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Aortic Valve Replacement with Single-Strip Autologous Pericardium

Ismail Dilawar[1] Jusuf Rachmat[1] Ito Puruhito[2] Idrus Alwi[1] Sudigdo Sastroasmoro[1] Suhendro Suhendro[1] Isabella Kurnia Liem[1] Minarma Siagian[1] Ahmad Aulia Jusuf[1] William Makdinata[1] Imamurahman Taslim[1] Stefanie Melisa[1]

[1] Faculty of Medicine, Universitas Indonesia, Jakarta, Indonesia
[2] Faculty of Medicine, Universitas Airlangga, Surabaya, Jawa Timur, Indonesia

Address for correspondence Stefanie Melisa, Faculty of Medicine, Universitas Indonesia, Jalan Salemba Raya No. 6, Senen, Jakarta Pusat, Jakarta 10430, Indonesia (e-mail: stefaniemelisa19@gmail.com).

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Abstract

Background Aortic valve replacement with mechanical valves is the standard treatment for aortic valve disease in Indonesia. Its usage is associated with high cost, risk of endocarditis and thromboembolic event, and lifetime consumption of anticoagulants. We performed a novel replacement technique of the aortic valve using an autologous pericardium and evaluated the short-term outcomes.

Methods From April 2017 to April 2020, 16 patients underwent aortic valve replacement with a single-strip autologous pericardium. Outcomes of the left ventricular reverse remodeling (LVRR), 6-minute walk test (6MWT), and soluble suppression of tumorigenicity-2 (sST-2) were measured at 6 months postoperation.

Results A total of 16 surgeries were performed using aortic valve replacement with single-strip pericardium without conversion to mechanical valve replacement. The patients included eight males and eight females, and the mean age was 49.63 ± 12.54 years. The most common diagnosis was mixed aortic valve stenosis and regurgitation (9 cases). Five patients underwent a concomitant coronary artery bypass graft (CABG) procedure and 12 patients underwent either mitral or tricuspid valve repair. The mean aortic cross-clamp time was 139.88 ± 23.21 minutes and cardiopulmonary bypass time was 174.37 ± 33.53 minutes. At 6 months postoperation, there was an increase in the distance walked at the 6MWT ($p = 0.006$) and a decrease of the sST-2 level ($p = 0.098$). Echocardiogram showed two patients had LVRR. Survival and freedom from reoperation are 100% at 1 year of follow-up.

Conclusion Aortic valve replacement with a single strip of pericardium is a good alternative to aortic valve replacement with a mechanical valve. Short-term evaluation at 6 months postoperation showed improvement in clinical status and echocardiographic parameters compared to baseline.

Keywords
- aortic valve replacement
- single-strip pericardium
- left ventricle reverse remodeling
- six minutes walking test
- soluble suppression of tumorigenicity-2

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Introduction

Aortic valve replacement with a mechanical valve is the standard treatment for aortic valve disease in Indonesia. However, there are some limitations regarding the use of mechanical valves including high cost, increased risk of endocarditis and thromboembolic event, and lifetime consumption of anticoagulants. Aortic valve replacement using an autologous pericardium is developed as an alternative to overcome these problems. The aortic valve neocuspidization (AVNeo) by Ozaki et al[1] is widely accepted worldwide. The Ozaki technique is challenging to perform as surgeons have to measure the intercommissure distances for each leaflet before trimming and molding the pericardium, significantly increasing the aortic cross-clamp duration. We developed a novel and easier aortic valve replacement technique with a single strip of pericardium.

Methods

This study had received ethical clearance from the Ethics Committee of the Faculty of Medicine, University of Indonesia, with protocol number 16-12-576. We performed aortic valve replacement with a single strip of pericardium on 16 patients from April 2017 to April 2020. We reviewed these 16 cases and evaluated the short-term results of the left ventricular reverse remodeling (LVRR) incidence, 6-minute walk test (6MWT) distance, and soluble suppression of tumorigenicity-2 (sST-2) level. The criterion for LVRR was an increase of the ejection fraction (EF) by more than 10% with a decrease of the left ventricular end diastolic diameter (LVEDD) by more than 10%.[2] The 6MWT was used to assess the patient's clinical function and sST-2 level to assess myocardial stress. Several studies have shown that both 6MWT and sST-2 test have a prognostic value following aortic valve replacement.[3,4]

