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Surgical Management of Infective Endocarditis

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1. Introduction

‘The advent of a wide spectrum of bactericidal antibiotic agents has enabled physicians to treat many cases of bacterial endocarditis with a high likelihood of success. There remain, however, a significant number of patients with endocarditis in whom the infection is more resistant to antimicrobial therapy, valve destruction more rapid, and a satisfactory response to medical therapy sufficiently infrequent to warrant consideration of a new therapeutic approach’.

Circulation 1965;13:450.

Thus began the first published case report of cardiac valve replacement for infective endocarditis by Doctors Wallace, Young and Osterhout of Duke University Medical Centre. They described a 45 year old man with Klebsiella endocarditis affecting the aortic valve in whom severe aortic regurgitation and congestive heart failure developed which failed to respond to medical therapy. Excision of the valve and replacement with a Starr-Edwards prosthesis was curative. [1]

In fact, the first surgical attempts to treat infective endocarditis date back to 1937, prior to the introduction of antibiotics, when John Strieder at the Massachusetts Memorial Hospital in Boston ligated an infected ductus arteriosus. The patient was a 22-year old female in grave condition. It was a matter of controversy whether ductus ligation would heal endocarditis or, on the contrary, perhaps even exacerbate it. [2] The surgery proved difficult, and although the patient’s immediate postoperative condition was excellent, with the typical sound of an open ductus no longer heard, she died four days later. Postmortem examination revealed vegetations extending from the origin of the ductus to the pulmonary valve.

Over the ensuing decades, developments in open-heart surgery and the evolution of cardiac valvular prostheses have since made surgery for endocarditis part of the routine work of every cardiac surgical unit. Nevertheless, such surgery still poses unique challenges and carries substantial risk of morbidity and mortality. Furthermore, the indications, timing, and type of surgery remain controversial as there are few randomized trials to guide patient management.

2. Surgical anatomy of the heart valves

It is important to appreciate that the four cardiac valves do not exist in isolation, but are closely related to each other and also to other vital intracardiac structures. [Figure 1]

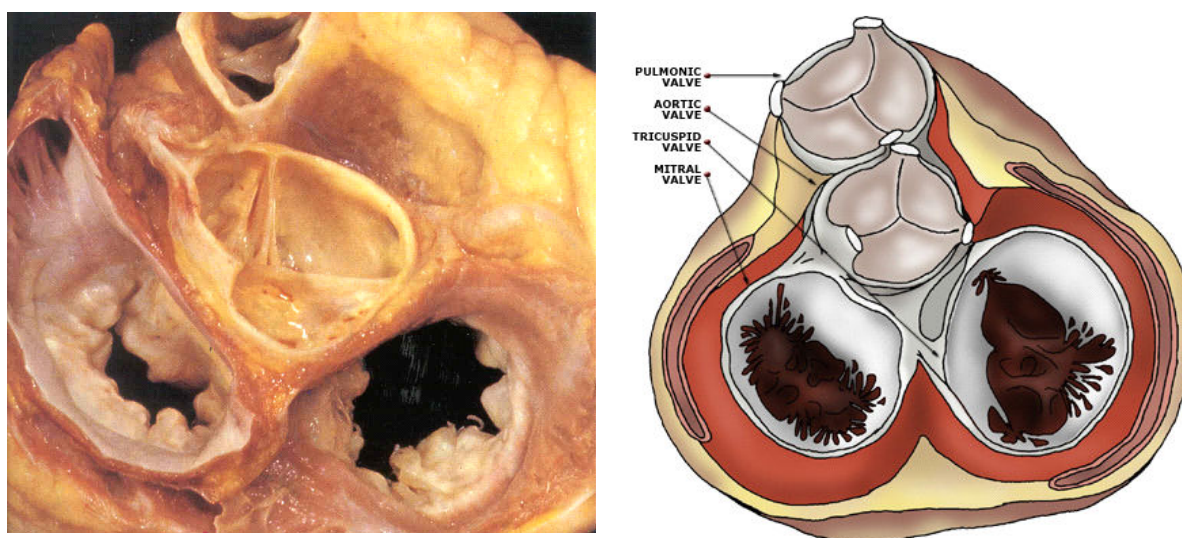


Figure 1. The four cardiac valves. Note the central position of the aortic valve and the fibrous skeleton of the heart connecting mitral, tricuspid and aortic valves. Reproduced from reference [3]

The aortic, mitral and tricuspid valves are all connected at the membranous septum [4], a small but crucial part of the heart [see Figure 2]. It separates the left ventricle from the right ventricle (interventricular component), and also separates the left ventricle from the right atrium (atrioventricular component). The conduction tissue (penetrating bundle) is intimately related to the membranous septum, being sandwiched between it and the muscular septum. [3] Only the pulmonary valve lacks fibrous continuity with the other valves, being situated on a circumferential sleeve of cardiac muscle known as the infundibulum.

It can therefore be appreciated how a virulent, invasive intracardiac infection might become potentially so destructive. Not only can the primary valve be affected, but infection can spread into adjacent valves, fistulas can develop into the cardiac chambers or pericardial space, the fibrous skeleton of the heart can be eroded and the conduction system can be destroyed.

