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CRYOLIFE-O'BRIEN STENTLESS VALVE: 10 YEAR RESULTS OF 402 IMPLANTS.
THE AORTIC ANNULUS EXTENSIBILITY IS RESTORED
Short Title: Ten Year Follow-up of CryoLife-O'Brien Stentless Valve

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ABSTRACT

Background

This *truly stentless* porcine valve is composite, without Dacron and implanted supra-annularly. Ten year analysis with magnetic resonance imaging is presented.

Methods

From 1992 to 2002, 402 patients (mean 73.5 yrs) had aortic valve replacement. Associated procedures were required in 252 patients (63%). Serial echoes provided 1340 studies. Clinical follow-up was 100%. Magnetic Resonance Imaging focused on aortic annulus extensibility.

Results

The 30 day mortality was 0.99% (4 deaths). Morbidity comprised (a) *thromboembolism* (40 patients including 18 patients with permanent strokes); (b) *endocarditis* (nine patients); (c) re-operation (nine patients) - peri-prosthetic leak (2), endocarditis (5), technical needle damage (1) and structural degeneration (1). Of 402 valves over 10 years, five valves were explanted, *one only for structural failure*. Except for endocarditis (2), no late deaths (69 pts, 1.5 months – 5.7 yrs) were valve related. Echocardiography demonstrated low gradients with good orifice areas, excellent ventricular regression (p = 0.0001 pre and post-operative comparisons) and late incompetence - mild (45 pts) and moderate (nine pts). No living patient has severe incompetence. Magnetic Resonance Imaging demonstrated the annulus ‘expanding and relaxing’ throughout the cardiac cycle, the mean increase in cross-sectional area being 37%, resembling normal aortic root dynamics.

Conclusion

Elderly patients received this hemodynamically acceptable valve with its simple, supra-annular implantation and satisfactory mid-term morbid-free lifestyle to 10 years maximum follow-up. With only one structural failure, restoration of valve annular extensibility may have a favourable influence on long-term durability.

Introduction

The first clinically implanted porcine aortic valve xenografts in 1965-69 were stentless [1-4], but the introduction of both a stent and glutaraldehyde preservation by Carpentier saw their rapid disappearance [5]. Their revival by David [6] in 1987 initiated the appearance of many designs with varying degrees of dacron cloth support of either the whole porcine valve or partial dacron support over the right coronary leaflet base, where, in the intact porcine animal, ventricular muscle gave support to this leaflet.

In 1991 the authors returned to the use of a composite trileaflet porcine valve constructed from three size-matched non-coronary leaflets [7] (CryoLife Inc. Atlanta, Georgia). Originally in 1967-69 this same composite design, but formaldehyde preserved, had been used by us at The Prince Charles Hospital in 129 patients. From this experience [8], the concept of a composite valve, single suture line technique and supra-annular implantation was established and proven to be reliable. However, the preservation solution proved inadequate. In the early 1970s the re-operation rate was 50% at 5 years. This poor valve durability was unacceptable. With the subsequent well documented performance of glutaraldehyde preservation of porcine valves, the reintroduction of the composite valve appeared justified in the early 1990s [9].

Previous reports have detailed the clinical performance of this stentless valve [7, 10-12] and the implementation techniques [13-16], which are very different to those of other stentless valves. These details are not repeated except to briefly summarize several very important features. The very small 5-6 mm cuff of xenograft aortic wall distal to the valve hinge and the absence of a proximal cuff of this composite valve enable a simple, rapid single suture line implantation technique [14]. Because of this small aortic cuff no problems have been encountered with low-lying host coronary ostia. Additional advantages of the supra-annular placement have included good exposure for the small aortic root, provision of an effective central flow and non-obstructive orifice with low transvalvar gradients mimicking those of the homograft valve. The chosen valve size, being one size larger i.e. a 25mm valve into a 23mm host annulus, allows for discrepancies of annular and sinotubular diameters.

The difference between supra-annular implantation and annular placement, very pertinent to the understanding of the hemodynamic performance and of the magnetic resonance imaging (MRI) findings of restoration of annular extensibility, are demonstrated in Fig. 1. The residual native annulus becomes subvalvar.

The purpose of this report is firstly to update previous clinical appraisals of this valve now that maximum follow-up is over 10 years. Secondly, it is to emphasize the ease of technical implantation with the low early mortality and mid-term morbidity in an elderly patient population, and thirdly, to focus on a novel postulation from MRI studies that the observed restoration of the extensibility of the aortic valve annulus following supra-annular implantation of a truly stentless device may favorably enhance long-term durability.

Patients and Methods

From 30th December 1992 to 4th December 2002, 402 patients received the CryoLife-O'Brien model 300 stentless porcine aortic xenograft for aortic valve replacement (AVR). All patients were either contacted by telephone, seen personally by a physician/cardiologist/surgeon and their records perused during 2002 through to the first half of 2003. The follow-up was 100% complete and although it has now entered its 12th year, this report focuses on the first 10 year analysis. All patient events up-to and including the year of 2002 have been included in this analysis. The evaluation of patient progress and the definitions and assessment of morbid events have been conducted strictly in accordance with the 'Guidelines for Reporting Morbidity and Mortality after Cardiac Valvular Operations' [17-18]. The mean patient age was 73.5 years (range 55 – 89 yrs), males 58%, 73 patients (18.2%) being 80 years or older at the time of operation. Concomitant procedures were required in 252 patients (63%), most of whom (186=46%) were coronary artery bypass operations (CABG: 2.4 grafts/patient). Forty-two patients (10.4%) had left ventricular (LV) myomectomy. While initially in this series, intraoperative transoesophageal echo examination was employed, later transthoracic echo performed at the pre-hospital or preoperative phase became sufficient. Subsequent echoes postoperatively at the 4-5th day, at 6 months, 1 year and 1-2 yearly thereafter were performed. Late serial echocardiography included some 1340 studies over the ten years in order to gain knowledge of the late valve function.

Magnetic Resonance Imaging: As an ongoing study, ten patients who some years previously had received this stentless valve (range 2-11 yrs: mean 6 yrs), were imaged to assess the change in the area of the aortic valve annulus throughout the cardiac cycle. MRI was performed on a 1.5 Tesla Signa Twinspeed system (GE Medical Systems, Milwaukee, WI) with a 4-element cardiac phased array coil. Steady state free precession imaging was used to identify the aortic valve annulus which was seen as an area of low signal intensity beneath the valve [Fig. 2]. ECG gated cine phase contrast images with full R-R coverage were then obtained directly through the annulus, orthogonal to the left ventricular outflow tract [Fig 3]. Image acquisition using a segmented k-space technique, occurred over approximately 16 cardiac cycles (depending on heart rate) to produce a single cine loop representing one cardiac cycle. Some through plane motion was apparent due to the fixed imaging plane relative to cardiac motion but due to the tubular nature of the annulus, this was thought not to introduce significant variation.

Image analysis was performed on an Advantage Windows workstation using Medis flow analysis software. The mean cross sectional areas and flow volumes were calculated and plotted (*Figs 4a* and *4b*) at 30 intervals throughout the cardiac cycle.

