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ORIGINAL ARTICLE

Anterior longitudinal aortotomy in aortic valve replacement

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Abstract

Objectives We adopted an anterior longitudinal aortotomy in some cases of aortic valve replacement (AVR), and report them here. The potential of this method is also discussed.

Methods We analyzed the data on 24 patients (75.5 ± 7.8 years of age) who had undergone AVR through anterior longitudinal aortotomy. The indications for surgery were prosthetic valve complication in 5 patients, aortic stenosis (AS) with left ventricular outflow tract stenosis (LVOTS) in 16 patients, and aortic regurgitation with moderately dilated ascending aorta in 3 patients. The Konno procedure was performed in 6 cases with small aortic annuli. A longitudinal aortotomy was made at the aortic root along the left side of the right coronary ostium, and extended beyond the right coronary annulus to the interventricular septum as needed.

Results Bioprostheses (21.1 ± 1.7 mm) were used in 23 patients and a 21-mm mechanical valve for one (a 59-year-old man). One high-risk patient died of low output syndrome, leading to a mortality rate of 4.2 %. All other patients recovered well, though atrioventricular block occurred in 2 cases.

Conclusions Anterior longitudinal aortotomy provides a good field of vision at the aortic annulus and the flexibility to develop into anterior annular enlargement. Major indications for this approach are small sino-tubular junction and very small aortic annulus. This approach could be an attractive option in AVR for cases of AS with small aortic annuli and LVOTS. It could also be useful for AVR cases with moderately dilated ascending aorta requiring aortoplasty.

Keywords Anterior longitudinal aortotomy · Aortic valve replacement · Konno procedure · Small aortic annulus · Left ventricular outflow tract stenosis

Introduction

When performing aortic valve replacement (AVR) in Japan, we sometimes encounter patients with small aortic annuli, especially among elderly women (who are often quite small in size). In one such case we were able to successfully treat a patient using the Konno procedure 7 years after AVR with the Nicks procedure [1]. The Konno procedure is an anterior aortic annular enlargement technique which is commonly applied in cases of aortic stenosis (AS) with small aortic annuli and left ventricular outflow tract stenosis (LVOTS) [2–5]. In the cases mentioned above, a good field of vision at the aortic annulus was obtained through an anterior longitudinal aortotomy of the aortic root. We have gradually been increasing our application of this approach in redo AVR without the Konno procedure, and also in first-time AVR with and without the Konno procedure. We hereby report such cases in which acceptable results were obtained, and discuss the potential of this aortotomy in AVR.

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Patients and methods

We analyzed the data on 24 patients (8 men and 16 women) who had undergone AVR through an anterior longitudinal aortotomy at our institution between July 2012 and August 2014. The indications for surgery were prosthetic valve complication in 5 patients, AS with LVOTS in 16 patients, and aortic regurgitation (AR) with moderately dilated ascending aorta in 3 patients. Data were obtained by retrospectively reviewing medical records and operative reports. The age range was from 59 to 86 years (mean 75.5 ± 7.8 years). All patients were Japanese with a mean height of 154 ± 8.7 cm, a mean weight of 55.7 ± 11.1 kg, and a mean body surface area (BSA) of 1.49 ± 0.18 m^2.

The patients are listed in Table 1. The first two cases (Nos. 1 and 2) suffered from mechanical valve dysfunction. The Konno procedure had to be used in these cases because of the very small aortic annuli involved in redo AVR. In the next 4 cases (Nos. 3–6), we performed AVR through an anterior longitudinal aortotomy in order to obtain a good field of vision at the aortic annulus under re-sternotomy. Two of them (Nos. 3 and 5) needed patch repair of the aortic annuli because of subannular abscesses due to prosthetic valve endocarditis (PVE). In 4 other cases (Nos. 7–10), the Konno procedure was used for AS with small aortic annuli and asymmetric septal hypertrophy (ASH), a kind of LVOTS. In the next 14 cases (Nos. 11–24), we performed AVR with an anterior longitudinal aortotomy right from the start. Their diagnoses were AS with LVOTS (ASH or hypertrophic obstructive cardiomyopathy) in 11 cases (Nos. 11–21) and AR with moderately dilated ascending aorta in 3 cases (Nos. 22–24). The aortic diameters in these 3 patients were 41, 47 and 48 mm, respectively. Concomitant coronary artery bypass grafting (CABG) was applied in 2 cases (Nos. 13 and 14) and ventricular septal myectomy was applied in 1 case (No. 17). One of the former (No. 13) needed a patch repair of the aortic wall because of a calcified aorta. There was one high-risk patient (No. 14) with a left ventricular ejection fraction (LVEF) of 26 %, who had suffered from chronic renal failure requiring dialysis and ischemic heart disease requiring CABG.