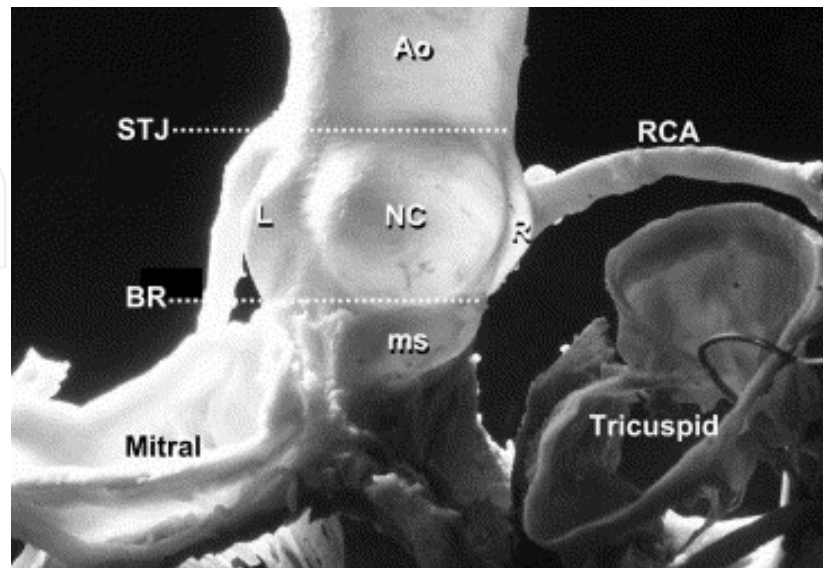


Figure 2. Membranous septum. The tricuspid annulus has been detached from the membranous septum in this prosection. Ao aorta, BR basal ring, L left coronary sinus, ms membranous septum, NC non coronary sinus, RCA right coronary artery, STJ sinotubular junction. Reproduced with permission from reference [4]

3. Indications for surgery in native valve endocarditis

The proportion of patients with endocarditis treated surgically varies widely amongst individual units, reflecting the fact that most indications for surgery are not absolute. Large multicentre studies report overall rates of surgery of approximately 40-50%. [5-7]

In recent years, international guidelines for valvular heart surgery and, more specifically, infective endocarditis have been published by a number of collaborative task forces. These task forces have examined the relevant scientific literature available and made evidence based recommendations accordingly for best practice guidelines.

The American College of Cardiology and American Heart Association (ACC/AHA) published their updated guidelines for valvular heart disease in 2008. [8] A section of these guidelines is devoted to infective endocarditis. In native valve endocarditis (NVE), the strongest recommendations for surgery apply to those patients with signs of heart failure, adverse haemodynamic effects from regurgitant valve lesions, antibiotic resistant organisms, or locally invasive cardiac infection with destruction of perivalvular structures. The recommendation for surgery is present, but weaker, in patients with recurrent embolic events and/or very large vegetations. Table 1 summarises these recommendations.

Class I

1. Surgery of the native valve is indicated in patients with acute infective endocarditis who present with valve stenosis or regurgitation resulting in heart failure. *(Level of Evidence: B)*
2. Surgery of the native valve is indicated in patients with acute infective endocarditis who present with AR or MR with hemodynamic evidence of elevated LV end-diastolic or left atrial pressures (e.g., premature closure of MV with AR, rapid decelerating MR signal by continuous wave Doppler (v-wave cutoff sign), or moderate or severe pulmonary hypertension). *(Level of Evidence: B)*
3. Surgery of the native valve is indicated in patients with infective endocarditis caused by fungal or other highly resistant organisms. *(Level of Evidence: B)*
4. Surgery of the native valve is indicated in patients with infective endocarditis complicated by heart block, annular or aortic abscess, or destructive penetrating lesions (e.g., sinus of Valsalva to right atrium, right ventricle, or left atrium fistula; mitral leaflet perforation with aortic valve endocarditis; or infection in annulus fibrosa). *(Level of Evidence: B)*

Class IIa

1. Surgery of the native valve is reasonable in patients with infective endocarditis who present with recurrent emboli and persistent vegetations despite appropriate antibiotic therapy. *(Level of Evidence: C)*

Class IIb

1. Surgery of the native valve may be considered in patients with infective endocarditis who present with mobile vegetations in excess of 10 mm with or without emboli. *(Level of Evidence: C)*

Class I: Conditions for which there is evidence for and/or general agreement that the procedure or treatment is beneficial, useful, and effective.

Class II: Conditions for which there is conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of a procedure or treatment.

Class IIa: Weight of evidence/opinion is in favor of usefulness/efficacy.

Class IIb: Usefulness/efficacy is less well established by evidence/opinion.

Class III: Conditions for which there is evidence and/or general agreement that the procedure/treatment is not useful/effective and in some cases may be harmful. In addition, the weight of evidence in support of the recommendation is listed as follows:

- Level of Evidence A: Data derived from multiple randomized clinical trials.
- Level of Evidence B: Data derived from a single randomized trial or nonrandomized studies.
- Level of Evidence C: Only consensus opinion of experts, case studies, or standard-of-care.

Table 1. AHA/ACC guidelines for NVE

The ACC/AHA guidelines also state that “prosthetic valve endocarditis and native valve endocarditis caused by *Staphylococcus aureus* are almost always surgical diseases”, suggesting that this organism causes particularly virulent intracardiac infection which tends to be more destructive and consequently more difficult to eradicate with antibiotic treatment alone.