Operative Procedures remained essentially standardized throughout the 10 years. These include full median sternotomy, aortic cannulation, intermittent anti-and retrograde crystalloid cardioplegia, CO2 insufflation into the pericardial cavity during cardiopulmonary bypass, LV decompression via right superior pulmonary vein cannulation and distal CABG graft anastimoses prior to transverse aortotomy. Valve excision was followed by aggressive calcific debridement of the native valve annulus remnant. As this area remains exposed to the blood stream with supra-valvar implantation, as much as possible, care was taken to leave this annulus area reasonably ‘smooth’ without obvious semi-loose fragments or spicules of calcium. Measurement of both annular and sinotubular diameter (STD) dictated the selection of valve size (Table 1). With supra-valvar implantation, using a single layer continuous 3/0 polypropylene suture, a valve of at least one size larger than the annulus is selected i.e. a 23mm porcine valve for a 21mm host annulus. If the STD was 29mm and the valve annulus only 25mm, a valve of 29mm would be implanted supra-annularly (i.e. 2 sizes larger than the annulus diameter). Therefore in assessing the level and importance of any gradient, appropriate analysis of echocardiographic transvalvar gradients demands recording of the host annulus diameter in addition to the larger porcine valve diameter. Table 1 outlines the sizes of the implanted porcine valve and host annulus.

Left ventricular myomectomy was carried out in 42 patients. The indication was made at operation rather than on any preoperative echo study. After native value excision, if the L.V. myocardium was prominent and the free edge of the anterior mitral valve leaflet was not readily visible through the aortic orifice, then longitudinal/vertical LV myomectomy was performed.

Institutional approval for the clinical use of this valve was obtained from The Prince Charles Hospital (14 October 1992) and St Andrews Ethics Committee (1994). The Therapeutic Goods Administration of Australia (TGA) was notified according to the Clinical Trial Notification (CTN) category (17 November 1992). All patients gave informed consent to their receiving this stentless valve.

Statistical analysis: Outcomes were reported according to the guidelines for reporting valve-related mortality and morbidity [17]. Descriptive statistics were presented as mean ± standard deviation. Actuarial survival was calculated using the Kaplan-Meier method with 95% confidence limits. Data was collated using Microsoft Access, and statistical analysis was performed using the SPSS statistical package (SPSS Inc, Chicago, Illinois).

Results

The mean follow-up of the patient cohort was 4.3 years (SD 2.6 years, range 0 - 10.4 years). All but four patients survived (*30 day/hospital mortality = 0.99%*). The early mortality was 0.6% for the 329pts<80 yrs of age and 2.7% for the 73pts>80 yrs. The four deaths were essentially valve unrelated (retroperitoneal haemorrhage from intra-aortic balloon insertion 1st day postoperative; aortic dissection from cardioplegic site 2nd day; ruptured spleen (patient fell out of bed, third day); and sudden death at home (arrhythmia 29th day). Of 398 patients, *late mortality* has occurred in 69 (17.3% - 39 days to 9.6 years after operation). Valve related deaths have occurred in two unoperated late endocarditis patients, dying of multisystem failure, beyond surgical retrieval. Except for the debatable relationship that embolism has as a tissue valve related cause of death, all other reasons for death were readily explained on natural causes in this elderly patient cohort (e.g. cancer, cerebro- vascular accident, non-cardiac induced renal failure, respiratory infections). The actuarial 8 year patient survival is 70.8% ± 7.1% (95% C.L.) [Fig 5] with thereafter, a less meaningful decline due to reduced patient numbers. Eight of a possible 14 patients who had their operation 11 years ago are still alive.

Table 2 summarizes the morbidity events of thromboembolism (56 episodes in 40 patients), endocarditis (9), paravalvar leaks (6), structural degeneration (1) and reoperation (9 from all causes).

Initially in this series, the first 83 patients were not temporarily warfarin anticoagulated during the initial postoperative weeks. Three patients, all in new early postoperative atrial fibrillation, sustained peripheral (2) and cerebral (1) embolism. Following this, all patients were anticoagulated for the first six to twelve weeks. Patients having a late thromboembolic event were medicated with warfarin or aspirin - there being no universal policy. Some patients who had a history of preoperative strokes eventually succumbed to late recurrent strokes while 23 elderly patients had a total of 29 episodes categorized as either Transient Ischaemic Attacks (TIA) or Reversible Ischaemic Neurological Deficits (RIND). Patients were very closely questioned and a diagnosis made according to the well-established and recognized guidelines (17-18). This final subjective conclusion was often considered difficult. The actuarial 8 year freedom *from thromboembolism* of all types (82.1% ± 6.5%) and of thromboembolism causing permanent disability (90.0% ± 5.4%) are depicted in Fig 6 and 7.

Other morbid events include 9 episodes of *endocarditis* (9 days to 5 years) over the 10 years of maximum follow-up. There were seven staphylococcal and two streptococcal infections. The event appearance comprised early endocarditis at nine days in one patient and late infection at five months to five years in the remaining eight patients. No patient, 5 years after AVR, sustained an infection. The actuarial freedom from the endocarditis was 97.1% ± 2.0% at 8 years [Fig 8]. In 5 of the 9 patients, the valve did not become dysfunctional, remaining completely competent on serial echocardiography. Of these 5 patients, two died of septicaemia and multi-organ failure and three were medically cured of the acute endocarditis. One of the latter three sustained a ventricular septal defect and another an expanding subvalvar abcess cavity as a result of the now sterile infection. Reoperations were performed, the VSD closed and the cavity patched. Both valves remained competent on the last echoes some two years after reoperation. Three patients required valve explantation in the acute phase of the endocarditis. One of the three patients died of continuing septicaemia and multi-organ failure after re-operation.

Paravalvar leaks have not been a problem of recent years. However two patients did require reoperation. One patient obviously had two loose a suture and, at reoperation at 10 days, valve repair cured the problem. The other patient at 3 months returned with severe acute incompetence. At reoperation a 4/0 polypropylene suture had broken. A stronger suture along the disrupted segment was sufficient to repair the valve. A successful long-term outcome following both valve repairs has been verified by late echocardiography. Since these episodes, occurring early in this series, a stronger suture has been used ie 3/0 polypropylene (No 8936 on a small taper cut half-circle V5 needle, Ethicon, Somerville, NJ). Four other patients without clinical murmurs of incompetence have presumed minor non-progressive paravalvar leaks detected echocardiographically.

The actuarial 8 year freedom from *reoperation* due to all causes was 96.7% ± 2.3% [Fig. 9] and the freedom from valve explantation was 97.8% ± 2.1% [Fig. 10]. Reoperation [Table 2] has been required for 9 patients with the explanting of 5 stentless valves. Explantation has been for endocarditis at 1.5yrs, 2yrs and 3.5yrs after initial operation; for technical needle damage in a patient who had moderate incompetence on hospital discharge with subsequent progression until reoperation at 1.3yrs, revealing an unusual square-shaped hole in the belly of the leaflet, which looked in all other respects normal; for structural degeneration at 5 years, the leaflet tearing away near one of but not at a commissure. *There has been therefore one structural valve failure in the 402 implants requiring reoperation over the ten years.* The graphical depiction of the actuarial freedom from structural failure is therefore unnecessary and not presented. An interesting observation has been made that this composite stentless valve, in the absence of endocarditis, is very easy to remove. The host aortic sinus wall attachment to the small rim of glutaraldehyde preserved xenograft wall is very easily separated with forceps alone once in the correct plane and after the knots of the continuous suture are cut. There has been no obvious macroscopic calcification detected in the xenograft wall of any of these explants (note, except for a diluted ether wash, this valve has no anti-calcium agent in the preservation protocol).

Echocardiography (conventional transthoracic) revealed that most patients, in the late post-operative phase, had a nil/trivial degree of non-progressive incompetence (Table 3). No living patient at last review during 2002-2003 had severe valve incompetence.