Aortic valve diameter (AVD) was measured in a parasternal long-axis view at rest by 2-dimensional transthoracic echocardiography. LVEF was estimated according to Simpson's rule. The aortic diameter (AoD) of the ascending aorta was measured at 2 cm above the sinotubular junction by computed tomography. The peak transvalvular velocity was estimated at rest using Doppler echocardiography from an apical view. The mean aortic transvalvular gradient was measured using continuous-wave Doppler velocity spectra from a transducer position that yielded peak velocity across the prosthesis and was calculated by the modified Bernoulli equation. The measurements are presented as numbers or percentages for each case in Table 1.

Surgical procedures

Following median sternotomy and pericardiotomy, direct epicardial echocardiography was used for verifying actual positions of the right coronary artery (RCA) and the pulmonary valve. We established cardiopulmonary bypass (CPB) with ascending aortic perfusion or arterial perfusion via the femoral artery and with bicaval drainage. A left ventricular venting tube was inserted through the right upper pulmonary vein. After clamping the ascending aorta under ventricular fibrillation, the heart was arrested by antegrade cardioplegia via a root cannula. Then a longitudinal aortotomy (Fig. 1) was performed at the anterior wall of the aortic root, about 10 mm along the left side of the RCA ostium, toward the commissure between the right and left coronary leaflets. This type of anterior longitudinal aortotomy provided a good field of vision at the aortic annulus (Fig. 2). In the cases of AR, aortotomy was performed first and then myocardial protection was achieved with selective cardioplegia. After the initial injection, myocardial protection was maintained with intermittent retrograde and antegrade cardioplegia during cardiac arrest.

AVR was carried out using conventional methods through anterior longitudinal aortotomy. When annular enlargement was needed, an aortotomy was extended beyond the right coronary annulus between the RCA ostium and the left-sided commissure. The incision was then further extended by about 20 mm to the interventricular septum, and also to the right ventricular outflow tract (Fig. 1). In order to enlarge the aortic annulus, we used a three-layer patch made with a Dacron patch sandwiched between two sheets of bovine pericardium. This composite patch was trimmed into the shape of a teardrop (approximately 25 × 60 mm), and its bottom half was sutured to the incised septum. A proper sized prosthesis was then implanted onto the reconstructed aortic annulus (Fig. 3). The outer bovine pericardium of the top half was used to close the right ventricle. Both the Dacron patch and the inner bovine pericardium were used together to close the aorta, or to repair the aortic root, if necessary. In AVR without the Konno procedure, the aortotomy was closed directly. In patients with a dilated ascending aorta, the aortotomy was sewed up with large margins to reduce the aortic diameter.

Mean operating time was 378 ± 110 min, mean CPB time was 207 ± 56 min, and mean aortic cross-clamp time was 153 ± 42 min.

