

Aortic valve repair with patch in non-rheumatic disease: indication, techniques and durability[†]

Zahra Mosala Nezhad^a, Laurent de Kerchove^a, Jawad Hechadi^a, Saadallah Tamer^a, Munir Boodhwani^b,
Alain Poncelet^a, Philippe Noirhomme^a, Jean Rubay^a and Gebrine El Khoury^{a,*}

^a Division of Cardiothoracic and Vascular Surgery, Université Catholique de Louvain, Cliniques Universitaires Saint-Luc, Brussels, Belgium

^b University of Ottawa Heart Institute, Ottawa, ONT, Canada

* Corresponding author. Service de Chirurgie Cardiovasculaire et Thoracique, Cliniques Universitaires Saint-Luc, UCL, Avenue Hippocrate 10, 1200 Brussels, Belgium. Tel: +32-2-7646107; fax: +32-2-7648960; e-mail: gebrine.elkhoury@uclouvain.be; elkhoury@chir.ucl.ac.be (G. El Khoury).

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Abstract

OBJECTIVES: To analyse the long-term outcomes of aortic valve (AV) repair with biological patch in patient with non-rheumatic valve disease.

METHODS: From 1995 to 2011, 554 patients underwent elective (AV) repair; among them, 57 (mean age 45 ± 17 years) had cusp restoration using patch for non-rheumatic valve disease. Seven (12%) patients had unicuspid valve, 30 (53%) patients had bicuspid valve and 20 (35%) had tricuspid valve. Autologous pericardium was used in 26 patients (7 treated, 19 non-treated), bovine pericardium in 26, autologous tricuspid valve leaflet in 4 and aortic homograft cusp in 1. Patching was used to repair perforation ($n = 20$, 35%), commissural defect ($n = 18$, 32%), raphe repair ($n = 17$, 30%) or for cusp extension ($n = 2$, 3.5%). Echocardiographic and clinical follow-up was 98% complete and mean follow-up was 72 ± 42.5 months.

RESULTS: No hospital mortality. At 8 years, overall survival was $90 \pm 5\%$ and freedom from valve-related death was $96 \pm 3\%$. Two patients (3.5%) needed early reoperation for aortic regurgitation (AR); they underwent re-repair and the Ross procedure, respectively. Late reoperation was necessary in 9 patients (16%) for AR ($n = 4$), stenosis ($n = 3$) or mixed disease ($n = 2$). They had the Ross procedure ($n = 6$) or prosthetic valve replacement ($n = 3$) with no mortality. At 8 years, freedom from reoperation was $75 \pm 9\%$. Freedom from reoperation was slightly higher in tricuspid compared with non-tricuspid valves (92 ± 7 vs $68 \pm 11\%$, $P = 0.18$) and slightly higher for bovine ($95 \pm 5\%$) compared with autologous pericardium ($73 \pm 11\%$, $P = 0.38$), but differences were statistically not significant. In tricuspid valves, freedom from reoperation was higher in perforation repair compared with other techniques (100 vs $50 \pm 35\%$, $P = 0.02$). In bicuspid valves, freedom from reoperation was similar between different repair techniques ($P = 0.38$). Late echocardiography showed AR 0–1 in 30 (53%) patients, AR 2 in 12 (21%) and no AR ≥ 3 . Three patients presented a mean transvalvular gradient of 30–40 mmHg. Thromboembolic events occurred in 2 patients (0.6%/patient-year), bleeding events in 1 (0.3%/patient-year) and no endocarditis occurred.

CONCLUSIONS: AV repair with biological patch is feasible for various aetiologies. The techniques are safe and medium-term durability is acceptable, even excellent for perforation repair in tricuspid valve morphology. Bovine pericardium is a good alternative to autologous pericardium.

Keywords: Aortic regurgitation • Aortic valve repair • Patch repair • Unicuspid aortic valve • Bicuspid aortic valve

INTRODUCTION

The surgical approach towards the repair of the diseased aortic valve had evolved significantly in the last two decades. Surgical strategies and techniques have been standardized to a certain extent. Emerging results from specialised centers are providing better understanding of the repair technique, and with that expanding its indication, and its beneficial diseased group. All of these changes have reflected positively on the long-term outcomes.

Unlike the mitral valve, the aortic valve has limited cusp tissue. Therefore, direct closure of the valve defect or after lesion resection is rarely an option in aortic valve repair, contrary to mitral valve repair. Bahnson *et al.* in 1969 studied the use of pericardium, peritoneum, pleura and fascia lata to reconstruct single aortic cusps [1]. Further reports thereafter demonstrated variable experimental usage of extravalvular biomaterial for aortic valve repair. While early reports of patch repair were encouraging, there is some concern regarding the durability of aortic valve repair in the setting of patch repair of cusp defects.

In bicuspid aortic valve repair, the need for patch material has been shown to reduce durability of the repair compared with repair without patch [2, 3]. Similar results were found in tricuspid

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valve repair with patch material [4]. The reason for mitigated results in valve repair with a patch may be multifactorial. First, the need for patch material corresponds generally to a higher degree of disease severity in terms of lesion size and aetiology of the disease (e.g. rheumatic, congenital and endocarditis).

Secondly, the patch material itself may have limited functional performance and may degenerate over time and this may be a function of the type of material used for patching (autologous or heterologous pericardium, artificial membrane).

During almost two decades, we have applied and developed techniques of aortic valve repair including patch techniques in various aetiologies of aortic valve disease with several types of patches. In this study, we analysed medium to long-term outcomes of patient having aortic valve repair with a patch. We also sought to determine the factors; like disease aetiology, repair technique, repair material and cause of failure that influence the outcomes.