The patient was put under general anesthesia and underwent median sternotomy. The anterior pericardium with a size of 5 cm × 13 cm was harvested. The harvested pericardium was preserved by soaking it in 0.6% glutaraldehyde for 10 minutes and then rinsed using NaCl 0.9% three times for 5 minutes each. The cardiopulmonary bypass (CPB) machine was established. We then performed a partial aortotomy to expose and remove all the diseased aortic valves (►**Fig. 1A**). The annulus diameter and the commissure height and intercommissure length were measured using the St. Jude aortic valve sizer (►**Fig. 1A**). In case of aortic root dilatation, we use the sinotubular junction diameter instead of the annulus as we believe the coaptation edge of the neoaortic leaflets is also determined by the sinotubular junction diameter. The threshold of the sinotubular junction diameter was less than 1.5 times of the expected normal diameter. Measurement results were converted as follows: annulus or sinotubular junction diameter to single-strip pericardium length, commissure height to single-strip pericardium width, and intercommissures length as suturing mark on the single-strip pericardium (►**Fig. 1B**). We used a self-developed marker to imprint the single-strip pericardium. This marker imprinted around 8 mm more in the single-strip pericardium length and 4 mm more in the width than the measured annulus to account for shortening after suture placement.

The pericardium is cut according to the measurement (►**Fig. 1B**) and sutured at three commissures on the aortic valve annulus, first at the right coronary cusp–left coronary cusp (LCC-RCC) commissure. The suture is placed exactly at the upper border of the annulus to avoid the membranous septum (►**Fig. 1C**). The single-strip pericardium is then sutured continuously along the aortic valve annulus. Then both edges of the single-strip pericardium were also sutured, forming a pericardial tube toward the left ventricle (►**Fig. 1C**). The pericardial tube is pulled outward from the ventricle toward the aorta, and then each commissure is sutured toward the sinotubular junction (►**Fig. 1D**), forming a new aortic valve with three leaflets (►**Fig. 1D**; ►**Video 1**). We evaluate the function of the newly developed aortic valve for any regurgitation. Transesophageal echocardiography is used to evaluate valve function and de-airing adequacy. If there is moderate aortic regurgitation (AR), then the neoaortic valve is repaired until no to mild AR is achieved. Then, the aorta is sutured, and the heart is de-aired. The patient is then removed from the CPB machine, and cannulations are removed. Drainage tubes are put in place, and the chest wall is closed layer by layer.

Video 1

Procedure of aortic valve replacement with a single strip of autologous pericardium. Online content including video sequences viewable at: https://www.thieme-connect.com/products/ejournals/html/10.1055/a-2111-1217.

Results

There were eight males and eight females. Their mean age was 49.6 ± 12.5 years. Three patients had aortic stenosis (AS), four patients had AR, and nine patients had mixed AS and AR. Infective endocarditis (IE) was observed in two patients. Concomitant procedures included five coronary artery bypass graft (CABG) operations and one left atrial appendage plication. In addition to aortic valve replacement, 12 patients underwent either mitral valve repair or tricuspid valve repair. There were no case of bicuspid aortic valve (BAV). The BAV cannot be replaced with this technique due to its elliptical annulus shape.

Preoperative echocardiography revealed the mean peak pressure gradient (PG) through the aortic valve was 25.7 ± 16.8 mm Hg. The mean aortic root diameter was 25.8 ± 3.2 mm. The baseline of LVEDD, left ventricular end systolic diameter (LVESD), and ejection fraction were 49.1 ± 10.8 mm, 34 ± 11.8 mm, and 61.4 ± 13.4% respectively. Preoperative 6MWT was 309 ± 126.6 m and sST-2 level was 18.3 ± 15.6 pg/mL.

There were no patients who needed to be converted to prosthetic valve replacement. The mean aortic cross-clamp

