Stentless Aortic Valves as an Alternative to Homografts for Valve Replacement in Active Infective Endocarditis Complicated by Ring Abscess

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Background. **The valve substitute of choice in active infective aortic valve endocarditis complicated by annulus abscess in our institution is the cryopreserved homograft. To avoid implantation of any prosthetic material, the Shelhigh No-React stentless valves and conduits may be considered an alternative when no suitable homograft is available.**

Methods. **Between March 1986 and January 2001, 452 homografts were implanted in the aortic position. From January 2000 to August 2001, 75 Shelhigh No-React prostheses were implanted at our institution. In 25 consecutive patients (study group) with aortic annulus abscess, urgent aortic valve replacement with the Shelhigh SuperStentless and Stentless Aortic Valve Conduit was undertaken. Patients (16 male, 9 female; age, 49 ± 19 years) were studied with follow-up until March 2002. The control group comprised 68 consecutive historical patients (46 male, 22 female; age, 53 ± 14.4 years) with similar disease treated between January 1997 and December 1999 in whom an aortic homograft was implanted. This group was also followed up until March 2002. Demographic data and preoperative characteristics of the patients were without significant differences. Patients were studied by echocardiography.**

Results. **Sixty-day mortality was 16% (11 patients) in the control group compared with 12% (3 patients) in the study group. Recurrent infection occurred in 4% in both groups. The instantaneous and mean Doppler gradients yielded no significant differences (19.4 ± 10.4 mm Hg and 11.8 ± 5.7 mm Hg versus 18.2 ± 8.7 mm Hg and 10.9 ± 5.3 mm Hg, respectively). The mean effective orifice area calculated from Doppler flow velocity for the stentless valve was 2.3 ± 0.6 cm^2. Preoperative evaluation of left ventricular dimensions and global left ventricular systolic function did not vary significantly between the two groups. However, postoperatively evaluated left ventricular end-diastolic diameter dimensions in the study group were significantly smaller than those in the control group (47.6 ± 7.9 mm versus 56 ± 9.5 mm; $p = 0.05$). Ejection fraction was similar in both groups (56.2% ± 12.8% for the study [Shelhigh] and 52.6% ± 16.8% for the control [homograft] group).**

Conclusions. **Our experience with both the Shelhigh No-React SuperStentless and Stentless Aortic Valve Conduit in patients with native or prosthetic aortic valve endocarditis appears to demonstrate good results, similar to those of cryopreserved homografts. Ease of implantation and favorable effective orifice area and pressure gradients, as well as the No-React anticalcification treatment, are promising factors.**

(Ann Thorac Surg 2003;75:803–8)

Native and prosthetic aortic endocarditis may often be complicated by involvement of the aortic annulus and the formation of aortic abscesses [1]. This serious complication is especially grave in patients with infection of prosthetic valves. It is associated with a higher rate of mortality as a result of the aggressive nature of the infection [2–6]. The appropriate and first choice of surgical treatment for aortic valve endocarditis complicated by aortic annular abscess is replacement with a homograft [7]. The reinfection rate has been documented to be lower for homografts [7], and function and longevity of the homograft are excellent [7, 8, 11].

Lack of availability of an aortic homograft may limit the surgical treatment of emergency cases with native or prosthetic aortic valve endocarditis with annular abscess. The use of the Shelhigh No-React SuperStentless and Stentless Aortic Valve Conduit may be an alternative for aortic endocarditis, as these stentless valves are devoid of fabric material and have biocompatible attributes.

In general the diagnosis of paravalvular abscess has long been based on surgical or necropsy findings [12], because clinical preoperative information is very often misleading [4]. In the past decade echocardiographic

Accepted for publication Oct 1, 2002.

