Indian Journal of Thoracic and Cardiovascular Surgery (January 2020) 36 (Suppl 1):S104–S112
https://doi.org/10.1007/s12055-019-00831-0

ORIGINAL ARTICLE

Aortic valve repair in endocarditis: scope and results

Silvia Solari[1] · Saadallah Tamer[1] · Gaby Aphram[1] · Stefano Mastrobuoni[1] · Emiliano Navarra[1] · Philippe Noirhomme[1] · Alain Poncelet[1] · Parla Astarci[1] · Jean Rubay[1] · Gébrine El Khoury[1] · Laurent De Kerchove[1]

Received: 8 February 2019 / Revised: 26 March 2019 / Accepted: 2 May 2019 / Published online: 19 July 2019

Abstract

Purpose Infective endocarditis (IE) remains a prevalent and life-threatening disease. The choice to repair or replace the infected valve still remains a matter of debate, especially in aortic valve (AV) infections. We retrospectively analyze our two decades of experience in aortic valve repair (AVr) in IE. Long-term outcomes are described with particular attention to the impact of valve configuration and the use of patch techniques.

Methods From September 1998 to June 2017, 42 patients underwent AVr in a single center for IE. Techniques include leaflet patch repair and resuspension and aortic annulus stabilization.

Results Hospital mortality was 2.4% ($n = 1$). The median follow-up was 90.6 months. Survival was 89 ± 9.4% and 76.6 ± 16% at 5 and 10 years, respectively, with no significant differences between tricuspid aortic valve (TAV) and bicuspid aortic valve (BAV). Freedom from reoperation was 100% and 92.9 ± 7.1% in TAV and 81.8 ± 18.2% and 46.8 ± 28.8% in BAV at 5 and 10 years, respectively (TAV vs BAV, $p = 0.02$). BAV, degree of preoperative aortic insufficiency, and AVr including patch were factors predicting a higher risk of reoperation during the follow-up.

Conclusion In our experience, AVr is a safe, feasible, and efficient choice in selected patients with healed or active IE. Durability of the repair is excellent in patients with limited lesions and in patients with TAV even with patch repair. Reoperations occurred principally in patients with BAV and severe preoperative AI, in whom patch repair was performed. In those patients, we actually recommend to replace the valve in case of active endocarditis.

Keywords Infective endocarditis · Aortic valve repair · Patch repair

Introduction

During the last two decades, valve repair is increasingly gaining ground in the treatment of young patients with aortic valve insufficiency (AI) with encouraging long-term results emerging from several specialized centers [1–3]. With a better understanding of AV anatomy, a correct evaluation of its pathophysiology, and the application of appropriate surgical techniques, the indications of valve repair are expanding. AVr is now proposed for all types of chronic AI with or without aortic root aneurysm, and all types of AV morphologies (tricuspid, bicuspid, or unicuspid AV).

✉ Silvia Solari
silvia.solari@outlook.com

[1] Department of Cardiothoracic and Vascular Surgery, Cliniques Universitaires Saint-Luc, Av Hippocrate 10, 1200 Brussels, Belgium

Among all these different anatomic configurations, one common determinant of durability is obviously the quality and quantity of leaflet tissues. Indeed, repair of acute or chronic AI in the context of AV IE is much less reported and performed, mainly because of the destructive nature of the infectious process. This could often compromise both quality and quantity of tissues available. Therefore, pericardial patch is frequently necessary to repair the valve. Unfortunately, patches are known to degenerate with time, leading to recurrent AI or stenosis [4, 5]. Furthermore, any extra-valvular extension of the infectious process almost precludes the repair. In conclusion, aortic valve repair might address only lesions limited to the leaflets.

In this study, we retrospectively analyze the two decades of experience in AV repair in the context of active or healed AV endocarditis. Our aim is to determine the impact of valve configuration and the use of patch on the long-term outcomes.

Materials and methods

Patient selection

This is a single-center, observational study. From September 1998 to June 2017, 42 patients underwent AVr for acute or healed aortic valve endocarditis. Preoperative characteristics are shown in (Table 1). The diagnosis of infective endocarditis was based on clinical, echocardiographic, and biological findings according to the revised Duke's criteria [6]. Urgent surgery was considered for patients with cardiac or septic shock, severe valve regurgitation, large and mobile vegetation, progressive heart failure, systemic embolism, or resistance to antibiotic treatment. All patients received 4 to 6 weeks of antibiotics treatment according to the offending organism. Endocarditis was defined as active during the period of antibiotic treatment and healed after completion of antiobiotics. Recurrence of valve infection was considered as defined by the 2015 European Society of Cardiology (ESC) Guidelines on the management of infective endocarditis [7].