Transvalvar gradients and effective orifice areas have been almost but not quite as good as the homograft valve [9] i.e. at 6 months post-implant stentless valve for a 21mm host annulus, the mean gradient is of the order of 9.8mmHg and orifice area 1.56cm^2; for a 27mm host annulus, the mean gradient is 7.3mmHg and the orifice area 2.7cm^2. Left ventricular mass regression has been previously reported [22]; comparison of pre and post- operative regression was significant (P = 0.0001). The mean of the mean and peak transvalvar gradients from the large number of echoes are summarized in Table 4. A similar analysis of those 42 patients who had an associated LV myomectomy is presented in Table 5. The gradients were similar to those patients who did not receive a myomectomy. All 42 patients survived and clearly experienced a very smooth immediate post-operative course. In fact it was a subjective clinical impression, over the years, that not only these patients, but virtually all stentless valve patients, had good post-op progress without low cardiac output states. The MRI studies with annular extensibility may be an explanation for this observation. Some years ago, more esoteric echocardiographic studies suggested interesting observations of the aortic root post-implant. Analysis by 3/4 dimensional echo demonstrated dynamic changes in the size of the aortic root and valve annulus during the cardiac cycle. In retrospect, these findings confirmed the more recent accurate and readily documented MRI studies

MRI Studies demonstrated significant variation in the cross sectional area of the aortic annulus throughout the cardiac cycle at rest in all 10 patients so far examined. The mean increase in cross sectional area of the aortic orifice was 37% of the smallest area in diastole. This would appear possible if, at operation, the calcified native valve is excised, the annulus aggressively decalcified and the valve implanted supra-annularly. The MR images demonstrated the ability of this valve annulus to 'expand and relax' significantly throughout the cardiac cycle. Peak flow volumes corresponding to peak ejection during ventricular systole occurred just prior to maximal annular dilation (Fig 4).

Comment

The long term durability of this stentless xenograft beyond 10 years is still unknown. This present review of the CryoLife-O'Brien valve to the beginning of the 11th year shows promise with only one reoperation for structural failure so far. Because the use of this valve has been largely confined to elderly patients, future analyses of both patient survival and valve durability will be influenced by the competing risk of death due to natural causes. The immediate results are very good with less than 1% early mortality in 402 patients who, at this age with 63% requiring associated procedures, would be classed as a moderately high risk group.

David et al [19-20] described a case controlled patient study with an actuarial survival at 8 years of 91% ± 4% with the Toronto SPV patient group and of 69 ± 8% for the Hancock stented porcine xenograft group (P = 0.0006). The study was perhaps flawed by dissimilar groups and by the individual fact that the stentless valve group seemed to be inexplicably 'immune' to the usual expected natural causes of death in any elderly patient group. Del Rizzo et al [21] analyzed survival with patients receiving either the Medtronic Freestyle stentless valve or the Hancock II porcine valve. Of interest, was the significant advantage of the stentless valve in patients younger than 60 years; the probability of death was five-fold greater with the Hancock than Freestyle valves. With advancing age the benefits of stentless valves were diminished.

In this study of 402 patients, a significant morbid event occurred in 35 patients (8.7%); 22 thromboembolism; 9 endocarditis; 4 reoperations – excluding those for acute endocarditis. The interesting observation with endocarditis is made that the actual infection may occur more on the native host annulus, where turbulence is maximum and speed of flow greatest, than primarily on the supra-annular xenograft. In support of this observation is that in the endocarditis patients all but four of the nine continued to have a competent valve and four of the nine were medically cured of the infection without replacement of the valve.

The incidence of thromboembolic events may seem high. The data collection has been assiduous and may, in comparison with other studies, tend to overestimate the overall incidence of thromboembolism, especially by including all "suggestive" TIA events. During data collection in our institutions, the determination of a higher incidence of thromoembolic events may likely be over-estimated as our many published clinical homograft analyses always had a patient thromboembolic incidence, unlike that of many similar publications by others. It is considered that a stentless tissue valve is unlikely to be the primary site of thromboemboli especially in this elderly group of patients, prone to innate carotid and cerebro-vascular disease and to developing early and late postoperative arrhythmias. Forty-six percent of patients required CABG for coronary atherosclerosis. Except in the presence of endocarditis, thrombus on any stentless tissue valve has not been seen by the surgical authors. However, although the stentless valve itself may be exonerated as the likely focus of thrombus giving rise to an embolic episode, the possibility does exist, especially with supra-annular xenograft valve implantation, that the subvalvar area i.e. the actual denuded native valve annulus, may be a primary thrombotic site. No early or late echocardiographic studies have suggested thrombus in these denuded areas. In addition, an early higher incidence of thromboembolism has not been found. Of the 40 patients who sustained thromboembolism, four episodes were early (less than one month after operation), and all of these were transient ischaemic episodes. Because thromboembolism in this patient study has been more of a late phenomenon than an early event, then the denuded native valve annulus site is far less of an important cause of thromboembolism. Of equal interest is the observation that of the 42 patients who had a myomectomy, only one (at 16 days postoperative) had a transient ischaemic episode. Of this group, a further six had a late thromboembolic episode (4 months to 6.3 years).

The details of serial echocardiography have previously been documented [10]. They have not changed over time and hence are not repeated in this presentation except to state that 94% of patients have either nil/trivial or mild degree of incompetence on echocardiography across time. In addition, echo studies have shown no dilatation of the aortic root in this elderly patient cohort. Therefore, no sino-tubular diameter changes have been observed and no specific surgical sino-tubular fixation techniques have been necessary in retrospect. Progression of incompetence has been rare and cannot be attributed to any root dimensional changes. An interesting comparison of hemodynamics and LV mass regression between the CryoLife-O'Brien stentless and the supra-annular Carpentier-Edwards stented porcine valve has been reported from our institution by Thomson et al [22]. Briefly, at 6 months the mean gradients were lower ($p = 0.001$), the effective orifice greater ($p = 0.05$) and the Dimensionless Performance Index higher in the stentless versus the stented group. There was important LV mass regression at 6 months after operation in both groups, but the reduction was greater in the stentless ($p = 0.04$).

Evidence has certainly accumulated that stentless valves enhance LV hypertrophic regression faster and more completely than do stented valves. Jin et al. [23] compared the hemodynamic data of homografts, stentless (Toronto SPV™) and stented valves. Both types of stentless valves caused less resistance to LV ejection and produced greater early improvement in LV function and consequently more complete resolution of LV hypertrophy. These important findings were verified by Del Rizzo et al. [26] with the Toronto SPV valve.

The highly favorable echocardiographic features probably reinforce the opinion that good hemodynamics facilitate good recovery, low mortality and morbidity. The subjective impressions that these elderly patients feel 'so well', much better than their stented valved colleagues, suggest also that exercise induced variations in cardiac output are more possible and better tolerated with a stentless valve. While a comparative study during exercise has not been completed, the new techniques of 3/4D echo and especially MRI studies are focusing our attention and that of Dagun et al [24] to the restoration towards normality of the aortic annulus during the dynamic phases of the cardiac cycle. During isovolumic contraction both the annulus and sinotubular junction underwent rapid circumferential expansion. The

MRI conclusions in all 10 patients examined so far were even more significant as the studies were carried out some years (mean 6yrs) after valve implantation. These recent findings with the CryoLife-O'Brien supra-annular valve raise several questions. Will the restoration of annular extensibility be an important reason for the improved durability of this particular valve implanted supra-annularly? If so, how can it be proven? The opposite view of course is – does stent mounting and annular fixation diminish durability? This was perhaps clearly answered years ago with our own experience and that of others with the stentless and stented homograft [25]. The latter valve had decreased durability. In addition, the former earlier version of this composite porcine valve in our hands in the late 1960s demonstrated that the actuarial 50% freedom from structural degeneration of the formaldehyde composite valve (if *stented*) was only 2.5 yrs while that of the similar preserved but composite *non-stented* three non-coronary leaflet valve was 5 yrs. In summary, it may be difficult to prove that the presence of annular extensibility is important in improving durability. No further assistance in this debate can come from the homograft which, in its late phase, becomes fibrotic and even calcified in its *intra-annular* implantation site. However the autograft may well show annular extensibility but other variables such as its ability to grow coupled with the presence of viable leaflet tissue capable of cellular replenishment, would confuse the issue and the debate.

