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Review

Aortic valve repair for aortic insufficiency in adults: a contemporary review and comparison with replacement techniques

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Abstract

In evaluating the goal of aortic valve preservation, there have been 11 reports of large series of aortic valve repair for aortic insufficiency in adults published in recent years. We sought to analyze the validity of these methods and compare them to published results for bioprosthetic valves, pulmonary autografts, and aortic homografts. From 1990 to 2002, 761 adult aortic valve repairs were reported. Perioperative morbidity ranged from 3.6 to 23% (mean 14%), early mortality 0–8% (mean 3.6%), and late mortality 0–8% (mean 2.8%). The 5- and 10-year freedom from reoperation rates for repair were 89 and 64%. Although early results are good, long-term analysis suggests that, as a group, the durability of repair is unclear. Patients with rheumatic valvular disease appear to have an increased incidence of recurrence and repair failure. Although suture line dehiscence continues to be both an early and late complication with repair, the long-term morbidity and mortality is low and valve repair may be an option in carefully selected patients. However, the inability to break down the results by techniques does not allow for a definitive conclusion. Further subanalysis is necessary as larger series are reported. Proponents must attempt to separate successful from unsuccessful techniques. Aortic valve repair is a technique in evolution.

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Keywords: Aortic valve; Valve repair; Aortic insufficiency; Aortic valve surgery; Valvuloplasty

1. Introduction

Repair of the aortic valve has received considerably less attention than repair of the mitral or tricuspid valves. Reasons for this may include the greater incidence of stenosis in the aortic valve relative to insufficiency, the degenerative processes that lead to valvular dysfunction reducing the number of potentially repairable valves, and the presence of a wider variety of valve substitutes with lower thromboembolic potential and greater longevity than for the mitral position. Furthermore, the functional structure and redundancy of the mitral and tricuspid valves may be more amenable to plastic techniques. Most surgeons treat all aortic valve pathology with a replacement. In part, this management strategy is justified by the excellent long-term results with available prostheses. Since valve replacement in the younger adult has the inherent problems associated with anticoagulation and/or prosthesis durability, repair, if durable, has the potential to be a good solution in this patient population.

Techniques of aortic valve repair have been documented for over 40 years. Starr and associates first reported a technique for aortic repair in 1960 [1]. This was followed by two case reports of aortic valve repair along with ventricular septal defect repair in young patients by Spencer in 1962 and later Trusler in 1973 [2,3]. Interest in reparative techniques grew in Europe after Carpentier reported on a large number of repairs in one of the first articles to report on the indications and outcomes in 1983 [4]. In the early 1980's, as percutaneous balloon valvotomy was performed with increasing frequency in the United States, surgeons became more involved in aortic valve repair after annular disruptions and other balloon-induced injuries caused acute insufficiency in young patients requiring immediate repair [5]. Starting in the 1990's, several authors began to report on their experiences with larger numbers of patients using different techniques. This review will examine the published experience with aortic valve repair, attempt to streamline

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Table 1
AV repair combined techniques

Author	Year	Patients	Mean age	Bic Val (%)[a]	Etiology			Pure AI/prolapse (%)	Aortic stenosis (%)	AI and AS (%)
					Congen (%)	Rheum (%)	Degen (%)			
Schafers [13]	2002	156	58	29	0	0	100	100	0	0
Al-Halees [12]	2001	86	28	3	10	79	?	60	7	33
Izumoto [11]	2001	63	53	29	29	0	71	100	0	0
Rao [10]	2000	54	> 18	61	100	0	0	87	4	9
Haydar [19]	1997	44	33	23	68	11	16	70	0	30
Duran [23]	1991	107	23	?	14	84	2	72	0	28
Amano [14]	1993	18	46	?	0	78	22	28	0	72
Cosgrove [43]	1991	28	47	75	80	?	?	100	0	0
Total		556	41	30	27	32	38	83	1	16

