Cardiac Autotransplantation for Mitral Valve Replacement

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ABSTRACT

We present an unusual case of a 69-year-old patient with severe mitral valve regurgitation and extensive coronary artery disease who required mitral valve replacement and myocardial revascularization. With the patient on cardiopulmonary bypass, distal vein grafting was performed first. This procedure was followed by a transatrial transseptal approach to the mitral valve, but visualization of valve structures was extremely difficult. Following the partial excision of the posterior leaflet and the placement of a few pledgeted annular sutures on which traction was applied, access to the mitral annulus remained impossible. There appeared no option but to explant the heart and perform the mitral valve replacement ex vivo. Cardiac explantation was performed by transecting the aorta and pulmonary artery and completing the already extended right and left atriotomies. Cold blood cardioplegic solution was administered intermittently into the coronary sinus during the period when the heart was ex vivo. A porcine bioprosthesis was easily seated into the mitral annulus. Cardiac reimplantation consisted of repair of the previously divided atria, and end-to-end anastomoses of both the aorta and the pulmonary artery. While rewarming was taking place, the 3 proximal vein graft anastomoses were performed. Temporary and permanent epicardial pacing leads were placed. Total ischemic time was 299 minutes, and the period on cardiopulmonary bypass was 359 minutes. The heart sustained good hemodynamics, and after full functional recovery, the patient was discharged home and remained well for 7 years. In view of this experience, a questionnaire was mailed to >3000 cardiothoracic surgeons, and responses were obtained from 1120. Inadequate mitral valve exposure had been experienced by 70%. To provide increased exposure, 50% had extended the initial atrial incision both horizontally and perpendicular to the atrial groove, 17% had divided the superior vena cava, 1% had divided the inferior vena cava, and 1% had divided both cavae. Furthermore, 4% of surgeons reported being forced to abandon the operation in 71 patients because of inadequate exposure. Three hundred twenty perioperative deaths were directly attributed to an incomplete surgical procedure. Explantation of the heart, with mitral valve replacement being performed ex vivo followed by reimplantation, should be considered when access to the mitral valve proves impossible with more standard techniques.

INTRODUCTION

With the advent of the heart-lung machine, mitral valve surgery became a routine operation. Several surgical approaches to the mitral valve have been described through right or left thoracotomy [Kumar 1993, Pratt 2000] or midline partial or complete sternotomy [Grossi 2001]. In our practice, all of these standard surgical approaches have been employed. A midline sternotomy is most frequently used. Right thoracotomy is mainly employed for redo mitral valve surgery [Guiraudon 1991].

The final decision with regard to access to the mitral valve is made after the heart has been examined. The right interatrial groove is frequently entered [Guiraudon 1991], and when exposure of the valve is poor, a transatrial transseptal (TATS) approach is used [Molina 1989]. When the left atrium (LA) is large, the valve can be approached through the roof of the LA [Kon 1993]. The advantages and disadvantages of each approach depend largely on the patient's individual cardiac anatomy. The TATS approach possibly offers the best exposure to all components of the mitral valve and allows good visualization for repair or replacement.

CASE REPORT

A 69-year-old man presented with progressive symptoms of heart failure secondary to ischemic heart disease (total left main occlusion and significant right coronary ostial stenosis), previous myocardial infarction, and severe mitral valve regurgitation secondary to annular dilation and calcification. The patient had pulmonary hypertension and right and left ventricular hypertrophy from long-standing pulmonary and systemic arterial hypertension, respectively. The left ventricular ejection fraction was 40%. The electrocardiogram showed sinus rhythm.