The possible advantages of stentlessness are many. This stentless valve has some of the early attributes of the aortic homograft valve. In the small aortic root, its performance is excellent and where an additional LV myomectomy is indicated, all such elderly patients have had a very smooth postoperative course. In essence *no stent should imply no obstruction*.

The effective orifice within a given host aortic root is much greater compared to other stented mechanical or stented biological protheses. This applies particularly to the CryoLife-O'Brien valve where, for example, a 27mm valve is inserted supra-annularly into a 25mm host annulus. Although the xenograft leaflets are a little stiff, they still produce a low mean transvalvar gradient almost but not quite as good as that of the homograft valve.

Although most elderly patients are suitable candidates for this valve, there are nevertheless, three contraindications. Firstly, excessive aortic root calcification may preclude suturing in the supra-annular and peri-commissural aortic wall tissue. This probably applies as well to other models of stentless valves using subcoronary implantation. Such calcification is not common, but if present, an alternative stented bioprosthesis should wisely be chosen. In this series, no stentless valve implantation has had to be abandoned in the middle of implantation because of aortic wall calcification. This decision has always been made on inspection of the aortic root, prior to selection of the particular valve. Secondly, the large aortic annulus (≥30mm) is a contraindication for this valve, the largest size of which is a 29mm CryoLife-O'Brien valve. Thirdly, for the subcoronary supra-annular implant of this type of stentless xenograft, gross asymmetry of the aortic root (bicuspid valve with a transverse orifice), although rare in the elderly, may produce a less desirable result than that obtainable with a stented xenograft valve. Fortunately, most elderly patients have a symmetrical trileaflet configuration to their calcific aortic valve stenosis.

Stentless valves are technically more difficult to implant compared to stented bio-prostheses or mechanical valves. In addition, implantation techniques are more difficult to learn and more difficult to teach. Not every surgical center is interested in adopting a program of stentless valve usage, which requires the interested surgeon to focus more on aortic root symmetry, orientation of a trileaflet valve, measurement of annular and sinotubular diameters. Ultimately patient understanding, cooperation and preference are essential for patient factors, pathological valve disease factors and surgeon factors dictate valve choice and the final short and long-term outcome. Why should a surgeon choose a stentless valve over a stented valve such as the commonly used stented pericardial valves? Surgical techniques are simpler with the stented bioprostheses and probably the immediate outcomes with either valve used by the same surgical team are no different. The authors consider it is a good forward-looking research concept to gather data from patients having a variety of valves in order that 15-20 years comparative analyses can be forthcoming. The authors have a large patient cohort with stented pericardial valves.

Patient Age Selection. From the very onset of this patient study with a new bioprosthesis in 1992, the decision was made to restrict this stentless valve to elderly patients. This was because the durability record of glutaraldehyde preserved stented aortic porcine valves in younger patients was so unsatisfactory, requiring many re-operations in the 1980s, that their use was virtually discontinued. The stented xenograft was relegated to elderly patients where the subsequent record proved and has remained acceptable. So, a careful approach in the early 1990s with this stentless valve was adopted in using it only for elderly patients.

The time has come to wisely use the stentless valve in the less than 60yr age group. While the homograft gives an excellent record in this age group, the supply of such valves is becoming in many countries more and more of an insurmountable problem. In such situations a stentless porcine valve may fill the hiatus. This latter scenario of use in younger patients is indicated even more in countries where rheumatic valve disease predominates and in countries where anticoagulants are best avoided. If this stentless valve begins to be used in younger, non-rheumatic patients, the more frequent findings of an asymmetrical aortic root may constitute a contra-indication to its use. Aortic root tailoring techniques may not reliably correct such asymmetry long-term. Therefore, for the younger patient, wise decisions in valve choice become more crucial for optimal long-term results.

Conclusion

The CryoLife-O'Brien stentless composite porcine aortic valve has proven itself to be a reliable device in the elderly patient cohort in this series in these two institutions by this surgical team. The low immediate operation mortality and good long term survival is most acceptable especially considering that the patient cohort is elderly and destined to die of natural causes. The incidence of morbid events is considered low for this patient group. Of the total patient cohort of 402, the solitary single valve structural failure requiring reoperation over the maximum ten years with a 100% patient follow up may be the crucial objective observation. This valve has rewarded its recipients with a good device.

From the research and scientific arena, the MRI findings of restoring the post-implant aortic annular extensibility, in relation to the dynamics of the cardiac cycle, may be one of the most important findings of a valve that is truly stentless and mounted supra-annularly.

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Table 1. Valve size, host patient valve annulus diameter and the number of patients

Size of Porcine Valve Selected (mms)	Likely Host Annulus Diameter (mms)	Number of Patients
19	<19	Nil
21	<20	17
23	21	53
25	23	125
27	25	114
29	27	93
	TOTAL	402

Table 2. Late Morbidity Events Of 398 Patients Dec 1992 – Dec 2002

THROMBOEMBOLISM (56 episodes in 40 patients)	
Cerebro-vascular	
- CVA permanent	• 23 episodes in 18 patients
- TIA and RIND	• 29 episodes in 23 patients
Retinal	• 1 patient
Peripheral arterial embolism	• 3 patients – two early post-op in atrial fibrillation (coiled embolus removed at embolectomy), one mesenteric artery embolus
ENDOCARDITIS (n = 9)	• 4 patients medically cured - no valve dysfunction. (See reoperations below for two of these patients) • 2 patients died - fulminating septicaemia and multi-organ failure • 3 patients explanted at reoperation
PARAVALVAR LEAK (n = 6)	• 2 patients reoperated and leak successfully repaired without valve replacement • 4 patients mild - echocardiographically detected only

STRUCTURAL DEGENERATION	(n = 1)	• 1 explanted - (Leaflet tear) see below in reoperations
REOPERATIONS	(n = 9)	• 2 Paravalvar leaks - successful repairs [10th day, 3 months (broken 4/0 polypropylene suture)] • 5 Acute Endocarditis - 3 explants at 1.5yrs, 2 yrs, 3.5yrs - 2 valves left in situ: both cured endocarditis: * closure of expanding subvalvar sterile 'abscess cavity' (7 mths), * VSD closure (2yrs) • 1 Technical - explant at 1.3yr for needle perforation damage • 1 Structural degeneration - leaflet tear (5yrs)

CVA – Cerebro-Vascular Accident
TIA – Transient Ischaemic Attacks
RIND – Reversible Ischaemic Neurological Deficit
VSD – Ventricular Septal Defect

Table 3. Aortic Valve Incompetence on Echocardiography

Degree	Grading Nomenclature	Number of Patients
0	Nil-Trivial	297
1	Mild	45
2	Moderate	9
3	Moderate +	3
4	Severe	0
Unknown		11
Total patients echoed		365
Patients with no late echo		33

Table 4. The Transthoracic Echocardiographic Transvalvar Gradients in the Late Post Operative Studies in Patients in Table 3.