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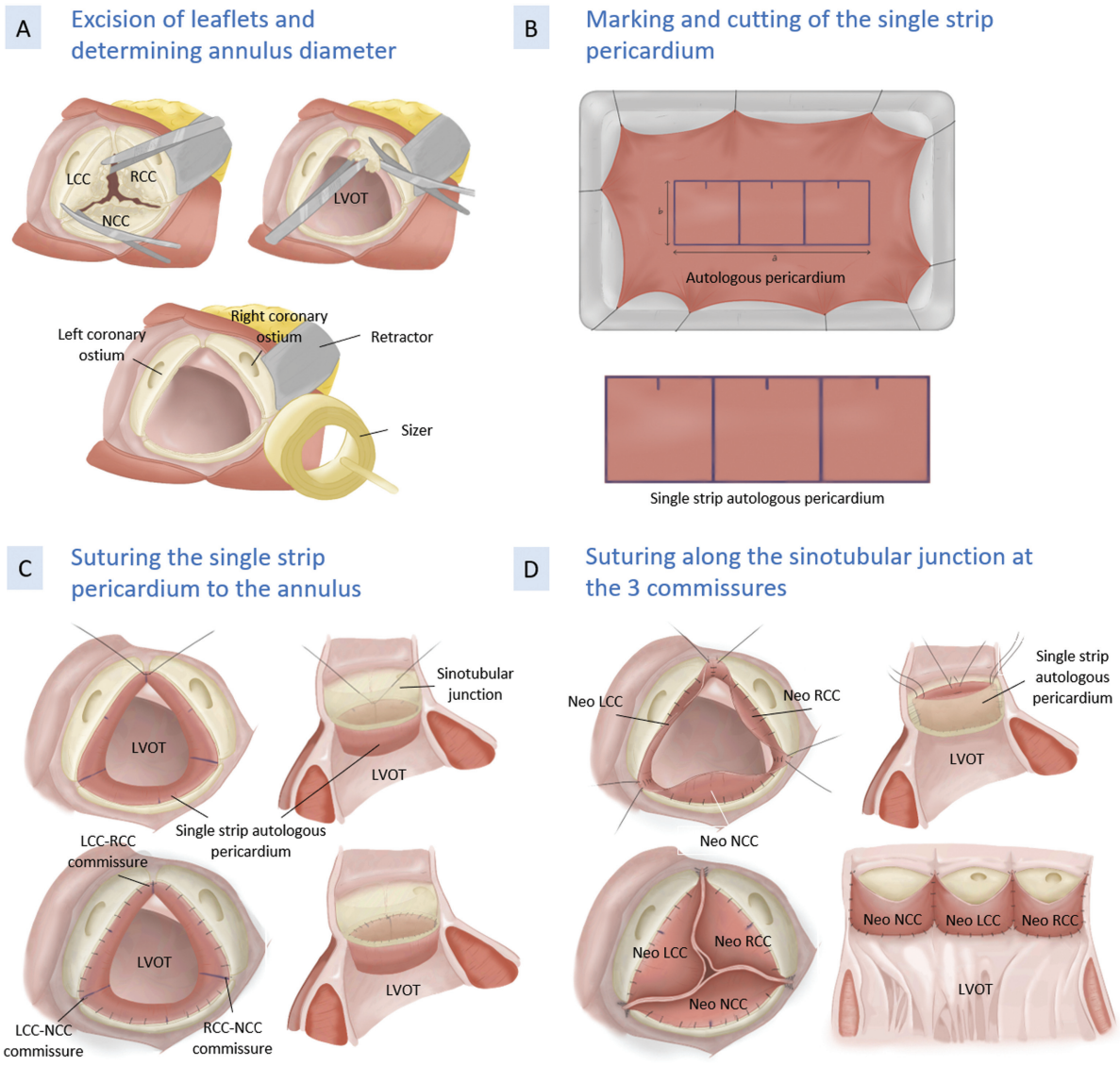

Fig. 1 Procedure of aortic valve replacement with a single strip of autologous pericardium. (**A**) Excision of leaflets and determining the annulus diameter. (**B**) Marking and cutting of the single strip of pericardium. (**C**) Suturing the single strip of pericardium to the annulus. (**D**) Suturing along the sinotubular junction at the three commissures. LCC, left coronary cusp; RCC, right coronary cusp; NCC, non-coronary cusp; LVOT, left ventricular outflow tract.

time was 139.9 ± 23.2 minutes and CPB time was 174.4 ± 33.5 minutes. In patients with isolated aortic valve replacement, the aortic cross-clamp time was 102 minutes and the CPB time was 123 minutes. There was no in-hospital death with cardiac or noncardiac causes. There was also no embolic event recorded in all the patients. The newly created aortic valves had a mean coaptation height at 5.27 (SD: 1.01) mm and effective height at 11.83 (SD: 0.82) mm.

At 6 months of follow-up, the mean PG through the aortic valve decreased significantly to 11.7 ± 6.5 mm Hg ($p = 0.007$). The 6-month LVEDD, LVESD, and EF, respectively, changed to 48.2 ± 4.5 mm ($p = 0.673$), 31.5 ± 4.2 mm ($p = 0.605$), and 59.5 ± 6.3% ($p = 0.179$). The rate of LVRR at 6 months was 12.5%. Four patients had moderate AR, six patients had mild AR, and six patients had no AR. The 6MWT distance significantly increased to 431.9 ± 93.4 m ($p = 0.006$), while sST-2 level decreased to 11.5 ± 7 pg/mL ($p = 0.063$). At 1 year of follow-up, survival and freedom from reoperation were 100%.

