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ORIGINAL ARTICLE

External suture annuloplasty for mild to moderate and moderate aortic regurgitation due to an isolated type Ic lesion

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Abstract

Objective Whether mild to moderate and moderate aortic regurgitation should be corrected surgically during other cardiovascular surgeries remains controversial. We evaluated the effectiveness of external suture annuloplasty in such cases.

Methods Among 95 patients undergoing aortic valve repair between December 2013 and March 2018, five patients with mild to moderate and moderate aortic regurgitation due to aortic annulus dilatation (type Ic lesion) underwent surgery for mitral regurgitation and/or thoracic aortic aneurysm. Aortic valves were repaired with external suture annuloplasty alone with a mean Hegar dilator size of 20.4 ± 0.8 (20.0–22.0) mm at the same time and were followed up echocardiographically.

Results There were no cases of mortality or major morbidity. Intraoperative direct measurement revealed ventriculoaortic junction size of 25.0 ± 0.8 (24.0–27.0) mm. The average cardiopulmonary bypass time and aortic cross-clamping time were 139 ± 46 (76–205) min and 105 ± 38 (58–172) min, respectively. Postoperative transthoracic echocardiogram during hospitalization showed trivial aortic regurgitation in all cases, with average ventriculoaortic junction size, aortic valve area, and peak and mean transvalvular gradient of 19.1 ± 0.7 (18.0–20.3) mm, 2.24 ± 0.48 (1.60–3.00) cm^2, 6.4 ± 1.9 (4.0–9.2) mmHg, and 3.5 ± 1.1 (2.1–5.2) mmHg, respectively. Ventriculoaortic junction size was significantly decreased ($P < 0.05$). There have been no changes in ventriculoaortic junction size ($P = 0.32$) or other echocardiographic findings for 24 ± 6 (17–36) months after surgery.

Conclusions Although concomitant with other cardiac surgeries, mild to moderate and moderate aortic regurgitation could be repaired without clinically relevant additional surgical duration. External suture annuloplasty is a useful, safe, and secure treatment choice for type Ic lesion-induced aortic regurgitation.

Keywords Aortic regurgitation · Complex surgery · External suture annuloplasty · Aortic valvuloplasty · Ventriculoaortic junction size

Introduction

Whether mild to moderate and moderate aortic regurgitation (AR) should be corrected surgically in patients undergoing operations for mitral regurgitation (MR) or thoracic aortic aneurysm (TAA) is controversial. Although mitral valvuloplasty (MVP) is the first-choice surgical treatment for MR, aortic valve replacement (AVR) is widely accepted for AR [1]. However, many surgeons hesitate to perform AVR for mild to moderate and moderate AR. Therefore, aortic valvuloplasty (AVP) may be considered in such cases [2]. Despite recent advances in AVP, this method is technically demanding and has a relatively long learning curve [3]. There is still debate regarding indications for AVP at the time of complex cardiovascular surgery as there is no evidence regarding

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valve durability after AVP and there is increased operative risk [4]. However, in cases where aortic annular dilatation is the main cause of AR (i.e., type Ic lesion) [5], AR could be managed by aortic annuloplasty alone without additional cusp procedures. While prosthesis-related complications and risk of reoperation have been highlighted [6, 7], AVR for mild to moderate and moderate AR with near-normal aortic cusps may not be justified, especially in cases with simultaneous MVP.

Among several annuloplasty techniques [8], we apply external suture annuloplasty (ESA) in such cases because it is the simplest procedure.

The present study was performed to evaluate the effectiveness of ESA for mild to moderate and moderate type Ic AR during concomitant cardiovascular surgery.

Materials and methods

Ninety-five patients underwent AVP between December 2013 and March 2018. Five patients [3 men, 69 ± 4 (63–74) years old; body surface area, 1.61 ± 0.18 (1.37–1.90) m^2] with mild to moderate and moderate AR underwent surgery for MR and/or TAA. Patients with Marfan syndrome, emergency cases, and those with non-tricuspid aortic valve were excluded. The study population consisted of three patients with MR, one with TAA, and one with both MR and TAA. Preoperative transthoracic echocardiography (TTE) revealed mild to moderate and moderate AR in all patients (Table 1). End-diastolic ventriculoaortic junction (VAJ) size was 23.5 ± 2.2 (20.5–27.0) mm in TTE, whereas three-dimensional computed tomography (3D-CT) yielded an estimate of 27.3 ± 3.1 (23.7–32.2) mm.