MATERIALS AND METHODS

Patient selection

This is a single-centre, observational study. From 1995 to 2011, 554 consecutive patients had elective aortic valve repair procedures for various aetiologies of aortic valve disease. Patients

undergoing emergency operation for acute type A dissection were excluded. For this study, we selected out from our institutional database all patients having valve repair surgery with the aid of biological tissue material to reconstruct aortic valve cusps. Patients with rheumatic valve disease were excluded. We identified 57 patients meeting the inclusion criteria with a mean age of 45 ± 17 years and 88% male. Aortic valve morphology was tricuspid in 20 (35%) patients, bicuspid in 30 (53%) and unicuspid in 7 (12%). Preoperative patient characteristics are listed in Table 1.

The study was approved by the ethics review board of the hospital.

Surgical techniques

All procedures were performed using a median sternotomy, cannulation of the distal ascending aorta and venous cannulation of the right atrium or both vena cavae in case of concomitant mitral or tricuspid valve surgery. Myocardial arrest was achieved with antegrade and ostial warm blood cardioplegia solution. Aortotomy incision and valve exposure for inspection was performed as previously described [3–8].

The surgical approach was performed according to our repair-oriented functional classification of aortic insufficiency [8]. All included patients presented with AV lesions necessitating the use of patch material to restore one or two cusps, or reconstruction of

Table 1: Clinical profile of all patients

Variables	Tricuspid valve, <i>n</i> = 20 (35%)	Bicuspid valve, <i>n</i> = 30 (53%)	Unicuspid valve, <i>n</i> = 7 (12%)
Age years (mean \pm SD, [range])	59 \pm 13.5 [39–82]	42 \pm 10 [28–61]	16 \pm 8 [6–28]
Male	15 (75%)	28 (93%)	7 (100%)
NYHA class			
1	5 (25%)	11 (37%)	5 (71%)
2	4 (20%)	13 (43%)	0
3	9 (45%)	6 (20%)	2 (29%)
4	2 (10%)	0	0
Previous cardiac surgery	2 (10%)	1 (3%)	2 (29%)
Previous AV surgery	1 (5%)	0	1 (14%)
Previous balloon valvotomy	0	0	3 (43%)
Valve aetiology			
Degenerative	3 (15%)	0	0
Connective tissue disease	1 (5%)	0	0
Endocarditis	15 (75%)	4 (13%)	0
Congenital	0	26 (87%)	7 (100%)
Fibroelastoma	1 (5%)	0	0
Grade of AR			
1	2 (10%) ^a	3 (10%) ^b	3 (43%) ^c
2	2 (10%) ^a	4 (13%) ^b	0
3	9 (45%)	15 (50%)	3 (43%)
4	7 (35%)	8 (27%)	1 (14%)
Moderate-to-severe AV stenosis	0	2 (3%)	4 (57%)
Left ventricular ejection fraction			
EF > 50	15 (75%)	27 (90%)	5 (71%)
EF 50–30	4 (20%)	2 (7%)	1 (14%)
EF < 30	1 (5%)	0	0
Left ventricular end-diastolic diameter (mm)	58 \pm 9	59.5 \pm 8	55 \pm 12

^aIndication for surgery was fibroelastoma (*n* = 1) or endocarditis (*n* = 3).

^bIndication for surgery was aortic aneurysm with restrictive congenital raphe (*n* = 4) or endocarditis (*n* = 1).

^cIndication for surgery was aortic valve stenosis.

SD: standard deviation; NYHA: New York Heart Association; AV: aortic valve; AR: aortic regurgitation, EF: ejection fraction.

commissures. In patients with low grade AR, indication of patch repair was cusp defect after resection of fibroelastoma, calcification or endocarditis lesion, or for mixed AV disease with restrictive cusp motion (e.g. congenital raphe). Operative findings and repair techniques are listed in Table 2. Patch repair was performed for the following lesions: cusp defect like perforation or fenestration and cusp restriction induced by raphe, fibrosis or calcification.

Perforations were generally due to endocarditis, and rarely due to resection of fibroelastoma. Perforation was defined as tissue defect at the belly of the cusp with preservation of the free margin. Fenestrations are congenital or degenerative defects along the free margin of the cusp; they are generally located in the commissural area. Regurgitation may be induced in the presence of a very large fenestration or by fenestration rupture. Diffuse cusp restriction was considered a contraindication for valve repair; however, localized restriction like a raphe in bicuspid or unicuspid valve or localized degenerative lesion in tricuspid valve was accepted for valve repair with patch material.

The surgical technique to repair cusp perforation was to have the patch trimmed in a form resembling the present defect in shape and adding 2 mm to its size, so as to prevent restriction of cusp surface following patch implantation. The patch was applied on the aortic surface of the cusp by running a continuous suture using prolene 5/0 or 6/0 (Fig. 1A and B).

Fenestration repair followed the same principle with the primary difference that one edge of the patch was used as neo-free margin

in case of ruptured fenestration or was used to reinforce the free margin when the fenestration was not ruptured. In the latter case, the running suture was passed over and over the free margin (Fig. 1C and D). For ruptured fenestrations, patches were generally used on one side of a commissure, while for large fenestrations they were generally used on both sides of the commissure, because large fenestrations are generally present on both sides.

In type 1 [9] bicuspid aortic valve with restricted raphe, patch repair was used only if direct closure after raphe resection would induce significant restricted motion of the conjoint cusp. In our early experience, a triangular patch was generally used to repair the defect leaving the valve bicuspid (Fig. 2A and B). Later on, we have adapted the technique of patching to respect the native morphology of the valve. In symmetric or nearly symmetric bicuspid ($\sim 180^\circ/180^\circ$), the raphe repair consisted of a triangular patch as described above leaving the valve bicuspid. However, in asymmetric bicuspid (\sim conjoint cusp 240° /non-conjoint cusp 120°) the raphe is generally not completely fused and after resection, the valve is made tricuspid by using one patch to create a neo-commissure at the place of the raphe (Fig. 2C and D). This technique, first proposed by Tolan *et al.* [10], has been adapted by our group and is described in detail in a previous work [11].