Author	Preop NYHA3 or 4 (%)	X-clamp (mins)	CPB (mins)	Leaf res/tri resec (%)	Comm annulo (%)	Leaf exten (%)	Other (%)	Morb (%)	Early mort (%)	Late mort (%)
Schafers	?	?	?	43	5	0	52	?	4	?
Al-Halees	71	88	137	30	77	0	1	?	8	8
Izumoto	?	107	157	76	63	0	21	?	3.2	1.6
Rao	?	?	?	39	61	0	0	?	1.9	5.6
Haydar	27	?	?	25	50	43	20	23	0	0
Duran	81	88	128	0	58	36	35	?	1.8	0
Amano	72	?	?	0	72	6	22	11	5.6	0
Cosgrove	36	42	?	100	100	0	0	3.60	3.6	0
Total	65	81	141	36	49	11	26	14	3.6	2.8

Author	Mean F/U (months)	TEE (%)	IE (%)	Survival 5/10 years (%)	Recurrence/ reoperation (%)[b]	Freedom from reoperation 5/10 years (%)
Schafers	?	0	?	?/?	3	97/?
Al-Halees	60	5	1	? /86	19	68 (8 years)
Izumoto	41	0	1.60	95/?	14	78/?
Rao	50	?	?	98/74	?	74/51
Haydar	31	?	?	? /?	18	? /?
Duran	'6–30'	0	0	? /?	9.5	? /?
Amano[c]	118	6	0	? /?	5.6	100/100
Cosgrove	7	0	0	? /?	3.6	?/?
Total	46	1	0.7	97/81	10	89/64

[a] Bicuspid valves, congen, congenital; rheum, rheumatic; degen, degenerative; AI, aortic insufficiency; AS, aortic stenosis; TEE, thromboembolic events; IE, infective endocarditis; CPB, cardiopulmonary bypass; leaf res, leaflet resuspension; tri resec, triangular resection; comm annulo, commissural annuloplasty or circular annuloplasty; leaflet exten, leaflet extension with pericardium; morb, morbidity; mort, mortality; ?, information unavailable.

[b] Only significant recurrences requiring reoperation.

[c] The one recurrence in Amano's series occurred after 11 years; numbers in the bottom row are weighted means.

Table 2
AV repair using leaflet extension with pericardium

Author	Year	n	Mean age	Etiology			Pure AI/prolapse (%)	Aortic stenosis (%)	Both (%)
				Congen (%)	Rheum (%)	Degen (%)			
Grinda [15]	2002	89	16	0	100	0	90	0	10
Ahn [16]	2002	34	31	?	?	?	100	0	0
Duran [17]	1995	82	29	3	87	10	52	17	31
Total		205	25	1	94	5	77	6	17

Author	Preop NYHA	X-clamp (min)	CPB (min)	Morb (%)	Early mort (%)	Late mort (%)	F/U (months)	TEE (%)	IE (%)	Mean survival 5-year (%)	Recur/reop (%)	Free reop
Grinda	?	68	76	16	2.2	1	62	0	2	96	8	92%–5 years
Ahn	?	102	128	?	0	2.9	50	?	3	94	6	94%–1 year
Duran	2.7	91	127	?	1.2	3.7	32	0	2	92	9	89%–5 years
Total		87	110		1.5	2.4	48	0	2.4	94	7.8	91%–5 years

congen, congenital; rheum, rheumatic; degen, degenerative; AI, aortic insufficiency; *n*, patients; X-clamp, cross clamp; CPB, cardiopulmonary bypass; morb, morbidity; mort, mortality; F/U, follow-up; TEE, thromboembolic events; IE, infective endocarditis; recur/reop, recurrence requiring a reoperation; free reop, freedom from reoperation; ?, information unavailable. Numbers in the bottom row are weighted means.

the results and draw conclusions regarding the success and applicability of aortic valve repair. To meet this end, we reviewed the worldwide experience with aortic valve repair for aortic insufficiency in adults and focused on the indications and outcomes of various techniques.

2. Methods

An online search of the databases Medline™ and Pubmed™ for English language articles from the world's literature was performed using various search terms such as aortic valvuloplasty and aortic valve repair (Appendix A). The search found over 400 references related to the topic since 1990. Few inclusive articles were found on the topic before 1990 and so this was chosen as the cutoff date. Articles were eliminated that did not directly relate to surgical aortic valve repair for aortic insufficiency in adults. Reports on aortic stenosis, insufficiency in the pediatric population, reconstruction of the aortic root for aneurysmal disease, and instructional articles were excluded. In addition, articles with only very short-term follow-up or lack of a clear operative description of what was done were excluded [6–8].

