

Reoperations on Cardiac Valves

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As the number of patients undergoing cardiac valve replacement has grown, valve reoperations have become increasingly frequent. The newer generations of mechanical valves are far more efficient and freer from structural failure than the older ones. However, other valve and non-valve related complications still constitute a major cause of morbidity and mortality. On the other hand, bioprostheses, implanted in large numbers in the 1970's and early 1980's, have now gone into the second decade of life since implantation, when biodegradation becomes more frequent. Reoperations are technically more demanding than the original valve procedures because of the mediastinal and pericardial adhesions and the condition of the anulus after removal of the previous prosthesis. Greater awareness of the most dangerous steps and refinements to surgical technique have contributed to the decreased mortality observed in recent years. The risk is higher in certain conditions, such as the presence of prosthetic valve endocarditis and the patient being operated on an

emergency basis in NYHA functional class IV. It may also be increased in females and the elderly. Multiple reoperations also carry a higher risk in most surgeon's experience. However, elective reoperations for defective mechanical valves and for replacement of a previously repaired mitral valve carry similar mortality rates to primary valve replacement procedures. The global mortality rates have not been significantly higher in the hands of experienced surgeons working in centers where reoperations are performed frequently. In smaller series high mortality rates are a constant, which underscores the importance of the learning curve. The indications for reoperation must therefore consider all risk factors and, when possible, the procedure must be performed by those who have the most experience. Under these circumstances, elective re-replacement of degenerating bioprostheses and of defective mechanical valves in asymptomatic patients may be advisable.

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Since the introduction of the first heart valve prosthesis in 1960, more than a million such devices have been implanted throughout the world and have contributed to saving the lives of many patients affected by all forms of valve disease (1). However, valve replacement only exchanges one disease for another since all types of prostheses have complications resulting in significant morbidity and mortality. Bioprostheses are subjected to degradation and calcification, which are accelerated in young patients and during pregnancy, while mechanical valves are prone to thromboembolic phenomena, especially in patients who are non-compliant with medical therapy, including anticoagulation.

As a result, reoperations have become more frequent as the number of patients subjected to valve surgery has increased (2). These operations may be technically more demanding than primary valve surgery, and patients often present in a precarious clinical

and hemodynamic condition, leading to higher operative mortality rates (3,4). Also, as the incidence of complications following valve replacement has increased exponentially, multiple reoperations have become a significant feature in all substantial series (5).

Definition and incidence

In the past, published reports adopted widely different definitions of valvular reoperation, from the very restrictive, allowing only the isolated replacement of an artificial valve in either the mitral or the aortic position (6,7), to the very wide, including any operation on any patient who had a previous intrapericardial procedure such as coronary artery surgery, closed mitral commissurotomy, pericardiectomy and other non-valve related intracardiac operations, even pericardial poudrage (8).

While accepting that a previous invasion of the pericardium is one of the factors that influence the technique and results of reoperation, it is this author's belief that *the definition should include only those procedures which are primarily directed at one or more cardiac valves, subsequent to an initial open heart*

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procedure in the same anatomical position. Patients who have had a previous valvuloplasty should be considered as a reference group because, in our own experience, the most important factor affecting the results is the condition of the anulus after removal of the previous prosthesis. This conforms to the recently adopted guidelines on reporting morbidity and mortality after cardiac valve operations, where reoperation is defined as "any operation that repairs, alters or replaces a previously placed prosthesis or repaired valve" (9). Other cardiac procedures performed during valvular reoperation, such as myocardial revascularization, significantly influence the results which should, thus, be differentiated from those of isolated valve procedures.

Because reoperations on the mitral and aortic valves are the most common, this paper deals essentially with the aspects pertinent to these two valves, based on a comprehensive review of the current literature on the subject and the author's personal and institutional experience, partially published previously (6,7,10). In this experience, reoperations constituted 16.1% of 4,956 valve procedures performed over a twelve year period from 1974 to 1986. Although equivalent figures have generally not been reported from other centers, the incidence of reoperation is mentioned in most series dealing with the late follow up of patients subjected to all types of valve surgery. For example, an incidence of 24% per patient year has been reported after replacement with a bioprosthesis in children (11), although it is generally much lower in adults (2%-5%). However, the hazard function curves show a marked increment

in the rate of reoperation 8-12 years after valve replacement (12).