Surgical techniques

All procedures were performed through a full median sternotomy and extra-corporeal circulation (ECC) with cannulation of the ascending aorta and venous cannulation of the right atrium (bicaval venous cannulation was used in case of concomitant mitral or tricuspid valve surgery). After transverse aortotomy 1 cm above the sinotubular junction, the

Table 1 Patients' demographics

	Patch group ($n = 34$)	No patch group ($n = 8$)	p value
Average age (years)	56.2 ± 14.7	50.9 ± 8.6	$p = 0.36$
Male gender	28 (82.4%)	8 (100%)	$p = 0.46$
Aortic valve anatomy			
Tricuspid	25 (73.5%)	6 (75%)	$p = 0.93$
Bicuspid	9 (21.4%)	2 (25%)	
Involved microorganism			
Staphylococci	8 (23.5%)	1 (12.5%)	$p = 0.49$
MSSA	2 (5.9%)	1 (12.5%)	$p = 0.51$
Other staphylococci	6 (17.6%)	0	$p = 0.37$
Streptococci	17 (50%)	1 (12.5%)	$p = 0.05$
E. coli	1 (2.9%)	0	$p = 0.87$
E. faecalis	3 (8.8%)	1 (12.5%)	$p = 0.75$
Negative HC	12 (35.3%)	5 (62.5%)	$p = 0.16$
AI*			
I–II	13 (38.3%)	7 (87.5%)	$p = 0.01$
III-IV	21 (61.7%)	1 (12.5%)	
NYHA class			
I–II	17 (50%)	6 (75%)	$p = 0.20$
III–IV	17 (50%)	2 (25%)	
Preoperative LVEF			
> 50%	31 (91.2%)	7 (87.5%)	
31–49%	3 (8.8%)	1 (12.5%)	$p = 0.75$
< 31%	–	–	
COPD	2 (5.9%)	1 (12.5%)	$p = 0.51$
IDDM	1 (2.9%)	2 (25%)	$p = 0.12$
Dialysis	1 (2.9%)	–	$p = 0.87$
Urgent	8 (23.5%)	4 (50%)	$p = 0.13$
Previous cardiac surgery	4 (11.8%)	–	$p = 0.05$
Active endocarditis	30 (88.2%)	6 (75%)	$p = 0.80$
Healed endocarditis	4 (11.8%)	2 (25%)	$p = 0.13$

MSSA, methicillin-sensitive *Staphylococcus aureus*; *HC*, hemoculture; *AI*, aortic insufficiency; *LVEF*, left ventricle ejection fraction; *COPD*, chronic obstructive pulmonary disease; *IDDM*, insulin-dependent diabetes mellitus

*In bicuspid AV, AR I–II $n = 2$ (18.2%), AR III–IV $n = 9$ (81.8%); in tricuspid AV, AR I–II $n = 18$ (58.1%), AR III–IV $n = 13$ (41.9%). p value = 0.02

aortic valve was exposed using exposure stitches placed at the tip of each commissure.

Careful evaluation of the AV and lesions is crucial. Quite often, and mainly in an acute urgent situation, an unsuspected annular abscess is found during this phase and prompt valve replacement. In case of leaflet-limited infection, the evaluation should focus on the size and number of leaflets involved. A perforation may clearly appear or it can also be covered by a vegetation. A general principle of valve repair in endocarditis is resection of infected tissue and respect of any healthy tissue, preserving, if possible, a solid edge and the free margin in order to facilitate the repair. Valve repair techniques depend on the quality and quantity of remaining tissue. A direct closure of perforation is performed in case of a very small defect. Vegetations are usually resected with their implantation basis and become perforations. Perforation edges must be cleaned, leaving healthy tissues in order to suture the patch. Patch reconstruction is usually performed with a running suture with some single stitches to reinforce (see Fig. 1). A good sizing of the patch is crucial; in fact, a too small patch may retract the leaflet and induce residual aortic regurgitation. Different patch materials were used in this study, including xeno-pericardium, glutaraldehyde-treated autologous pericardium, fresh autologous pericardium, and in one occasion a piece of tricuspid valve autograft. Since 2015, we used decellularized xeno-pericardial patch which promises better tissue remodeling and less calcific degeneration compared to the previous generation of xeno-pericardium [8]. Several patch techniques have already been described in previous publications to repair the perforation in the cusp belly, commissure area, or the cusp free margin [4, 9–12]. The choice of patch material was generally not related to the type of lesion but rather dependent on surgeon preference at that time and the availability of the material. Leaflet repair also included Gore-Tex® running suture to the free margin (at the beginning) or central plication (more recently) to correct a prolapse.

After leaflet repair, annuloplasty was systematically performed using generally sub-commissural annuloplasty in case of active endocarditis, or external ring or valve-sparing reimplantation in case of healed endocarditis. Operative findings and repair techniques are listed in (Table 2).

Follow-up

Clinical follow-up was conducted by outpatient visits or telephone follow-up by a research nurse in order to obtain information on survival, valve-related complications and cardiovascular symptoms, and recurrent endocarditis as per the guidelines [13, 14]. The standard follow-up included transthoracic echocardiography assessment at regular intervals. The follow-up was complete at 95.2%. The median follow-up was 90.6 months (IQ range 17.7–163.5). Morbidity and mortality were described according to the guidelines for reporting outcomes after valve surgery [14].