This search found eight retrospective patient series from 1991 to 2002 that contained sufficient information and follow-up for analysis of the various techniques used for valve repair. These are detailed in Table 1. In addition, there were another three articles that dealt with only the cusp extension technique using glutaraldehyde-treated autologous pericardium, and these were analyzed separately since a single reparative technique was used. These are detailed in Table 2. The numbers given in the tables are weighted means to accurately reflect the trends across all series.

2.1. Surgical anatomy and the mechanisms of insufficiency

One source of confusion when reviewing reports of repair procedures for the aortic valve is terminology. Therefore, a brief review of the details of aortic root anatomy is necessary to establish common terminology. The aortic valve is composed of three semilunar leaflets of approximately equal size suspended in the aortic tube (Fig. 1). Each leaflet is suspended in a semicircular fashion such that it is self-supporting in the closed position. Competence of the valve is obtained by the coaptation of these self-supporting leaflets. The 'aortic annulus' is not a true, discrete, fibrous annulus [9]; rather, there is a transition zone where the ventricular muscle and the cardiac fibrous skeleton transition into the aortic tissue. This 'annulus' refers to the transitional junction that is approximated by the lowest point of the semicircular attachment of the valve leaflet within the aortic root. The highest point of attachment is at the junction point of the adjacent leaflets, the commissure. The top of the commissures defines the sinotubular junction. Aortic insufficiency can result from

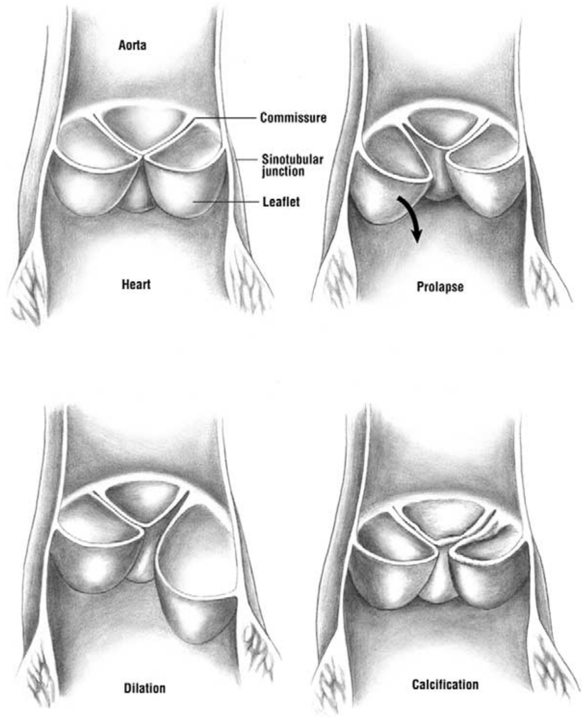

Fig. 1. Normal anatomy and pathology of the valve leaflets.

(Fig. 1): (1) deformation of the leaflets from destruction or alteration of the leaflet structure; (2) prolapse of one or more leaflets; or (3) dilation of the annulus, sinotubular junction or both, preventing coaptation of structurally normal leaflets.

2.2. Valve repair techniques

Depending upon the indication, the type of repair performed by each author varied. However, most repairs could be grouped into the following categories. For pure annular dilation of the valve (not aortic aneurysmal dilation), there were three mainstays of treatment: circular annuloplasty, commissural annuloplasty (commissural plication or the 'Cabrol stitch'), and valve extension with pericardium. For prolapse, the common techniques used were triangular resection, leaflet resuspension, and plication of the free edge of the leaflet. For stenosis, the repairs consisted of commissurotomy, or leaflet shaving to unroll and improve coaptation of the leaflets. And finally, for those patients with perforation, the repair was performed by closing the perforation with a simple suture or a small patch. For clarity, a brief description of each technique follows.