Size of Valve (mms)	Patient Annulus (mms)	Mean of all MEAN gradients (mmsHg)	Mean of all PEAK gradients (mmsHg)
19	<19	0.0	0.0
21	<20	12.7	23.4
23	21	10.0	19.13
25	23	8.8	16.7
27	25	8.0	14.7
29	27	6.8	12.7

Table 5. The Late Echocardiographic Results of the 42 Patients who have had an Associated LV Myomectomy

Size of Valve (mms)	No of Patients Echoes Performed	Mean of all MEAN Gradients (mmsHg)	Mean of all PEAK Gradients (mmsHg)
19	0	0.0	0.0
21	16	9.1	18.3
23	34	10.7	20.4
25	46	8.6	15.9
27	26	7.6	13.8
29	6	8.5	16.0

LV – Left Ventricular

LEGEND FOR FIGURES

Fig 1 Supra-annular implantation maximizes the effective orifice compared to the reduced orifice with the intra-annular implantation. With complete valve excision and thorough annular decalcification, the exposed annulus would appear capable of having its ability 'to dilate' restored.

Fig 2 The aortic valve annulus is seen as an area of low signal intensity beneath the valve on Steady-state free precession imaging.

Fig 3 (a) Phase Contrast images are acquired directly through the annulus, orthogonal to the left ventricular outflow tract; (b) resultant Magnitude and (c) Phase images of the aortic valve annulus.

Fig 4 The mean cross-sectional area of the aortic valve annulus (4a) and the mean flow volumes (4b) were calculated at 30 intervals throughout the cardiac cycle and plotted against each point of the cardiac cycle.

Fig 5 Actuarial patient survival expresses the number of patients at risk over 10 years. The actual number of deaths over 10 years and the actuarial freedom at 8 years is expressed with CL = 95% Confidence Limits.

Fig 6 Actuarial freedom from thromboembolism of all grades of severity (See Table 2) Depiction as in Fig 5.

Fig 7 Actuarial freedom from thromboembolism causing a permanent disability (see Table 2). Depiction as in Fig 5.

Fig 8 Actuarial freedom from endocarditis. The nine episodes all occurred within the first 5 years after aortic valve replacement (see Table 2). Depiction as in Fig 5.

Fig. 9 Actuarial freedom from reoperation due to all causes (see Table 2). Depiction as in Fig 5.

Fig 10 Actuarial freedom from valve explantation at 8 years was 97.82% ± 2.08%. Depiction as in Fig 5.

Figures

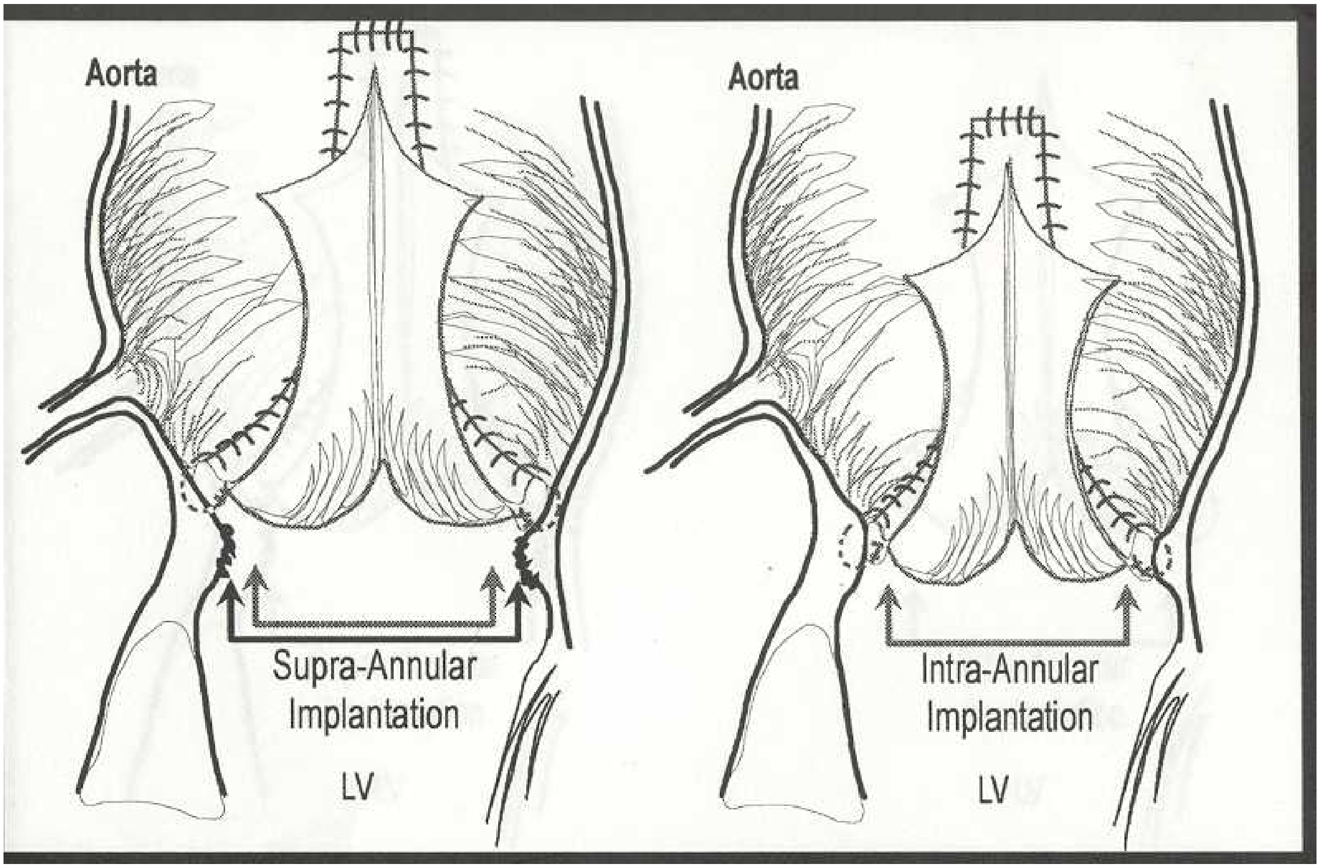
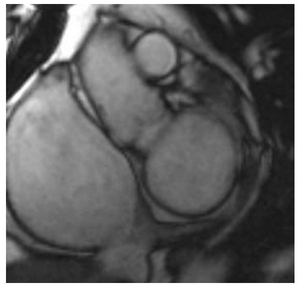
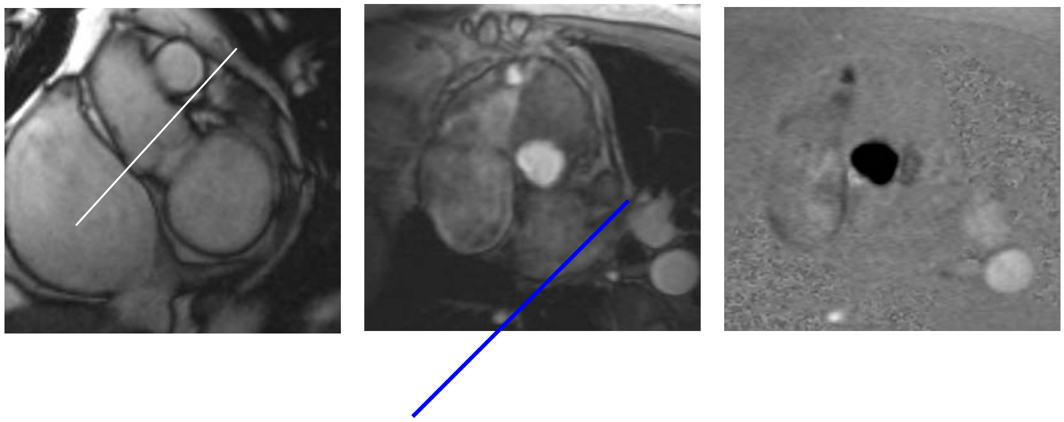