Table 1 Perioperative clinical data and measurements of the patients

No	Age (years)	Sex	Diagnosis	BSA (m²)	AVD (mm)	AoD (mm)	Pre-op EF (%)	Surgical procedure	Prosthesis (mm)		EOAI (cm²/m²)	Post-op EF (%)	PeakV (m/s)	MeanPG (mmHg)	Major complication	Hospital stay (days)	Outcome
1	79	F	Stuck valve	1.33	17	30	58	Redo AVR with the Konno	Mosaic	19	0.90	60	1.83	8		27	Alive
2	77	M	Paravalvular leakage	1.69	20	30	69	Redo AVR with the Konno	Magna	23	1.07	77	2.06	7	A-V block	30	Alive
3	59	M	PVE	1.75	22	33	67	Redo AVR, annulus repair	Regent	21	1.66	58	2.61	12		68	Alive
4	80	F	SVD	1.18	13	36	67	Redo AVR	Trifecta	19	1.18	65	1.81	12		24	Alive
5	76	M	PVE	1.74	19	42	45	Redo AVR, annulus repair	Magna	21	0.86	45	3.47	27		40	Alive
6	83	F	AS post-CABG	1.32	18	31	55	AVR under re-sternotomy	Trifecta	19	1.06	61	1.60	5		23	Alive
7	70	F	AS	1.60	20	37	75	AVR with the Konno	Magna	23	1.13	70	1.99	9		17	Alive
8	83	M	AS	1.56	18	32	69	AVR with the Konno	Magna	23	1.15	83	1.47	4		18	Alive
9	80	F	AS	1.34	17	26	72	AVR with the Konno	Magna	19	0.97	64	2.55	13		21	Alive
10	70	F	AS	1.63	20	27	63	AVR with the Konno	Magna	21	0.92	81	2.62	14		13	Alive
11	71	F	AS, calc. aorta	1.28	24	36	78	AVR, aortoplasty	Trifecta	23	1.41	61	2.54	11	A-V block	24	Alive
12	84	F	AS	1.55	20	41	75	AVR	Trifecta	21	1.04	76	2.27	9		18	Alive
13	75	M	AS, AP, calc. aorta	1.63	21	31	65	AVR, CABG, aortoplasty	Trifecta	21	0.98	55	1.87	8		16	Alive
14	69	F	AS, OMI, PH, CRF	1.31	22	34	26	AVR, CABG	Trifecta	21	1.23				LOS	2	Dead
15	79	F	AS, OMI, post-CEA	1.54	18	34	82	AVR	Trifecta	19	0.91	75	2.30	13		17	Alive
16	83	F	AS, CKD, calc. aorta	1.41	20	37	66	AVR	Trifecta	19	0.99	64	2.10	8		45	Alive
17	69	F	AS, HOCM	1.43	22	42	70	AVR, septal myectomy	Trifecta	21	1.12	65	2.27	11		17	Alive
18	86	F	AS	1.14	23	37	72	AVR	Magna	19	1.14	81	3.05	16		20	Alive
19	82	F	AS	1.36	19	43	71	AVR	Trifecta	21	1.18	55	2.22	11		24	Alive

Table 1 continued

No	Age (years)	Sex	Diagnosis	BSA (m²)	AVD (mm)	AoD (mm)	Pre-op EF (%)	Surgical procedure	Prosthesis (mm)	EOAI (cm²/m²)	Post-op EF (%)	PeakV (m/s)	MeanPG (mmHg)	Major complication	Hospital stay (days)	Outcome
20	83	F	AS	1.42	20	37	66	AVR	Trifecta 21	1.13	67	2.01	7		26	Alive
21	79	M	AS	1.67	20	35	79	AVR	Trifecta 21	0.96	79	1.70	6		19	Alive
22	74	M	AR	1.63	21	41	60	AVR	Magna 23	1.10	54	3.20	18		14	Alive
23	63	M	AR	1.56	27	47	50	AVR	Magna 25	1.35	50	2.36	12		27	Alive
24	59	F	AR	1.66	23	48	50	AVR	Magna 23	1.09	56	2.72	19		16	Alive
Mean	75.5			1.49	20.2	36.1	64.6		21.1	1.11	65.3	2.29	11.3		23.6	
SD	7.8			0.18	2.8	5.8	12.5		1.7	0.18	10.8	0.51	5.2		12.8	

