic valve of the adult by removal of calcium and scar from the cusp remnant,[1, 2, 8] but in some instances this valvuloplasty results in perforation of the thinned-out cusp. For these reasons we believe the development of a prosthesis is a necessary step in the treatment of diseases of the aortic valve.

Valvuloplasty on patients with aortic stenosis has shown that in some instances, if only a single cusp can be made pliable and functional, adequate relief of the obstruction can be obtained. This indicates that complete valve replacement is not always necessary. In fact, since the aortic valve does not open entirely during normal function,[7] insertion of a single freely movable cusp may restore nearly normal valve action, even though a portion of the rigid original valve is left. For these reasons we have focused attention upon replacement of single cusps, at the same time realizing that in some instances a more extensive valve replacement may be necessary. The gratifying results obtained in treating four patients with replacement of single cusps have led us to believe that this method may be satisfactory in a high proportion of the patients accepted for surgical treatment.

Developmental work was based upon three premises. First, the material used should ideally become incorporated into body tissues. A fabric seemed ideal in this respect, particularly when compared with an impervious material. Second, the prosthesis should be placed in the region of the normal aortic valve, proximal to the coronary arteries and in a noncontractile portion of the heart. Third, duplication of the normal valve seemed the simplest approach.

Teflon (tetrafluoroethylene), as a jersey knit, has been used throughout our experience. This material is almost totally inert in the body and is extremely resistant to flex abrasion, two characteristics which enhance its value as a functioning substitute. Although a simple flat piece of material may function if properly placed in the valve, greater margin of error and wider applicability can be achieved if the concavity of a normal aortic cusp is provided, and the prosthesis can more easily be sutured to the aorta if a selvage edge is provided for sutures.

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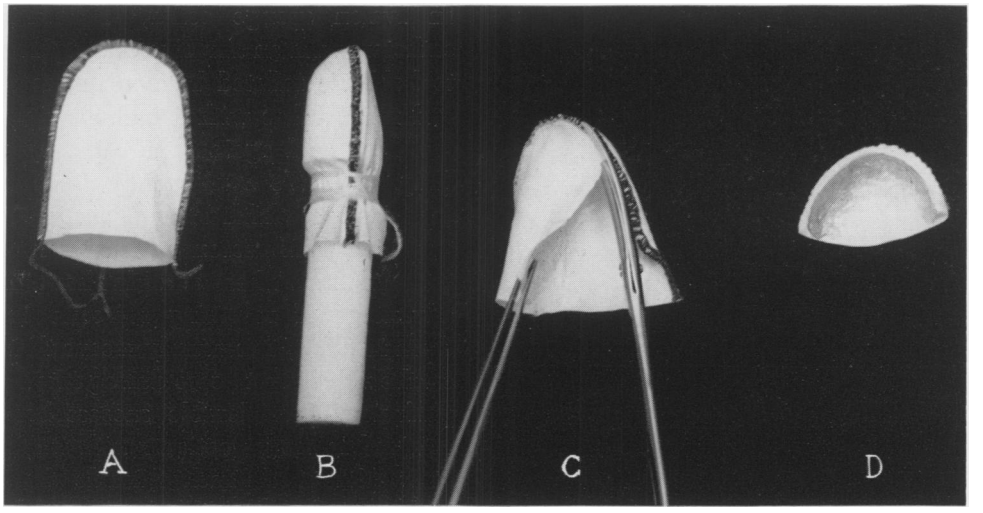


FIG. 1. Steps in fabrication of Teflon cusps. A. Two pieces of knitted fabric of appropriate size are joined by a special applied selvage. B. The fabric is tied to a Teflon mold and baked for 30 minutes at 287.7° C. C. The backing of the cusp is removed. D. The finished cusp after boiling in concentrated sulfuric and nitric acids to remove impurities.

Injection negative molds were made of the aorta and valve in a number of normal human specimens. The molds were made so that individual cusps could be separated, and from these the contour of the normal human cusp was duplicated in solid Teflon. Pieces of Teflon jersey knit are placed on the front and back of the Teflon mold and joined by a special knit of the edge (Fig. 1). The reinforced and selvaged edge serves to strengthen the form of the cusp and prevents fraying. The mold with its loose fabric cover is heated at 287.7° C. for one-half to one hour. The Teflon fibers contract and the fabric assumes the desired shape. Impurities formed by the heat are then removed by boiling the cusp and mold in concentrated sulfuric and nitric acid.***