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Published by Elsevier Science Inc

0003-4975/03/$30.00
PII S0003-4975(02)04555-1

Ann Thorac Surg
2003;75:803–8

Table 1. Preoperative Characteristics of Treatment Groups

Characteristics	Homograft Group (n = 68)	%	Shelhigh Group (n = 25)	%
Prosthetic endocarditis	28	41.2	11	44.4
Severe heart failure	31	45.6	9	36
Epinephrine	19	27.9	7	28
S. aureus infection	19	28	7	28
AV dehiscence	22	32.4	6	24

AV = aortoventricular; *S. aureus* = *Staphylococcus aureus.*

techniques, particularly transesophageal echocardiography, have become the gold standard for the diagnosis of abscess with high sensitivity and specificity [7, 9, 13–15].

The aim of this study was to classify patients according to echocardiographic criteria, validated intraoperatively, who were operated on using stentless valves, and to compare the results with those of a historical group treated with homograft replacement. The initial study concentrates on the early results and rate of infection in a short postoperative period and on remodeling of the left ventricle 3 and 6 months postoperatively.

Patients and Methods

Patients

Between March 1986 and January 2001, 452 homografts were implanted in aortic position in adults and from January 2000 to August 2001, 75 Shelhigh No-React stentless valves and conduits were implanted in our institution. In this group 25 patients had active infective endocarditis with ring abscess. This group of patients was studied extensively. Mean age was 49.2 ± 18.9 years; there were 16 men and 9 women. The control group consisted of 68 consecutive historical patients with similar disease operated on between January 1997 and December 1999 in whom an aortic homograft was inserted for aortic valve endocarditis with ring abscess. There were 46 men and 22 women with a mean age of 53 ± 14.4 years. Follow-up study was conducted until March 2002.

There were no significant differences in the demographic data or preoperative characteristics of the patients. Patients were studied by complete echocardiography to determine the extent of endocarditis and left ventricular (LV) valve function.

All patients were studied using standard transthoracic and transesophageal echocardiography examination. The diagnosis was based on echocardiography and clinical features. The results of selection of the patients are listed in Table 1. All patients had annular abscess, and 11 patients (44.4%) had prosthetic endocarditis. Severe heart failure was present in 9 patients (36%), and treatment with infusion of epinephrine was necessary to maintain adequate blood pressure in 7 patients (28%) preoperatively. Two types of Shelhigh stentless valves were implanted. For patients who had annular abscess or extensive infection, the Shelhigh Stentless Conduit was used (miniroot replacement) because aggressive debridement was necessary. The rest of the patients had the Shelhigh SuperStentless (skeletonized porcine) valve implanted in the subcoronary position.

Echocardiography

Echocardiographic examination and postoperative follow-up were performed using the commercially available ALOKA 5.5 equipment with a 3.5-multifrequent ultrasonic transthoracic probe (ranging between 2.5 MHz and 5.0 MHz) with the second harmonic imaging modality and a rotary transesophageal probe (multiplane) with the multifrequent modality (3.5 to 7.0 MHz).

The time course of investigation was as follows: preoperative investigation (on the day of operation, which in urgent cases was the day of admission), intraoperatively if the reconstruction procedure was undertaken, and at least 8 hours after operation. Follow-up investigation was carried out if hemodynamic instability developed or before release from hospital.

Definition of Active Infective Endocarditis

Active endocarditis was defined if the patient had positive blood cultures (prospective diagnosis) or valve cultures (postoperative diagnosis), signs of ongoing sepsis (epinephrine use and echocardiographic signs of endocarditis), or echocardiographically detected development of abscess, or if the patient experienced recurrent embolic events with echocardiographically demonstrated presence of vegetation.

In 28% of patients in both groups, staphylococcal infection was found (Table 1) Antibiotic medication was directed specifically at the cultured organism in known cases; otherwise a broad-spectrum antibiotic was used.

Operation and Indication for Operation

The out-of-hospital diagnosis was based on echocardiography and in some patients on angiography and positive blood cultures. These were revised after completing in-hospital transesophageal examinations.

Extension of infection below the valves with formation of abscess was diagnosed in all cases after in-hospital complete echocardiographic examination and confirmed in all cases by the surgeon intraoperatively. Surgical diagnosis of ring abscess was based on the intraoperative presence of paravalvular cavity.