In unicuspid valves, the commissural reconstruction technique was performed to make the valve bicuspid. The neo-commissure is placed opposite to the normal commissure, generally the non/left commissure, at the place of one of the two raphe or in-between

Table 2: Operative data

	Tricuspid valve (n = 20)	Bicuspid valve (n = 30)	Unicuspid (n = 7)
Cusp repair			
Cusp prolapse repair			
Central plication	5 (25%)	5 (17%)	0
Gore-Tex resuspension	0	13 (43%)	0
Raphe repair without patch			
Direct closure after resection	0	3 (10%)	0
Cusp defect or restriction repair with patch			
Perforation	15 (75%)	5 (17%)	0
Commissural reconstruction	5 (25%)	6 (20%)	7 (100%)
Raphe	0	17 (57%)	0
Fenestration	4 (20%)	1 (3%)	0
Cusp extension	0	2 (7%)	0
Patch materials used			
Autologous treated pericardium	3 (15%)	2 (7%)	2 (29%)
Autologous non-treated pericardium	7 (35%)	11 (37%)	1 (14%)
Bovine pericardium	9 (45%)	13 (43%)	4 (57%)
Autologous tricuspid valve leaflet	1 (5%)	3 (10%)	0
Aortic valve homograft cusp	0	1 (4%)	0
Functional aortic annulus repair			
Subcommissural annuloplasty	15 (75%)	15 (50%)	2 (27%)
Ascending aorta replacement	1 (5%)	5 (17%)	0
Reimplantation	1 (5%)	10 (33%)	1 (14%)
Partial root remodelling	0	4 (13%)	0
Aortic cross clamp time (mean \pm SD, min)	86 \pm 35	104 \pm 29	92 \pm 24
Cardiopulmonary bypass time (mean \pm SD, min)	100 \pm 40	119 \pm 33	117 \pm 34
Second pump run ^a	2 (10%)	3 (10%)	1 (14%)
Associated procedures			
Coronary artery bypass grafting	3 (15%)	2 (7%)	0
Mitral or tricuspid valve repair	4 (20%)	1 (3%)	0
Myectomy and resection of subaortic stenosis			1 (14%)

^aFor residual moderate aortic insufficiency (AI) eccentric AI or too low coaptation, after repair all patients had AI 0-1.

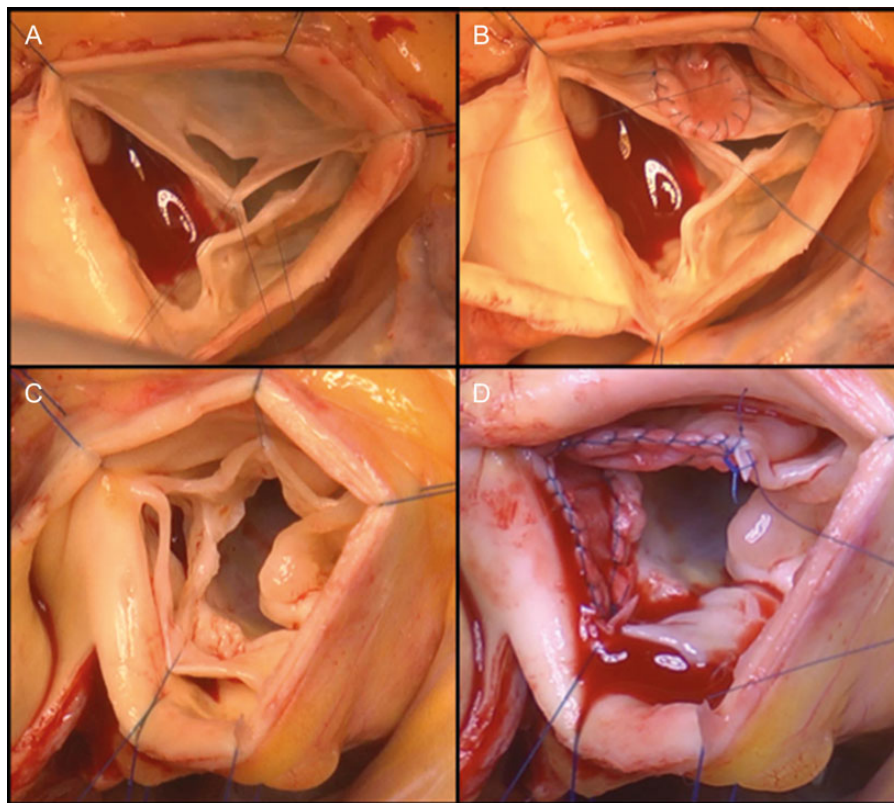


Figure 1: (A and B) Leaflet perforation in a case of aortic endocarditis repaired with a circular bovine pericardial patch. (C and D) Dual fenestration of the right-to-left commissure repaired with bovine pericardial patch.

the two raphe as proposed by Aicher *et al.* [12] (Fig. 3). Raphe were resected and cusps were thinned to optimize valve motion. Unicuspid valve repair was the technique usually requiring the largest patch in comparison with other types of valve repair described above.

Cusp extension for non-rheumatic as well as rheumatic AV disease was rarely performed in our experience. Generally, it requires a patch strip ~4–5 mm in height sutured along the free margin from one commissure to the other to increase the functional height and coaptation surface of the cusp [13, 14]. In this series, it was performed in bicuspid valve on the conjoint cusp after direct closure of raphe resection.