Statistical analysis

Statistical analyses were performed using GraphPad Prism 7.0 (San Diego, CA, USA). Continuous data are presented as mean ± standard deviation or median (interquartile range) for non-parametric data. *P* values were calculated with the χ^2 test for categorical variables and Student's *t* test for continuous variables. Survival and reoperation were presented using the Kaplan–Meier curves calculated considering all the events that occurred during the follow-up. The long-term outcomes were calculated using the Mantel–Cox log-rank test. Valve repair with or without the patch technique was compared using the log-rank test. p values ≤ 0.05 were considered statistically significant.

Results

Perioperative data

The mean age was 55 years and 90% were male. Thirty-six patients (85.7%) had active endocarditis. Aortic valve

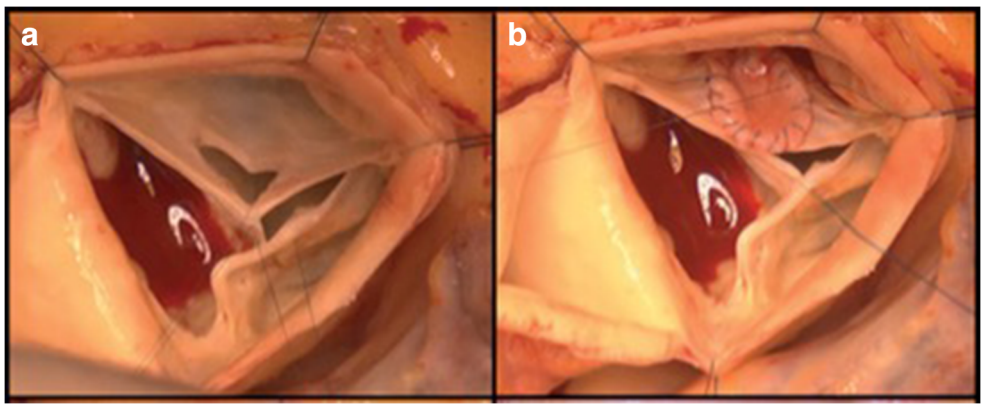

Fig. 1 Patch reconstruction usually performed with a running suture with some single stitches to reinforce

Table 2 Operative findings and repair techniques

	Patch group ($n = 34$)	No patch group ($n = 8$)
Intraoperative findings		
Cusp analysis		
Normal	34 (36.5%)	9 (40.9%)
Prolapse	6 (6.5%)	2 (9.1%)
Fenestration	3 (3.2%)	1 (4.5%)
Perforation	28 (30.1%)	1 (4.5%)
Calcification	2 (2.2%)	2 (9.1%)
Retraction	1 (1.1%)	–
Vegetation	27 (29%)	9 (40.9%)
Operative techniques		
Aortic valve sparing (Tirone David)	3 (8.9%)	–
In acute endocarditis	–	–
In healed endocarditis	3 (8.9%)	–
External ring stabilization	1 (2.9%)	6 (75%)
Sub-commissural annuloplasty	24 (75%)	6 (75%)
Central cusp plication	13 (38.2%)	4 (50%)
Vegetation resection	14 (41.2%)	8 (100%)
Gore-Tex® free margin re-suspension	–	1 (12.5%)
Cusp decalcification	–	1 (12.5%)
Patch reconstruction	34 (100%)	–
Treated autologous pericardium	4 (11.8%)	–
Fresh autologous pericardium	11 (32.4%)	–
Xeno-pericardium	17 (50%)	–
Tricuspid patch	1 (2.9%)	–
Decellularized pericardial patches	1 (2.9%)	–
Patch localization		
Cusp belly	28 (82.4%)	–
Free margin	2 (5.9%)	–
Commissure	6 (17.6%)	–
CPB time (min)	106.3 ± 33.2	70 ± 26.1
Cross-clamping time (min)	86.6 ± 27.1	45.5 ± 13

CPB cardio-pulmonary bypass

morphology was tricuspid (TAV) in 31 patients (73.8%) and bicuspid (BAV) in 11 patients (26.2%). A responsible microorganism was found in 59.5% ($n = 25$). Moderate to severe AI was found in 22 patients (52.4%), 81.8% ($n = 9$) of BAV, and in 41.9% ($n = 13$) of TAV ($p = 0.02$). No patient had aortic stenosis. Patch repair was used in 34 patients (81%). The remaining had AVr without patch (19%, $n = 8$). Preoperative characteristics are listed in (Table 1) distinctively for patients with and without patch repair. Patient characteristics were similar between these two groups except for severe AR which was more frequent in patients having had patch repair. Patch repair was performed on 81.8% ($n = 9$) of the patients with BAV and on 80.6% ($n = 25$) of the patients with TAV ($p = 0.93$).