Surgical Procedure

In January 1995, the patient was scheduled to undergo elective myocardial revascularization and mitral valve replacement. In view of the severe coronary artery disease, an intra-aortic balloon pump was placed with the patient under local anesthesia, and contrapulsation was initiated on a 1:1 ratio. Induction of anesthesia was followed by endotracheal intubation. A midline sternotomy was performed, the pericardium

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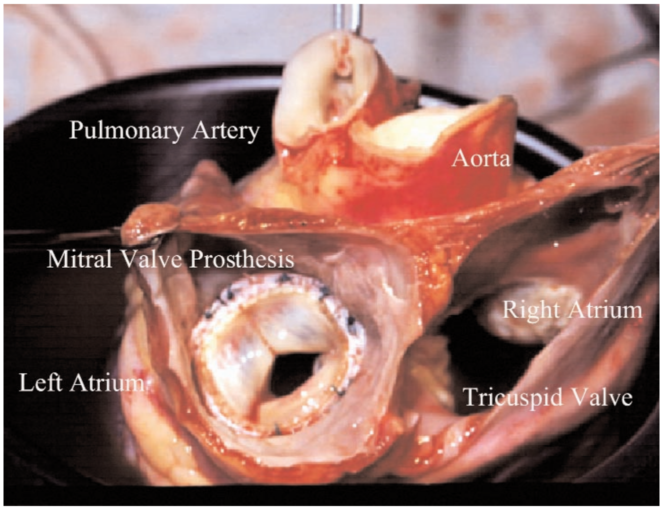

Figure 1. The explanted heart has been placed in a bowl with cold saline. The base of the heart is facing the surgical team, and the replaced mitral valve is clearly visualized. The transseptal atriotomy allows tricuspid valve and atrial septum visualization. The left and right atrial cuffs have been retained with the patient.

was incised, the heart was examined, and the coronary arteries requiring grafting were identified. The extent of right ventricular hypertrophy and the size of the main pulmonary artery were striking. Following heparinization, cannulae were placed in the distal ascending aorta and in the superior (SVC) and inferior (IVC) venae cavae. Cardiopulmonary bypass (CPB) was initiated. The core temperature was reduced to 28°C, and the heart was vented though the pulmonary artery. A coronary sinus cannula was placed for the administration of cold cardioplegic solution.

Following placement of the aortic cross-clamp, retrograde cardioplegic solution was administered, and topical cold saline was applied over the heart. Four saphenous vein grafts were applied to the distal left anterior descending (and sequentially into its D1 branch), to the obtuse marginal, and to the posterior descending coronary arteries.

A wide TATS approach was used to expose the mitral valve. Several pledgeted 4-0 sutures were placed on the edges of the right atrium (RA) and atrial septum to facilitate visualization and exposure of the valve. An atrial retractor was placed in the LA, mobilizing the atrial septum anteriorly. Exposure of the mitral valve was extremely difficult. Exposure of the lateral commissure of the valve proved impossible.

To obtain better exposure, we incised the roof of the LA toward the base of the left atrial appendage, and the interatrial septal incision was extended to the junction of the IVC and the coronary sinus. Following the placement of an atrial retractor, the exposure of the mitral valve did not improve. In an attempt to expose the anterior mitral leaflet, the posterior leaflet was grasped with a surgical clamp and pulled toward the surgeon. Some chordae were divided, and the thickened leaflet tore in its midportion. The posterior leaflet was partially excised, and 4 2-0 polyester (Ti-cron) pledgeted sutures were placed though the posterior annulus. Traction on these sutures did not allow visualization of the anterior leaflet. By this stage, the interventricular septum had been injured from excessive traction exerted by the surgeon and the assistant. There appeared no option other than to excise the entire heart and replace the mitral valve ex vivo on the operating table; it was not anticipated that the patient would survive if the valve were not satisfactorily replaced.

Cardiac Explantation. After the infusion of further cardioplegic solution, the ascending aorta was divided midway between the aortic cross-clamp and the aortic valve. This step was followed by transection of the main pulmonary artery and the remainder of the LA and RA. The sinus node remained with the SVC in the patient. The heart was then removed from the pericardial cavity and placed in a bowl containing cold saline and slush.

With the base of the heart facing toward the surgical team, both atria were widely opened, providing excellent exposure of the entire mitral valve. The previously placed annular sutures were removed, and the anterior leaflet and remnants of the posterior leaflet were excised. Although a no. 35 porcine bioprosthesis (Carpentier-Edwards) would fit easily, in view of the need for cardiac reimplantation and to avoid potential injury to the left ventricular cavity, we selected a no. 33 bioprosthesis. Pledgeted 2-0 Ti-cron sutures were placed through the mitral annulus and afterwards through the sewing ring of the prosthesis. The valve struts were maneuvered into the left ventricle, the prosthesis sewing ring was positioned on the mitral annulus, and the sutures were tied down (Figure 1). During the insertion of the prosthesis, two further doses of cardioplegic solution were administered though the coronary sinus.