There was no significant difference in indication for operation between the study group (n = 25) of patients selected for stentless Shelhigh valve prostheses and the control group (n = 68) of patients diagnosed with endocarditis-associated paravalvular abscess in whom a homograft was implanted. The principal indications for operation were (1) septic shock, (2) persistent sepsis despite adequate antibiotic therapy, (3) severe aortic regurgitation (grade ≥ 3), (4) congestive heart failure, or (5) recurrent emboli. Cardioplegic arrest was achieved by using antegrade cold crystalloid cardioplegic solution.

Operative Principles

LOCALIZED ABSCESS. After localization and opening of the abscess, surgical excision of infected contents followed

by resection of infected tissue was performed as far as it was possible to distinguish it from noninfected parts of the root tissue.

EXTENDED ABSCESSES (CIRCULAR ABSCESS AND AORTOVENTRICULAR DISCONTINUATION). The abscess was surgically excised to an extent sufficient to leave only vital tissue. The defective parts of the annulus were reconstructed with autologous pericardium if necessary and a homograft (control group), or the Shelhigh stentless valve with the tissue conduit model NR-2000C (study group) was implanted.

In all cases, all affected areas were washed with peridone iodine solution.

Statistical Analyses

The data are expressed as mean and standard deviation. The difference between groups was analyzed using Student's *t* test.

Table 2. Preoperative and Postoperative Echocardiographic Data[a]

Variable	Measurement	Homograft (n = 68)	Shelhigh (n = 25)	*p* Value
LVEDD (mm)	Preoperative	56.95 (9.52)	54.5 (13.1)[b]	NS
	Postoperative	55.96 (9.52)	46.9 (7.89)[b]	<0.001
ESD (mm)	Preoperative	40.14 (10.71)	38.6 (10.0)	NS
	Postoperative	39.52 (12.09)	31.1 (8.32)	<0.01
FS (%)	Preoperative	30.80 (10.19)	33.8 (10.8)	NS
	Postoperative	30.83 (13.35)	28.2 (7.07)	NS
EF (%)	Preoperative	52.65 (11.11)	49.7 (16.0)	NS
	Postoperative	52.61 (16.80)	56.2 (12.8)	NS

[a] Values are mean and standard deviation. [b] In the Shelhigh group a significant reduction of end-diastolic dimension postoperatively was noted ($p < 0.02$).

EF = ejection fraction; ESD = left ventricular end-systolic dimension; FS = fractional shortening; LVEDD = left ventricular end-diastolic dimension; NS = not significant.

Results

Characteristics of Patients

A total of 25 cases were studied that were classified for Shelhigh aortic valve replacement. Eleven patients (44.4%) had prosthetic valve endocarditis, and 14 patients had native valve endocarditis (Table 1). This study group would have required homograft implantation according to our previous policy. Twenty-two patients (88%) had infective endocarditis, with positive blood cultures. In 3 patients, there were classic signs of infection, and the patients had mobile structures on the aortic valves during echocardiography, which were interpreted as vegetations, but the blood cultures gave negative results. Intraoperatively in these patients, classic signs of acute infective endocarditis were found with positive cultures of the vegetations. The historical control group was defined as those with homograft implantation having aortic ring abscess (100%).

There were 7 (28%) patients in the study group compared with 19 (27.9%) in the control group in whom epinephrine was used to maintain blood pressure at an adequate level. These patients exhibited shock symptoms before operation. There were another 9 (36%) patients with severe heart failure in the study group and 31 (45.6%) in the control group with signs of congestion on roentgenographic examination and clinical evidence of left heart failure (pulmonary, auscultative rhonchi, and presence of gallop rhythm and tachycardia).

Left ventricular function was studied by echocardiography before and after the operation; the results are presented in Table 2. There were no significant differences in LV end-diastolic dimension or systolic ventricular function (ejection fraction and fractional shortening) between the two groups before operation. After operation, the mean end-diastolic and systolic dimensions in the study group were significantly ($p > 0.001$ and $p > 0.01$, respectively) smaller than in the control group (LV end-diastolic diameter, 46.9 ± 7.89 mm versus 55.96 ± 9.52 mm and end-systolic diameter, 39.52 ± 12.09 mm versus 31.1 ± 8.32 mm).