In 2009, the European Society of Cardiology (ESC) published their own set of guidelines on the prevention, diagnosis and treatment of endocarditis. [9] The recommendations for surgery follow similar themes to the ACC/AHA guidelines, with heart failure, uncontrolled infection and prevention of embolism representing the three broad categories of indications for surgery (see Table 2).

Indications for surgery in NVE	Timing	Class	Level
A – HEART FAILURE			
Aortic or mitral IE with severe acute regurgitation or valve obstruction causing refractory pulmonary oedema or cardiogenic shock	Emergency	I	B
Aortic or mitral IE with fistula into a cardiac chamber or pericardium causing refractory pulmonary oedema or cardiogenic shock	Emergency	I	B
Aortic or mitral IE with severe acute regurgitation or valve obstruction and persisting heart failure or echocardiographic signs of poor haemodynamic tolerance (early mitral closure or pulmonary hypertension)	Urgent	I	B
Aortic or mitral IE with severe regurgitation and no HF	Elective	IIa	B
B-UNCONTROLLED INFECTION			
Locally uncontrolled infection (abscess, false aneurysm, fistula, enlarging vegetation)	Urgent	I	B
Persisting fever and positive blood cultures >7-10 days	Urgent	I	B
Infection caused by fungi or multiresistant organisms	Urgent/elective	I	B
C- PREVENTION OF EMBOLISM			
Aortic or mitral IE with large vegetations (>10mm) following one or more embolic episodes despite appropriate antibiotic therapy	Urgent	I	B
Aortic or mitral IE with large vegetations (>10mm) and other predictors of complicated course (heart failure, persistent infection, abscess)	Urgent	I	C
Isolated very large vegetations (>15mm)	urgent	IIb	C

Table 2. ESC guidelines for NVE

More recently published data from a large non-randomised prospective multicentre trial of 1552 patients with NVE found an overall survival benefit for surgery compared with medical therapy (12.1% mortality versus 20.7%). [10] In subgroup analysis using propensity scores, surgery was found to confer a survival benefit compared with medical therapy among patients with a higher propensity for surgery and those with paravalvular complications, systemic embolization, *Staphylococcus aureus* NVE and stroke.

Surprisingly, neither valve perforation nor congestive heart failure predicted a survival benefit for early surgery in this study, which goes against prior assumptions and experiences. [11] It

may be that the severity of heart failure, which was not specified in the study, does in fact influence outcome as reported by others. [12]

4. Timing of surgery

Deciding upon the optimal timing of surgery is one of the great difficulties in managing patients with endocarditis. As Farzaneh-Far and Bolger state in a recent editorial, “the decision to commit to a surgical procedure that might possibly be avoided is quite difficult for the patient, the surgeon, and the referring physician...Because patients with endocarditis span such a wide range of comorbidities, complications, and manifestations, generalization from a disparate population is unsatisfying.” [11]

The difficulty is compounded by the fact that available evidence to recommend timing of surgery in endocarditis is largely limited to observational data and expert opinion. Studies employing propensity modelling to try and overcome selection bias have been reported. [10] More recently, the first randomized controlled trial in endocarditis was published to help define the optimal timing of surgery, [13] as discussed below.

The timing of surgery can be considered in the following clinical situations:

a. Congestive heart failure.

The ESC guidelines advise emergency surgery for patients with persistent pulmonary oedema or cardiogenic shock, and urgent surgery when heart failure is less severe. [9] In patients with well tolerated severe valvular insufficiency (i.e. mild or no heart failure) and no other reasons for surgery, the guidelines recommend ‘medical management with antibiotics under strict clinical and echocardiographic observation’ with surgery to be considered ‘after healing of infective endocarditis, depending on tolerance of the valve lesion’.

b. Systemic embolism

Systemic embolism occurs in up to 50% of patients with infective endocarditis, most frequently to the central nervous system and specifically to the territory of the middle cerebral artery [14]. A number of studies have demonstrated that embolic risk falls substantially after the first 2-3 weeks of treatment. [15, 16] The presence of large (>15mm on echocardiogram) vegetations has been considered a relative indication for early surgery, particularly in Staphylococcal endocarditis affecting the mitral valve. [15]

Recently the benefit of early surgery in this context was investigated in the first randomized trial in endocarditis [13]. In this study, 76 patients with left-sided native valve infective endocarditis, vegetations greater than 10 mm, and severe valve dysfunction were randomly assigned to surgery within 48 hours or antibiotic therapy. The primary end point was a composite of embolic events or death within 6 weeks after randomization. Secondary end points were embolic events, recurrent endocarditis, repeat hospitalization due to the development of congestive heart failure, or death from any cause at 6 months.

The major finding in this study was that early surgery significantly reduced the composite end point of embolic events and death from any cause, by effectively decreasing the risk of systemic embolism. The authors suggest that early surgery is therefore a valuable therapeutic option to prevent embolism.

c. Embolic stroke

Timing of surgery after embolic stroke poses an especially difficult dilemma. Early surgery carries a risk of haemorrhagic transformation of cerebral infarction, whilst delaying surgery may lead to further embolic events and/or worsening of cardiac function. In a recent review of 100 published studies, Rossi et al concluded that “evidence is conflicting because of lack of controlled studies” [17]. They state that “the optimal timing for the valve replacement depends on the type of neurological complication and the urgency of the operation.”