Early outcomes

Hospital mortality was 2.4% ($n = 1$). This patient, from the patch group, died from multiorgan failure. Neither relapse nor reinfection was observed during hospitalization. Six (14.3%) patients needed chest re-exploration for bleeding or tamponade in the immediate postoperative period. No patient needed early AV reoperation.

Late outcomes

Forty-one patients were available for long-term analysis. A patch was used in 80.6% ($n = 25$) of TAV and in 81.8% ($n = 9$) of BAV. Nine patients died during follow-up. Of them, six suffered a non-cardiac death and three a cardiac death (acute

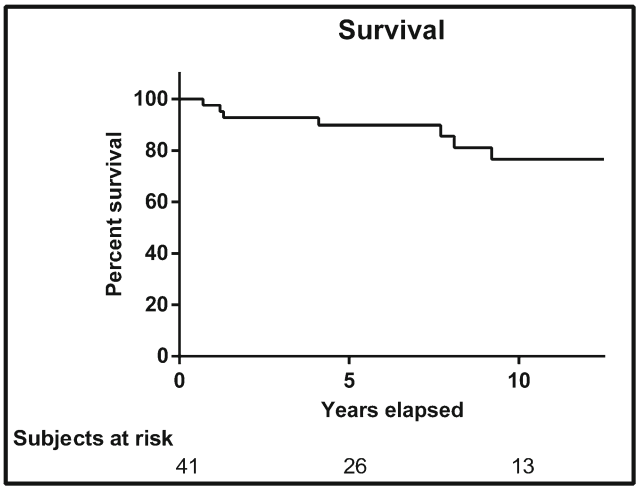

Fig. 2 Patient survival at 5 and 10 years

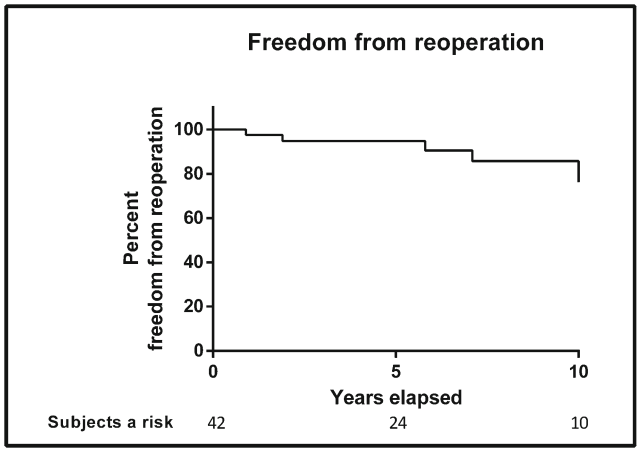

Fig. 4 Freedom from reoperation

myocardial infarction and two sudden cardiac arrests). Survival was 89 ± 9.4% and 76.6 ± 16% at 5 and 10 years, respectively (Fig. 2). Survival was 83.3 ± 13.2% and 68.7 ± 21.5% in TAV and 100% and 88.9% ± 15.8% in BAV at 5 and 10 years, respectively ($p = 0.15$) (Fig. 3). Six patients needed AV reoperation due to recurrent AI (12.2% $n = 5$) or aortic valve stenosis (2.4% $n = 1$). Of those six reoperated patients, four had a BAV with patch repair and two had a TAV including one with patch repair. Reoperation in the TAV occurred after 6 years for the patch repair and after 18 years for the repair without patch. AV replacement was performed on all patients having had AV reoperation. All patients survived the reoperation and were discharged without major complication. Freedom from reoperation at 5 and 10 years was 94.8 ± 6.1% and 76.2 ± 21.3%, respectively (Fig. 4). Freedom from reoperation was 100% and 92.9 ± 7.1% in TAV and 81.8 ± 18.2% and 46.8 ± 28.8% in BAV ($p = 0.02$) (Fig. 5). At 5 and 10 years, freedom from valve reoperation was 100% for patients without patch repair and 93.5 ± 11.9% and 71.5 ± 25.3% for patients with patch repair ($p = 0.3$) (Fig. 6). Freedom from valve reoperation was 100% in patients with a preoperative AI grade 0 to 2 and 90.5 ± 11% and 77.1 ± 20.3% in patients with a preoperative AI grade 3 to 4 ($p = 0.06$) (Fig. 7).

No relapse of endocarditis or reinfection was detected during the follow-up. Three patients suffered an embolic stroke and no bleeding event occurred. The linearized rate of thromboembolic and hemorrhagic events was 0.94% per patient-year.