Cardiac Reimplantation. The atrial suture line was reinforced by first placing longitudinal polytetrafluoroethylene (Teflon) pledgets along the edges of the divided LA. The heart was positioned in the left chest and covered with cold sponges (Figure 2). Reimplantation was initiated as for standard orthotopic heart transplantation. The LA was anastomosed with a 3-0 polypropylene suture, beginning at the base of the atrial appendage and pulmonary vein. Once the suture line had progressed along the lateral wall of the atrium, the heart was placed within the pericardial cavity, and the caudal suture line was directed toward the IVC–coronary sinus and interatrial septum. This step was followed by repair of the LA roof and the cranial portion of the atrial septum. At this stage, the LA was filled with cold saline, and the ends of the 2 sutures were tied together.

The LA anastomosis was performed with 4-0 polypropylene suture, starting at the cranial part of the atrial septum. The suture was brought along the inflow of the SVC into the RA toward the midpoint of the free wall of the RA. A second 4-0 suture, beginning at the junction of the IVC and the atrial septum, was carried around the IVC toward the RA free wall. The RA was then irrigated and filled with cold saline, and the sutures were tied.

The pulmonary artery and the aorta were each repaired in an end-to-end fashion with 4-0 polypropylene sutures.

Throughout the implantation, care was exerted to take small tissue bites to avoid undue tension. At this stage, patient rewarming was initiated, 3 aortotomies were performed distal

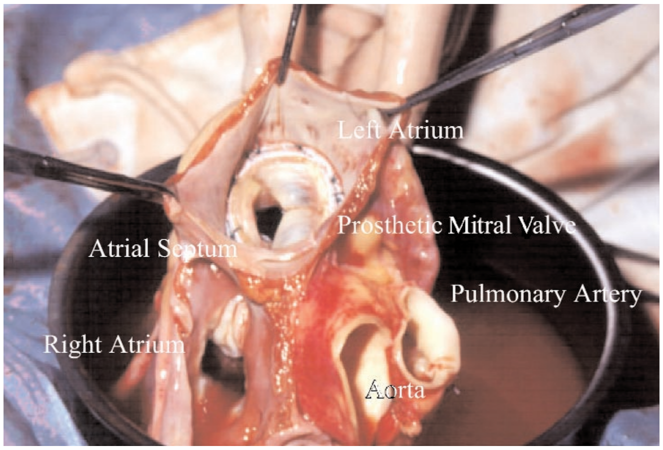

Figure 2. Patient's heart is being removed from the bowl with cold saline, ready for implantation.

to the aortic anastomosis, and the proximal anastomoses of the saphenous vein grafts were carried out. Following release of the SVC-IVC snares, the heart was deaired, the aortic cross-clamp was removed, and the heart was reperfused.

Because the heart had been denervated by the autotransplantation procedure (the sinus node remaining attached to the SVC and not being excised with the heart), a permanent epicardial pacemaker lead was placed on the lateral wall of the apex of the left ventricle for future pacemaker placement. Temporary epicardial pacing leads were placed on the RA and right ventricle. During rewarming, the heart was paced at 90 beats/minute, intra-aortic balloon pump support was provided (1:1 contrapulsation), epinephrine was administered at 0.05 μg/kg per minute as inotropic support, and the patient received a loading dose of 0.5 μg/kg of triiodothyronine [Novitzky 1989, Novitzky 1990, Novitzky 1996].

Within a short period, heart function was good, and CPB was discontinued. After protamine administration and a few extra aortic hemostatic sutures, hemostasis was adequate, and the chest was closed in the usual fashion. The total ischemic time of the heart had been 299 minutes, and the CPB period was 359 minutes. Approximately 40 minutes were spent trying to obtain adequate access to the mitral valve.