Aorta
Supra-Annular
Implantation
LV
Aorta
Intra-Annular
Implantation
LV

Fig 2





a

Fig 3

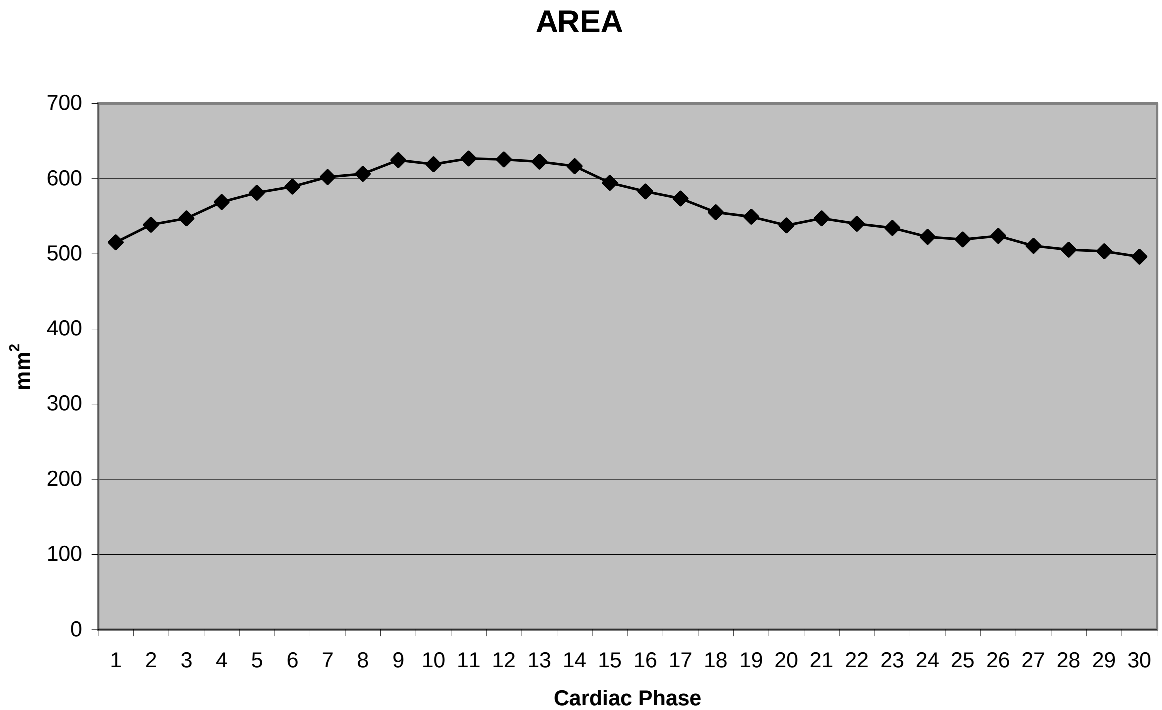

AREA
700
600
500
400
300
200
100
0
mm2
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Cardiac Phase

Fig 4a

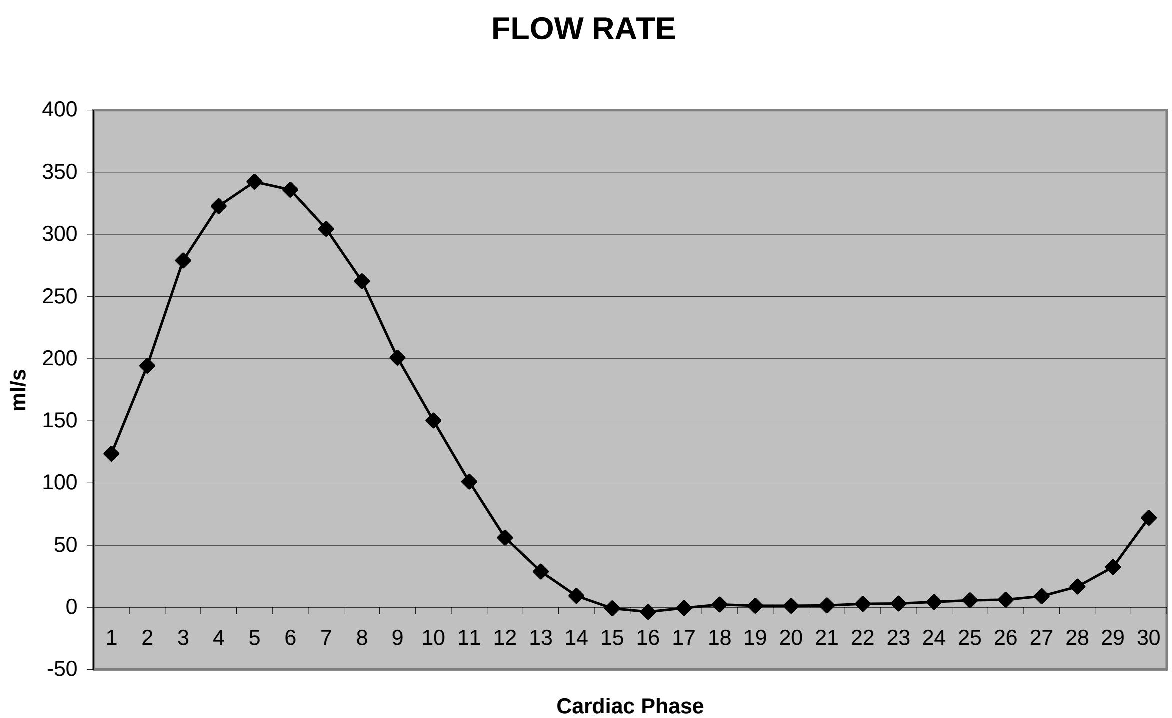

FLOW RATE
400
350
300
250
200
150
100
50
0
-50
ml/s
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Cardiac Phase

