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Midterm result of leaflet extension technique in aortic regurgitation☆

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Abstract

Objectives: Aortic valve leaflet extension using glutaraldehyde-fixed autopericardium in aortic regurgitation (AR) is technically demanding, and it is not a popular procedure among surgeons. This study evaluates the effectiveness and clinical feasibility of the leaflet extension technique as a treatment modality for AR. **Materials and methods**: From March 1995 to March 2001, 34 consecutive patients underwent the leaflet extension technique. The mean age of the 26 men and eight women was 31.0 ± 14.3 years (range 16–68). They were all diagnosed with pure aortic valve regurgitation, and nine (27.3%) had associated mitral valvular heart diseases. Accurate measurement of the leaflet free margins was performed with a pair of compasses before leaflet extension. Glutaraldehyde-fixed autopericardium was designed according to the free margin lengths. Leaflet extension was performed in three aortic leaflets for 29 patients but only one leaflet was extended in the remaining four. The nine patients with associated mitral valvular heart disease also underwent mitral valvuloplasty. Mean cardiopulmonary bypass time and ischemic time in 25 isolated AR group were 128.7 ± 26.5 min (range 70–180) and 101.5 ± 25.5 min (range 41–150), respectively. **Results**: There was no incidence of in-hospital mortality. Immediate postoperative echocardiography revealed grade II AR in one, grade I AR in ten and no AR in the remaining 23 patients. Mean follow-up duration was 49.6 ± 18.8 months (range 4.1–77.1). Echocardiographic AR grades during follow-up were grade II in 13, grade I in 11 and no AR in eight. The remaining two patients underwent reoperation, one aortic valve replacement because of subacute bacterial endocarditis that occurred 7 months after leaflet extension, and the other Ross operation because of the dehiscence of the valvuloplasty suture site that developed 4 months later (AR associated with Behcet's disease). There was one case of mortality due to malignant mesothelioma 4 years after aortic valvuloplasty. The cumulative survival rate was 94.1% at 5 years. Freedom from reoperation was 93.8% at 1 year and after. **Conclusions**: The leaflet extension technique is an acceptable surgical treatment modality for AR and its clinical results were confirmed in this study to be very good. A careful long-term follow-up study will be necessary to evaluate the long-term durability of the glutaraldehyde-preserved autologous pericardium as a leaflet tissue.

Keywords: Leaflet extension; Aortic regurgitation

1. Introduction

Although aortic valve repair was introduced as a surgical technique prior to the advent of the cardiopulmonary bypass, it has been performed in a very limited fashion because of inadequate development of repair material and questions concerning the long-term durability of the procedures. Aortic valvuloplasty fell into disuse with the introduction of reliable artificial valves. However, more recently, as awareness of the limitations of artificial valves increased, attention has been focused again on valve repair. Among the various repair techniques, the leaflet extension for the aortic valve has been used in cases of severe cusp retraction that cannot be corrected by cusp slicing, free edge unrolling or other valve repair techniques. The frequency of the leaflet extension technique is increasing slowly following improvements in the fixation technique for the pericardium. This report reviews our experience with the leaflet extension technique in order to evaluate the effectiveness and clinical feasibility of this method using glutaraldehyde-fixed autopericardium for pure aortic regurgitation (AR).