The decision for the type of patch material was principally at the surgeon's discretion. As no strong evidence exists on the superiority of one material over another, different types of patches were used during the study period and we currently use either bovine pericardial patch or autologous pericardium. Treated autologous pericardium, with a glutaraldehyde 0.6% solution, was used principally when patch repair was planned before starting valve assessment and repair. When patch repair was indicated during valve assessment, non-treated autologous or bovine pericardium was used as both are readily available. Non-treated autologous was favoured in cases of easy repair with less demanding technical manoeuvres, like perforation patching, and bovine pericardium was favoured in more complex repair like commissural reconstruction or when autologous pericardium was not available. Bovine pericardial patch from Synovis® (Vascu-Guard, Surgical Innovation, Deerfield, IL, USA) was used until 2010, and then both bovine pericardial patches from Synovis® and St Jude Medical (pericardial

patch with EnCap Technology, St Jude Medical, Inc., USA) were used. The last one being thinner and available for immediate use without rinsing, we found it more appropriate for AV repair.

In a few patients, autologous tricuspid valve leaflet was used as patching material. Those cases were performed during the early period of our experience (before 2004) in certain patients having concomitant tricuspid valve repair. The reason to use this autotissue was driven by the optimistic early results we had with the autologous tricuspid valve patch in mitral valve repair. The use of this material in aortic position was abandoned after cases of patch dehiscence. In 1 patient, a patch made from cusp tissues of an AV homograft was used. This opportunity occurred because AV replacement with a homograft was initially scheduled and at the time the valve was judged amenable to repair with a patch, the homograft was already prepared.

Echocardiographic assessment

Our echocardiographic protocol, derived from the American Society of Echocardiography Guidelines [15], indicated that the patients will have two-dimensional transthoracic echocardiography, with Doppler methods to assess the direction and severity of the valve regurgitation, upon elective admission, before discharge and at regular intervals during follow-up. Similarly, all patients had intraoperative transoesophageal echocardiography. Only mild central residual AR was accepted post-repair; moderate AR, eccentric AR or low coaptation (at annulus level) justified second pump run for revision of the repair.

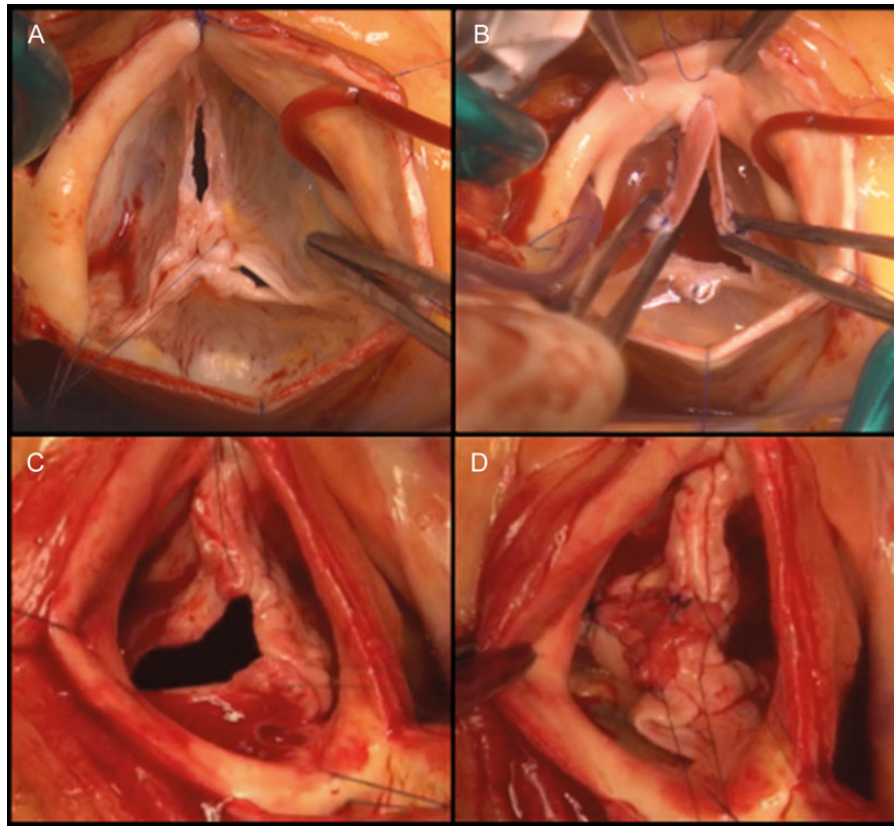


Figure 2: (A and B) Tricuspidization of asymmetric type I bicuspid valve ($120^{\circ}/240^{\circ}$) using bovine pericardial patch to split the conjoint leaflet and raise the commissure insertion point. (C and D) Raphe repair with triangular autologous patch in a nearly symmetric bicuspid valve.