The normal semilunar cusp is prevented from prolapsing by apposition with the other cusps and by suspension of its edge from its attachment to the aorta. If an inelastic cusp is too large, the edge may buckle with prolapse and insufficiency. Insufficiency will also occur if the cusp is too small to fill its share of the orifice. In order to establish a means of estimating the proper size cusp to use, latex molds of the normal left ventricle and aorta were made without the semilunar cusps. Teflon cusps were sutured in place and the valves tested on a pulse duplicator. Simple observation demonstrated that in the normal valve the free edge of the cusp measures twice the radius of the aorta if the cusps converge in the center of the aortic lumen. This is true whether the cusp is part of a bicuspid or tricuspid semilunar valve. Consequently cusp replacement has worked most satisfactorily in models when the length of the free edge of the cusp equalled the diameter of the aorta. Cusps of different sizes were made, the length of the free edge varying, in 2 mm. increments, from 25 to 42 mm. Further variation was made with deep (more concave) and shallow (less concave) cusps.

Evaluation of cusps and experience in the technic of placing them have been largely attained with autopsy specimens, calf hearts, and latex models on a pulse duplicator. Cusps have been placed in the aorta

*** The Teflon cusps have been made by U. S. Catheter and Instrument Corp., Glens Falls, N. Y. The important contribution of Mr. Norman Jeckel in their development is recognized and appreciated.

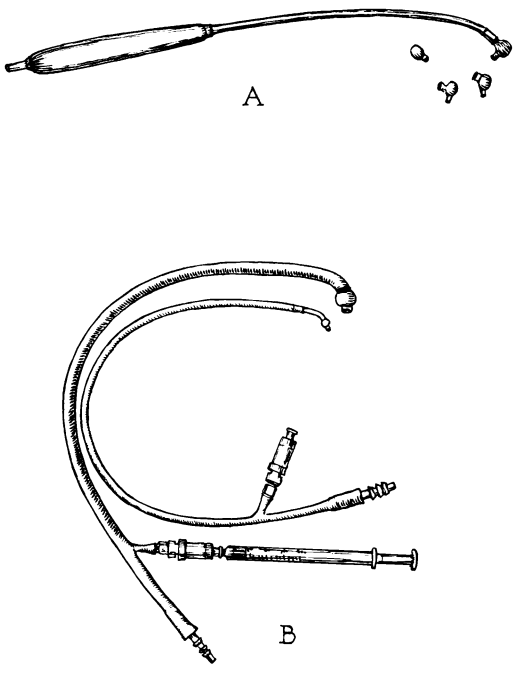


FIG. 2. A. Metal ball-tipped perfusion cannula with changeable tips for either right or left coronary artery. B. Perfusion cannulae with inflatable balloon. The smaller catheter has a thin-walled metal tip to minimize obstruction in the small diameter. Balloons can be kept filled with saline by a one-way valve.

of a number of dogs during cardiopulmonary bypass; no long-term survivors have been obtained, probably because of the small size of the aorta in laboratory animals and also because the inelastic cusps offer too much restriction to the normal canine heart.

A second important, and as yet unresolved, problem concerns maintaining or suspending nourishment of the heart for a time adequate to allow unhurried work upon the aortic valve during cardiopulmonary bypass and open aortotomy. Perfusion of the coronary arteries has seemed advisable to us in spite of the fact that aortic valvuloplasty is possible during arrest from potassium citrate, ischemia, or with hypothermia. A number of methods of perfusing the coronary arteries have been investigated. Cannulae for this included small plastic ones which were tied in place about an Ivalon sponge collar,[2] balloon-tipped catheters with an abrasive coating designed to hold the inflated balloon in the artery, and metal tubes with a bulbous tip which could be held against the coronary orifice (Fig. 2a). We continue to use the last, especially in children with aortic stenosis or patients with coronary arteries too small to cannnulate. These cannulae have the disadvantage of requiring someone to hold them in place; this usually means that work on the valve must cease during intermittent perfusion. Considerable success has been attained in recent patients with small catheters (0.1 to 0.2 inches inside diameter) with an inflatable balloon tied on the end (Fig. 2b). One cannula is placed in the left coronary artery and a purse-string suture placed in the adjacent aorta is tied around the edge of the balloon. Inflation of the balloon with saline prevents leakage of blood around it. A cannula in the right coronary artery can be secured by a tape passed around the artery from the outside. Perfusion rates, as estimated with an electromagnetic flowmeter, have varied from 100 to 500 ml. per minute. We have been impressed with the difference in cardiac contractions, the infrequency of fibrillation, and the appearance of the electrocardiogram when perfusion of the right coronary artery is added to that of the left.