The patient's postoperative course was relatively benign. An early tracheotomy was performed for ventilatory support and comfort. Intra-aortic balloon pump support was discontinued on the second postoperative day. A permanent pacemaker was implanted on the fourth postoperative day and set on a VVI mode at a rate of 90 beats/minute. The patient was discharged home in good functional condition on the 19th postoperative day. His postoperative course was of a fully functional patient; however, he died 7 years later.

COMMENT

The difficulty of access to the mitral valve in this case was from a combination of severe pulmonary hypertension and biventricular hypertrophy. Despite wide exposure gained through incising the interatrial septum and dividing the roof of the LA, adequate exposure of the mitral valve was impossible. The decision to proceed with ex vivo mitral valve replacement was based on a similar past experience. In contrast to the excellent outcome obtained in the current case, the previous attempt was unsuccessful because it was a redo operation, and, despite good cardiac functional recovery, the patient died in the operating room from exsanguination. The earlier patient, who had required the replacement of a previously implanted mitral valve prosthesis, had dense adhesions and a calcified interatrial septum, which necessitated prolonged CPB support and led to an inability to stop the bleeding from the divided adhesions.

Results of the Questionnaire

In view of the problems presented by these two patients, an assessment of the magnitude of this surgical problem was made. A questionnaire was prepared and mailed to all Veterans Affairs medical centers performing open heart surgery, as well as to heart surgeons listed by the Society of Thoracic Surgeons. Of the 3000 questionnaires mailed, 1120 responses were received.

Of these responses, 70% of the surgeons indicated that during their postfellowship clinical practice they had experienced difficulty in obtaining access to and exposure of the mitral valve. In this event, most respondents indicated that they would enlarge the original atriotomy, and, if this proved insufficient, 50% said they would extend the initial atriotomy perpendicular to the incision in the atrial groove into the RA and divide the atrial septum.

Even with the help of these procedures, 19% of the surgeons indicated experiencing a problem similar to ours in obtaining exposure of the mitral valve. In such cases, they proceeded to divide the SVC (17%), divide the IVC (1%), or divide both the SVC and the IVC (1%) in an effort to increase exposure. Forty-four surgeons (4%) responded that they had been forced to abandon the surgical procedure and thus took the patient off CPB without performing surgery on the mitral valve in 71 cases. Finally, in the experience of this group of 1120 surgeons, the deaths of 320 patients were directly attributable to an incomplete mitral valve operation because of inadequate access to the annulus.

Autotransplantation of the heart has been reported previously in the experimental animal [Novitzky 1988] and in patients with Prinzmetal angina [Clark 1977], cardiac tumors [Akiyama 1988, Scheld 1988, Goldstein 1995], an enlarged LA [Livi 1998, Lessana 1999], chronic atrial fibrillation [Garcia-Villarreal 2001, Pfeiffer 1992], and repair of ventricular laceration [Winlaw 1998]. An extensive literature search did not reveal any reference to cardiac autotransplantation for mitral valve replacement. However, repair or replacement of the mitral valve of a donor heart has been carried ex vivo prior to heart transplantation [Massad 1996, Myers 1996, Michler 2000, Wei 2001].

The responses to the mailed questionnaire clearly indicated that surgeons performing mitral valve procedures might unexpectedly have difficulty obtaining adequate exposure of the valve. The extent of the problem would appear to be more extensive and underreported than initially thought. Considerable ingenuity and rapid decision-making are sometimes required. If a member of the surgical team is acquainted with cardiac transplantation techniques, the use of autotransplantation may resolve the problem.

We conclude that autotransplantation of the heart for mitral valve replacement will be a rare event, but in cases where all other maneuvers have failed to provide adequate access to the valve, it may allow completion of the operation and be life saving.