2. Materials and methods

2.1. Patients

From March 1995 to March 2001, 373 patients underwent

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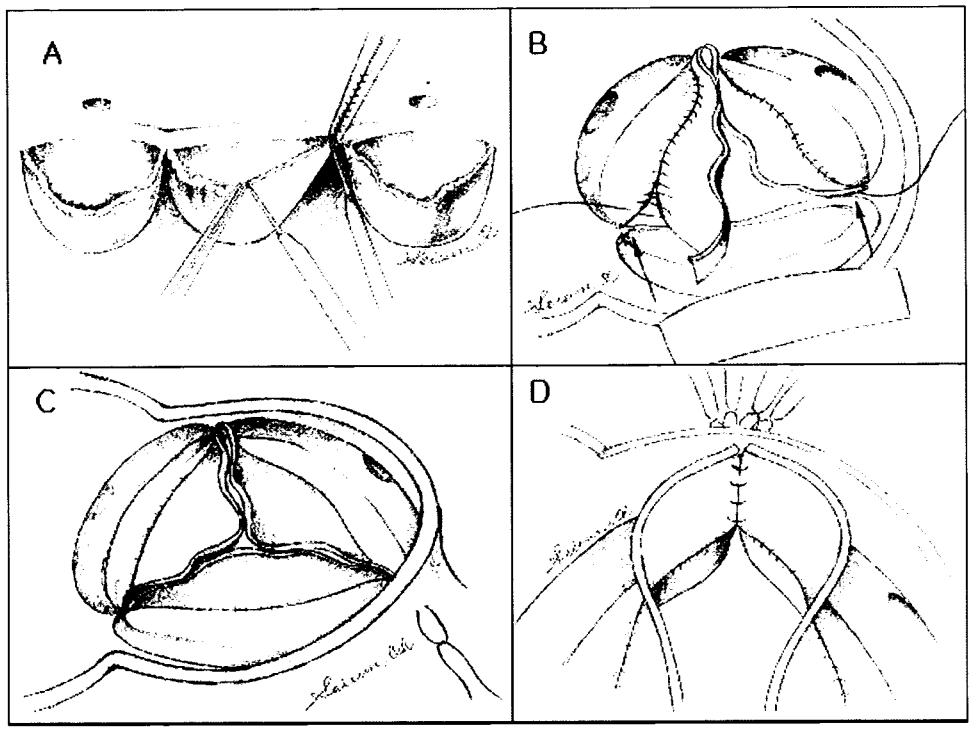

Fig. 1. Operative techniques of leaflet extension. (A) Measurement of leaflet free margin. (B) Implantation of glutaraldehyde-fixed autopericardium. (C) Completion of single running suture through commissure across the aortic wall. (D) Formation of neocommissures.

aortic valve operations. Among them, aortic valve repair was possible in 107 patients (28.7%). Leaflet extension technique was performed on 34 (31.8% of aortic valve repair), 26 male and eight female. The mean age of this group was 31.0 ± 14.3 years, ranging from 16 to 68 years. All 34 patients had pure AR, 25 isolated AR and the remaining nine had associated mitral insufficiency requiring mitral valve repairs. The preoperative distribution of the New York Heart Association functional class was as follows: five patients in functional class I, 15 in class II and 14 in class III. The degree of AR was assessed preoperatively by transthoracic echocardiography, and assessed before, during and after operation by transesophageal echocardiography and was graded on a scale of 0–4 according to the height of the regurgitant jet relative to the left ventricular outflow tract height, measured from a parasternal long axis just below the aortic valve [1]. Preoperative chest radiography showed more than moderate cardiomegaly in all patients. Electrocardiography revealed normal sinus rhythm in 28 patients and atrial fibrillation in five. One patient exhibited complete AV block and a VVI type permanent pacemaker was inserted. Preoperative transthoracic echocardiographic findings showed isolated AR without aortic stenosis with following grades of AR: II in two patients, III in 12 patients and IV in 20 patients. The mean regurgitation grade was 3.6 ± 0.6. The left ventricular end-systolic and diastolic dimensions were 48.8 ± 8.4 and 71.2 ± 9.8 mm, respectively. And the left ventricular ejection fraction was 54.5 ± 8.3%.

2.2. Operative procedures (Fig. 1)

Cardiopulmonary bypass was established by cannulation of the ascending aorta and both the superior and inferior vena cavae. Myocardial preservation was achieved by intermittent perfusion of the coronary arteries with cold high potassium blood cardioplegic solution. The left ventricular vent was inserted into the left ventricle through the right superior pulmonary vein and systemic moderate hypothermia was used (28°C). The aorta was cross-clamped after the onset of ventricular fibrillation. The aorta was opened by a transverse incision approximately 1–1.5 cm above the ostium of right coronary artery. All three aortic valve cusps were examined thoroughly and extension of the cusp was not attempted in the case of severe calcification and severe thickening which might reduce the leaflet mobility. Mild commissural fusion was not considered to be an absolute contraindication of this procedure. In the cases of associated mitral insufficiency, mitral valvuloplasty was performed with or without annuloplasty. Autologous pericardium was fixed in 0.625% glutaraldehyde solution for 15 min and rinsed in three successive normal saline solutions. After the measurement of leaflet free margins with compass, the autologous pericardium was designed as the height of the autologous pericardium was about 8–10 mm, and its length was same as the free margin of each cusp. Implantation commenced at the commissures between the right and left cusps using 5-0 polypropylene continuous suture. The direction of the suture was clockwise in the