Discussion

Infective endocarditis still remains a prevalent and life-threatening disease, especially if we consider the significant increased incidence in certain countries [15] over the past 10 years. Despite the up-to-date recommendations and the introduction of an "Endocarditis Team" [16], hospital mortality still remains high, standing between 15 and 30% [17, 18]. The key in fighting this pathology is microbial eradication

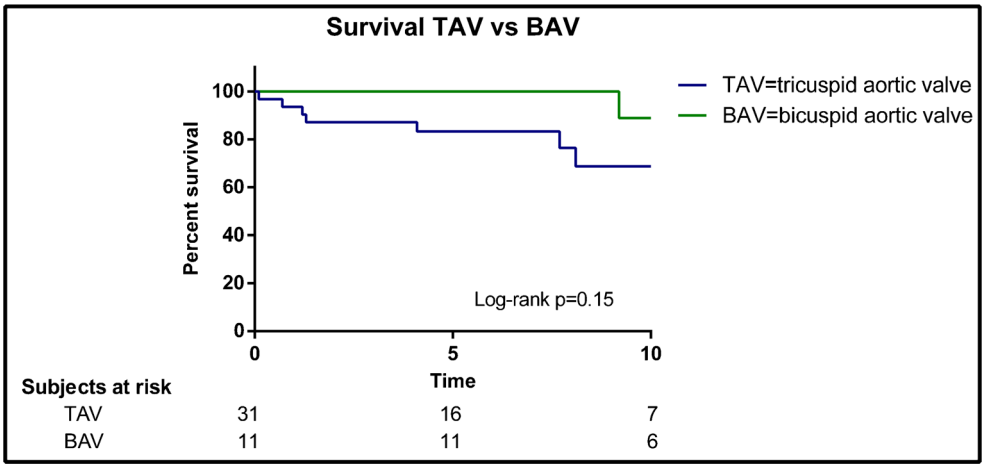

Fig. 3 Survival in TAV and in BAV at 5 and 10 years

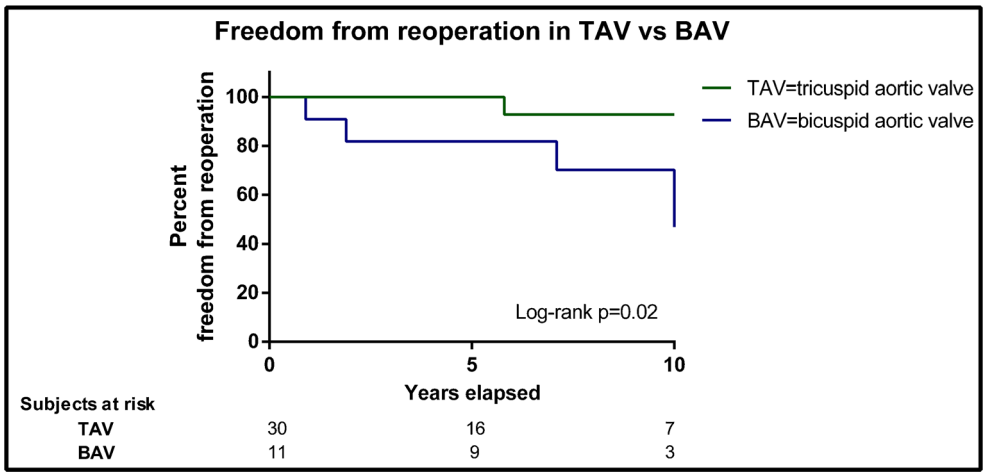

Fig. 5 Freedom from reoperation in TAV vs BAV

together with management of IE complications. This goal has been shown to reduce the 1-year mortality from 18.5 to 8.2% [19] and can only be reached with a multidisciplinary skilled team composed of microbiologists, infectiologists, cardiologists, neurologists, and surgeons. In fact, nowadays, near 50% of the patients need to undergo cardiac surgery to completely eradicate infection [17, 18].

In valve endocarditis, either mitral or aortic, we generally favor a repair approach because of its acknowledged advantages over replacement in terms of avoiding prosthetic-related complications and infection recurrence. Nevertheless, there are some differences in the approach of mitral and aortic endocarditis. First, in the case of a mitral valve endocarditis, we can tolerate bigger tissue destruction than we could tolerate on the aortic valve without compromising the chance for repair. Moreover, while annular abscess does not contraindicate mitral valve repair, an extension of infection beyond AV annulus turns AV repair almost impossible. Finally, the only alternative to mitral valve repair is a prosthetic replacement of the valve, while full biological alternatives exist for the AV (like Ross procedure, AV homograft, or stentless root biologic prosthesis).

Young age and valve-limited infection are peculiar characteristics of our population that make it perfectly suitable for AVr. In this cohort, AVr has shown its main benefits namely in providing a very low risk of endocarditis recurrence, even though until now no significant differences have been clearly demonstrated between AVr and replacement [18–20].