Statistical analysis

All values are presented as mean ± standard deviation. Differences in parameters measured at different time points were examined by the paired *t* test using SPSS, version 19 (IBM Corp., Armonk, NY). In all analyses, two-sided $P < 0.05$ was taken to indicate statistical significance.

Results

MVP, ascending aorta replacement, and MVP with replacement of the ascending aorta and partial aortic arch were performed in three, one, and one patients, respectively. After careful dissection of the aortic root up to VAJ, ESA was performed using an expanded polytetrafluoroethylene (ePTFE) suture (Gore-Tex CV-0; WL Gore and Associates, Flagstaff, AZ), which was passed deep enough to stabilize the basal ring in the muscular portion through the entire circumference of the outer annular plane and tied around a Hegar dilator (20 or 22 mm in diameter) (Figs. 1, 2). A vascular graft one size larger than the Hegar dilator diameter was used for sinotubular junction (STJ) remodeling in TAA patients. Intraoperative measurement revealed VAJ size of 25.0 ± 0.8 (24.0–27.0) mm. The cusps seemed almost normal in all cases, with geometric height (gH) of 18.3 ± 1.6 (15.0–20.0) mm and effective height (eH) of 8.2 ± 0.4 (8.0–9.0) mm. The minimum gH values in each of the five patients were 20, 19, 17, 15, and 18 mm, respectively. They had sufficient coaptation height (cH) after ESA alone. No cusp procedures were necessary during each operation. Average cardiopulmonary bypass (CPB) time and aortic cross-clamping time (AXC) were 139 ± 46 (76–205) min and 105 ± 38 (range 58–172) min, respectively. The procedural time for ESA was 10 ± 1 (range 7–17) min. Homologous blood transfusion was required in four patients.

There were no cases of mortality or major morbidity, and all patients were discharged on foot. TTE during hospitalization showed trivial AR in all cases, with average VAJ size, aortic valve area, and peak and mean transvalvular gradient of 19.1 ± 0.7 (18.0–20.3) mm, 2.24 ± 0.48 (1.60–3.00) cm^2, 6.4 ± 1.9 (4.0–9.2) mmHg, and 3.5 ± 1.1 (2.1–5.2) mmHg, respectively. VAJ size was significantly decreased after surgery ($P < 0.05$) (Table 1) (Fig. 3).

Follow-up TTE at 24 ± 6 (17–36) months after surgery revealed trivial AR in all cases, with VAJ size, aortic valve area, and peak and mean transvalvular gradient of 19.2 ± 0.8 (18.0–20.3) mm, 2.42 ± 0.33 (2.10–3.00) cm^2, 5.9 ± 1.2 (3.7–7.2) mmHg, and 2.9 ± 0.8 (2.1–4.2) mmHg, respectively. There was no significant difference in VAJ size compared to that at discharge ($P = 0.32$) (Table 1) (Fig. 3).

Discussion

For successful complex cardiovascular surgery, it is necessary to minimize CPB and AXC time. This is more important in double-valve surgery than single-valve surgery [9–12]. The Japanese Association for Thoracic Surgery annual report indicated 30-day and hospital mortality rates of 4.9% and 7.3%, respectively, in concomitant aortic valve and mitral valve surgery cases, whereas these values were only 1.5% and 2.6%, respectively, in isolated mitral valve surgery [4]. The Society of Thoracic Surgeons reported operative mortality rates of 10.2% in double-valve surgery and 5.8% in isolated mitral valve surgery [13]. Surgeons must weigh the risks and benefits of AVP during concomitant cardiac surgery when considering treatment of mild to moderate and moderate AR with nearly intact cusps.