right cusp and counterclockwise in the remaining left and non-coronary cusps. The single running suture was completed at the commissure between the right and non-coronary cusps, being threaded into the aortic wall and the ligature was made. Commissures were then extended by approximating every two adjacent pericardial strips with several interrupted 5-0 polypropylene stitches placed through the aortic wall and tied over it (formation of neocommissures). During the procedure, the mesothelial surfaces of the autologous pericardium were faced toward the left ventricle.

2.3. Echocardiographic follow-up

In all cases, transthoracic echocardiography was performed before the operation. Later in the operating rooms, transesophageal echocardiography carried out by the anesthesiologist was used to assess the competence of the valve. We also checked the amount of left ventricular vent after release of aortic cross-clamp and after weaning from cardiopulmonary bypass. Transthoracic echocardiography was performed before discharge, 3–6 months after operation and periodically thereafter. The Doppler echocardiographic grade of AR was measured with color Doppler flow and graded from the width and length of the regurgitant jet in the left ventricle (grades 0–IV) according to previously described criteria. The left ventricular end-diastolic and end-systolic diameters were measured at the midpapillary level in the standardized parasternal transthoracic long axis and short-axis positions.

2.4. Statistical analysis

Continuous data were expressed as mean ± standard deviation and changes between measurement time points were analyzed by means of the paired Student's t test. All tests were two-tailed. The AR grade was presented as a frequency distribution. Kaplan–Meier methods were used to derive the probability for survival.

3. Results

We performed triple leaflet extensions in 29 patients and single leaflet extension in four patients. The main etiology of AR was rheumatic (29 patients, 85.0%). Other causes were as follows: healed endocarditis (two), degenerative (one), Behcet's disease (one) and AR after VSD repair (one). In nine patients, mitral valve repairs were performed concomitantly. In the cases of single leaflet extension, the shape of autopericardium was crescent rather than rectangle. Mean cardiopulmonary bypass time and ischemic time in 24 isolated AR group were 128.7 ± 26.5 min (range 70–180) and 101.5 ± 25.5 min (range 41–150), respectively. No patient required a second period of aortic occlusion to correct residual AR. Two patients who had concomitant severe mitral regurgitation had mild AR. Although they did not have a severe AR, we thought it might be valuable to try leaflet extension in aortic valve because of the central regurgitation by the poor coaption of three cusps. We tried and they showed trivial AR until now.

There was no incidence of hospital death. Except for minor wound problems in two patients, there were no remarkable in-hospital complications. The amount of AR determined intraoperatively by the color Doppler technique was 3.6 ± 0.6 before repair and 0.4 ± 0.4 after repair ($P < 0.01$). The amount of AR checked echocardiographically before discharge was the same as the intraoperative findings. The left ventricular end-systolic and diastolic dimensions were 42.0 ± 8.6 and 58.0 ± 9.5 mm, respectively, and showed significant decrease ($P = 0.03$, 0.001, respectively). The left ventricular ejection fraction was 48.7 ± 8.5% (Fig. 2). These findings showed slightly decreasing tendency of left ventricular function, however, there was no statistical significance ($P > 0.05$). Short-term anticoagulation was done in nine patients who underwent associated mitral valve procedures. Two patients were in the New York Heart Association functional class II and the remaining patients were in class I.