In this cohort of patients, we could distinguish two different clinical scenarios of IE. The easiest are endocarditis with limited tissue destruction like small free margin vegetation or small perforation (2–3 mm) that can be closed directly, where repair consists essentially in treating cusp prolapse. In those specific conditions, we think that the valve could, in most

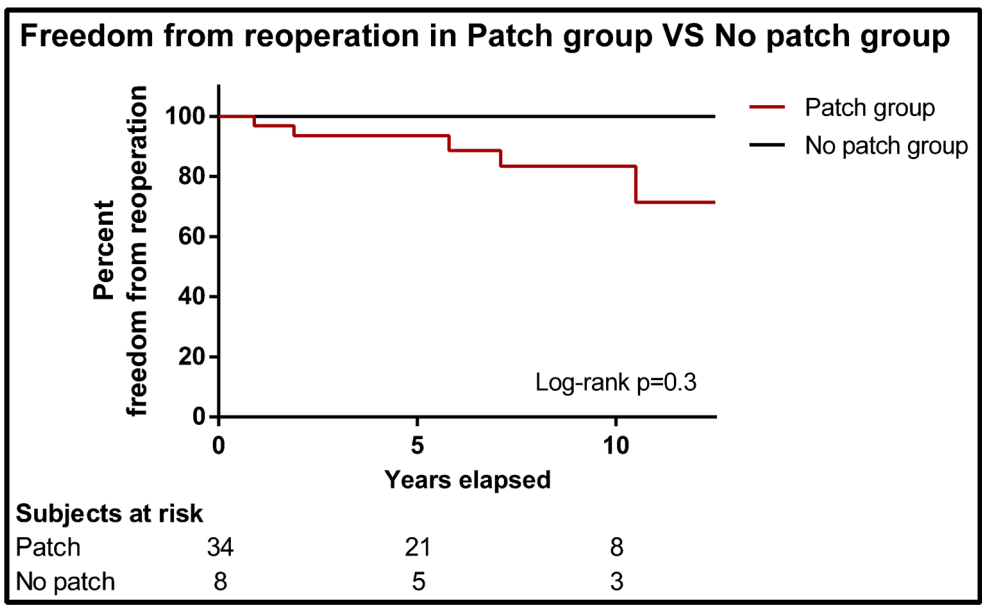

Fig. 6 Freedom from reoperation in patch group vs no patch group

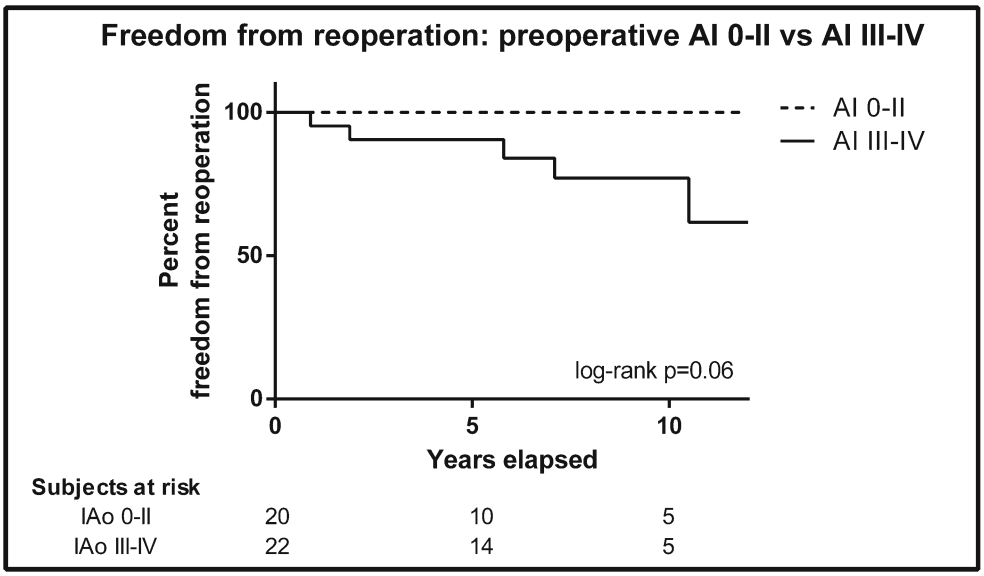

Fig. 7 Freedom from reoperation: preoperative AI 0–II vs AI III–IV

instances, be repaired and the long-term outcomes are excellent with a freedom from reoperation and infectious recurrence of 100% at 10 years. The second more frequent scenario includes a valve with relatively larger tissue destruction that needs pericardial patch repair. In this study, the xenopericardium has performed at least as good if not better than autologous ones (see Fig. 8). In our current practice, the new generation of matrix pericardium is the material of choice used for aortic valve repair in adults. However, further experience and longer follow-up are required to confirm their superiority compared to autologous pericardium and classic xenopericardium.

In this study, hospital and long-term survival rates are comparable to those reported for valve replacement in IE [21–23]. Good survival together with the absence of reinfection supports the choice of a repair approach as already suggested by other similar publications [24, 25]. On the other hand, patients with BAV required reoperation more frequently compared with patients with TAV, an observation that was also already made by one other study [24].