The first type of repair used for annular dilation was called a circular annuloplasty, also known as a circular suture, which is anatomically more accurate (Fig. 2). The circular suture is a continuous mattress of 2-0 non-absorbable suture that is passed through the aortic wall at the attachment point of the leaflet caudad toward the ventricle and then cephalad from the ventricular side back

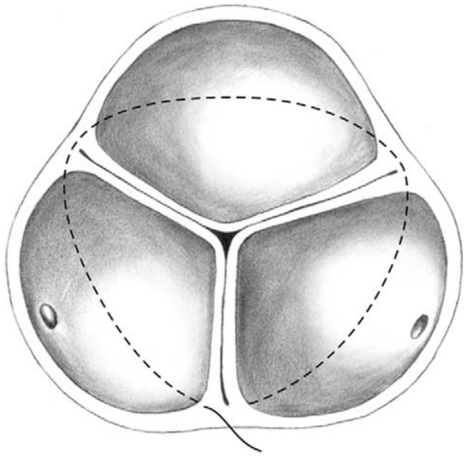

Fig. 2. Circular annuloplasty.

up through tissue at the leaflet attachment point and brought around the entire circumference of the valve. The suture is pulled tight at the ends to imbricate the wall of the aorta, decrease the circumference, and bring the leaflets to better coaptation. Thus, this suture is not at what might be defined as the annular level; rather it traces the attachment point of the valve leaflets.

The second method of repair for annular dilation is called a commissural annuloplasty, but for reasons similar to those detailed above, is better described as a commissuroplasty or commissural plication, since the sutures are placed at the commissural, not the annular level. In this method, the aortic wall is plicated at each commissure with a separate pledgeted, horizontal mattress or U-stitch (Fig. 3). This also results in a reduced aortic circumference. This technique is appealing because it is easy to perform and adds very little time to the operation.

The most complex method of repair is valve extension. Three strips of pericardium, 3–8 mm wide depending upon the amount of annular dilation, are sewn to the free edges of the valve cusps to extend them and increase the surface area for coaptation (Fig. 4).

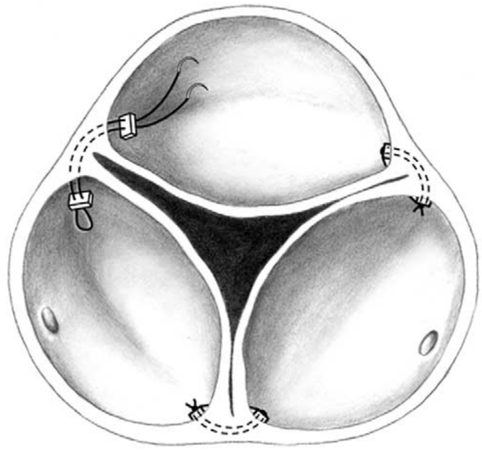

Fig. 3. Commissural plication.

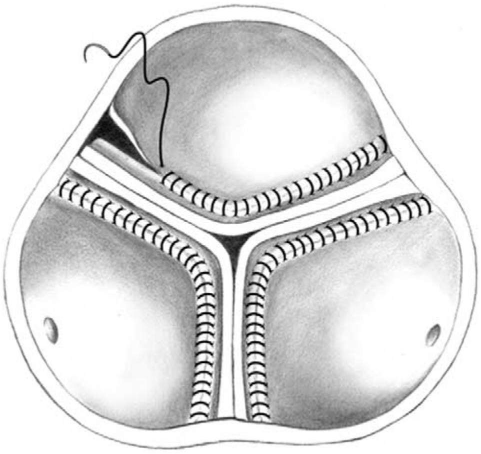

Fig. 4. Leaflet extension using autologous pericardium.

For prolapsing valves, the redundancy in the valve must be corrected. The triangular resection involves excising a triangle of tissue in the middle of the prolapsing valve and then suturing the edges back together to decrease the transverse length, which brings all the leaflets together (Fig. 5). A continuous suture is recommended instead of interrupted sutures because it decreases the chance of a leak and lessens the thrombogenic 'knot-burden'. Although this method is more commonly used for bicuspid valves to excise the median raphe, it has also been described with tricuspid valves if one leaflet is redundant and prolapsing.

Another option to repair a prolapsed valve is leaflet resuspension. To perform leaflet resuspension, the prolapsing cusp is identified and the free edge near the aortic wall is then plicated (with a suture reinforced with a Teflon or pericardial pledget) to the aortic wall to remove the redundancy in the valve. This takes the slack out, returning the coaptive surfaces to the same level, correcting malalignment, and reestablishing competency. A third alternative is to shorten the free edge of the leaflet with a continuous running suture, commonly referred to as free edge leaflet plication.