Fig 4b

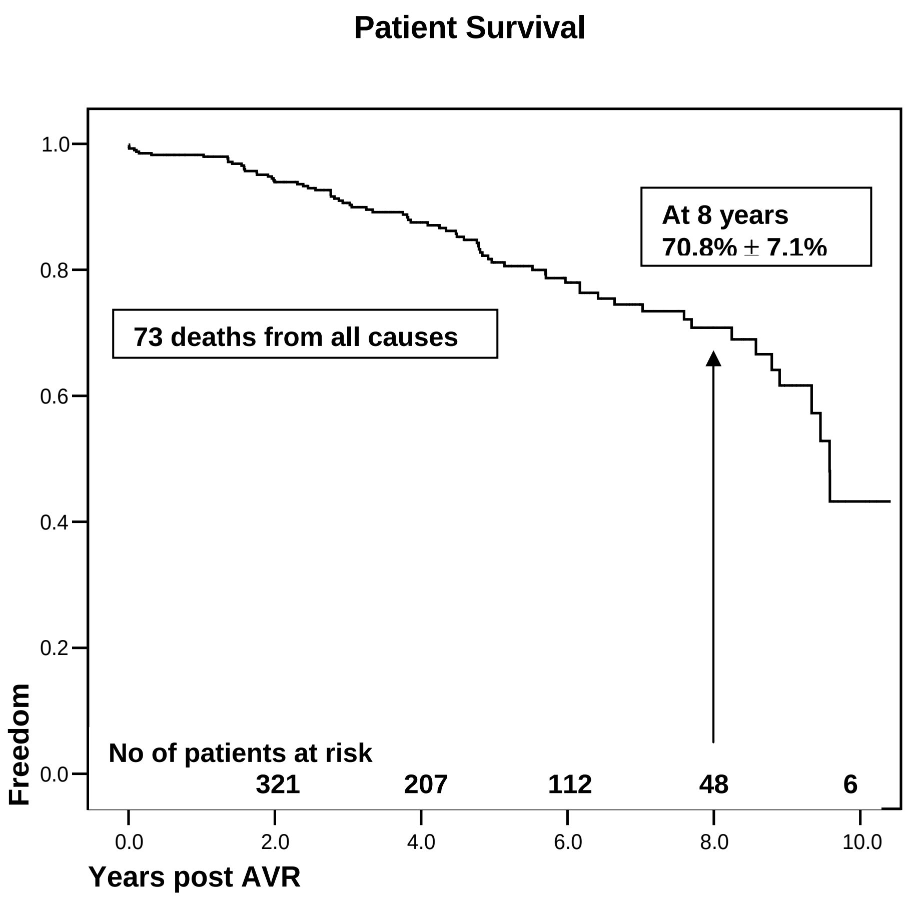

Patient Survival
1.0
0.8
0.6
0.4
0.2
0.0
Freedom
At 8 years
70.8% ± 7.1%
73 deaths from all causes
No of patients at risk
321
207
112
48
6
0.0
2.0
4.0
6.0
8.0
10.0
Years post AVR

Fig 5

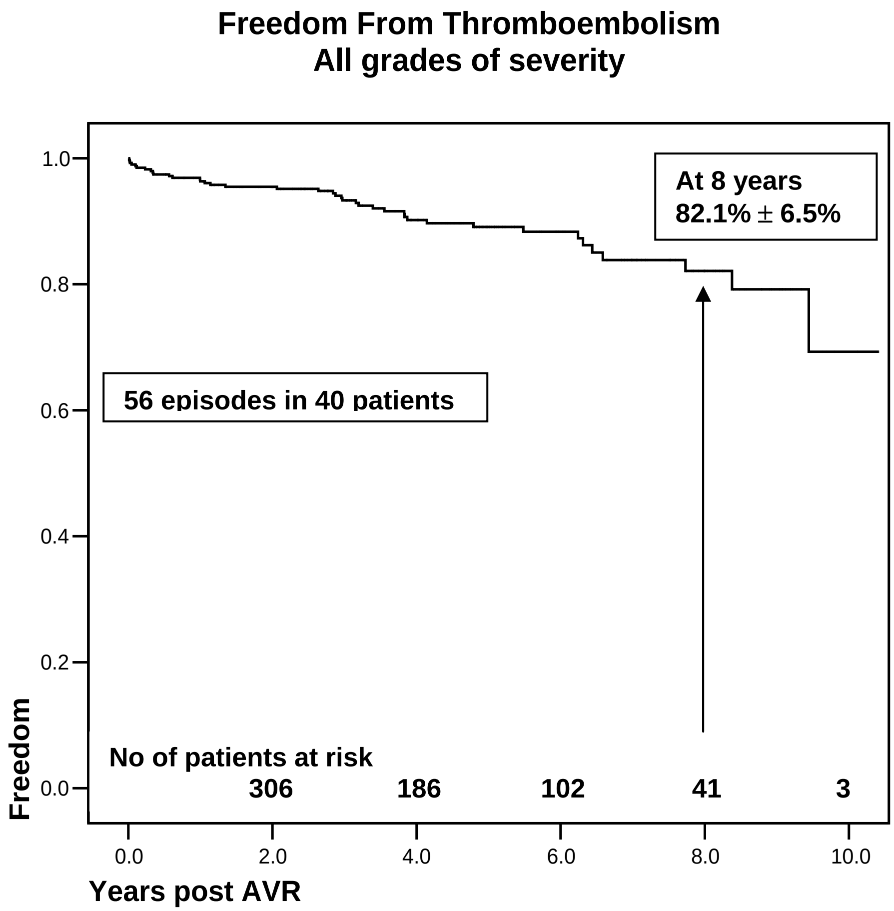
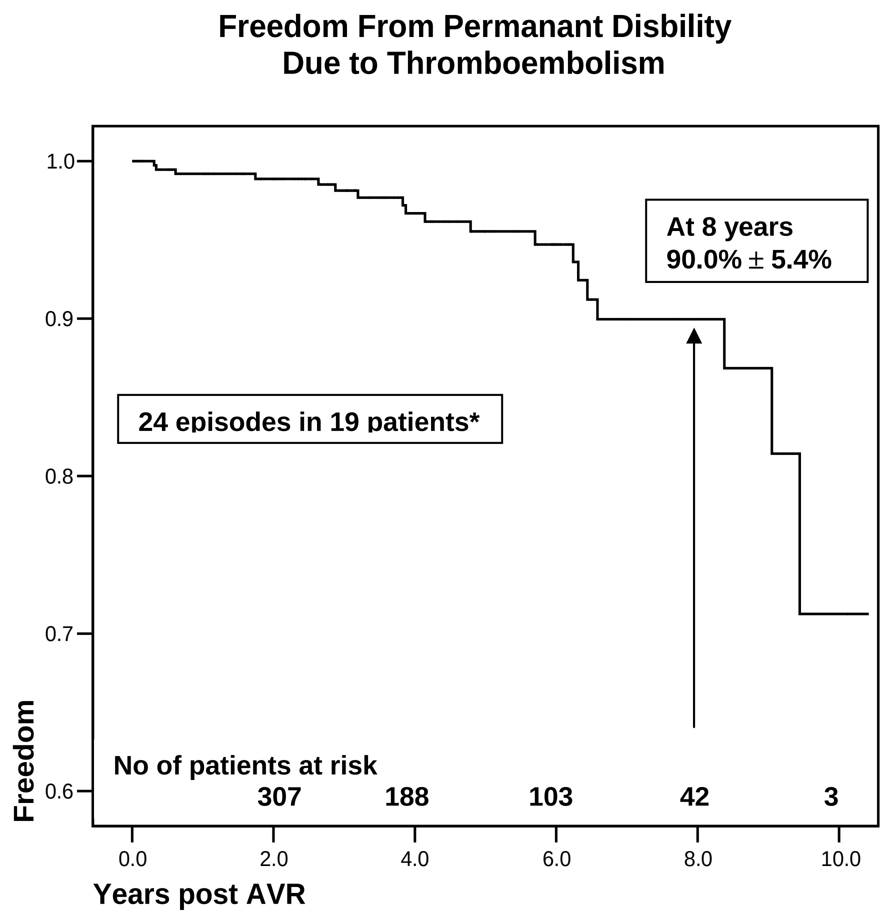

Freedom From Thromboembolism
All grades of severity
At 8 years
82.1% ± 6.5%
56 episodes in 40 patients
No of patients at risk
306
186
102
41
3
Freedom
1.0
0.8
0.6
0.4
0.2
0.0
0.0
2.0
4.0
6.0
8.0
10.0
Years post AVR