Those differences are probably explained by the fact that patients with BAV have a more important preoperative AI and more often require patch repair compared with patients with TAV, two factors associated with a higher rate of reoperation. In patients with BAV and endocarditis, the surgeon must generally deal not only with infective lesions but also with lesions specific to BAV degeneration (conjoined cusp prolapses, cusp retraction, raphe fibrosis). Moreover, from experience, we know that in those valves the repair must address not only the leaflets but also the annulus and the root in case of dilatation. These two latter anatomic structures are best treated using external ring annuloplasty or a valve-sparing procedure. Both techniques require prosthetic material which is best avoided in the setting of active IE. In this small series of

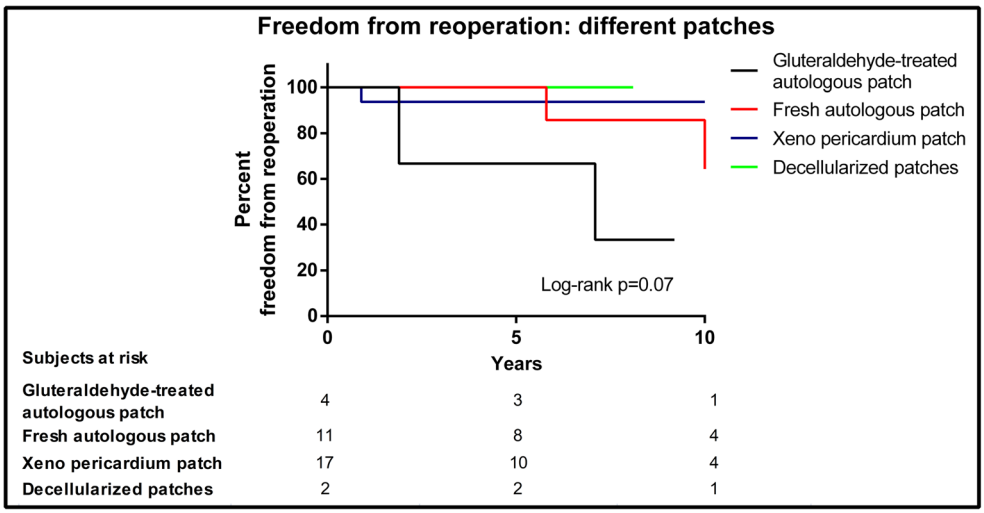

Fig. 8 Freedom from reoperation: different patches

BAV repair for IE, the sub-commissural annuloplasty was the most common ring stabilization technique used in order to reduce foreign materials as much as possible. Unfortunately, as we have already shown in a previous publication [26], this procedure does not offer durable repair over time. Consequently, aortic valve replacement with pulmonary autograft, aortic homograft, or prosthetic valve (depending on patient age, comorbidities, and infectious lesions extension) probably remains the best option in BAV with acute IE, especially when a severe AI is present.

Study limitations

This is a retrospective study covering a long period of almost 20 years during which surgeons' experience and knowledge in aortic valve repair have increased, the techniques have evolved, and some selection bias most probably occurred. Our cohort is a relatively small group of highly selected patients on the basis of their age, comorbidity, and relatively limited valve lesions. Therefore, survival and recurrence of IE could have been favorably influenced by this selection excluding old patients with multiple comorbidities and IE with extensive lesions and annular abscess. Long-term medical treatment was managed mainly by the referring physicians of the patients; therefore, differences in the individual treatment and lack of standardization may have impacted long-term outcomes.

Conclusions

In the context of IE, surgical approach (repair vs replacement) is oriented by a meticulous evaluation of the infectious lesions and of the valve anatomy. In our experience, AVr is safe and feasible in selected patients with healed or active IE. Durability of the repair is excellent in patients with limited lesions and in patients with TAV even with patch repair. Reoperations occurred principally in patients with BAV and severe preoperative AI, in whom patch repair is required. In those patients, we actually recommend replacing the valve in case of active endocarditis.

Acknowledgments The authors thank Corinne Coulon for her outstanding work as data manager.

Compliance with ethical standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent was obtained from all individual participants included in the study

Conflict of interest The authors declare that they have no conflict of interest.