In contrast, there is a far greater homogeneity in the reported incidence of reoperation after mechanical valve replacement. It varies between 2% and 4% per patient year, but results from an array of complications of variable importance in different populations (13,14). In this case, the incidence of reoperation appears greater in the first year after valve replacement because of the prevalence of early prosthetic valve endocarditis and of bland periprosthetic leakage (Fig. 1). The freedom from reoperation five years after mechanical valve replacement is identical to that obtained with a bioprosthesis, at around 90%, with the figure being around 80% at 10 years (15).

Causes and indications

The major pathology groups involved are structural dysfunction or deterioration, prosthetic valve endocarditis, bland periprosthetic leakage, thrombosis, embolism and native dysfunction following a previous valvuloplasty. Less frequent causes include hemolysis, tissue overgrowth, other causes of non-structural failure and patient-valve mismatch. With the exception of structural failure, each category may be related to either valve or patient factors, or may result from technical errors during implantation of the prosthesis or performance of the valvuloplasty (16).

Structural dysfunction - Defined as "any change in valve function resulting from an intrinsic abnormality causing stenosis or regurgitation", structural dys-

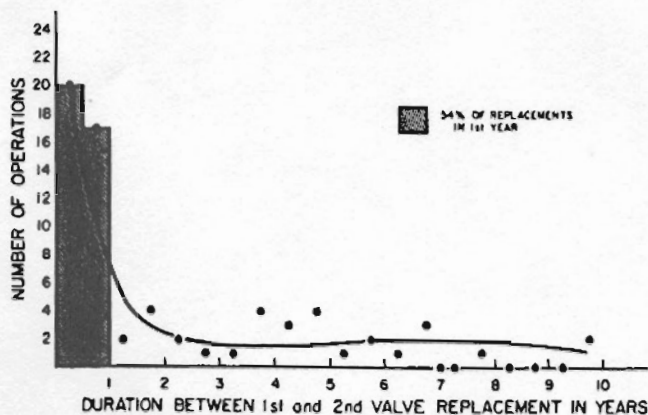


Figure 1. Relationship between the number of reoperations for replacement of a prosthetic heart valve and the duration between the first and second replacement. Note that 54% of the group underwent reoperation within 12 months. (Reproduced from Sandza et al. *J Thorac Cardiovasc Surg* 1977;74:864-74, with permission)

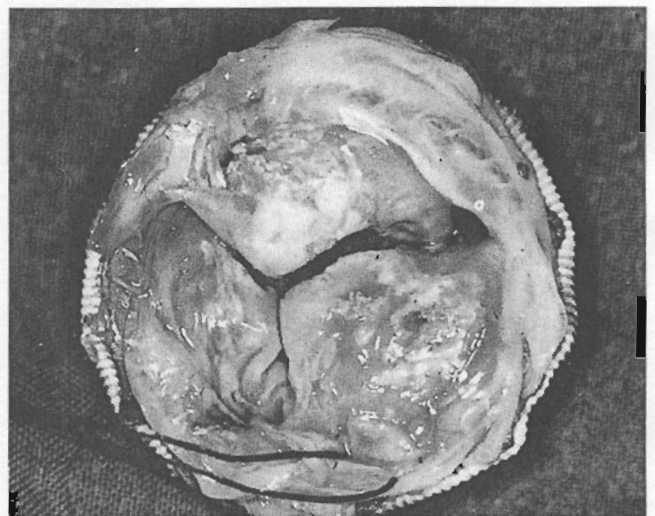


Figure 2. Degenerated porcine bioprosthesis explanted three years after implantation in a 14-year old patient. Note the egg-shell calcification of all three cusps.

function includes biodegradation of tissue valves, mechanical failure and functional deterioration of reconstructed valves.