Clinical follow-up was complete in 34 patients at a mean of 49.6 ± 18.8 months (range 4.1–77.1) after operation. Recurrent AR requiring reoperation developed in two patients (5.9%). The first developed fungal endocarditis due to *Trichosporon beigelii* 7 months after operation and exhibited severe AR. At reoperation, although the original suture line for leaflet extension was maintained, leaflet perforation and vegetations were found in one remaining valve cusp. The valve was replaced at this point but 4 months later, endocarditis recurred, to be subsequently controlled by medical treatment. The second patient was suspected to have features of Behcet's disease. Leaflet extension was performed in one retracted cusp and postoperative echocardiography revealed grade I AR. Wound dehiscence followed this first operation and 3 months

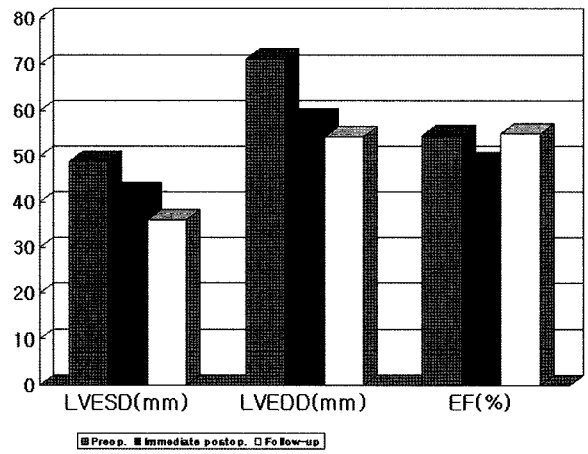

Fig. 2. Echocardiographic results (LVESD, left ventricular end-systolic dimension; LVEDD, left ventricular end-diastolic dimension; EF, ejection fraction).

Table 1
Echocardiographic changes of AR

AR grade	Preoperative	Discharge	Follow-up
None (0)	0	23	8
Trivial (I)	0	10	11
Mild (II)	2	1	13
Moderate (III)	12	0	0
Severe (IV)	20	0	0

later, the patient experienced sudden dyspnea on exertion and palpitations and echocardiography revealed grade IV AR. At this time Ross operation was performed, and it was apparent that the insufficiency was due to a partial dehiscence in the leaflet extension suture line. There was one late death 4 years after operation due to malignant mesothelioma. The patient exhibited no postoperative evidence of AR.

Color flow Doppler echocardiography studies were done during the follow-up period in 32 patients. The amount of AR determined during follow-up (done at a mean interval of 31.8 ± 21.8 months) was 1.0 ± 0.8 (eight in grade 0, 11 in grade I, 13 in grade II) and the change in AR between the immediate postoperative period (Table 1) and the midterm follow-up period showed no statistical significance. The left ventricular end-systolic and diastolic dimensions were 36.2 ± 5.8 and 54.2 ± 6.7 mm, respectively, and the left ventricular ejection fraction was 55.0 ± 9.7% (Fig. 2). No evidence of progression of AR was found. The cumulative survival rate at 5 years was 94.1 ± 5.7% and the freedom from reoperation was 93.8 ± 4.3% at 1 year and after (Fig. 3). Transaortic pressure gradients were detected in four patients, and mean gradients were 11, 12, 15 and 15 mmHg, respectively. There were no progressions of pressure gradients during follow-up period.

4. Discussion

Aortic valve repair has had a long history in parallel with the development of cardiac surgery. Lillehei et al. [2] in 1958 introduced single cusp enlargement and bicuspidalization using Ivalon sponge, and thereafter, various types of valve repairs using autopericardium, bovine pericardium, Teflon and fascia lata have been attempted [3–5]. However, the prediction of postoperative valve function has remained difficult, and furthermore, the higher mortality, possibility of calcification and leaflet hypertrophy, and generally poor long-term results lead to the substitution of aortic valvuloplasty by valve replacement following the advent of the valve prostheses. With an increasing awareness of the limitations of both mechanical prostheses and bioprostheses, valve repair has been tried constantly in patients with infantile aortic stenosis and AR associated with ventricular septal defect [6]. Yacoub et al. [7] reported a survival rate of 89% at 7 years in 45 patients who underwent cusp enlargement using 0.2% glutaraldehyde-fixed bovine pericardium. Batista et al. [8] used a stentless bovine pericardial aortic monopatch fixed in 0.6% glutaraldehyde solution and concluded that it was particularly suitable for patients with infective endocarditis because of the minimization of the amount of foreign material. In Ghandour's report [9], transient myocardial ischemia after leaflet extension was observed via the endoscopic technique, as was the potential for the excessive length of the pericardium to compromise the coronary ostia. Duran et al. [10–13] reported aortic valve replacement with glutaraldehyde-treated autologous pericardium. Freedom from failure of the aortic reconstruction was stated to be 83.3 ± 8.6% at 5 years.