Funding Nil

References

1. Aicher D, Fries R, Rodionycheva S, Schmidt K, Langer F, Schäfers HJ. Aortic valve repair leads to a low incidence of valve-related complications. Eur J Cardiothoracic Surg. 2010;37:127–132.
2. Price J, De Kerchove L, Glineur D, Vanoverschelde JL, Noirhomme P, El Khoury G. Risk of valve-related events after aortic valve repair. Ann Thorac Surg. 2013;95:606–612.
3. Lansac E, Di Centa I, Sleilaty G, et al. Long-term results of external aortic ring annuloplasty for aortic valve repair. Eur J Cardiothoracic Surg. 2016;50:350–360.
4. Nezhad ZM, De Kerchove L, Hechadi J, et al. Aortic valve repair with patch in non-rheumatic disease: Indication, techniques and durability. Eur J Cardiothoracic Surg. 2014;46:997–1005.
5. Schneider U, Feldner SK, Hofmann C, et al. Two decades of experience with root remodeling and valve repair for bicuspid aortic valves. J Thorac Cardiovasc Surg. 2017;153:S65–S71.
6. Li JS, Sexton DJ, Mick N, et al. Proposed modifications to the Duke criteria for the diagnosis of infective endocarditis. Clin Infect Dis. 2000;30:633–638.
7. Chu VH, Sexton DJ, Cabell CH, et al. Repeat infective endocarditis: differentiating relapse from reinfection. Clin Infect Dis. 2005;41:406–409.
8. Bell D, Prabhu S, Betts K, et al. Durability of tissue-engineered bovine pericardium (CardioCel®) for a minimum of 24 months when used for the repair of congenital heart defects. Interact Cardiovasc Thorac Surg. 2019;28:284–290.
9. Tamer S, de Kerchove L, Glineur D, El Khoury G. Video-atlas of aortic valve repair. Ann Cardiothorac Surg. 2013;2:124–126.
10. Boodhwani M, de Kerchove L, Glineur D, et al. Repair-oriented classification of aortic insufficiency: Impact on surgical techniques and clinical outcomes. J Thorac Cardiovasc Surg. 2009;137:286–294.
11. Boodhwani M, De Kerchove L, Glineur D, et al. Repair of regurgitant bicuspid aortic valves: A systematic approach. J Thorac Cardiovasc Surg. 2010;140:276–284.
12. Van Dyck M, Glineur D, de Kerchove L, El Khoury G. Complications after aortic valve repair and valve-sparing procedures. Ann Cardiothorac Surg. 2013;2:130–139.
13. Habib G, Lancellotti P, Antunes MJ, et al. 2015 ESC Guidelines for the Management of Infective Endocarditis. Eur Heart J.2015;36:3075–3128.
14. Akins CW, Miller DC, Turina MI, et al. Guidelines for reporting mortality and morbidity after cardiac valve interventions. J Thorac Cardiovasc Surg. 2008;135:732–738.
15. Van Den Brink FS, Swaans MJ, Hoogendijk MG, et al. Increased incidence of infective endocarditis after the 2009 European Society of Cardiology guideline update: A nationwide study in the Netherlands. Eur Hear J Qual Care Clin Outcomes. 2017;3:141–147.
16. Habib G, Lancellotti P, Antunes MJ, et al. 2015 ESC Guidelines for the management of infective endocarditis. Eur Heart J. 2015;36:3075–3128.
17. Leone S, Ravasio V, Durante-Mangoni E, et al. Epidemiology, characteristics, and outcome of infective endocarditis in Italy: The Italian Study on Endocarditis. Infection. 2012;40:527–535.
18. García-Cabrera E, Fernández-Hidalgo N, Almirante B, et al. Neurological complications of infective endocarditis risk factors, outcome, and impact of cardiac surgery: A multicenter observational study. Circulation. 2013;127:2272–2284.
19. Botelho-Nevers E, Thuny F, Casalta JP, et al. Dramatic reduction in infective endocarditis-related mortality with a management-based

approach. Arch Intern Med. 2009;169:1290–1298. https://doi.org/10.1001/archinternmed.2009.192.
20. David TE, Gavra G, Feindel CM, Regesta T, Armstrong S, Maganti MD. Surgical treatment of active infective endocarditis: A continued challenge. J Thorac Cardiovasc Surg. 2007;133:144–149.
21. Savage EB, Saha-Chaudhuri P, Asher CR, Brennan JM, Gammie JS. Outcomes and prosthesis choice for active aortic valve infective endocarditis: analysis of the society of thoracic surgeons adult cardiac surgery database. Ann Thorac Surg. 2014;98:806–814.
22. Klieverik LM, Yacoub MH, Edwards S, et al. Surgical treatment of active native aortic valve endocarditis with allografts and mechanical prostheses. Ann Thorac Surg. 2009;88:1814–1821.
23. Moon MR, Miller DC, Moore KA, et al. Treatment of endocarditis with valve replacement: the question of tissue versus mechanical prosthesis. Ann Thorac Surg. 2001;71:1164–1171.
24. Mayer K, Aicher D, Feldner S, Kunihara T, Schäfers HJ. Repair versus replacement of the aortic valve in active infective endocarditis. Eur J Cardiothorac Surg. 2012;42:122–127.
25. Zhao D, Zhang B. Are valve repairs associated with better outcomes than replacements in patients with native active valve endocarditis? Interact Cardiovasc Thorac Surg. 2014;19:1036–1039.
26. De Kerchove L, Boodhwani M, Glineur D, et al. Valve sparing-root replacement with the reimplantation technique to increase the durability of bicuspid aortic valve repair. J Thorac Cardiovasc Surg. 2011;142:1430–1438.