The ESC guidelines suggest that if cerebral haemorrhage has been excluded and neurological damage is not severe, surgery should not be delayed. [9] The risk of further neurological complication is low and full neurological recovery may be possible.

Conversely, in cases with intracranial haemorrhage, neurological prognosis is worse and ESC guidelines suggest that surgery should be postponed for at least one month. If the possibility of mycotic aneurysm is suspected, the patient should be evaluated with cerebral angiography as such aneurysms are a contraindication for anticoagulation as well. [18]

In all such cases, consultation with neurology and neurosurgical teams is advisable.

d. Paravalvular extension

As emphasized in the preceding section on cardiac anatomy, paravalvular abscess formation has a high probability of impairing cardiac conduction and leading to multi-valve involvement. Extension of infection is very common in prosthetic valve endocarditis and affects 10-40% of native aortic valve infection. The diagnosis is best made by transoesophageal echocardiography and should be suspected whenever there is any degree of atrioventricular block present. Urgent surgery is indicated once the diagnosis is made.

5. Decision making

It is evident from the above that decision making with regards to both the indications and timing of surgery is still problematic. Because infective endocarditis can have such variable clinical manifestations, treatment must of necessity be tailored to individual patient circumstances, the nature of the organism, its effect on the heart and other organs, duration of antibiotic therapy already received, progression of disease over time, and numerous other considerations.

Currently available guidelines aid decision making but are founded largely on observational data. Despite the protean difficulties in designing randomized trials in endocarditis, the pioneering study cited above [13] illustrates that the task is not impossible. Given that

endocarditis remains a frequent, important and potentially lethal condition, the challenge of acquiring more definitive evidence should be accepted.

6. Operative management

Surgery for endocarditis can be amongst the most challenging operations faced by the cardiac surgeon. Debriding infected cardiac tissue and restoring anatomical and functional integrity can be a test of considerable surgical skill. Furthermore, patients present for operation in varying degrees of septicaemia, cardiac failure, multiorgan failure, shock, coagulopathy, hypoproteinemia and anasarca, to which the further insults of surgical trauma and cardiopulmonary bypass are added.

6.1. Surgical principles

The primary objectives of surgery are (1) eradication of all infected, necrotic and non-viable tissue and (2) reconstruction of cardiac morphology. [9] How this is achieved surgically is very dependent upon the local extent of intracardiac infection. Surgery may thus entail repair or replacement of one or more valves, complete aortic root replacement, debridement and patching of abscesses, closure of fistulas, or reconstruction of part of the fibrous skeleton of the heart. Cardiac transplantation has even been reported in an extreme case of relapsing 'burnt out' endocarditis with multiple previous unsuccessful surgeries over many years. [19]

6.2. Valve repair

Valve repair, rather than replacement, is theoretically an attractive option in endocarditis when infection is limited in its local extent. Not only does repair avoid the inherent problems of prosthetic valves (e.g. anticoagulation, thromboembolism, paravalvular leak, structural valve deterioration) but it reduces the risk of recurrent endocarditis when compared with valve replacement. [20].

Techniques may involve simple vegetectomy alone, patching of leaflet perforations with pericardium, or more sophisticated methods of leaflet and/or chordal reconstruction. The method used must be tailored to the individual pathology present (see Figure 4). Eradicating the infection and achieving a durably competent valve is the goal of repair.

Valve repair techniques are now well established for the treatment of degenerative mitral valve disease, but are not always feasible in the setting of endocarditis. In a metanalysis of 24 studies comparing repair versus replacement in 1194 patients, 39% of patients underwent repair whilst the remainder required replacement. Repair was associated with superior early and late outcomes, with reduced need for repeat mitral surgery, fewer cerebrovascular events and fewer episodes of recurrent endocarditis. Operative mortality was less than 10% and 5-year survival greater than 80%. [20]

It is important to appreciate, however, that all 24 studies in the metanalysis were retrospective observational series and thus subject to both selection bias and publication bias. As was noted