## Operative Technic

A midline sternal splitting incision has been used and found satisfactory in all cases. The right coronary artery is dissected out adjacent to the aorta. The superior and inferior venae cavae are cannulated individually, and a femoral artery is used for arterial return. The diameter of the aorta is measured adjacent to the valve and prosthetic cusps selected with a free edge of the same dimension. These are preclotted in a few milliliters of the patient's blood before heparin is given. After the bypass is started, a catheter is placed into the left atrium through the appendage; blood re-

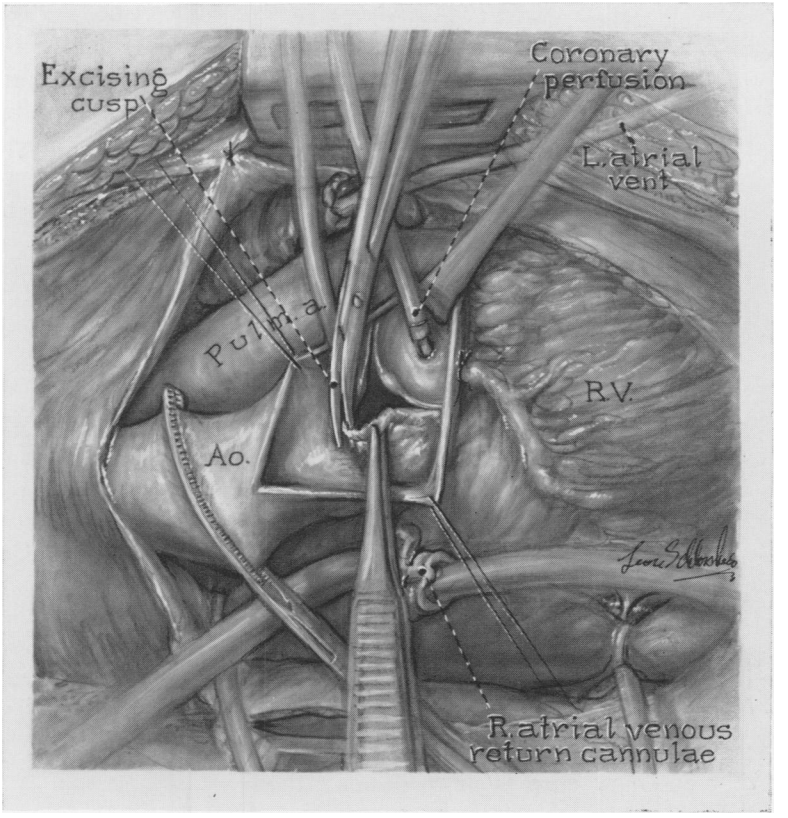


FIG. 3. Exposure of aortic valve through median sternotomy. Coronary perfusion cannulae and left atrial venting catheter are in place.

moved from the heart by siphon and gentle suction through the catheter is returned to the pump-oxygenator.

The ascending aorta is clamped proximal to the innominate artery, and an incision is made into the aorta curving slightly posteriorly toward the heart and ending just to the right of the commissure between the right and the noncoronary cusps. From inside a purse string suture is placed about the orifice of the left coronary artery, a balloon-tipped catheter is inserted and tied in place, and the balloon is filled with saline. The right coronary artery is similarly cannulated, the cannula being held by a No. 4 silk ligature around the artery adjacent to the aorta. As each artery is cannulated, perfusion through it is begun through a sidearm of the arterial line. An electromagnetic flowmeter in the perfusion line has been valuable in allowing an estimate of the rate of flow. If the arteries cannot be cannulated, as sometimes happens, ball-tipped metal cannulae are used which can be held against the orifice.

The valve is inspected to determine if valvuloplasty can be performed without prosthetic replacement. This is always attempted since most stenotic valves can be treated by simple excision of the calcified scar. If this is not feasible or if large perforations are made in attempted valvuloplasty the prosthesis is then used (Fig. 3). When the valve is predominantly insufficient, a condition usually resulting from contraction or actual destruction of the cusps by endocarditis, one is less likely to encounter a valve which can be made competent by utilization of existing tissue.