Degeneration and calcification of bioprostheses is destined to become one of the most frequent causes of reoperation since all tissue valves will eventually require replacement if the patients survive long enough; degeneration is clearly a time-related phenomenon (17). The incidence of this complication varies with the type of prosthesis (porcine, pericardial or homograft), make, position (aortic or mitral) and age of the patient population (Fig. 2). In general, the latter is the most influential. The rate of failure may reach 20% per patient year in patients less than 20 years of age (actuarial freedom from failure 19% at 5 years (11)). However, it averages 2%-4% per patient year in patients over 30 years in whom the freedom from reoperation is 85%-90% at five years and 70-75% at 10 years, but probably less than 40% at 15 years (18). For patients over the age of 70 years, primary tissue failure occurs at a rate of 0.2% per patient year (19). The durability of these prostheses also varies with the position (it is lower in mitral than in aortic prostheses), with the type (lower in pericardial than in porcine) and make. Certain types of tissue valve were associated with earlier failure, and some were removed from the market therefore (20). Reoperation is indicated, irrespective of the patient's symptomatic status, as soon as the signs of valve dysfunction appear, especially when there is regurgitation, which is usually a sign of imminent disintegration (21).

In contrast, modern mechanical valves have been proven to be remarkably free from structural failure, although there have been some recent examples of valves bedevilled by mechanical failures which forced their withdrawal from the market. Failures may result from stress fractures of the valve ring, struts and occluders, or from poppet or disc wear, erosion and escape. These are catastrophic events which often cause the immediate death of the patient. In those that survive, reoperation is required on an emergency basis and carries a very high mortality. However, elective replacement has been performed for defective Braunwald-Cutter prostheses (22) and, more recently, for the series 1000 Starr-Edwards valve (23). Although it has not so far been considered necessary for the convexo-concave Bjork-Shiley prosthesis (24), it may be justified by the very high rates of structural failure of some batches of these valves, which outweigh the morbidity and the mortality of elective reoperation (21).

Reoperation for persistent, recurrent or new regurgitation or stenosis is virtually the only significant complication following mitral valve reconstruction. In

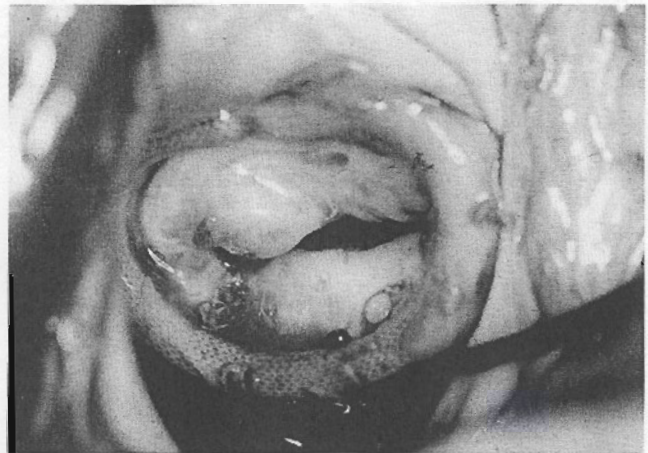


Figure 3. Intraoperative photograph of a mitral valve, three years after repair, in a 12-year old child. The leaflets are scarred and distorted by recurrent acute rheumatic carditis.

rheumatic cases the incidence varies from 2%-4% per patient year (freedom from reoperation; 90% at 5 years and 80% at 10 years) (25,26), higher in younger than in older patients. Reoperation is predominantly required in the first year after the repair procedure, although a peak may also occur much later in the follow up. It may be related to erroneous indications, technical error or progression of the rheumatic pathology, especially in younger patients (Fig. 3) (4). On the other hand, valve failure occurs probably at a rate of less than 1% per patient year in patients operated on for degenerative (Barlow's) disease (27). The need for reoperation after repair of ischaemic mitral regurgitation is as yet unknown because there are only a few, usually small, reported series. The indications for reoperation after valvuloplasty are identical to those followed for the primary valve operation, but emergency surgery may be required in cases of sudden disruption.