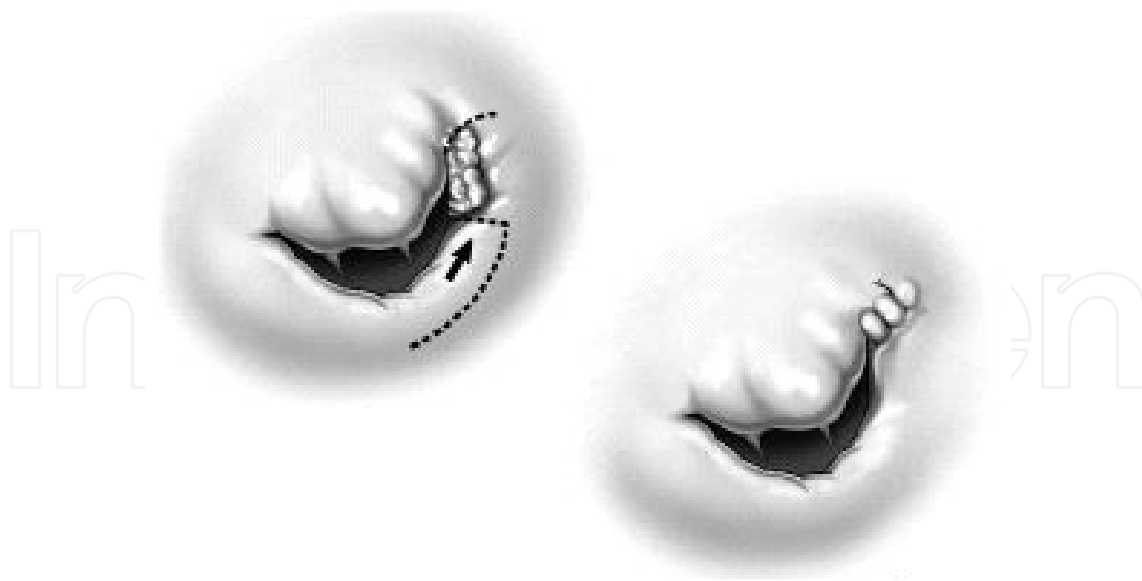


Figure 3. Mitral valve repair. Reproduced with permission from reference [21]. The vegetation involving the postero-medial commissure has been resected, and the posterior leaflet mobilised and advanced into the commissure. The valve must be competent following repair, otherwise replacement will be necessary.

in the meta-analysis, “the validity of comparing mitral valve repair with mitral valve replacement may be questioned. Mitral valve replacement is often reserved for the sickest patients in whom mitral valve repair cannot be performed. Therefore, it would not be surprising that postoperative results would be worse for these patients.” [20]

Valve repair is a much less well established but nonetheless emerging technique in aortic valve disease. Mayer et al reported a series of 100 patients undergoing surgery for aortic valve endocarditis; 33 treated by repair and 67 by replacement. [22] Five year survival was significantly higher in the repair group, although again this was a retrospective series with inherent selection bias. In addition, it is worth noting that the subgroup of patients with repaired bicuspid valves had a higher rate of late aortic regurgitation.

6.3. Valve replacement

Valve replacement, as first performed by Dr W Glenn Young Jr at the Duke University Medical Center [1] nearly 50 years ago, remains the standard of care in the majority of cases of endocarditis treated surgically.

The optimal choice of valve substitute in the setting of infective endocarditis has long been debated. Once again, only observational data rather than randomized clinical trials are available to guide clinical practice.

Some investigators have reported that valve replacement using a homograft results in a lower rate of recurrent endocarditis. [23, 24] Most surgeons now believe that the choice of valve substitute is less important in determining recurrence than the completeness of debridement at the time of operation. Homografts have the disadvantage of more difficult reoperation at

the time of their inevitable structural deterioration. For NVE confined to the valve leaflets, operative results are similar for mechanical and biological prostheses. [25, 8]

6.4. Aortic root replacement

Sometimes, simple valve replacement may not be sufficient when dealing with paravalvular infection, resulting in reinfection of the prosthesis, valve dehiscence, or both. [18] This is often the case in prosthetic valve endocarditis (see below) Aortic root replacement, as opposed to simple aortic valve replacement, may therefore be necessary in these circumstances. Aortic root replacement involves excision of the aortic valve cusps, the sinuses of Valsalva, and a variable amount of the distal ascending aorta. The coronary arteries have to be reimplemented into the replaced root.

In these situations, root replacement with a homograft can be advantageous. The homograft aortic root is soft, pliable, and can be tailored to patch abscess cavities and rebuild tissue defects, especially if the anterior mitral leaflet of the homograft has been left attached. [24]