Function was maintained at a similar level in both groups and was 28.2% ± 7.07% and 56.2% ± 12.8% in the study group for LV fractional shortening and ejection fraction, respectively, compared with 30.83% ± 13.35% and 52.61% ± 16.80% for fractional shortening and ejection fraction in the control group (not significant).

Sensitivity and specificity of in-hospital echocardiography for the study group reached 100%; for the control group sensitivity was 98.6% and specificity, 100%.

Hospital Mortality and Morbidity

In the study group 2 patients died early after aortic valve replacement. The cause of death in both patients was persistent low cardiac output resistant to therapy. There were no signs of infection after operation. One patient died 2 months later, because of severe heart failure. These patients experienced aortoventricular dehiscence and septic-cardiogenic shock preoperatively. In-hospital 60-day mortality was 12.0%. In the control group (68 patients) there were 11 (16%) deaths (not significant). No survivor in the study group had stroke or signs of reinfection except 1 patient, and renal function returned to normal. There was the same rate of reinfection (4%) in both groups.

Function of Implants: Continuous Doppler Investigation

High flow velocities in the LV outflow tract could not be detected by echocardiography in either group studied. The calculated instantaneous (maximal Doppler) gradient and mean pressure gradient through aortic implants were comparable for homografts and the Shelhigh stentless prostheses (Table 3).

Mean effective orifice area for the study group was 2.3 ± 0.6 cm^2, with a range of 1.7 to 3.2 cm^2 (mean size, 23.2 mm; range, 21 to 27 mm; Figs 1 and 2).

Table 3. Postoperative Doppler Gradients in Homograft and Shelhigh Groups[a]

Gradient	Homograft (n = 68)	Shelhigh (n = 25)
Max P (mm Hg)	19.4 (10.4)	18.2 (8.7)
Mean P (mm Hg)	11.8 (5.7)	10.9 (5.3)

[a] Values are mean and standard deviation. Gradients were not significantly different between groups.

Max P = Doppler calculated instantaneous gradient; Mean P = Doppler calculated mean gradient.

Comment

Only patients having primarily aortic valve endocarditis with ring abscess were selected for the study. This helped to avoid an influence of different factors. In general, surgical patients with mitral valve disease had a less favorable prognosis than patients with aortic valve disease [16].

Timing of Operation

Delay in surgical treatment has a very great influence on mortality and morbidity (reinfection, reversibility of congestive heart failure) in patients with extended infection [17]; however, some controversies exist [18, 19].

The dimensions of the LV normalized after operation, indicating optimal timing and optimal quality of operation. The control group (homograft) consisted of patients with a later stage of the disease, which possibly reflects the past trend in cardiology to send patients to operation as late as possible or may be related to the availability of the proper size of homograft. The survivors in the control group even maintained LV function but had significant LV dilatation after operation compared with the study group. Persistent dilatation of the LV has a significant negative influence on longevity of the patients [16].

Problem of Reinfection in Destructive Forms of Endocarditis

Staphylococcus aureus is known to cause progressive and destructive forms of the disease. There was a similar incidence of this virulent agent in both groups studied: one third in each group. The antibiotic treatment did not vary between the two groups.

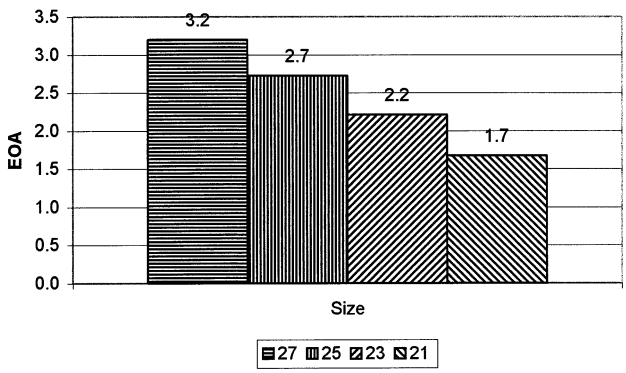

Fig 1. Effective orifice area (EOA; *measured in square centimeters) by the continuity equation in the Shelhigh group.* Size *refers to size of Shelhigh No-React stentless valves and conduits, in millimeters.*