BSA body surface area, *AVD* aortic valve diameter, *AoD* aortic diameter of the ascending aorta, *EF* ejection fraction, *EOAI* effective orifice area index, *PVE* prosthetic valve endocarditis, *SVD* structural valve deterioration, *AS* aortic stenosis, *AP* angina pectoris, *OMI* old myocardial infarction, *PH* pulmonary hypertension, *CRF* chronic renal failure, *CEA* carotid endoarterectomy, *CKD* chronic kidney disease, *HOCM* hypertrophic obstructive cardiomyopathy, *AR* aortic regurgitation, *AVR* aortic valve replacement, *CABG* coronary artery bypass grafting, *Mosaic* Medtronic Mosaic bioprosthesis (Medtronic Inc, Minneapolis, MN, USA), *Magna* Carpentier–Edwards Perimount Magna bioprosthesis (Edwards lifesciences Corp, Irvine, CA, USA), *Regent* St Jude Medical Regent mechanical prosthesis, *Trifecta* St Jude Medical Trifecta bioprosthesis (St Jude Medical Inc, St Paul, MN, USA), *PeakV* peak transvalvular velocity, *MeanPG* mean pressure gradient, *A–V block* atrioventricular block, *LOS* low output syndrome
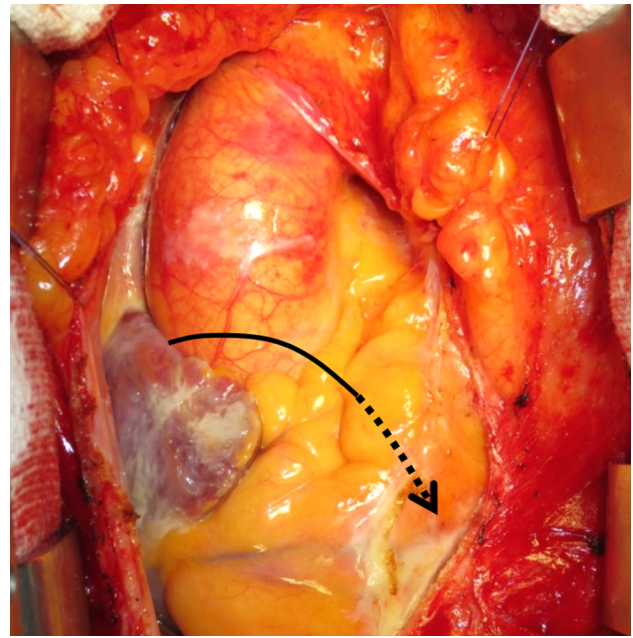
Fig. 1 A longitudinal aortotomy was made at the anterior wall of the aortic root toward the commissure between the right and left coronary leaflets. When aortic annular enlargement was needed, a longitudinal aortotomy was extended beyond the right coronary annulus and further extended to the interventricular septum
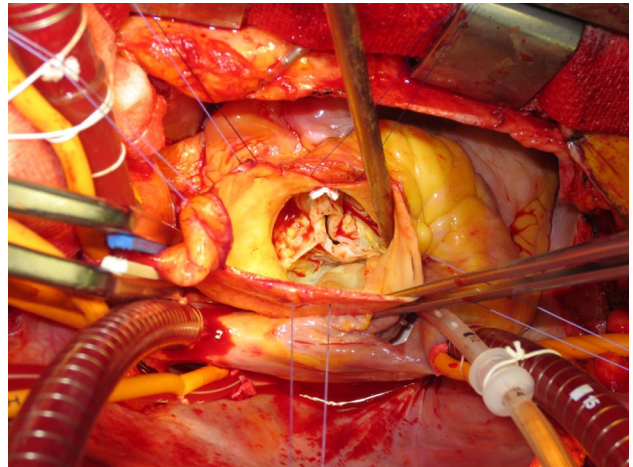

Fig. 2 An anterior longitudinal aortotomy provided a good field of vision at the aortic annulus

Results

Among the present cases, the Konno procedure was applied to 4 first-time AVRs and 2 redo cases. We used bioprostheses of 21.1 ± 1.7 mm in diameter for 23 patients, and implanted a 21-mm mechanical prosthesis in a 59-year-old man with PVE (Table 1). Bioprostheses with effective orifice area indexes (EOAI) of 0.85 cm²/m² or more were implanted in all patients 70 years or older. As
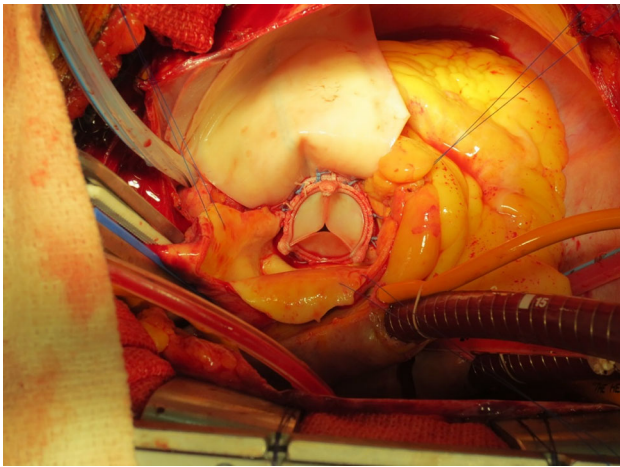
Fig. 3 A bioprosthesis was implanted onto the aortic annulus, reconstructed using the Konno procedure

for patients younger than that, prostheses with EOAI of 1.0 cm^2/m^2 or more were used for all. Actually implanted valve sizes (21.1 ± 1.7 mm) were slightly larger than preoperative AVD (20.2 ± 2.8 mm) as estimated by echocardiography. There was no difference between preoperative LVEF (64.6 ± 12.5 %) and post-operative LVEF (65.3 ± 10.8 %). The post-operative peak transvalvular velocity and mean pressure gradient of the implanted prostheses were 2.29 ± 0.51 m/s and 11.3 ± 5.2 mmHg, respectively.