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REVIEW AND COMMENTARY

Editor's Commentary by Mark M. Levinson, MD, Hutchinson Hospital, Hutchinson, Kansas, USA:

This case report by Novitzky et al deals with a delicate and troublesome subject. Inadequate exposure to the mitral valve can be the undoing of a well-planned operation, even in the presence of experience and talent. This subject is almost never discussed at national meetings or published in peer-reviewed journals, but this situation does constitute a source of major disasters in cardiac surgery. Not all mitral valve operations are the same. Even though successful repair and replacement techniques have been around for decades, an occasional patient dies because of the technical frustrations related to inadequate exposure of the mitral apparatus. Every surgeon has faced the situation described by these authors in which the posterior mitral annulus is (barely) visualized but the anterior structures are completely out of view.

It has been taught that the patient with acute mitral regurgitation has a small left atrium and that the mitral valve is thus hard to expose. In my experience, this situation is not a universal rule. In some patients with a normal or small atrium, the view is very good. I heartily agree with the authors that right ventricular enlargement, especially hypertrophy, makes the right ventricle override, reducing the ability to expose the mitral valve with conventional handheld or self-retaining retractors. These devices work by elevating the atrial septum, the ventricular outflow tract, or the aortic annulus and yet do not always provide adequate exposure. Although retension sutures on the posterior left atrium and mitral annulus can pull the apparatus toward the surgeon, too much tension on these sutures can predispose to a fatal type I annuloatrial disruption, especially in redo cases in which the ventricle is fixed in place by adhesions. Another factor that was not discussed is the presence of a deep chest. Some patients have an unfavorable body habitus for mitral surgery with an increased antero-posterior chest dimension. In these cases, the mitral valve is buried deep with no way to safely raise the septum and aortic annulus so that the mitral valve can appear over the shelf of the right hemisternum.

The authors correctly state that quick thinking must be part of the surgical attitude in such difficult situations. More importantly, the surgeon must have a full library of techniques to draw upon and progress carefully from simple to increasingly complex exposure techniques to gain leverage on the valve without causing harm. In my experience, there are a couple of relevant exposure techniques that the authors did not discuss. First, after exposure is found to be limited despite the division of the atrial septum and dome, the overriding right ventricular outflow tract can be moved away by simple transverse division of the ascending aorta [Machiraju 2000]. After aortic transection, retension sutures are placed in the adventitia of the posterior portion of the aortic annulus to retract the aortic valve and base of the left ventricular outflow tract toward the feet. This maneuver greatly improves the exposure of the anterior mitral leaflet. This move is far less invasive and complex than cardiac autotransplantation but may also be considered the "first stage" of the autotransplantation procedure. If the exposure is still not adequate, the pulmonary artery can be divided and retracted in like manner to pull both great vessels inferiorly. This maneuver can be considered the "second stage" of autotransplantation while leaving all the atrial and caval structures in situ posteriorly. Now, nothing is left to inhibit the view of the mitral valve, and yet reconstruction consists of only end-to-end suture lines of the aorta and the pulmonary artery.

If the aortic valve is also diseased, surgeons should also consider the Manouguian double-valve technique [Manouguian 1979]. Through an oblique aortotomy, the aortic annulus is divided through the anterior leaflet of the mitral valve, and the edges of the combined orifice of both valves are suspended with sutures. The view is directly into the plane of the mitral annulus, not from a posterior or lateral perspective. The exposure is unrestricted by any cardiac structure and is vast, expansive, and easy to work in. The entire posterior left atrium remains undisturbed, and the surgeon can see all the way down to the apex of the LV as well. The only disadvantage of this technique is the need to patch the dome of the left atrium and carry the patch into the aortic annulus before replacing the aortic valve. For pure mitral disease, this technique is not an option, but it should be part of the surgeon's toolbox for double-valve disease.

I have no objections to the autotransplantation concept proposed by the authors, but I think it should be pointed out that the lead author is a pioneer in cardiac transplantation with his career beginning in Cape Town under Dr. Barnard. The average surgeon cannot boast such credentials for this procedure nor withstand the impact from the family and hospital staff if something goes wrong after the heart has been completely removed. My advice is to proceed in the steps as outlined above rather than excise the heart in one move. Division of the ascending aorta can be considered the first extra step, followed by division of the pulmonary artery, and, at the very end of this process, complete cardiac excision only if no other choice exists.

I compliment the authors for their courage in provoking this discussion.

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