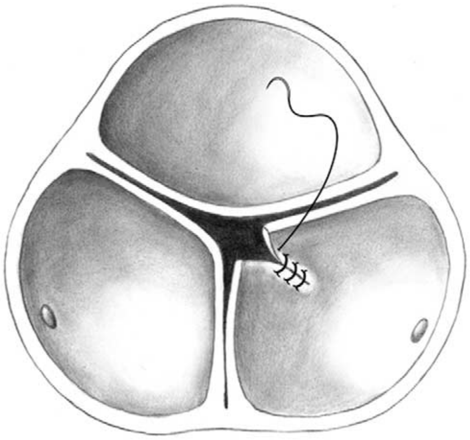

Fig. 5. Triangular resection.

For patients with aortic stenosis and/or insufficiency, caused by thickening of the free edges of the leaflets, leaflet shaving can be performed to unroll the free edge and allow better coaptation. A scalpel is used to incise the free edge and unroll or thin out the edge to allow the cusps to come together. This may be combined with cusp extension using pericardium to allow the leaflets to touch and become competent.

In our review, we noted that different authors used various methods of repair and commonly used more than one technique to repair the valve in any given patient, i.e. a triangular resection and commissural annuloplasty. This is why the total of percentage usage of the various procedures exceeds 100% in some series (Table 1b). The types of repair were grouped according to whether the intervention was only on a single leaflet (leaflet resuspension, triangular resection), on the annulus (commissural annuloplasty, circular annuloplasty), or on all three leaflets (pericardial extension). Depending upon the author, differing terms may have been used to describe what was done (leaflet plasty, commissural plication) and we categorized these under the above headings for comparison as best as could be gleaned from the author's description of what occurred. With multiple reparative techniques commonly being used in a single patient and with diverse pathology occurring in every series, organizing the patients into pure subgroups by specific technique, or discrete categories of pathology, was difficult. The exception to this was the articles describing the outcome using the pericardial extension technique only. Thus, the results were organized separately into Tables 1 and 2.

3. Results

3.1. Results of the combined techniques

From 1990 to 2002, there have been 761 adult patients (>18 years, mean age 36) reported worldwide that have undergone aortic valve repair for aortic insufficiency using the previously described techniques. Patients in New York Heart Association (NYHA) classification III or IV comprised 65%. Bicuspid valves were present in 30%. The etiologies of aortic insufficiency were congenital (27%), rheumatic (32%), and degenerative (38%) (Table 1a). The vast majority of patients had either pure aortic insufficiency (83%) or mixed aortic insufficiency with some degree of stenosis (16%). A few patients in two of the series had isolated stenosis (1%).

The indications given for aortic valve repair as determined from this collective review were isolated aortic insufficiency (without another valve being diseased) due to:

- pure annular dilation without significant degeneration of the leaflets themselves;

- single leaflet prolapse with normal mobility and excursion of the leaflets by echocardiography;
- mild stenosis with aortic insufficiency due to one of the above causes without significant calcification or leaflet destruction;
- a small leaflet perforation amenable to simple suture repair.

Procedures on a single leaflet (leaflet resuspension, triangular resection) were performed in 36%, circumferential reduction (various 'annuloplasties, etc.') in 49%, leaflet extension with pericardium in 11%, and other additional procedures in 26%.

The perioperative morbidity ranged from 3.6 to 23% (mean 14%) and the early mortality ranged from 0 to 8% (mean 3.6%). Only patients in atrial fibrillation or patients with another indication for anticoagulation were treated with warfarin. The vast majority were given only antiplatelet agents. For all patients, the incidence of thromboembolic events and infectious endocarditis was 1 and 0.7%, respectively. Late mortality ranged from 0 to 8% (mean 2.8%).

There were only two series that reported on 5-year survival [10,11]. The average 5-year survival for 117 reported patients was 97%. Only two documented 10-year actuarial survival for 140 patients (with 95 and 96% follow-up) of 74 and 86% (mean 81%) [10,12]. Most of the reports gave early to mid-term follow-up (range 6–118 months, mean 46 months).

There was a higher than expected recurrence rate, with significant recurrence of aortic insufficiency requiring reoperation occurring in 10% of patients across all series during a mean 4 year follow-up. The reasons for recurrence included suture line failure or dehiscence of the repair, endocarditis, late failure of autologous pericardium, and progression of disease to involve the repair. This resulted in a 5-year freedom from reoperation of 74–100% (from four series, mean 89%) and a 10-year of 51 and 100% (from two series, mean 64%) [10,12–14].