A high-risk patient (No. 14) died of low output syndrome, leading to a mortality rate of 4.2 % in this series. With the inclusion of 2 PVE cases treated for about 6 weeks with antibiotics, mean post-operative hospital stay was 23.6 ± 12.8 days. Atrioventricular block (A-V block) occurred in 2 cases, one of which had undergone redo AVR with the Konno procedure. In another case, a patch repair of the aortic root had been performed around the RCA ostium. Both these patients were provided with permanent pacemakers and recovered well thereafter. There was no post-operative bleeding requiring re-exploration, stroke, or deep sternal infection. Blood transfusion was required in 67 % of the reported cases. New atrial fibrillation occurred postoperatively in 33 % of the cases, all of which resulted in complete recovery within hospitalization.

Discussion

At first, anterior longitudinal aortotomy was adopted only for high-risk AVR cases of redo surgery with the Konno procedure [1]. Next, this approach was further applied to cases of redo AVR without the Konno procedure, or first-time AVR with the Konno procedure. And then, it was used in standard AVRs for AS with LVOTS. Furthermore,

we applied this method to a few cases of AR complicated by moderately dilated ascending aorta. As a result, there were many complicated cases in our early series. One patient died of low output syndrome, which led to the relatively high mortality (4.2 %). This patient had suffered from severe AS with very low cardiac function, pulmonary hypertension, chronic renal failure and ischemic cardiomyopathy. Therefore, anterior longitudinal aortotomy is not believed to have influenced this patient's prognosis. Including the cases presented here, operative mortality of isolated AVR at our institution was 2.1 % between 2010 and 2014. This result was acceptable and encouraged us to further investigate the potential of this approach.

The method provided a good field of vision at the aortic annulus by opening the sino-tubular junction from the front. In particular, it was helpful when strong adhesion remained around the aortic root [1], when the sino-tubular junction was very small, or when a small aortic annulus had squeezed the aortic valve [2]. If necessary, anterior annular enlargement techniques such as the Konno procedure could be added through the same aortotomy. A 20-mm interventricular incision made the aortic annulus wide enough for prostheses two sizes larger than the original valves [6]. Furthermore, the level of annular enlargement and surgical invasion could be regulated by modifying the extent of the interventricular incision [7]. Our purpose with the Konno procedure was not greater enlargement of the aortic annulus as it would be in pediatric cases. A one or two valve-size increase was sufficient for our reported cases with the Konno procedure. In a few recent cases, invasive damage could be reduced by making a non-transmural incision within the left ventricular side of the septum. In short, this type of aortotomy makes it possible to modify the range of annular enlargement from a zero to three size increase, as needed. Alternatively, the aortotomy can be sewed up with large margins in order to make the ascending aorta smaller than before. An AoD reduction of 2.4 mm was achieved in this series, except for the cases in which the Konno procedure was applied. Though the effectiveness of our procedure was not significant, anterior longitudinal aortotomy would be useful in cases of moderately dilated ascending aorta. If necessary, reduction aortoplasty can be performed by resecting a strip of the aortic wall along this aortotomy. Some studies have shown that this type of aortoplasty during cardiac surgery is a safe and attractive option for moderately dilated ascending aorta associated with aortic valve disease [8–10]. However, surgical indication of this procedure depends on the morphology and histology of the dilated aorta [9]. For example, this procedure is not suitable for treating severe aortic dilatation larger than 55 mm in diameter or aortic root lesions such as annuloaortic ectasia. Another limitation is that the potential risk of re-dilatation of the ascending aorta remains.

There are some disadvantages associated with this method. First, special attention must be paid so as not to interfere with the RCA because the anterior longitudinal aortotomy passes near the RCA ostium. When the Konno procedure is applied, there is concern that an extended incision into the interventricular septum might lead to A-V block or pulmonary valve dysfunction [3]. In fact, we experienced A-V block after the Konno procedure in case No. 2. Intraoperative epicardial echocardiography is a useful option for detecting the exact sites of the RCA ostium and the pulmonary valve. Once the ascending aorta is opened safely, a direct look at the RCA ostium contributes to the prevention of RCA injury. In order to prevent conduction block, an incision should not be extended beyond the nadir of the right coronary annulus to the right side of the interventricular septum [4]. Next, the aortotomy must be modified when a large amount of calcification occupies the anterior wall of the ascending aorta. In case No. 13, a huge calcified plate was completely removed and the aortic root was repaired using a composite patch.