Fig 6



includes 1 death from mesenteric artery embolism

Fig 7

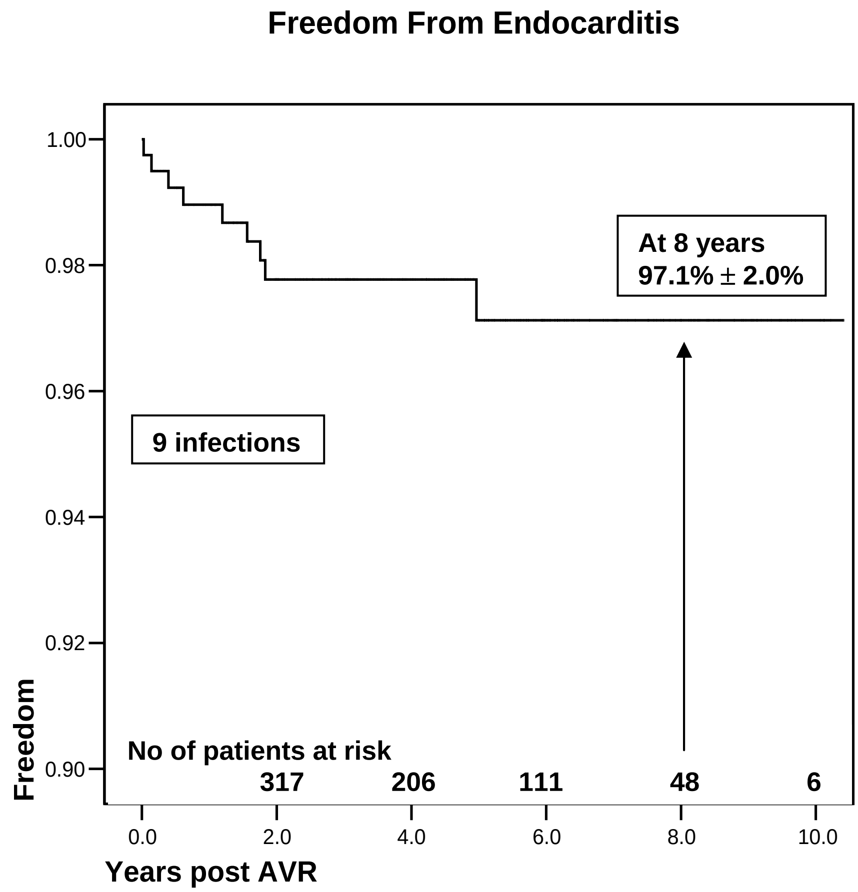

Freedom From Endocarditis
At 8 years
97.1% ± 2.0%
9 infections
No of patients at risk
317
206
111
48
6
1.00
0.98
0.96
0.94
0.92
0.90
Freedom
0.0
2.0
4.0
6.0
8.0
10.0
Years post AVR

Fig 8

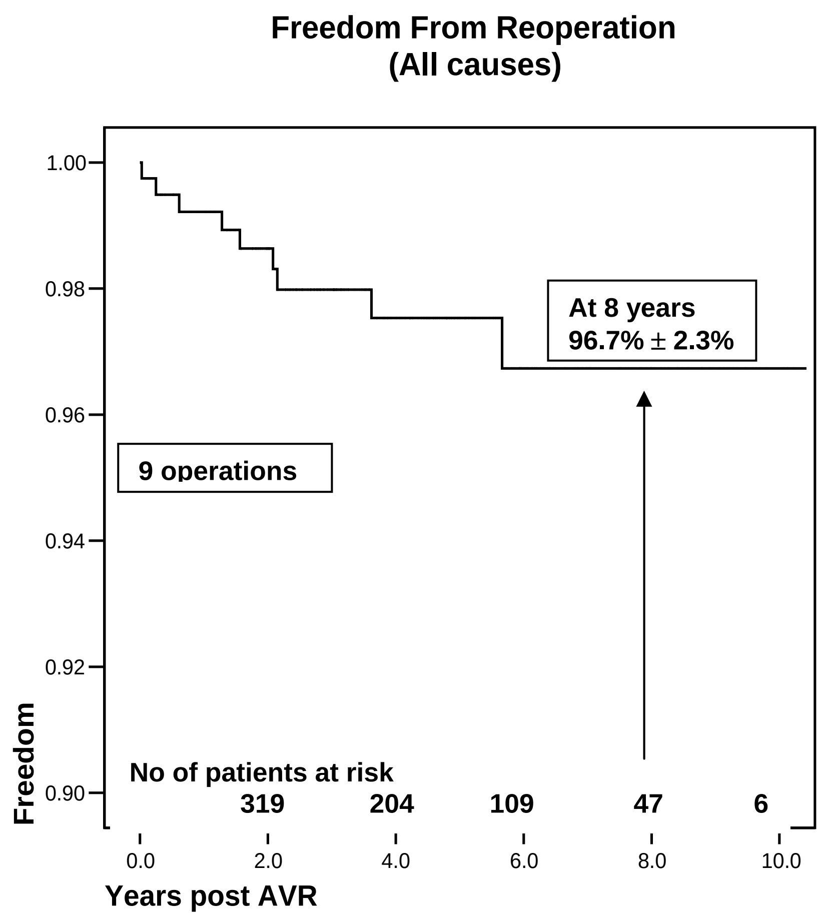

Freedom From Reoperation
(All causes)
1.00
0.98
0.96
0.94
0.92
0.90
Freedom
At 8 years
96.7% ± 2.3%
9 operations
No of patients at risk
319
204
109
47
6
0.0
2.0
4.0
6.0
8.0
10.0
Years post AVR

Fig 9

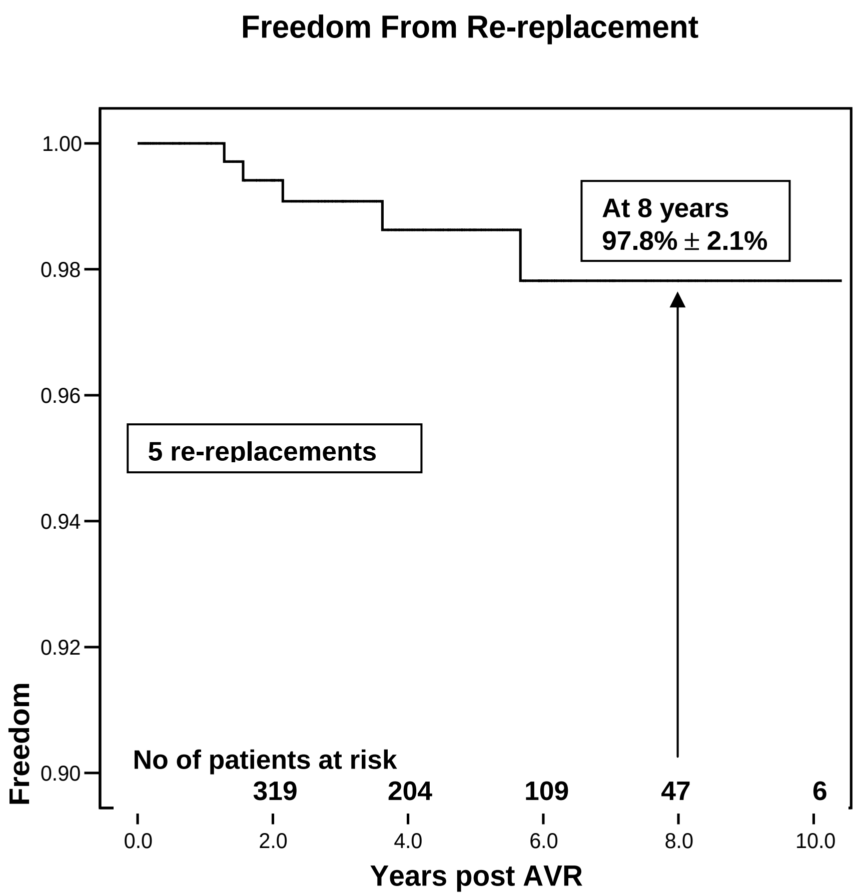

Freedom From Re-replacement
1.00
0.98
0.96
0.94
0.92
0.90
Freedom
At 8 years
97.8% ± 2.1%
5 re-replacements
No of patients at risk
319
204
109
47
6
0.0
2.0
4.0
6.0
8.0
10.0
Years post AVR

Fig 10

Fig 4b