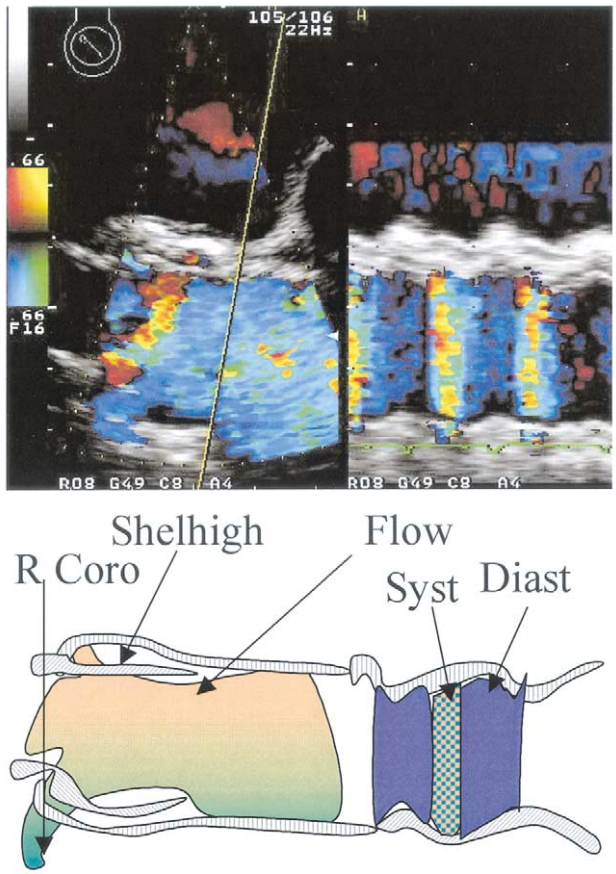

Fig 2. (Top left) Stentless Shelhigh valve (Shelhigh) in aortic position viewed from transesophageal position. (Top right) M-mode color Doppler echocardiography demonstrates flow inside the valve. (Bottom) Schematic presentation. Note coronary flow in right coronary sinus and artery (R Coro). (Diast = *flow in diastole;* Flow = *Doppler flow in systole in two-dimensional echocardiography;* Syst = *flow in systole.)*

Severe destruction of the annulus entails severe surgical problems, and improvisation of the surgical technique is often necessary [12, 20]. Nevertheless, the development of abscess may limit the aim of the surgeon to excise the diseased tissue totally, which may influence the mortality and morbidity. In such cases it is of utmost importance to implant a valve that can resist infection. In the Shelhigh group, only one of the patients exhibited reinfection after valve replacement, and this is comparable to the rate of reinfection in the homograft group. As we demonstrated with echocardiography (Table 1), patients who are admitted to our institution usually have very developed forms of the illness in which destruction of paraannular tissue is far progressed, leading to aortoventricular discontinuity (32.4% of the control group and 24% of the study group). We compared our historical group of patients treated with homograft implantation with the more standard, ordinary endocarditic patients

who are usually candidates for operation in our institution. The condition of the cardiac function and the presence or absence of left heart failure have a major influence on the in-hospital mortality independent of other factors such as extension of the infection below the aortic valve or the presence of causative microorganisms. The groups were hemodynamically comparable, as the rate of septic shock incidence preoperatively (the rate of epinephrine use) for the two groups was the same.