Transverse or oblique aortotomy is commonly used in AVR, but anterior longitudinal aortotomy is almost exclusively limited to cases involving the Konno procedure. In regard to the field of vision at the left ventricular outflow tract, oblique aortotomy is inferior to the others. In cases with a small sino-tubular junction, great exposure of the aortic valve can be obtained by a longitudinal aortotomy. In regard to the flexibility allowing for development into annular enlargement, transverse aortotomy poses greater difficulty than the others. Anterior longitudinal aortotomy is advantageous at these points in cases with small aortic annuli and LVOTS. Furthermore, this method is the only aortotomy which can develop into aortoplasty for dilated ascending aorta. As for aortic annular enlargement, the Konno procedure provides a greater enlargement ratio than the Nicks or Manouguian procedures [6]. Despite concern regarding related complications, some studies have reported good long-term results with the Konno procedure [3, 4]. The Nicks procedure is less invasive, but the enlargement ratio is the smallest. With the Manouguian procedure, there is concern regarding mitral valve dysfunction. Above all, posterior enlargement procedures are ineffective against LVOTS like ASH which is sometimes encountered in AVR for patients with AS. The Konno procedure is suitable for such cases complicated with small aortic annuli [2–5].

Though further investigation is needed, anterior longitudinal aortotomy might become one of the effective options in AVR. The indications for which this approach would be very useful are small sino-tubular junction and very small aortic annulus. We are currently applying this approach as a standard procedure in AVR for cases of AS with small aortic annuli and LVOTS. This approach could also be an attractive option for AVR cases with moderately dilated ascending aorta requiring concomitant aortoplasty.

Conclusion

Anterior longitudinal aortotomy is advantageous in providing a good field of vision at the aortic annulus, and also has the flexibility to develop into anterior annular enlargement. Major indications of this approach are small sino-tubular junction and very small aortic annulus. Though further investigation is needed, this approach could be an attractive option in AVR for cases of AS with small aortic annuli and LVOTS. It could also be useful for AVR cases with moderately dilated ascending aorta requiring aortoplasty.

References

1. Matsuzaki K, Kudo Y, Ikeda A, Konishi T, Jikuya T, Hiramatsu Y. The Konno procedure in redo aortic valve replacement after the Nicks procedure. J Heart Valve Dis. 2015;24:1–3.
2. Misumi H, Katayama Y, Takaji K, Oshitomi T, Uesugi H, Hirayama T, et al. Use of the Konno procedure in an 80-year-old woman with aortic stenosis, a narrow left ventricular outflow tract, and a small aortic annulus. Ann Thorac Cardiovasc Surg. 2013. doi:10.5761/atcs.cr.12.02199.
3. Suri RM, Dearani JA, Schaff HV, Danielson GK, Puga FJ. Long-term results of the Konno procedure for complex left ventricular outflow tract obstruction. J Thorac Cardiovasc Surg. 2006;132:1064–71.
4. Sakamoto T, Matsumura G, Kosaka Y, Iwata Y, Yamamoto N, Saito S, et al. Long-term results of Konno procedure for complex left ventricular outflow tract obstruction. Eur J Cardiothorac Surg. 2008;34:37–41.
5. Takahashi Y, Hanzawa Y. Modified Konno procedure: surgical management of tunnel-like left ventricular outflow tract stenosis. Gen Thorac Cardiovasc Surg. 2014;62:3–8.
6. Konno S, Imai Y, Iida Y, Nakajima M, Tatsuno K. A new method for prosthetic valve replacement in congenital aortic stenosis associated with hypoplasia of the aortic valve ring. J Thorac Cardiovasc Surg. 1975;70:909–17.
7. Yamaguchi M, Ohashi H, Imai M, Oshima Y, Hosokawa Y. Bilateral enlargement of the aortic valve ring for valve replacement in children. J Thorac Cardiovasc Surg. 1991;102:202–6.
8. Kamada T, Imanaka K, Ohuchi H, Asano H, Tanabe H, Kato M, et al. Mid-term results of aortoplasty for dilated ascending aorta associated with aortic valve disease. Ann Thorac Cardiovasc Surg. 2003;9:253–6.
9. Gill M, Dunning J. Is reduction aortoplasty (with or without external wrap) an acceptable alternative to replacement of the dilated ascending aorta? Interact Cardiovasc Thorac Surg. 2009;9:693–7.
10. Kiessling AH, Odwody E, Miskovic A, Stock UA, Zierer A, Moritz A. Midterm follow up in patients with reduction ascending aortoplasty. J Cardiothorac Surg. 2014;9:120. doi:10.1186/1749-8090-9-120.