3.2. Results of pericardial extension

In an independent analysis, we reviewed three reports in the literature in which a single method of repair, cusp extension using glutaraldehyde-treated autologous pericardium, was used [15–17]. These three reports were analyzed separately since only one method of valve repair was used in all patients and allowed for a more pure comparison of results.

There were a total of 205 patients (mean age 25) who had the aortic valve repaired using this technique. The etiology was rheumatic in 94%, degenerative in 5%, and congenital in 1%. Seventy-seven percent of the patients had pure aortic insufficiency, 17% had mixed aortic insufficiency with some degree of stenosis, and 6% had pure stenosis. The early mortality was 1.5%, with a late mortality of 2.4% after a mean follow-up of 48 months. During follow-up, no patient suffered a thromboembolic event, but 2.4% of patients did develop infectious endocarditis. The average 5-year survival was 94%. Significant recurrences requiring reoperation occurred in 7.8% during the 4-year follow-up. The 5-year average freedom from reoperation was 91%.

3.3. Reasons for failure of the repair

From all articles reviewed (both groups above), six articles reported the reasons for failure of the valve repair [12,15–19]. These six papers described a total of 363 repairs, of which, 48 (13%) failed. The most common reason for failure was progression of rheumatic disease to involve the repair in 24 (50%) patients. The second most common reason was suture line dehiscence, which occurred in 11 (23%). The suture line dehiscence occurred within the first 24 h postoperatively in two patients, and at 8 days, 2.5 months, 4 months, 8 months, 14 months, 42 months, 3.5 years, and 5.3 years after surgery in one patient each. The time after surgery was not described for the final dehiscence. Endocarditis was the reason in six (13%). Four other failures were due to calcification or retraction of the pericardial extension tissue (8%). The etiology behind the remaining three failures was unknown.

When all of the articles covered by this review are taken into account, the early recurrences were always attributed to technical mistakes. This included suture line dehiscence, pericardial tissue tears, and one patient whose pericardial extension tissue strips were excessively redundant and flapped over the left main ostium, causing intermittent, dynamic occlusion and ischemia leading to cardiac arrest. The late recurrences were due to progression of rheumatic disease, late suture line dehiscence, pericardial tissue tears, or calcification and retraction of the pericardial tissue. Grinda studied the explanted valves from three patients who developed recurrent insufficiency and found that the pericardial extension tissue showed fibrosis, small calcifications, and retraction as early as 14 months after surgery [15].

4. Discussion

The optimal treatment of aortic insufficiency would be to replace or repair the valve to its pre-disease state without the need for long-term anticoagulation and obtain life-long durability. Currently, no such treatment exists. Although mechanical valves can last for the patient's lifetime, overall complications from life-long anticoagulation occur with a frequency of 2.3–6.8/100 patient-years [20]. Specifically, bleeding complications from anticoagulation for mechanical aortic valves occur with a frequency of 1.7% per patient-year [21]. Lower rates of these complications may be expected with improved anticoagulation management. Emery et al. recently reported rates of thromboembolism of 0.3% per year, anticoagulant related hemorrhage of 0.3%

per year and valve thrombosis of 0.1% per year for patients under age 50 with St. Jude valves in the aortic position [22]. Other treatment options are replacement with a bioprosthesis, aortic homograft, pulmonary autograft, or valve repair. Since none of these approaches obligates permanent anticoagulation, it is appropriate to compare the outcome and durability of repair with that of bioprosthetic replacement, aortic homografting, and pulmonary autografting (the Ross procedure).

The authors cited in Tables 1 and 2 almost uniformly used aspirin, another antiplatelet agent, or no medication after surgery, with warfarin being reserved only for those patients who developed postoperative atrial fibrillation. For example, Duran reported that after surgery, 53% of patients were on an antiplatelet agent, 42% were receiving no prophylaxis, and 5% were on warfarin [23]. For all types of repair, the combined incidence of thromboembolic events in 458 reported patients during a mean follow-up of 49 months was 1%. For the pericardial extension groups, their incidence of thromboembolic events in 171 reported patients during a mean follow-up of 47 months was zero. This compares favorably with the long-term outcome studies of bioprosthetic valves in the aortic position, for which their reported incidence of thromboembolic events in 495 patients over 60–79 months without anticoagulation was 2.3–3% [24,25]. Thromboembolic events did not occur at all after pulmonary autografting in 271 patients from 27 months to 4.2 years after surgery [26,27]. Similarly, there were no thromboembolic events reported after aortic homografting in 195 patients followed from 50 months to 7 years [28,29]. The low incidence of thromboembolic complications after valve repair without anticoagulation justifies continued interest in these techniques.