Discussion

The single-strip autologous pericardium technique is performed by creating three symmetric aortic valve leaflets without the need to measure the size of each leaflet, making this technique easy to perform. For isolated aortic valve repair, the single-strip pericardium technique had a similar or shorter aortic cross-clamp time and CPB time compared to previous studies by Ozaki et al[1] who reported a mean aortic cross-clamp time of 110.1 ± 26 minutes with mean CPB time of 149 ± 29.9 minutes and Duran et al,[5] who reported a mean aortic cross-clamp time of 110.1 ± 26 minutes with a mean CPB time of 149 ± 29.9 minutes. Based on a study by Iino et al,[6] the length

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of the duration of the aortic cross-clamp time is an independent predictor of postoperative morbidity and mortality after aortic valve replacement in AS. The mortality risk is increased along with an increment in aortic cross-clamp time. The cutoff duration is >150 minutes (odds ratio [OR]: 2.68; 95% confidence interval [CI]: 1.66–4.32; $p < 0.001$).[6] Meanwhile, the study by Chalmers et al[7] showed that the CPB time was significantly associated with mediastinal blood loss ($p < 0.001$), duration of intensive care unit (ICU) stays ($p = 0.01$), postoperative length of stays ($p < 0.001$), and in-hospital mortality (OR: 1.02; 95% CI: 1.01–1.04; $p = 0.01$).

The newly created aortic valves had a mean coaptation height of 5.27 (SD: 1.01) mm and effective height of 11.83 (SD: 0.82) mm. Aortic valve replacement is considered a success if the coaptation height is greater than 4 mm and the effective height is greater than 10 mm. Coaptation height less than 4 mm increased the risk of recurrent aortic valve regurgitation by 40 and >70% if it is lower than the aortic annulus.[8]

At 6 months postoperation, we found a significant decrease of mean PG through the aortic valve and significant increase of 6MWT distance. The results of this study are in line with the results of the study by Straiton et al,[9] which assessed the functional capacity and quality of life of patients after transcatheter aortic valve replacement. The study showed an increase in 6MWT distance of 41.48 m (95% CI: 9.69–73.28; $p = 0.01$) after transcatheter aortic valve replacement. Currently, there are no studies comparing functional capacity before and after aortic valve replacement with autologous pericardium.

The level of sST-2 also decreased at 6 months postoperation with an LVRR incidence of 25%. Lupón et al[10] reported that the sST-2 level was an independent predictor of reverse remodeling and clinical variables. LVRR is mostly observed at 1 to 2 years postoperation. There is a high chance that the incidence of LVRR will increase with longer follow-up period.

One known predictor factor for long-term aortic valve repair failure is aorto-ventricular dilatation. Schäfers[11] reported that suture annuloplasty with Ethibond and polytetrafluoroethylene Gore-Tex significantly improved patient's outcomes compared to those without annuloplasty, especially in bicuspid valve cases. Continuous suture of the single-strip pericardium to the aortic annulus automatedly creates a suture annuloplasty that can prevent aorto-ventricular dilatation. Annuloplasty created with the single-strip pericardium technique is expected to prevent aorto-ventricular dilatation and increase valve durability.

We reported a new aortic valve replacement technique using single-strip autologous pericardium with good hemodynamic and clinical outcomes. It is a feasible alternative to aortic valve replacement, especially in limited resources country like Indonesia.

Authors' Contribution

I.D., J.R., I.P., I.A., S.S., S., I.K.L., M.S., A.A.J., and W.M. contributed to conception and design of the work. Data collection was done by I.D., W.M., I.T., and S.M. Analysis and interpretation of the data were done by I.D., I.A., S.S., S., I.K.L., M.S., A.A.J., W.M., I.T., and S.M. Statistical analysis was performed by I.D., J.R., I.P., I.A., S.S., S., I.K.L., M.S., A.A.J., W.M., I.T., and S.M. Drafting the manuscript was done by I.D., J.R., I.P., S.S., S., I.K.L., M.S., A.A.J., W.M., I.T., and S.M. Critical revision of the manuscript was done by I.D., J.R., I.P., and I.A.

Conflict of Interest

None declared.

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