Valve-preserving surgery is an attractive alternative to valve replacement. The benefits of valve-sparing procedures by eliminating life-long anticoagulation (in contrast

Table 1 Baseline characteristics and TTE findings

	Age (years)	Sex	BSA (cm^2)	Concomitant surgery	Preoperative TTE		Intraoperative measurement			Hegar dilator (mm)	Postoperative TTE					Follow-up TTE				
					VAJ size (mm)	AR grade	VAJ size (mm)	Minimum gH (mm)	eH (mm)		VAJ size (mm)	Peak PG (mmHg)	Mean PG (mmHg)	AVA (cm^2)	AR grade	VAJ size (mm)	Peak PG (mmHg)	Mean PG (mmHg)	AVA (cm^2)	AR grade
1	70	M	1.70	MVP, TAP, LAA resection	22.0	Moderate	26.0	20.0	8.0	22	19.0	9.2	5.2	2.2	Trivial	19.0	7.2	4.2	2.1	Trivial
2	74	F	1.47	Ascending aorta replacement	25.0	Moderate	25.0	19.0	8.0	20	19.5	4.0	2.1	3.0	Trivial	19.5	7.0	not applicable	3.0	Trivial
3	66	M	1.64	MVP, TAP	23.2	Moderate	24.0	17.0	9.0	20	18.8	6.3	3.4	1.9	Trivial	18.8	3.7	2.1	2.4	Trivial
4	73	F	1.37	MVP, TAP	20.5	Mild-to-moderate	24.0	15.0	8.0	20	18.0	8.2	4.5	1.6	Trivial	18.0	6.6	2.4	2.1	Trivial
5	63	M	1.90	Ascending aorta replacement, MVP, TAP	27.0	Moderate	26.0	18.0	8.0	20	20.3	4.7	2.5	2.5	Trivial	20.3	5.4	3.0	2.5	Trivial

VAJ size was measured with a Hegar dilator intraoperatively

TTE transthoracic echocardiogram, *BSA* body surface area, *VAJ* ventriculoaortic junction, *AR* aortic regurgitation, *gH* geometric height, *eH* effective height, *PG* pressure gradient, *AVA* aortic valve area, *MVP* mitral valvuloplasty, *TAP* tricuspid annuloplasty, *LAA* left atrial appendage

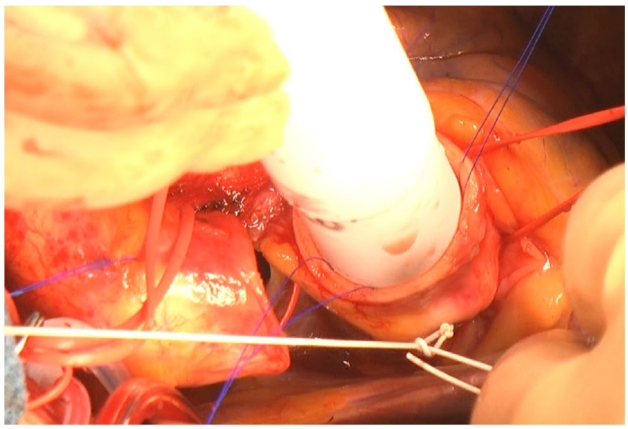

Fig. 1 External suture annuloplasty using an expanded polytetrafluoroethylene suture passed circularly around the outside of the root at the level of the basal ring. The suture was tied after insertion of the Hegar dilator into the annulus

to mechanical valve), improved survival, and reduced major adverse events, including structural valve deterioration, endocarditis, thromboembolism, and hemorrhage, has been emphasized [1, 2]. Despite these advantages of aortic valve-sparing procedures, AVR is still the major treatment of choice for aortic valve disease.

A better understanding of the functional anatomy and development of appropriate selection criteria for cases and techniques are required for standardization of AVP and acceptable valve durability [8, 14–16].

Two recent reports indicated the survival benefit of AVP over AVR [1, 17]. The AHA guideline 2014 recommends AVR for patients with moderate AR undergoing other cardiac surgery (Class IIa) [18]. However, the application of AVP for mild to moderate and moderate AR during concomitant cardiovascular surgery is still controversial. Relatively favorable durability after AVP is anticipated when aortic valve cusps are near normal. Thus, AVP may be justified in such cases.