Which of the three cusps should be excised, if one has a choice, is determined principally by the degree of involvement but also by the ease of replacement. The noncoronary cusp is most accessible and

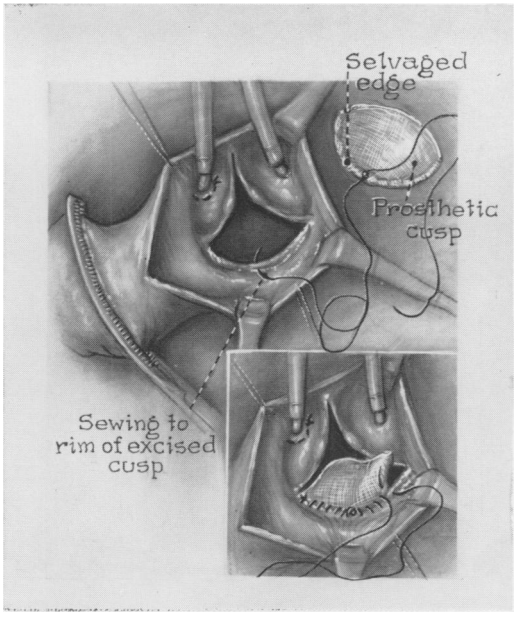


FIG. 4. Noncoronary cusp being replaced with Teflon fabric. The suture is begun at the bottom of the cusp and carried up on each side.

most easily replaced; replacement of the right coronary cusp is more difficult than replacement of the left.

When the cusp is excised, a small rim approximately one millimeter wide is left as a guide for replacement. A double-armed 3-0 silk suture is begun at the bottom of the cusp and carried up on either side (Fig. 4). Small 3/8 circle K needles (with a special cutting point) have been valuable.† Suture of the cusp is continued for 1 to 2 mm. above the attachment to the aorta of the adjacent cusp to give added support.

The left atrial catheter is clamped and the left ventricle allowed to fill with blood as the aortotomy is closed. The apex of the heart is tilted up and gas is evacuated from the left atrium and ventricle. The operative field is continuously flooded with carbon dioxide during the aortotomy to minimize the harmful effects of residual gas within the heart. Perfusion cannulae are removed after deflation of the balloons just before the closure is completed. The left ventricle must not be allowed to overdistend when the aorta is unclamped. If ventricular contractions are not immediately effective the left atrial catheter is reopened and, when necessary for decompression, passed into the ventricle until good contractions return.

This method has been developed and used during the treatment of four patients with aortic valvular disease, three of whom have been strikingly improved. The fourth died with a myocardial infarction after initial improvement.

† Supplied by J. A. Deknatel and Son, Inc., Queens Village 29, N. Y., as needle KT-11 and KT-12.

## Case Reports

**Case 1.** R. McG. (J.H.H. 859731), a 42-year-old former miner, had rheumatic fever at age 12. At 25 he had been rejected for military service because of a heart murmur. Ten years before admission he noted easy fatigability and gradually increasing dyspnea. Eighteen months before admission he had the first of many episodes of severe oppressive substernal pain radiating to the left elbow, accompanied by dyspnea, lasting from a few hours to several weeks and usually persisting for a couple of days. Nitroglycerin gave partial and temporary relief. In the last year the pain became more frequent, and he developed two pillow orthopnea, besides experiencing increasingly severe dyspnea, and several bouts of hemoptysis. Digitoxin had been taken for the last year.

On examination blood pressure was 100/70 mm. Hg. There were inconstant rales at both bases. Neither first nor second sound was heard in the aortic area, but there was a grade IV harsh pansystolic murmur transmitted to the neck associated with a thrill. There was a grade II diastolic murmur along the left sternal border. Roentgenograms showed a cardiothoracic ratio of 0.58, the predominant enlargement being of the left ventricle. A left bundle branch block was present on electrocardiogram. On needle puncture left ventricular pressure was 156/17–28 mm. Hg and femoral arterial pressure was 109/58. Cardiac index was 3.1 liters per minute per square meter; the dye dilution curve suggested moderate aortic regurgitation.

On September 15, 1959 the aorta was occluded for 39 minutes during cardiopulmonary bypass. Coronary perfusion was used; the volume of flow was not measured but was probably low because of difficulty with perfusion cannulae.