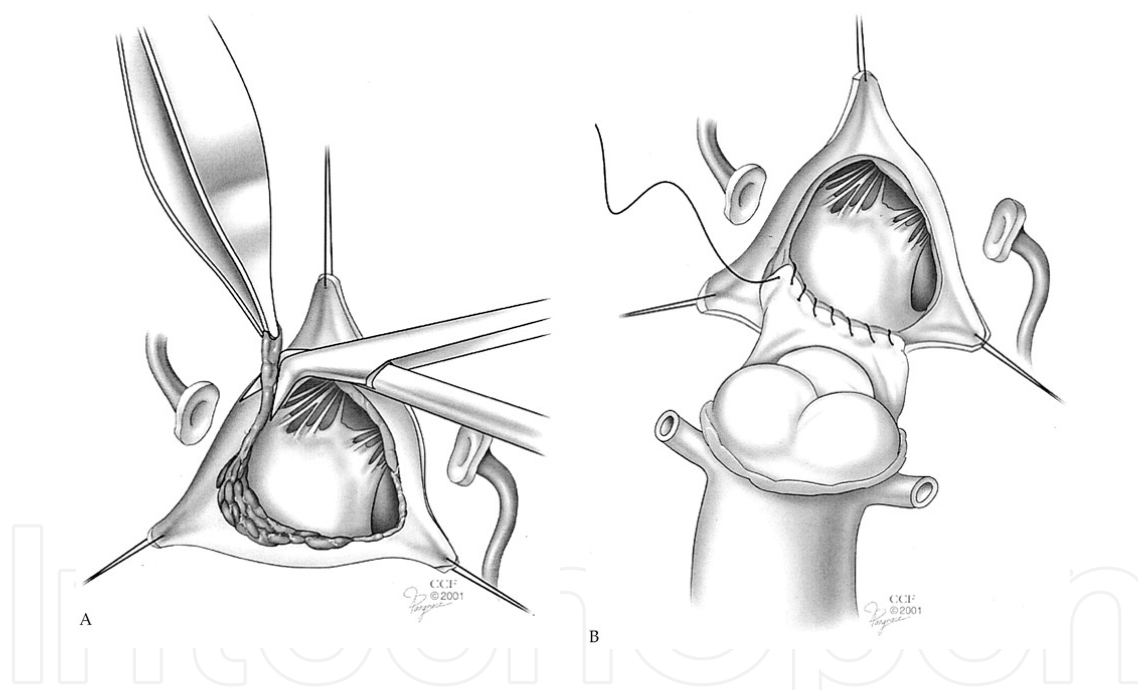


Figure 4. Aortic root replacement using a homograft. Reproduced with permission from reference [24]. The attached homograft mitral leaflet has been used to reconstruct the debrided abscess cavity in the aortic-mitral curtain

Homografts, however, are limited in their availability. Stentless xenograft valves exhibit similar properties to homografts and have been used in this setting as an alternative. [26] Standard mechanical valved conduits have also been used with very satisfactory results. [27, 28] The pulmonary autograft (Ross procedure) is another option although this adds greater complexity to an already difficult procedure in a sick patient. As previously emphasised, the completeness of debridement is probably more important than the type of cardiac replacement tissue used.

6.5. Reconstruction of the fibrous skeleton

In very advanced cases of endocarditis, there may be extensive tissue destruction around the aorto-ventricular junction, mitral annulus and aorto-mitral curtain. In addition to replacing both aortic and mitral valves, the fibrous skeleton of the heart itself may need to be reconstructed. (see Figure 5). Such patients may in fact prove to be beyond surgical repair and deemed inoperable. Complex techniques of surgical reconstruction have been reported by some groups, notably David et al. [29]

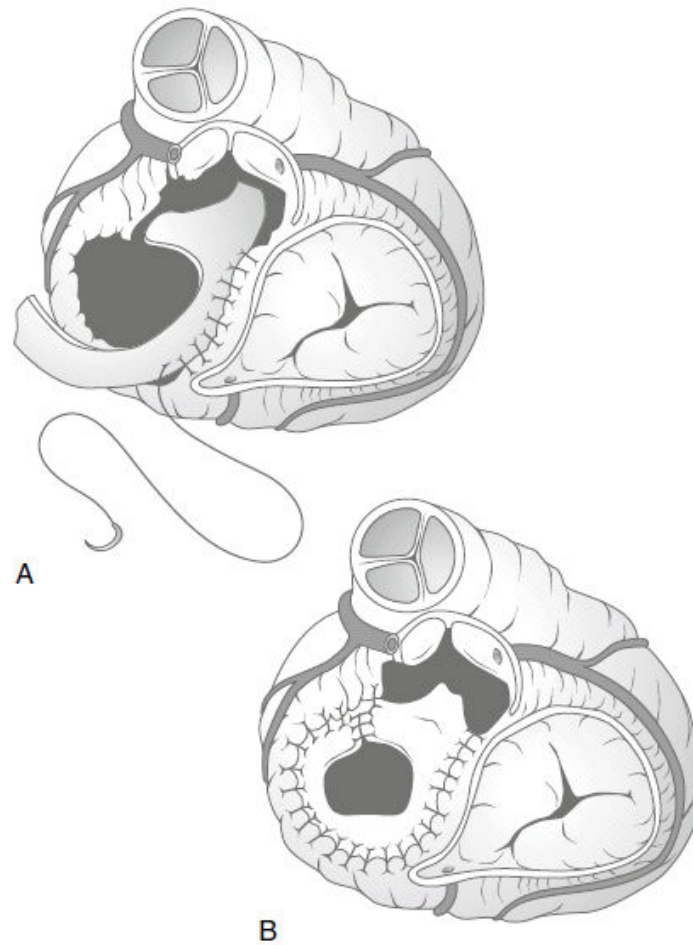


Figure 5. Complex reconstruction of the mitral annulus and aortic-mitral curtain using a pericardial patch. Reproduced with permission from reference [29]. Both aortic and mitral valves have been excised, as well as the intervening area of fibrous continuity (aortic-mitral curtain). The patch acts as a new fibrous skeleton upon which to anchor sutures to secure the aortic and mitral valve prostheses.

7. Prosthetic valve endocarditis

Prosthetic valve endocarditis (PVE) is one of the most feared conditions in cardiac surgery. It accounts for approximately 20% of cases of IE. [7] Mechanical and bioprosthetic valves are equally affected at a frequency in the order of 1% per patient year.

PVE is traditionally classified into early (within 60 days of original valve replacement surgery) and late (greater than 60 days), although a cut-off of 12 months has been suggested by some. [30] The implication is that in early PVE the infection has been acquired at the time of original surgery, whereas in late PVE it complicates a subsequent unrelated bacteraemic episode.

The rate of paravalvular infection is much higher in PVE than NVE, owing to the presence of the prosthetic sewing ring. With mechanical valve prostheses, paravalvular abscess is present in virtually all cases. With bioprosthetic valves, infection is sometimes confined to the valve leaflets, but more often the sewing ring is involved as well.