Several annuloplasty approaches have been proposed for annular size reduction [8]. In AR due to isolated dilatation of the VAJ (i.e., type Ic lesions), annuloplasty is the first choice for AVP [5]. This method can also be applied for type Ia + Ic lesions. For appropriate candidate selection, in addition to TTE, electrocardiogram-gated enhanced computed tomography (CT) with an Aquarius® workstation (TeraRecon, Foster City, CA) and 3D transesophageal echocardiography (TEE) are useful for detailed measurement of root geometry and

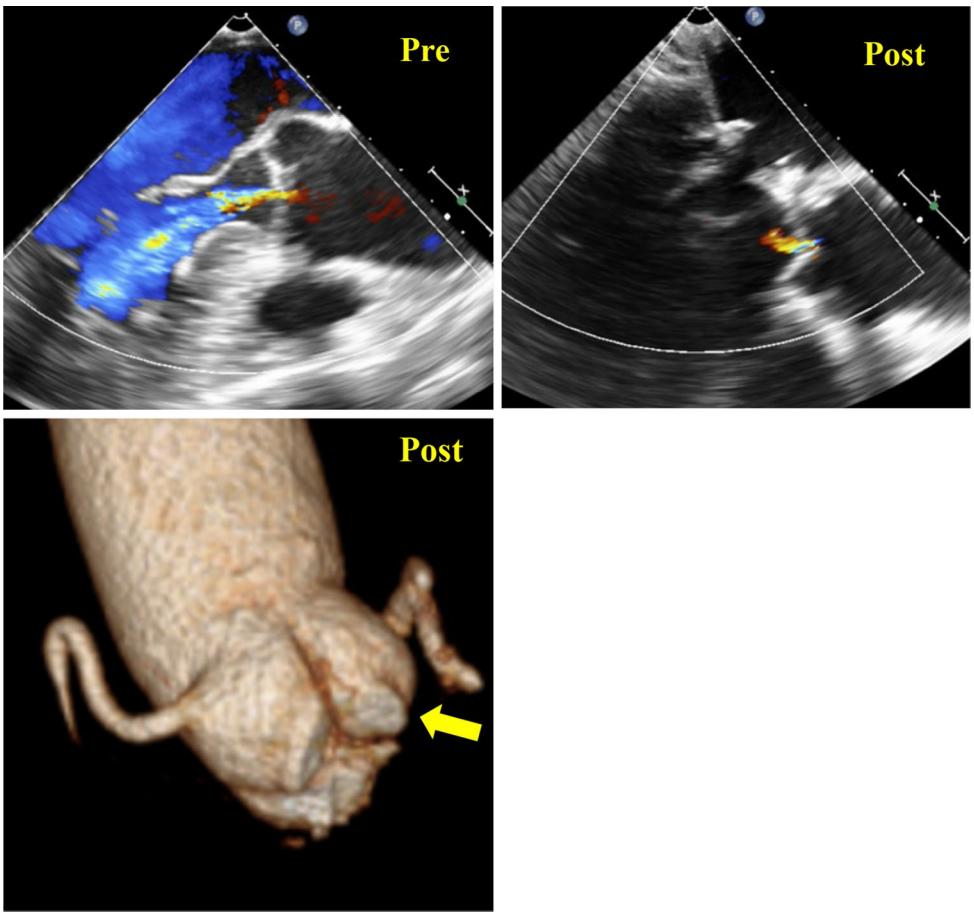

Fig. 2 The echocardiogram showed the reduced ventriculoaortic junction size, sufficient coaptation height, and less aortic regurgitation postoperatively. Postoperative computed tomography revealed the position of the external suture annuloplasty (arrow), which was far from each coronary artery ostium and stabilized the basal ring