Prosthetic valve endocarditis - This group includes all cases of infection of the prosthesis and surrounding annular tissues, confirmed by preoperative positive blood cultures, echocardiographic evidence of vegetations or prosthetic dysfunction, and by intraoperative verification by the surgeon of the signs of active infection. Patients with a past history of endocarditis that was cured by antibiotic therapy or healed spontaneously should not be included in this group when they are reoperated for another reason, such as periprosthetic leak, because the risk and prognosis are different. Patients with positive blood cultures not accompanied by clinical and/or echocardiographic evidence of valve dysfunction are usually managed medically.

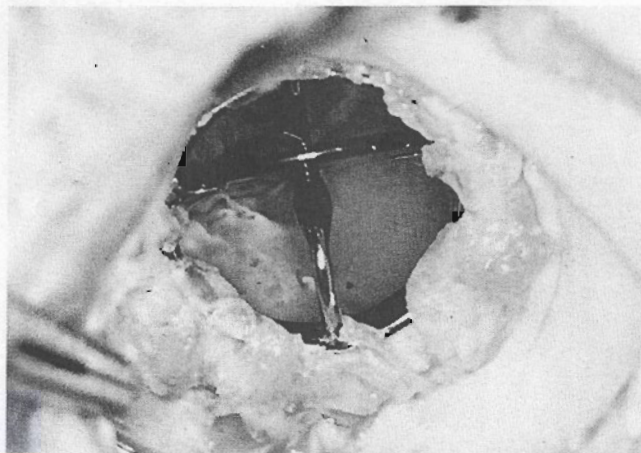


Figure 4. Fungal prosthetic valve endocarditis. This photograph was obtained 18 days after mitral valve replacement with a Medtronic Hall prosthesis in a patient not infected previously.

Early prosthetic valve endocarditis is one of the most important causes of morbidity and mortality following valve replacement. Endocarditis is the result of perioperative contamination by aggressive micro-organisms, often resistant to antibiotics, of which the most common is *Staphylococcus epidermidis*. The reported incidence averages between 1% and 4% and the mortality with medical therapy alone reaches 50% (28,29). Early surgery is thus indicated, especially if there are signs of prosthetic dysfunction. In contrast, late prosthetic valve endocarditis is often associated with infections elsewhere, or with instrumental/surgical manipulation of natural body cavities or tracts. The most common agents are *Streptococci* and gram negative bacilli, usually sensitive to the most commonly used antibiotics. The mortality is also high, but lower than that associated with early prosthetic valve endocarditis. If the diagnosis is made early and there are no signs of prosthetic dysfunction or of periprosthetic leakage, cure may be possible by medical treatment alone. Otherwise, reoperation is indicated and should be performed sooner rather than later since there is no evidence that prior sterilization by antibiotic therapy, if possible at all, leads to improved results. Fungal prosthetic endocarditis (Fig. 4) carries the poorest prognosis with a mortality of over 50%, and surgery is always indicated as it usually constitutes the only hope for a cure.

Infection often recurs and leads to multiple reoperations. In point of fact, the strongest incremental risk factor for prosthetic valve endocarditis is the presence of infection at the time of implantation of the prosthesis (29). The inability to cure the endocarditis

is related to the destruction of the annular tissues preventing adequate insertion of a new prosthesis. Homograft aortic root replacement has been used in these circumstances as these valves are known to be more resistant to infection than other replacement valves (30,31). In some cases, however, the infection seems to perpetuate itself and cardiac tissues are destroyed to such an extent that cardiac transplantation may become the only alternative (32).

Bland periprosthetic leakage – This category includes all non-infected cases as well as those of infective origin but sterile at the time of surgery. The reported incidence is 1%-4%, but it is probably underestimated since many minor leaks remain undiagnosed or may close with time. Periprosthetic leakage represents 13%-30% of the causes of reoperation in the larger series (10,33,34). With prosthetic valve endocarditis, it is also the most important causes of multiple reoperations, which account for 14% of both our series and that of Husebye et al (22).