Paravalvular infection in the aortic position can rapidly lead to aortic root abscess, fistulas into cardiac chambers, disruption of the aortic-mitral curtain, and even complete aorto-ventricular dehiscence. [24, 26] Surgery to remedy these problems is made substantially more complex in view of the fact that these are reoperations. This degree of surgical complexity is reflected in the operative mortality, which is typically double that for NVE surgery [7, 31, 32] (see ‘Results of Surgery’ section below).

The decision as to whether to operate or not for PVE is difficult. Operative risk is much greater for PVE than NVE, but the mortality with medical treatment alone is similarly higher, resulting in a management dilemma. Essentially, patients with early PVE, Staphylococcal PVE and complicated PVE (abscess, heart failure, prosthetic valve dysfunction) are more likely to require surgery whereas late PVE, non-Staphylococcal PVE and uncomplicated PVE can be managed medically with close follow-up. [9]

Tables 3 and 4 summarise the AHA/ACC and ESC guidelines respectively for PVE.

Class I
1. Consultation with a cardiac surgeon is indicated for patients with infective endocarditis of a prosthetic valve. <i>(Level of Evidence: C)</i>
2. Surgery is indicated for patients with infective endocarditis of a prosthetic valve who present with heart failure. <i>(Level of Evidence: B)</i>
3. Surgery is indicated for patients with infective endocarditis of a prosthetic valve who present with dehiscence evidenced by cine fluoroscopy or echocardiography. <i>(Level of Evidence: B)</i>
4. Surgery is indicated for patients with infective endocarditis of a prosthetic valve who present with evidence of increasing obstruction or worsening regurgitation. <i>(Level of Evidence: C)</i>
5. Surgery is indicated for patients with infective endocarditis of a prosthetic valve who present with complications (e.g., abscess formation). <i>(Level of Evidence: C)</i>
Class IIa
1. Surgery is reasonable for patients with infective endocarditis of a prosthetic valve who present with evidence of persistent bacteremia or recurrent emboli despite appropriate antibiotic treatment. <i>(Level of Evidence: C)</i>
2. Surgery is reasonable for patients with infective endocarditis of a prosthetic valve who present with relapsing infection. <i>(Level of Evidence: C)</i>
Class III
1. Routine surgery is not indicated for patients with uncomplicated infective endocarditis of a prosthetic valve caused by first infection with a sensitive organism. <i>(Level of Evidence: C)</i>

Table 3. AHA/ACC guidelines for PVE

Indications for surgery in PVE	Timing	Class	Level
A – HEART FAILURE			
PVE with severe prosthetic dysfunction (dehiscence or obstruction) causing refractory pulmonary oedema or cardiogenic shock	Emergency	I	B
PVE with fistula into a cardiac chamber or pericardium causing refractory pulmonary oedema or cardiogenic shock	Emergency	I	B
PVE with severe prosthetic dysfunction and persisting heart failure	Urgent	I	B
Severe prosthetic dehiscence without HF	Elective	I	B
B-UNCONTROLLED INFECTION			
Locally uncontrolled infection (abscess, false aneurysm, fistula, enlarging vegetation)	Urgent	I	B
PVE caused by fungi or multiresistant organisms	Urgent/elective	I	B
PVE with persisting fever and positive blood cultures >7-10 days	Urgent	I	B
PVE caused by staphylococci or gram negative bacteria (most cases of early PVE)	Urgent/elective	IIa	C
C- PREVENTION OF EMBOLISM			
PVE with recurrent emboli despite appropriate antibiotic treatment	Urgent	I	B
PVE with large vegetations (>10mm) and other predictors of complicated course (heart failure, persistent infection, abscess)	Urgent	I	C
PVE with isolated very large vegetations (>15mm)	urgent	IIb	C

Table 4. ESC guidelines for PVE

8. Right heart endocarditis

Endocarditis can affect the tricuspid valve, pulmonary valve, right ventricle or right atrium and accounts for up to 10% of cases. Predisposing risk factors for right sided endocarditis include intravenous drug abuse and the presence of foreign bodies such as pacemaker leads, haemodialysis catheters, other central venous catheters and valvular prostheses. Congenital anomalies such as ventricular septal defects and bicuspid pulmonary valves also predispose to right heart endocarditis.

Right heart endocarditis is characterised by large, friable vegetations which embolise readily to the pulmonary circulation. The resultant lung abscesses occasionally rupture causing empyema and bronchopleural fistula (see Figure 6). *Staphylococcus aureus* is the dominant organism, but fungal and Gram negative infections also occur.

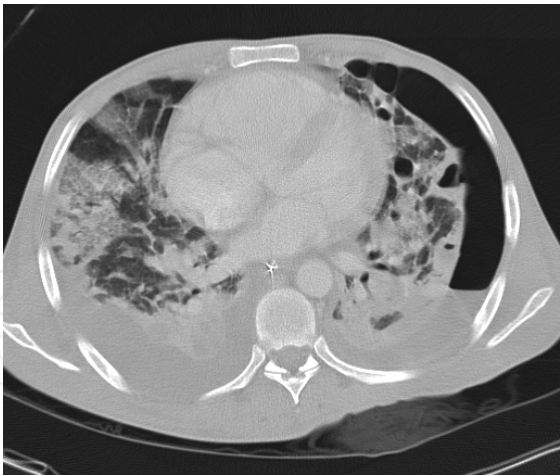


Figure 6. Computed tomography scan demonstrating florid embolic lung abscesses with cavitation, bronchopleural fistula and pyopneumothorax in a patient with pulmonary valve endocarditis due to *Staphylococcus aureus*.