By preserving the native valve, there should be a theoretical advantage to reducing the incidence of infectious endocarditis after surgery. The reported incidence of infectious endocarditis after all types of repair for 302 reported patients over a mean follow-up period of 49 months was 0.7%. In the pericardial extension groups, the incidence in 205 reported patients over 48 months was 2.4%. This also compares favorably with the reported incidence in bioprosthetic valves in the aortic position. In two large studies covering 658 patients over 5 years, the reported incidence was 1–2% [30,31]. For pulmonary autografts, the incidence is also 1% [26,27]. Infectious complications are rare after homograft replacement, with an incidence less than 1% [29].

With the risk of thromboembolism and infectious endocarditis being roughly equivalent, the determining factor in selecting the operative approach for a patient; be it valve repair or the use of a bioprosthetic, pulmonary autograft or homograft replacement valve; might be durability. Including all repair techniques, examining 502 patients followed for a mean of 46 months, significant recurrences that required reoperation occurred in 10%. The 5- and 10-year freedom from reoperation rates were 89 and 64%. For the 205 pericardial extension patients followed for a mean of 48 months, the reoperation rate was 7.8%. The 5-year freedom from reoperation rate was 91%. Long-term outcome studies that examined the results of bioprosthetic replacement in the aortic position have found five, eight, ten, 12 and 13 year freedom from reoperation rates of 96, 90–99, 96, 83 and 91%, respectively [24,25,30–32]. Based solely on reported numbers the results for valve repair seem less favorable than bioprosthetic replacement. However this comparison is not valid, as most studies of bioprosthesis durability are in the elderly (mean age 72) while the average age of patients in these studies was 36. Early generation bioprostheses did not demonstrate similar durability in younger people leading to the abandonment of their use in favor of mechanical prostheses. With pulmonary autografts, 5- and 7-year freedom from reoperation for autograft failure is 91 and 93% [33,34]. The 5- and 7-year freedom from reoperation for failure of the homograft in the pulmonic position is 97 and 98% [33,34]. The overall 7-year freedom from any valvular reintervention after the Ross procedure is 88% [35]. For aortic homografts, the 7, 10 and 15-year freedom from reoperation rates are 89, 86, and 58% [29,36]. However, differences in procurement, sterilization, preservation, and implantation of these homografts prevent a scientifically valid comparison of overall performance [37]. These results suggest that early durability of aortic valve repair is similar to that of pulmonary autograft, or homograft replacement valve in younger people, but later durability is worse (Table 3), though probably better than early generation bioprostheses. Repair may not be justified in older patients with excellent proven longevity of bioprostheses. With better proven durability, third generation

Table 3
Comparison of techniques

	TEE (%)	IE (%)	FFR 5 years (%)	FFR 7 years (%)	FFR 10 years (%)	FFR 12 years (%)	FFR 15 years (%)	Sur 5 years (%)	Sur 7 years (%)	Sur 10 years (%)
Repair	0–1	0.7–2.4	89–91		64			95		80
Biopro	2.3–3	1–2	96	90–99	96	83		80–88	70–81	
Ross	0	1	91	93			85	94	97	86
Homog	0	<1		89	86		58		94	

TEE, thromboembolic events; IE, infectious endocarditis; FFR, freedom from reoperation; Sur, survival; Biopro, bioprosthetic; and Homog, homograft. See text for references.

bioprostheses are now being recommended for younger patients instead of mechanical prostheses, the results in younger patients remain unknown. The application of simpler repair techniques (such as annular reduction techniques) may have a better long-term success than techniques that involve direct repair of leaflet abnormalities. This is borne out by the higher long-term failure rate of rheumatic valves. The data show that the outcome for rheumatic valves repaired was worse than for other etiologies. This is also true for mitral valve repair. Additionally, the most common mode of early failure, suture line dehiscence, may not be as common a problem with simpler methods of repair. However, the published data does not allow this discrimination by type of repair, and so no independent data for annuloplasty alone can be isolated and scrutinized.