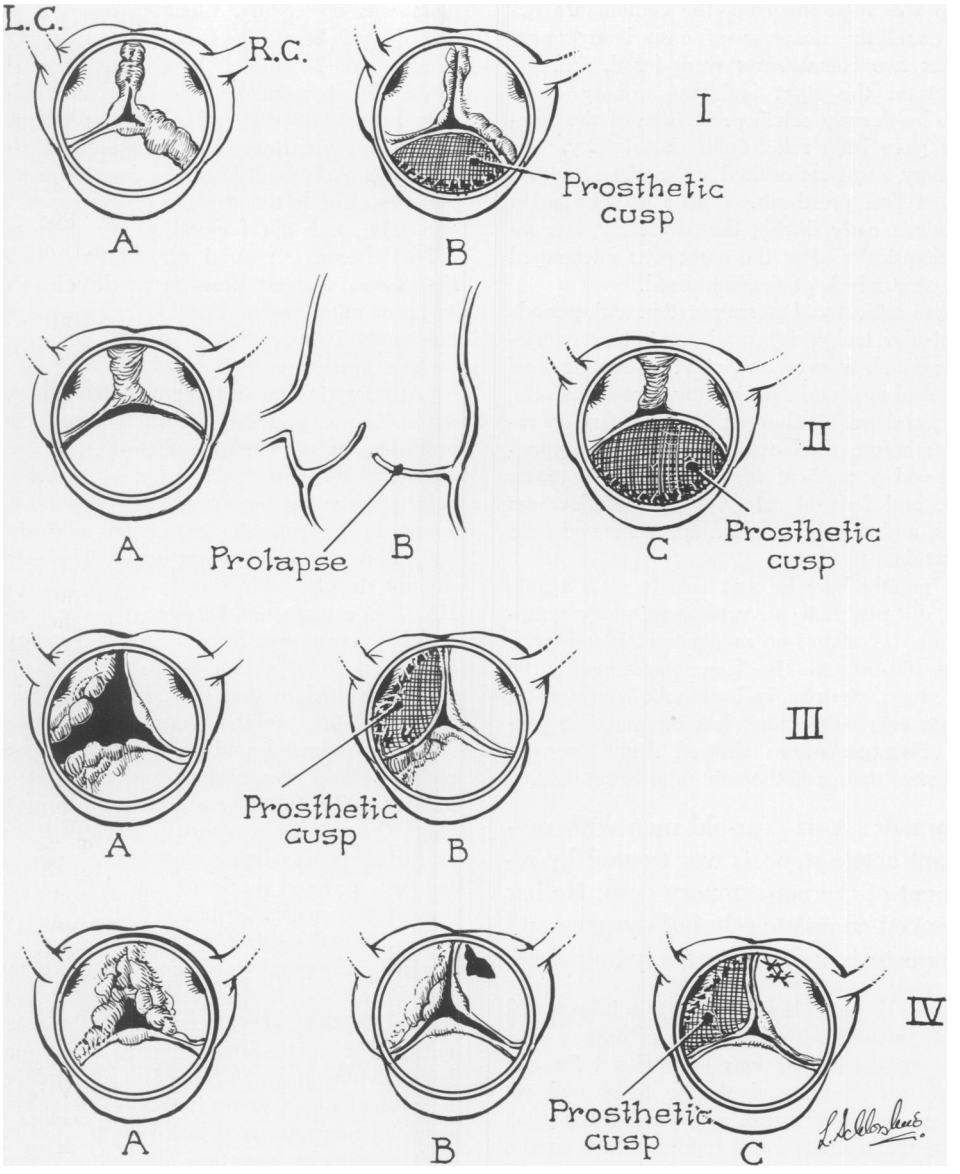


FIG. 5. Condition of the aortic valve in cases reported before and after insertion of Teflon cusp.

I. Case 1: Incision of the two fused commissures failed to relieve the stenosis; the noncoronary cusp was replaced.

II. Case 2. The noncoronary cusp was pliable but contracted so that prolapse and insufficiency occurred; this was relieved by the prosthesis.

III. Case 3: The left and noncoronary cusps were scarred, contracted, and the adjacent portions destroyed; the deficient portion of the noncoronary cusp was sutured to the prosthesis.

IV. Case 4: Right and left coronary cusps were fused, calcified, and contracted; valvuloplasty on the right cusp failed to relieve the insufficiency from contraction and resulted in a tear which could not be closed because of calcium in the adjacent cusp; excision of the left cusp allowed repair of the right and further correction of the deformity.

The valve was rigidly calcified (Fig. 5, I). The left cusp was least involved, the commissure between it and the noncoronary cusp being open. The other two commissures were fused, and the one between the right and noncoronary cusps found to be densely calcified. Incision of the commissures gave little relief from the rigidity. The noncoronary cusp was excised and replaced with a 40 mm. Teflon prosthesis. Ventricular fibrillation which began early during the aortotomy was reverted electrically after the aorta was unclamped and the ventricle kept decompressed.