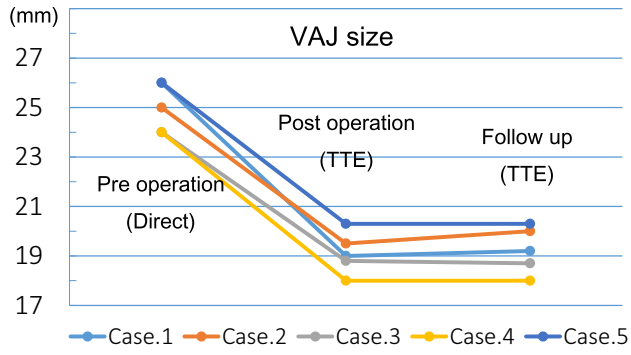

Fig. 3 Time course of VAJ size in each patient. Preoperative VAJ size was examined directly with a Hegar dilator, and was examined postoperatively and at follow-up time points with TTE. *TTE* transthoracic echocardiogram, *VAJ* ventriculoaortic junction

cusp configuration. Intraoperative measurements of VAJ size, gH, and eH are important in decision-making for AVP. Assuming a minimum required eH for AVP of 8 mm [19, 20], minimum gH must be > 15 mm for annuloplasty of 20 mm and > 16 mm for annuloplasty of 22 mm. All of our cases had sufficient gH, which may explain the good outcomes. This information is crucial to success due to time limitations of procedures for aortic valve disease with other concomitant cardiac surgeries.

The target VAJ size for annuloplasty is determined from the normal aortic valve annulus diameter defined according to body surface area (BSA) [21] for conventional AVP. The target VAJ size is the same or one size smaller for patients undergoing annuloplasty alone. The Hegar dilator diameter for ESA was 20 and 22 mm in four and one cases in our series, respectively, which were within the range of the normal aortic valve annulus diameter according to BSA [21] (Table 1). Indeed, there were no significant issues in transvalvular pressure gradient after surgery.

One of the most important advantages of ESA compared to other annuloplasty techniques is its simplicity [22]. This method requires less root dissection compared to the other procedures, such as external ring annuloplasty, which requires dissection until the basal ring. Therefore, ESA does not excessively prolong myocardial ischemia time, and can be repeated to further reduce annulus size and obtain a greater coaptation depth. In cases with conversion to AVR after failed AVP, this method can be reversed easily without increased risk of bleeding and providing adequate VAJ size for prosthesis implantation.

The second advantage of ESA is that it allows reduction of the VAJ diameter evenly maintaining the preoperative natural VAJ configuration [8, 23]. This seems reasonable because other parts of the aortic root are not pathologically altered.

The third advantage is that postoperative VAJ size can be predicted accurately according to the Hegar dilator size, which is not true for external ring annuloplasty or aortic valve reimplantation because human root base thickness varies from 3.3 to 6.2 mm at the right coronary sinus [8, 22]. In fact, postoperative VAJ size in our series was 19.1 ± 0.7 (18.0–20.3) mm after ESA with mean Hegar dilator size of 20.4 ± 0.8 (20.0–22.0) mm. The success of AVP depends on precise measurement of VAJ size and gH, which also influence postoperative valve durability.

This study had some limitations. Follow-up VAJ size was measured with TTE because of its noninvasiveness. However, measurement by TTE underestimates VAJ size compared with 3D-CT. Nevertheless, the most important issue is that there was no dilatation of the VAJ for at least 2 years after surgery. This study was not intended to measure VAJ size intensively after ESA, which was examined in other studies [22].

Other limitations include small size of the study population, short follow-up duration, and absence of controls receiving conventional treatment for mild to moderate and moderate AR [24–26]. However, AR was well controlled without significant increases in VAJ at 24 ± 6 months after surgery in each case. We hope that our observations will prompt other researchers to perform further studies in larger patient series.

Conclusion

Type Ic (± Ia) AR lesions can be managed simply with ESA alone concomitant with other cardiac surgeries. This approach can eliminate the disadvantages of AVR, i.e., prosthesis-related adverse events and prolonged operation time. Further long-term studies in larger patient series are required to confirm our findings.

Compliance with ethical standards

Conflict of interest The authors declare that no conflicts of interest exist.

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