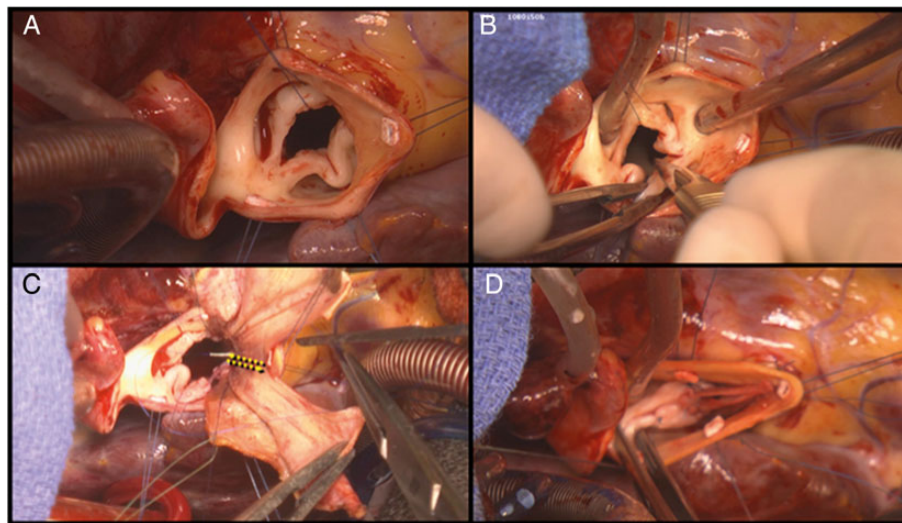


Figure 3: (A) Exposition of a unicuspid valve, (B) resection of the raphes, (C) and (D) reconstruction of the neocommissure with patch.

Data collection and follow-up

Patient demographics and operative data were collected prospectively in our institutional valve database and analysed retrospectively. Clinical follow-up was conducted through either outpatient visits or telephone follow-up by a research nurse.

Information on survival status and valve-related complications, including thromboembolism, haemorrhage, endocarditis, reoperation and cardiovascular symptoms, was obtained. Data are reported according to the guidelines for reporting mortality and morbidity after valve surgery [16]. The closing interval for the study was between May and September 2013. Clinical follow-up

was 98% complete at a mean follow-up time of 6 ± 3.5 years. Echocardiographic follow-up was 91% complete at a mean follow-up time of 5 ± 4 years.

Statistical analysis

The statistical analysis was performed with SPSS v15.0 (IBM, Inc., Chicago, IL, USA). Categorical variables were reported as absolute numbers and percentages. Continuous variables were expressed as mean \pm standard deviation. Linearized event rates were calculated for valve-related events. Survival and freedom from valve reoperation were calculated using the Kaplan–Meier method and compared using the log-rank test. Freedom from reoperation was evaluated for different subgroups of valve morphology, patch material and repair techniques. Repair techniques were compared following the type and location of the repair; therefore, commissural and fenestration repair were grouped and compared with perforation repair and raphe repair with triangular patch. Very small subgroups, such as the homograft patch ($n = 1$) and cusp extension ($n = 2$) were not taken into account in comparison analyses. Graphs were constructed using GraphPad Prism 5.0 (San Diego, CA, USA). Statistical significance was considered for a P -value of ≤ 0.05 .

RESULTS

Mortality and morbidity

There was no hospital mortality. Postoperatively, re-exploration for bleeding occurred in 6 (10.5%) patients and superficial sternal wound infection in 2 (3.5%) patients. There were no thromboembolic or bleeding events and no permanent pacemaker implantations. During follow-up, 5 patients died. Causes of death were unknown in 2 patients, sudden death in 1, sepsis in 1 and cirrhosis in 1. At 8 years, overall survival was $90 \pm 5\%$ and freedom from valve-related death was $96 \pm 3\%$. There was no late mortality in the unicuspid valve group; overall survival was slightly higher in the bicuspid compared with the tricuspid valve group (96 ± 4 vs $77 \pm 23\%$, $P = 0.24$) (Fig. 4).

Valve reoperation

Two of 11 patients (3.5%), both with bicuspid valve, had early reoperation for recurrent AR; one presented dehiscence of the autologous tricuspid valve patch and the other presented residual cusp prolapse and annular dilatation. They underwent re-repair and the Ross procedure, respectively.

During the follow-up, 9 patients needed late AV reoperation (bicuspid $n = 7$, tricuspid $n = 1$, unicuspid $n = 1$); one of them had early re-repair. Late reoperation occurred after the mean follow-up of 6 ± 4 years (range: 2–14). Indications for reoperation were AR (bicuspid $n = 3$, tricuspid $n = 1$), stenosis (bicuspid $n = 3$) and mixed disease (bicuspid $n = 1$, unicuspid $n = 1$). In patients with AR, mechanisms of failure were cusp prolapse with annular dilatation ($n = 2$) and unknown ($n = 2$). In patients with stenosis, mechanisms were calcification ($n = 2$) and calcification with cusp perforation ($n = 1$). In patients with mixed disease, mechanisms were patch dehiscence with cusp calcification ($n = 2$). Those