Homograft Versus Shelhigh

Surgical problems in severe destruction of the annulus are well known, and very often surgical skills and flexibility help to optimally reconstruct parts of the heart that have been destroyed. Certainly from this point of view, homografts [7, 11] are the optimal material. Implantation techniques and determination of the optimal size of the homograft are not easy [21]. Adequate sizing of the homograft for patients with annulus destruction to avoid mismatch in size is an important task for the echocardiographer, because a satisfactory homograft has to be ordered earlier before the operation. Mismatch in the size of the homograft may lead to distortion of the homograft and suboptimal durability and function of the implant [11, 21]. The planned delay in operation has to be taken into account. On the other hand, using stentless valves means that adequate echocardiography (characterized by high sensitivity and specificity for abscess diagnostic) is not a sine qua non for operative planning and decision-making. In operative strategy there is no delay between the decision to operate and the surgical procedure, inasmuch as the appropriate valve size can be adjusted intraoperatively. The ready availability of the Shelhigh stentless valves and the ease of their implantation may have contributed to the improved outcome.

In general no technical problems were reported during the Shelhigh stentless valve operation in patients with severe destructive forms of endocarditis (discontinuation between the aorta and the left ventricle).

Function of Implants

In the Shelhigh group the results of gradients are comparable to those for homografts. None of our patients had high flow velocities in the LV outflow tract that would suggest a problem of sizing of the valve or the homograft. Recently, more attention has been focused on the quality of life of patients, which depends on good hemodynamic function of the implants not only at rest but also during prolonged exercise [10]. High cardiac output can produce signs of valve stenosis when the implant has a low effective orifice area. The effective orifice area measured in the Shelhigh group ranged from 1.7 to 3.2 cm^2 and is sufficient to accommodate high cardiac output without producing a nonphysiologic gradient.

Conclusions

Our experience with both the Shelhigh SuperStentless and the Stentless Aortic Valve Conduit in patients with native or prosthetic aortic valve endocarditis demonstrates good results that are similar to those achieved when cryopreserved homografts are used. Precise echocardiographic differentiation and aortic root measurements are not necessary when homograft implantation is not considered as the choice for patients with endocarditic aortic root abscess. The ease of implantation and ready availability and the fact that the hemodynamics are comparable to those of homografts make these stentless valves preferable to the homograft in cases of aortic endocarditis.

We thank Anne Gale, Medical Editor of the Deutsches Herzzentrum Berlin, for her editorial assistance.

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INVITED COMMENTARY

Three principles are important for successful aortic root surgery in patients with endocarditis complicated by abscess formation. First, the surgeon must aggressively and extensively debride all infected tissue. Second, defects may need to be reconstructed, sometimes including pericardial patch closure of fistulas or holes into other cardiac chambers. Finally, aortic valve (and root) replacement with the least amount of foreign body possible (ideally no foreign body) should be performed. Previous reports described the use of prosthetic valves or the preferred option for most experienced surgeons: homograft aortic root replacement. This paper not only addresses the first two principles but reports the use of a stentless aortic valve that is "devoid of fabric material" for aortic valve replacement. Their results are good with an acceptable mortality, good hemodynamic and quality of life outcomes, and, most importantly, a low rate of reinfection (4% in patients treated with stentless valves and 4% for a similar group of patients previously treated with an aortic valve homograft).

Recent U.S. reports show similar early and late results [1, 2], but one paper reported reinfection results similar to the Berlin and Cleveland Clinic experience with the use of nonhomograft prosthetic valves [2]. Therefore, the extensive debridement is probably more important than the choice of prosthesis. However, if a prosthesis free of fabric were more readily available than homografts, most surgeons would likely prefer this to the use of prosthetic valves with extensive fabric.

Use of a stentless aortic valve in lieu of a homograft in this clinical situation has advantages, including ready availability of the stentless valve, access to a variety of different valve sizes, and cost of the prosthesis. Furthermore, at least in the U.S., there has been a chill surrounding the implantation of cryopreserved human tissue because of the risk of transmitting infection.

Unfortunately, the stentless aortic valves approved for use in the United States (Medtronic Freestyle, St. Jude Toronto™ SPV, and Edwards Prima Plus) include fabric material, which therefore violates the principle of minimizing foreign material in an infected field. The approach in this report from Berlin intuitively makes sense, and fits these three principles. Surgeons should look forward to further confirmation from other centers with a low rate of reinfection with this stentless aortic prosthesis.

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0003-4975/03/$30.00
PII S0003-4975(02)05012-9