He was critically ill after operation with periods of ventricular tachycardia and respiratory embarrassment which were treated with tracheostomy and a mechanical respirator. He improved progressively, however, and was discharged 21 days after operation. Just before discharge left ventricular puncture showed a gradient of 10 mm. Hg between ventricle and femoral artery. Cardiac index was 4.0 liters, and the dye dilution curve showed mild regurgitation.

Five months later he was able to walk a mile without distress, had no cardiorespiratory symptoms, and was taking no medication. Blood pressure was 160/90 mm. Hg. There was a loud aortic second sound. Systolic and diastolic murmurs in the aortic area were much less intense than previously. Roentgenograms showed slight decrease in heart size, the cardiothoracic ratio being 0.52.

**Comment:** A 42-year-old man with predominant aortic stenosis was treated by replacement of the noncoronary cusp. He has experienced complete relief of dyspnea and angina pectoris and is objectively improved.

**Case 2.** E. T. (J.H.H. 298346), a 27-year-old housewife, was admitted because of angina pectoris. At age seven she was hospitalized for one year because of acute rheumatic fever and remained on bed rest for an additional three years and nine months. Six years before admission she began taking digitalis because of shortness of breath, paroxysmal nocturnal dyspnea, and mild ankle edema. Two weeks before admission she began to have severe crushing chest pains over the left precordium, radiating into both arms and appearing both at rest and with activity.

On examination there were visible forceful pulsations of the cervical vessels. Blood pressure by auscultation was 180/0 mm. Hg. Systolic sounds were heard over the brachial and femoral arteries. A loud blowing systolic murmur was heard over the entire precordium, it being loudest in the right second interspace. A high-pitched diastolic murmur was heard along the right and left sternal borders. The liver was not felt, and there was no edema. Electrocardiogram showed first degree heart block and abnormal ST segments and T waves. Roentgenograms showed moderate enlargement of the heart, cardiothoracic ratio being 0.66 with enlargement predominantly of the left ventricle. Catheterization of the left heart was performed through a dorsal percutaneous puncture. The left ventricular pressure was 157/14 mm. Hg, and the femoral artery pressure was 157/41. Mean left atrial pressure was 13.5 mm. Hg. There was no pressure gradient across the aortic or mitral valve. Cardiac index by dye dilution method was estimated at 2.86 liters per minute per square meter.

At operation on October 13, 1959 the ascending aorta was occluded for 76 minutes. Coronary perfusion did not work satisfactorily and was used intermittently with balloon-tipped catheters and ball-tipped metal cannulae. There was no interval longer than eight minutes without perfusion and no period of actual cardiac arrest. The valve was slightly stenotic and severely insufficient (Fig. 5, II). The commissure between the right and left coronary cusp was fused; the noncoronary cusp covered a large portion of the circumference but was contracted so that the edge prolapsed below the opposite combined cusp. All three cusps seemed contracted and foreshortened. The noncoronary cusp was excised and replaced with a molded Teflon fabric prosthesis measuring 31 mm. along the free edge. Ventricular fibrillation began as the aorta was being closed, but after circulation was restored the heart was defibrillated with one electric shock. Cardiac action and blood pressure remained satisfactory thereafter.

Her postoperative course was not unusual. Blood pressure at the time of discharge ranged from 130/68 to 160/90 mm. Hg. She was readmitted four months later for study having increased her activities and remaining free of cardiorespiratory symptoms. A grade II systolic and a grade III diastolic murmur were heard in the aortic area. Left ventricular puncture showed a pressure of 163/7 mm. Hg, compared with a brachial artery pressure of 158/74. The dye dilution curve suggested mild valvular regurgitation.

**Comment:** A 27-year-old woman with cardiac failure and severe angina pectoris because of aortic insufficiency was treated by excision and Teflon replacement of the noncoronary cusp. She has been greatly improved both objectively and subjectively.

**Case 3.** E. G. (J.H.H. 868726), a 26-year-old woman, was admitted because of aortic insuffi-

ciency. At age five she had scarlet fever followed by the first of many episodes of acute rheumatic fever, chronic sinusitis, and a draining right ear. Three years before admission she developed shortness of breath. Eighteen months before, she had substernal pain with radiation down the left arm, and this subsequently recurred at more frequent intervals. Digoxin, nitroglycerin, and glyceryl trinitrate were begun and continued. Although recurrent and nearly continuous rheumatic activity limited her activities, the most distressing symptoms were palpitation and angina pectoris. She was receiving steroid therapy for persistent signs and symptoms of rheumatic activity.

On examination blood pressure was 126/40 mm. Hg, the heart being moderately enlarged. There was a grade III blowing, decrescendo, diastolic murmur heard best in the aortic area but transmitted over the entire precordium. A grade II aortic systolic murmur was also heard. Peripheral pulses were bounding with audible systolic snaps over the brachial and femoral arteries.