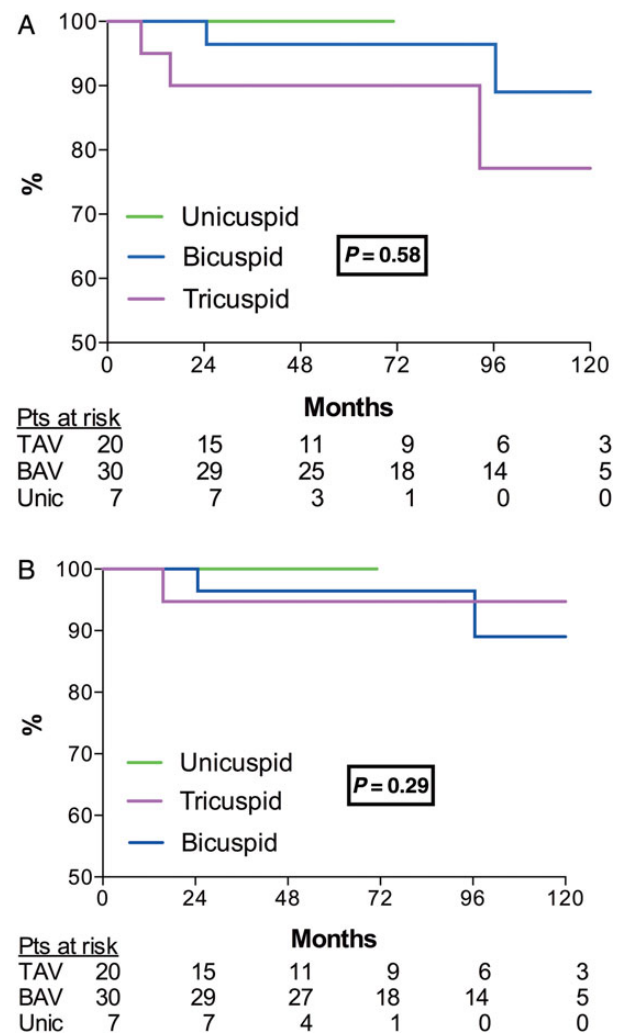


Figure 4: (A) Actuarial survival curve showing overall survival in tricuspid, bicuspid and unicuspid valves. (B) Actuarial survival curve showing freedom from valve-related death in tricuspid, bicuspid and unicuspid valves.

patients underwent the Ross procedure ($n = 6$) or prosthetic valve replacement ($n = 3$) with no mortality at reoperation.

At 8 years, freedom from aortic valve reoperation was $75 \pm 9\%$. Freedom from reoperation was slightly higher in tricuspid compared with bicuspid/unicuspid together but the difference did not reach statistical significance (92 ± 7 vs $68 \pm 11\%$, $P = 0.18$) (Fig. 5A). Freedom from reoperation was slightly higher for bovine pericardium ($95 \pm 5\%$) compared with autologous pericardium ($73 \pm 11\%$) but the difference did not reach statistical significance ($P = 0.38$) (Fig. 5B). No difference were found between treated and non-treated autologous pericardium (80 ± 11 vs $86 \pm 13\%$, $P = 0.78$). Among the 4 patients receiving autologous tricuspid valve leaflet, 3 underwent late reoperation (freedom from reoperation at 8 years: $50 \pm 25\%$). In tricuspid valves, freedom from reoperation was significantly higher in perforation repair compared with commissure/fenestration repairs (100 vs $50 \pm 35\%$, $P = 0.02$) (Fig. 6A). In bicuspid valves, freedom from reoperation was similar between the different techniques of repair (commissure/fenestration repair 100% versus perforation repair $60 \pm 22\%$ versus raphe repair with triangular patch $71 \pm 15\%$, $P = 0.38$) (Fig. 6B).

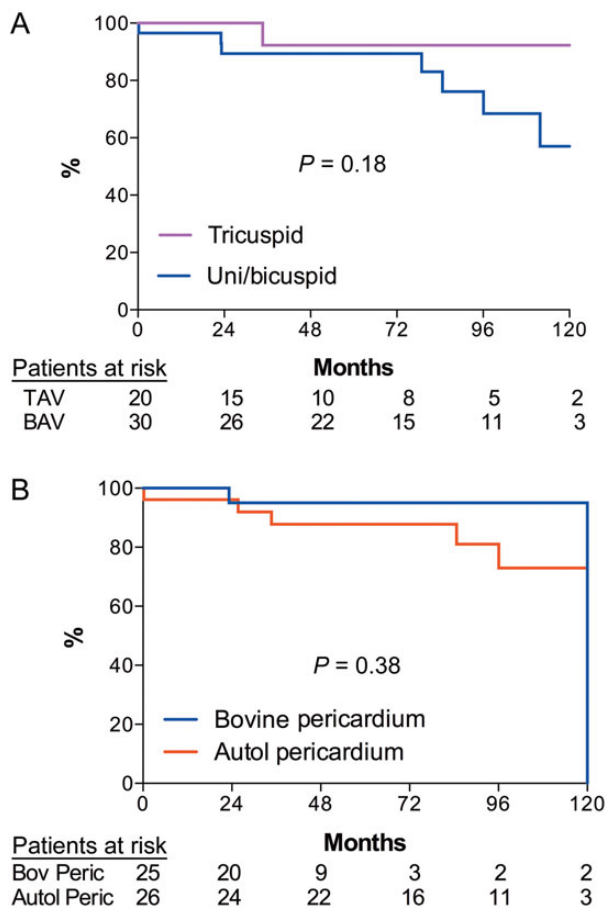


Figure 5: (A) Actuarial survival curve showing freedom from aortic valve reoperation in tricuspid valve versus bicuspid valves together. (B) Actuarial survival curve showing freedom from aortic valve reoperation in bovine pericardial patch versus autologous pericardial patch.

Echocardiographic results

At follow-up, last echocardiography in non-reoperated patients showed AR 0–1 in 30 (53%) patients, AR 2 in 12 (21%) and no AR ≥ 3 . Three patients presented mean transvalvular gradients of 36, 38 and 39 mmHg at 48, 112 and 161 months of follow-up, respectively; 2 of them had bicuspid and 1 had unicuspid valve.

Valve-related events

Thromboembolic events occurred in 2 patients for a total of 335.5 patient-years of follow-up, corresponding to a linearized rate of 0.6%/patient-year. Bleeding event occurred in 1 patient corresponding to a linearized rate of 0.3%/patient-year. No endocarditis occurred.