Clinical manifestations are typically those of fever and respiratory distress, but severe haemodynamic compromise and shock may occasionally occur due to sepsis, rather than direct effects on valvular heart function. [33]

Decision making in right heart endocarditis is often problematic, because the indications for surgery are less well defined than for left-sided endocarditis. Many cases can be managed successfully without the need for surgical intervention; however large vegetations (>2cm), fungal infection, heart failure and intractable sepsis should prompt consideration for operative intervention. [33-35, 9] Table 5 summarises the indications for surgery in RSE according to the ESC guidelines.

Recommendations: right-sided endocarditis	Class	Level
Surgical treatment should be considered in the following scenarios: <ul style="list-style-type: none">• Microorganisms difficult to eradicate (e.g. persistent fungi) or bacteraemia for >7 days (e.g. <i>S. aureus</i>, <i>P. aeruginosa</i>) despite adequate antimicrobial therapy or• Persistent tricuspid valve vegetations >20mm after recurrent pulmonary emboli with or without concomitant right heart failure or• Right heart failure secondary to severe tricuspid regurgitation with poor response to diuretic therapy	IIa	C

Table 5. ESC guidelines for right-sided endocarditis

In cases of infected transvenous pacemaker leads, percutaneous removal is generally recommended, despite the risk of dislodging vegetations and causing pulmonary embolism. Surgery is reserved for cases where percutaneous removal is incomplete or impossible, where vegetations are very large (>25mm) or where there is associated severe destructive tricuspid valve disease. [9]

The principles of surgery for right heart endocarditis are similar to left-sided disease, namely thorough debridement of infected and necrotic tissue, removal of all infected foreign material and valvular reconstruction or replacement as required. Many cases of tricuspid valve endocarditis can be treated successfully with vegetectomy and valve repair, but replacement may be necessary with more extensive infection.

Because of the risk of recurrent infection in intravenous drug abusers, valve replacement should be avoided whenever possible in this patient group. If replacement is necessary, future compliance with anticoagulation becomes an important consideration when deciding upon mechanical versus bioprosthetic valves. An alternative is valvectomy without replacement, but the resultant free valvular regurgitation may not be tolerated acutely in some patients and late results are less satisfactory.

9. Results of surgery

The contemporary results of surgery for infective endocarditis indicate that this is still a difficult surgical condition with substantial risk of postoperative morbidity and mortality.

The Cleveland Clinic reported a series of 428 patients undergoing surgery between 2003 and 2007 with an overall hospital mortality of 10%. [32] Prosthetic valve endocarditis had a significantly higher mortality compared with NVE (13% versus 5.6%). Infection with *Staphylococcus aureus* also predicted a higher early and late mortality in this series.

Toronto General Hospital reported a series of 383 patients undergoing surgery for infective endocarditis over a 26-year period between 1978 and 2004. [31] Hospital mortality was 12%. Age, shock, prosthetic valve endocarditis, left ventricular ejection fraction less than 40%, and recurrent endocarditis were independent predictors of death from all causes in this series.

A multicentre prospective study of 1516 patients with NVE was published by Cabell et al in 2005 [5]. Six hundred and ten patients underwent surgery and the remaining 906 were treated medically. Hospital mortality was similar in the two groups (13.6% versus 16.4%). However, propensity analysis identified a significant survival benefit for surgery (11.2% mortality versus 38%) in the subgroup with the most number of predictors for surgery, namely male gender, congestive heart failure, aortic valve involvement, and intracardiac abscess. The authors conclude that the benefits of surgery are most realised in a targeted population.

The same investigators also examined the results of treatment for PVE. [7] Of 355 patients with PVE, 148 underwent surgery and 207 received medical treatment alone. Unadjusted hospital mortality was similar in the two groups (25% versus 23.4%). Brain embolism and *Staphylococcus aureus* were independent predictors of mortality.

In the 2010 prospective multicentre study of NVE by Lalani et al [10] quoted earlier, mortality in 720 patients treated surgically was 12.1%. This compared favourably with the 20.7% mortality for medical treatment.

In summary, surgery for infective endocarditis is associated with an overall hospital mortality of approximately 10-20%. The risk is roughly doubled in PVE compared with NVE.

10. Summary

Surgery for infective endocarditis has evolved enormously since its origins 75 years ago. Guidelines now exist to recommend the indications, timing, and type of surgery, yet much of the evidence is founded on observational data rather than randomized clinical trials. More than perhaps any other surgical issue, decisions rely as much on the experience and judgement of the individual surgeon as the largely observational evidence accumulated in the literature. The principles of surgery remain essentially unchanged, namely the debridement of all infected and non-viable tissue. Valve replacement is the standard of care in the majority of cases, but valve sparing techniques of repair have also gradually evolved. More extensive cardiac reconstruction with root replacement and other methods are sometimes necessary in locally advanced infection. Operative mortality and morbidity is still significant, particularly for prosthetic valve endocarditis.

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