Electrocardiogram showed first degree heart block, an early precordial transition, and a deep Q-3. Roentgenograms showed moderate cardiac enlargement, principally of the left ventricle, with a cardiothoracic ratio of 0.58.

Submucous resection of the nasal septum, removal of tonsillar tags, and irradiation of adenoid tissue resulted in great improvement in drainage from the right ear, sinusitis, and joint symptoms.

At operation on December 11, 1959 the aorta was found to be collapsing, and there was a diastolic thrill palpable over the heart. The aorta was occluded for 70 minutes, during 56 of which perfusion of the coronary arteries was carried out through balloon-tipped catheters at a rate of 300 ml. per minute. The electrocardiogram showed no significant change during this period.

The insufficiency was caused mainly by contraction of the adjacent portions of the left and noncoronary cusps (Fig. 5, III). The right cusp was minimally affected. The left cusp was excised and replaced with a 30 mm. Teflon prosthesis, the outside diameter of the aorta being 32 mm. The posterior portion of the noncoronary cusp was sutured to the prosthesis as it would otherwise have prolapsed under it. The orifice then readily admitted an index finger. Ventricular fibrillation occurred as the aorta was unclamped, probably because air was trapped in the coronary circulation, but the rhythm was corrected with the second electrical shock.

Convalescence was uneventful except for pleuritic pain during the second week, variously interpreted as due to pericarditis or a pulmonary embolus. Anticoagulants were given, and the dosage of steroids was increased. Blood pressure remained around 120/80 mm. Hg. There was a faint aortic diastolic murmur. She was discharged on the twenty-second postoperative day. Three months after operation she had a normal blood pressure and no cardiorespiratory symptoms.

**Comment:** A 26-year-old woman with severe rheumatic aortic insufficiency was treated by valvuloplasty with replacement of the left coronary cusp. She has had complete relief of cardiorespiratory symptoms and maintains a normal blood pressure.

**Case 4.** P. I. (J.H.H. 778063), a 50-year-old music teacher, was referred by Dr. E. Cowles Andrus for treatment of aortic stenosis and insufficiency. He had probable rheumatic fever as a child and again at age 20. At age 37, at the time of a thyroidectomy for thyrotoxicosis, cardiac murmurs were heard, and following this he noted exertional dyspnea. This increased five years before admission. In the last two years he had taken digitalis and diuretics regularly. In the last six months there had been increasing shortness of breath, with paroxysmal nocturnal dyspnea, ascites, and ankle edema. He was unable to stand to shave because of dyspnea and remained in bed, breathing oxygen much of the time, despite the use of digitalis, diuretics, and a low salt diet.

Blood pressure was 130/90 mm. Hg. He was thin and dyspneic on slight exertion. The heart was greatly enlarged with the left border of dullness in the midaxillary line. There was a harsh grade IV systolic murmur over the base of the heart, radiating into the neck, and also a short blowing diastolic murmur along the left sternal border. The second sound could not be heard in the aortic area. There was a rumbling grade II diastolic murmur at the apex. The liver was barely felt, and there was pitting edema of the feet.

Roentgenograms showed enlargement of the left atrium in addition to the large heart and cardiothoracic ratio of 0.72. The electrocardiogram showed atrial fibrillation, left axis deviation, prolonged intraventricular conduction, and indications of an old anterior myocardial infarction.

Transeptal catheterization of the left side of the heart showed a cardiac index of 1.03 liters per minute per square meter. Left atrial diastolic pressure was 27 mm. Hg compared with that in ventricular diastole of 22 mm. Hg. Systolic pressures in the ventricle and femoral artery were 162 and 120. A dye dilution curve indicated gross valvular insufficiency.

The patient's edema cleared with bed rest and his dyspnea lessened slightly.

Operation was performed on January 13, 1960. The left atrium was nearly filled with clot, and a tight mitral stenosis admitted only the tip of the index finger. To avoid emboli the aorta was occluded and the coronary arteries perfused through balloon-tipped catheters with 500 to 800 ml. of blood per minute for 110 minutes. When a catheter became kinked during our manipulations, it was quickly evident in a drop in flow, as indicated on an electromagnetic flowmeter, and electrocardiographic evidence of ischemia. Large masses of clot were removed from the atrium and the mitral valve was fractured with the finger and a Brock dilator. The mitral leaflets were thickened and contained calcium deposits.