DISCUSSION

In this study, we mainly looked at patients with class 1d (perforation) AR following our functional classification and class 3 (cusp restricted motion) wherein regurgitation can be combined with stenosis [8]. Those patients represent 10% of our global experience in AV repair from 1995 to 2011. Abnormal congenital

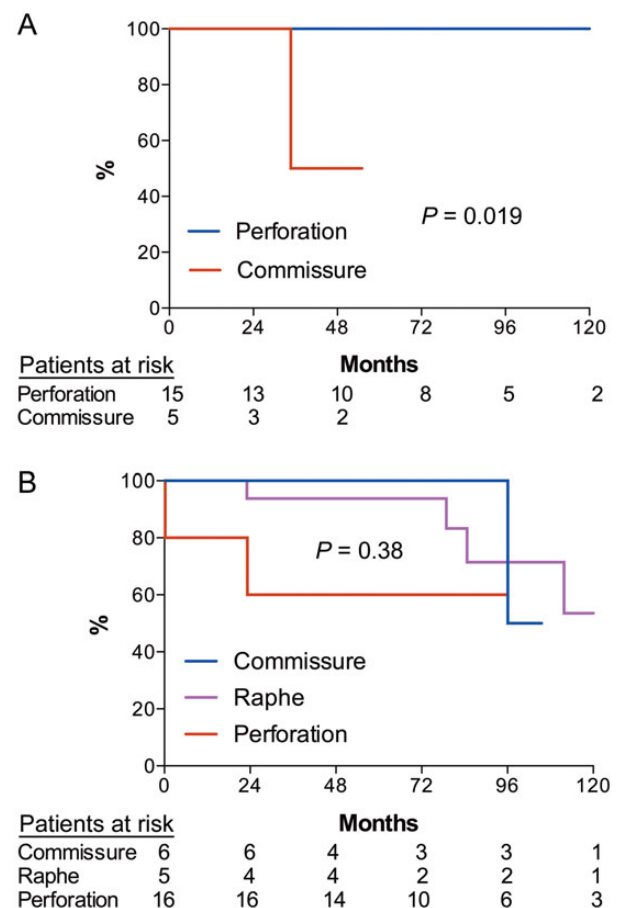


Figure 6: (A) Actuarial survival curve showing freedom from aortic valve reoperation in tricuspid valve regarding the type of repair technique performed: perforation repair versus commissural and fenestration repair together. (B) Actuarial survival curve showing freedom from aortic valve reoperation in bicuspid valve regarding the type of repair technique performed: perforation repair versus commissure/fenestration repair versus raphe repair with triangular patch.

valve (unicuspid or bicuspid) was involved in 60% mainly with type 3 lesion and tricuspid valve was involved in 40% mainly with type 1d lesion. Surgically, tricuspid aortic valve requires relatively simple repair with less added tissue compared with congenitally abnormal valves that demand a more complex repair technique with a larger amount of biomaterial and more combined repair techniques on the cusp and the aortic root.

The results from this retrospective study show that AV repair with patch, though complex, can be performed with low mortality and an acceptable reoperation rate, even very low in certain indications like perforation repair in tricuspid aortic valve (TAV). Good results have also been noted in unicuspid valves, but this subgroup had a relatively shorter follow-up. Autologous tricuspid valve leaflet patch is not recommended since it is fragile, which leads to dehiscence, and bovine pericardium is at least as good as autologous pericardium.

Our analysis revealed excellent survival and this is largely related to two factors. The first and most important factor is patient age. They were young with less comorbidities and better recovery. The second factor is related to surgery: increasing the number of routine elective surgeries has positively increased and advanced technical confidence and safety. Along with it is the optimization of perioperative care which together has affected valve-related events.

In our experience, early reoperation was almost always due to technical reasons. In the beginning (1998 and 2003) we had two incidents of reoperation due to unsuitable patch material and not addressing correctly cusp and annulus lesions. On the other hand, the mode of long-term failure was mixed, partially resulting from technical failure and partially related to the ongoing degenerative changes in bicuspid and unicuspid valve patients.

In perforation repair, patch reconstruction is anatomical not functional. The free margin remains intact and cusp motion is not affected. Our results are probably excellent in this regard particularly in TAV. Schäfers *et al.* [17] also reported the mid-term outcome of perforation or fenestration repair with patch to be satisfactory. A similar principle applies to resection of valvular abscess or vegetation/masses. We had 19 patients with endocarditis. They had no recurrence of infection. Two of them had bicuspid aortic valve and had late reoperation for mixed valve disease. This makes the repair technique with patch very suitable in the presence of infected tissues or vegetations that require limited resection. Mayer *et al.* [18] reported satisfactory outcomes of valve repair in infective endocarditis as opposed to valve replacement. Similarly, d'Udekem *et al.* [19] reported valvular reconstruction with patch after radical resection of infected tissues to provide an excellent chance of eradication of the infection.

Other factors that would influence the outcome are patch related. The size and the type of the material being used, and the location and the extent of the patching are equally important. In some cases, additional Gore-Tex sutures were added to the cusp as an additional repair technique, which might as well have had an influence on the longevity of the repair. Several authors have well described various techniques as well as biomaterials to restore the aortic valve with excellent early result and good mid-term outcomes, in both paediatric and adult populations for various pathologies [13, 20–23]. They have identified the use of pericardium to be quite durable.

The added biomaterial naturally does not possess those native characteristics of the cusp tissues and this could be one of the reasons of patch failure. As the degeneration of the valve progresses with time, so does that of the patch. At reoperation, the patch can be found matching the process of native cusp changes. So patch failure is caused by patch dysfunction or/and significant native valve deterioration.

In our experience, we have found that patch use can be avoided in BAV repair with the use of the reimplantation technique. Effectively, this technique has shown to induce more intense and more stable annuloplasty compared with the subcommissural annuloplasty. In BAV presenting generally large annulus, the consequence of a more intense annuloplasty during surgery is the increase in the ratio cusp/annulus surface resulting in a reduction of the need for a patch to close the defect after raphe resection. Moreover, we have shown that the reimplantation technique, despite the relatively higher degree of restrictive annuloplasty, does not induce increased postoperative transvalvular gradient and confer a better durability compared with subcommissural annuloplasty [24].