Valve repair should add no additional morbidity to the operation. Including all types of repair, the mean cross-clamp and cardiopulmonary bypass times that were reported for 284 operations were 81 and 141 min, respectively. The 205 reported operations to perform pericardial extension required similar mean times of 87 and 110 min, respectively. This is similar to large reported series of stented and stentless bioprosthetic replacements for which cross-clamp and bypass times were 80–96 and 91–129 min, respectively [33].

We found that the actual mean 5-year survival after all repairs in a reported 322 patients was 95%. The actuarial 10-year survival was 80%, although only two articles reported 10-year survival in a total of 140 patients. Five, 7, and 10-year survival after the Ross procedure is 94, 97, and 86%, respectively [27,33–35]. For replacement, reported 5, 8 and 13-year survivals are 80–88, 70–81, and 31–53%, respectively [24,25,30,31,33]. Since a relatively larger percentage of the valve repairs were done in younger patients (mean age 36 years, versus 72 years for replacement), the improved survival at 5 and 10 years may be attributed to better left ventricular function, which is associated with a younger and more vigorous patient population. Indeed, the NYHA class was dissimilar at the time of operation. Sixty-five percent of the patients undergoing repair were in NYHA class III–IV, while two large studies in the literature reported that patients in NYHA class III–IV comprised 78–85% of the patients having valve replacement [30,33]. Therefore, it is imprudent to state that repair has an improved survival when compared to replacement, because the populations are not comparable. Additionally, survival in the older patient population of the replacement cohort is negatively impacted by other comorbid conditions, as all deaths were not directly related to heart disease, but rather, confounding disease states not commonly found in the younger patients.

As expected, the younger patients undergoing repair in the studies reviewed within this article had a higher incidence of bicuspid valves, when compared to large outcome studies of valve replacement, for which the indications were usually rheumatic or degenerative disease. The percentage of bicuspid valves ranged from 3 to 75% (mean 30%) (Table 1a). Bicuspid valves are more likely to calcify and degenerate over time. Early preliminary findings from clinical trials of aortic valve repair suggested that bicuspid valves may be less amenable to reparative techniques than tricuspid valves [38,39]. The reason for this is that the histoarchitectural distribution of calcific deposits in the bicuspid valve is more diffuse, involving both leaflets completely from free margin to aortic wall; while calcification of tricuspid valves occurs in nodular form with a sporadic distribution [40]. Although this remains to be proven, the higher incidence of bicuspid valves in the patients undergoing repair may be responsible in part for the increased recurrence and reoperation rates. An intermediate follow-up report; including 94 patients with bicuspid aortic valves and insufficiency due to a prolapsing leaflet, all repaired by either triangular resection or mid-leaflet plication; documented 5 and 7-year freedom from reoperation rates of 87 and 84%, respectively [41].

As with all new surgical techniques, as time passes and more experience is gained, the results improve. In 2000, a 22-year study (the article reviewed with the longest follow-up) found that only 57% of aortic valve repairs remained competent over two decades, and that most adults would eventually require valve replacement [42]. Most recently, results from a 15-year retrospective series found that freedom from reoperation after aortic valve repair was 87% at 5 years with a 0.6% early mortality [18] (abstract only, details unavailable for analysis).

5. Conclusion

Although in the short term aortic valve repair has similar results as compared to bioprosthetic replacement, homografting, and pulmonary autografting in terms of morbidity, mortality, and operating times, the long term durability of repair as a group has not been shown to be equivalent. Patients with rheumatic valvular disease appear to have an increased incidence of recurrence and repair failure. Although suture line dehiscence continues to be both an early and late complication with repair, the long-term morbidity and mortality is low and valve repair may be an option in carefully selected patients, though the inability to break down the results by techniques does not allow for a definitive conclusion. Further sub-analysis is necessary as larger series are reported to define durable repair techniques. Valve repair is an established part of the treatment armamentarium for aortic valvular disease but is a technique in evolution, requiring better definition of successful approaches.

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Appendix A. Search terms

Aortic valvuloplasty
Aortic valve repair
Aortic insufficiency
Aortic valve plication
Aortic annuloplasty
Aortic valve extension
Aortic leaflet repair
Triangular resection
Leaflet resuspension
Commissural plication
Commissural annuloplasty

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