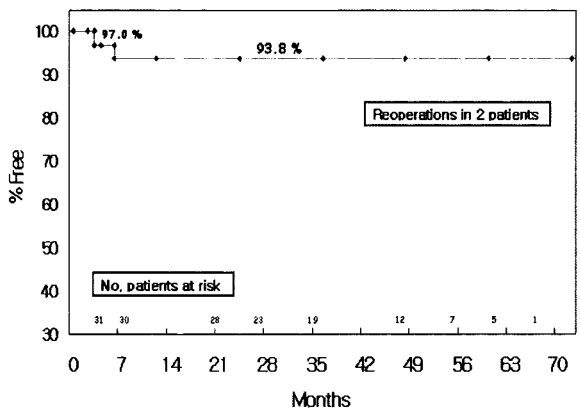

Fig. 3. Freedom from any reoperation on the aortic valve after leaflet extension.

In the technical aspect of leaflet extension, Batista used one patch folded lengthwise in thirds and tailored according to the shape of the patient's native valve leaflets [8], while Duran used a mold for tailoring the pericardium [11–13]. They excised diseased cusps and the pericardium was sutured to the resected margins. We thought they tried to standardize their technique by remaining almost equal size of native pericardium. In the present study the leaflet tissue was not resected. In case the lengths and heights of the cusp free margins were not equal, we tailored the upper border of the autopericardial patch after careful coaptation of the three autopericardial patches. Although it was somewhat difficult to adjust the size of autopericardium, we thought this technique had the advantages of leaving the native leaflets attached to the annulus, thus the natural hinge mechanism was considered to be preserved and coaptation of the three cusps improved as Al Fagih et al. described earlier [14].

The problems after leaflet extension in AR were revealed as early failures like patch dehiscence and late leaflet calcification [14–16]. The reasons for calcification remain unclear, with mechanical stress, biochemical factors and immunological factors having been suggested. Calcification is known to develop more frequently in xenograft patches, therefore immunological factors are considered to be important items. Therefore, we considered the use of autopericardium to be superior to that of bovine pericardium. Fixation in glutaraldehyde solution reduces tissue retraction and

promises good long-term results. Chauvaud and Jebara [17] reported that 15 min fixation in 0.625% glutaraldehyde solution reduced the immunologic reaction due to the stabilizing effect induced by the cross-linkage of collagen materials. This fixation method was adopted in the present study. On the other hand, Kalangos et al. [18] reported aortic valve repair by cusp extension with the use of fresh autologous pericardium in children with rheumatic AR. They stressed the problems associated with calcification and primary tissue failure particularly in the pediatric population.

The accurate assessment of the adequacy of valve repair after leaflet extension is of utmost importance, but this assessment is difficult in aortotomy status. Austin et al. [19] described a method to measure the regurgitant volume obtained through the left ventricular vent, yet it is very rudimentary and cannot determine the reason for valve insufficiency. Duran and co-workers [9] reported on the use of the valvoscope before aortic unclamping. They were able to detect the left coronary part of the pericardium prolapsing outwardly toward the sinus of Valsalva. The aortotomy was reopened and a few millimeters of the pericardial free edge was resected in three patients. Intraoperative color Doppler echocardiography is the most important method and similar to many other surgeons who are interested in aortic valve repair [20,21], we ourselves routinely performed transesophageal echocardiography after the induction of anesthesia and checked the AR both during and after cardiopulmonary bypass weaning. Such a technique was essential in allowing advance planning of appropriate technical strategies by offering fairly precise information on the anatomy and function of the aortic valve. The leaflet extension technique for the aortic valve in isolated AR was determined to be an acceptable surgical treatment modality for AR and its clinical results were confirmed to be very good. As the midterm period of follow-up does not allow the long-term structural and functional integrity of the repaired valve, further careful long-term follow-up will be necessary to evaluate the durability of the glutaraldehyde-fixed autologous pericardium.

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