We learnt from our experience that any available tissue material can be used as a patch. In the last decades, as the experience of many centres have accumulated, the literature has been enriched with data reporting the use of the pericardium, autologous and bovine, and the discussion about those is still ongoing and is controversial. Duran *et al.* [25] reported favourable results of treated autologous pericardium in comparison with bovine; however, they have mainly used bovine pericardium in rheumatic disease while autologous pericardium was used for various pathologies.

This would explain our similar results between bovine and autologous pericardium. Rheumatic valve disease is aggressive and ongoing and it might have an impact on a xenograft in aortic position. We would have a positive view of treated xenograft due to commercial competitive efforts to improve decellularization and fixation processes. While brief treatment of autologous pericardium with glutaraldehyde might not be sufficient to stand the test of time. As more variable pericardial xenografts (bovine, porcine and equine), or other tissues, are being readily available for use, the debate would increase unless strong preclinical or prospective studies are presented.

This study reports medium-term outcomes of aortic valve repair with a patch in non-rheumatic valve disease utilizing either bovine or autologous pericardium with similar results. By reporting these results, we might have better insights into and guidance towards better patient selection using certain techniques that would benefit the most from the repair procedure. Moreover, to limit or restrict the use of patch material to specific conditions that would be of more advantage, and when is possible with better alternative, to avoid patching. The solution would be to have close-to-ideal patch material that possesses cusp structure and function and is surgically pliable and readily available for use.

STUDY LIMITATIONS

The main limitation of this study is related to its retrospective design with the inherent risk of data misinterpretation and data loss. Particularly, we found limitation deducting data related to mechanisms of failure, or the specific outcome of the patch itself. Our data gathering was from echocardiography and operative notes. Unfortunately, outcomes of the patch itself were not systematically described. Furthermore, we evaluated our evolving experience in aortic valve repair with patch, and we have fine-tuned our approach. Early failure of these repaired valves could be related to initial high tolerance of residual AR, technical evolution and understanding to address the entire components of the aortic valve. Our cohort is small in number, in total and for each subgroup. This limits the power of our analysis. Therefore, interpretation of the results should be taken with caution and the patients need continuous follow-up to confirm observations made at this stage.

CONCLUSIONS

Aortic valve repair with a biological patch is feasible for various aetiologies. The techniques are safe and medium-term durability is acceptable, even excellent for perforation repair in tricuspid valve morphology. Repair durability in congenitally abnormal valve is dependent on the degeneration process of the native as well as the patch tissues. Bovine pericardium is a good alternative to autologous pericardium.

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APPENDIX. CONFERENCE DISCUSSION

Dr S. Thelin (Uppsala, Sweden): I found this manuscript really interesting and it could be discussed for a long time, but in the interests of time I will give you three short questions. First, I see that you included about 10 patients with grade 1 and 2 aortic regurgitation. I suppose that these patients also had other indications for surgery.

Dr Mosala Nezhad: That is true.

Dr Thelin: My question is, what degree of aortic regurgitation do you accept postoperatively?

Dr Mosala Nezhad: Right now I can say that we should not accept any degree of aortic regurgitation; however, trivial regurgitation is thought to be acceptable.

Dr Thelin: Trivial, so that is grade 1?

Dr Mosala Nezhad: Yes, 0 to 1.

Dr Thelin: Secondly, the diseases you treated have a higher incidence among males. Still, there is an non-proportionate over-representation of male patients in your material, up to 90 or 100% in some groups. Does this reflect in some way the fact that women are more reluctant to choose traditional surgery instead of valvuloplasty or do you have other explanations for this?

Dr Mosala Nezhad: I can say from my very limited experience that this centre is a centre that is dedicated fully to a valve repair procedure for indicated patients. So definitely every patient will go through the process of consultation and a discussion about the options that they would have. I believe that whatever has been presented before you and the audience here is what we had. And Drs De Kerchove and Boodhwani can support me here; they are senior to me, and they have more experience with this, and I believe that male preference for AV repair is not the case.

Dr Thelin: Finally, your results are impressive but in some subgroups the results could have been even better if you had used traditional methods with prosthetic implants. Have you in any way changed your indications during the last year?

Dr Mosala Nezhad: I'm sorry, I couldn't hear your question well.

Dr Thelin: For example, looking at tricuspid valves, some of your procedures have quite a high degree of reoperations. Does this mean that you have changed your indication and you go for more standard procedures in these cases?

Dr Mosala Nezhad: Well, this study is mainly concerned about those patients who required a valve repair using a patch, and that ideally will be class 3 patients or those who had perforation of a leaflet. So if you have a defect, you need to repair that defect. Certainly in the bicuspid population, when we do the reimplantation technique with more intense annuloplasty, that will result in more additional tissue of the cusp being available. So after resection, a simple direct closure may be done, so the use of patch could be limited in those particular patients. This is all I can say about this at this time.

Dr Thelin: But that means that in some subgroups you have moved away from the use of patches and gone to more traditional methods in one way or another?

Dr Mosala Nezhad: For indicated patients, yes. If the indication for the use of patch is there and it is inevitable, yes, we do the repair surgery.

Dr M. Ahmed-Nasr (Cairo, Egypt): We have used fresh autologous pericardium and we had a bad experience; it degenerates very rapidly. And then when we started to tan this pericardium using glutaraldehyde, but in a diluted form, and then washed it many times before use, we had better results; is this your experience?

Dr Mosala Nezhad: Was this experience in rheumatic or non-rheumatic patients?

Dr Ahmed-Nasr: In rheumatic.

Dr Mosala Nezhad: In rheumatic!