All three aortic commissures were fused and there were large masses of calcium especially on the right and left coronary cusps resulting in a rigid central opening (Fig. 5, IV). Calcified scar was removed from the right cusp, but in the process a tear was made adjacent to the left cusp. The cusps did not approximate in spite of the now pliable right cusp. Hence, the left coronary cusp was excised and replaced with a Teflon fabric one measuring 32 mm. along its free edge. Suture of the tear in the adjacent right cusp was possible after removal of the calcified left cusp and commissure.

Large quantities of blood were allowed to escape through the aortotomy in an effort to wash out residual clots, as closure was completed and before removing the perfusion cannulae. Pressure measurements showed no systolic gradient across the aortic valve and no diastolic gradient across the mitral.

Because of his preoperative dyspnea and poor condition a tracheotomy was performed and the Mörch respirator used for four days. Although severely ill he appeared to be making satisfactory progress until the seventh postoperative day when his blood pressure dropped from the usual 120/75 to 90/60 mm. Hg. His condition worsened and he died several hours later.

Autopsy showed the aortic valve to admit an index finger readily and to be apparently competent. There was a thin transparent film over the fabric cusp which did not seem to limit its motion to the extent that stiffness limited the right cusp on which valvuloplasty had been done. There was a recent posterior myocardial infarction.

**Comment:** A critically ill 50-year-old man with aortic and mitral stenosis and insufficiency was treated with aortic valvuloplasty including replacement of the left coronary cusp, mitral commissurotomy, and removal of clots from the left atrium. His slow improvement was terminated on the seventh postoperative day by a myocardial infarction.

## Discussion

The need for a prosthesis for the aortic valve is evident from the number of reported efforts to replace it.[2, 4-6, 9, 10] That the available prostheses are unsatisfactory is suggested from the diversity of valves described. Up to the present the only prosthesis which has been consistently successful clinically is the Hufnagel ball valve which is placed in the upper thoracic aorta.[4] Most investigators, with the exception of Muller, have used a prefabricated complete substitution for the existing valve. We believe that in many instances a better solution would be replacement of single cusps, although in some instances two or three cusps might have to be replaced.

In two patients we have attempted to replace more than a single cusp. In both instances the effort failed. In one case three cusps were used, one of which was probably too large; revision of this cusp at reoperation the following day resulted in a normal blood pressure, but the patient failed to survive. In the other patient, an adult with a probable congenital stenosis, the small size of the aortic valve ring, considerably smaller than the aorta measured just above the valve, was not appreciated, and two overly large cusps were used with resulting insufficiency. Smaller cusps and a greater range of sizes will, we believe, allow us to prevent this in the future. Use of the proper size is essential for a good result with the inelastic cusps.

The ultimate fate of the Teflon cusps as functioning parts of the aortic valve is unknown. A thin transparent layer which did not stiffen it covered the cusp in Case 4 when seen at autopsy seven days after operation. Clinical improvement in the three surviving patients and the absence of objective evidence of obstruction at the aortic

valve in Case 2, four months after operation, support our belief that the cusps will continue to function satisfactorily. Certainly during the time of observation of these patients the prosthetic cusp has been a distinct improvement over the patient's own diseased one.

How best to protect the heart during the required time of open aortotomy remains a question in our minds. We have used coronary perfusion in treating patients with aortic stenosis without cusp replacement because arrhythmia and myocardial damage were prominent when ischemic arrest was used. The method described allows perfusion with a high rate of flow, the catheters can be held out of the way, and one can work on the valve while perfusion continues. In some cases intermittent perfusion has been used with ball-tipped metal cannulae; although less time is consumed in placing the cannulae in position, extreme care is required to hold them in place, and vision of the valve may be obstructed. Despite perfusion, myocardial infarctions have been seen in some patients (from the group with aortic stenosis treated without cusp replacement), and it is possible that our perfusion method is inadequate. We have searched in vain for coronary emboli to explain the infarctions. General body hypothermia and selective cooling of the heart have been used experimentally, but we have not yet demonstrated to our satisfaction the superiority of this method over normothermic coronary perfusion.

## Summary and Conclusions

Teflon prosthetic cusps have been used in four patients with aortic stenosis or insufficiency. In the cases described, replacement of a single cusp was adequate to restore proper valve function. The three surviving patients have been much improved clinically and by objective measurements.

Perfusion of both coronary arteries has been used during the period of open aortotomy, special cannulae having been devised for this purpose.

Replacement of a single cusp in patients with aortic valve disease will often suffice, although complete valve replacement may in some instances be required.

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