Periprosthetic leaks occur more frequently with mechanical valves than with bioprostheses (Fig. 5). This may be related to the technique of implantation, allegedly more often associated with continuous than with interrupted sutures (35), although this author believes that the real factor is accuracy rather than the type of technique.

The decision to reoperate on perivalvular leaks is difficult because the symptomatic status of the patient does not bear a close relationship to the size of the defect (36). Due to the increased risk of prosthetic endocarditis, reoperation is probably indicated in all patients with more than mild regurgitation.

Valve thrombosis and systemic embolism – These two together constitute the most important cause of composite mortality and morbidity after mechanical valve replacement.

The combined incidence is variable and may be influenced by many factors, including the type of prosthesis, technique of implantation, position, chamber size and cardiac rhythm, but the most important is the compliance of the patient to anticoagulation.

Thrombosis is a catastrophic complication of mechanical prostheses. The reported incidence is 0%-1.2% per patient year (average 0.5% per patient year) (37-39). In our experience it led to death in two thirds of the cases (13,14). It may evolve slowly with deposition of successive layers of platelet-rich clot, causing progressive dysfunction of the prosthesis, or rapidly, with formation of fresh red thrombus, often over an older layer of white thrombus (40). In this case the sudden dysfunction causes acute deterioration in the condition of the patient, requiring emergency surgery, while in the other case a timely

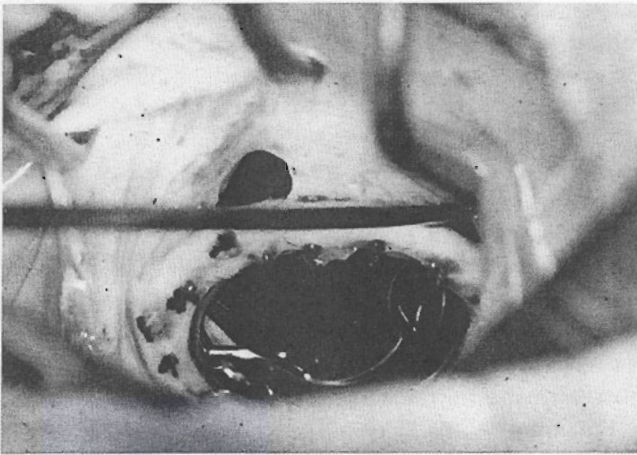


Figure 5. Mitral periprosthetic leak after replacement with a Bjork-Shiley prosthesis, using interrupted suture technique.

diagnosis often permits elective or semi-elective reoperation.

It has been said that this complication is less serious in bileaflet than in tilting disc valves. However, this does not conform to our experience which includes both compliant and non-compliant population groups, where the incidence and respective mortality were identical with the St. Jude Medical (Fig. 6) and the Medtronic Hall prostheses (41,42). Although successful thrombolysis has been reported (43), it is suggested that surgery remains the only safe treatment of thrombosed aortic and mitral prostheses and is indicated as soon as the diagnosis is made, especially when a mitral prosthesis is involved. The affected prosthesis should be replaced during reoperation. Some groups, including ours, have performed thrombectomy with excellent early results (44), but late results have been somewhat more disappointing (45). It is not known whether the removal of clot from hidden valve recesses was incomplete or thrombosis inevitably recurs in patients who are non-compliant with anticoagulation. This method should certainly not be used in bileaflet valves, which have very delicate and tight hinge areas, and in other valves with grooves where minor clot remains unseen to the surgeon.

Thrombosis of bioprostheses is much rarer and is usually reported together with degeneration, to which it is often associated (46). The indications for reoperation are also similar to those for degenerated valves (47).

Repeated systemic embolism originating from cardiac prostheses may also become an indication for reoperation, but only when other sources of emboli have been excluded, which is often difficult to do. In some cases, however, a history of multiple em-

bolic episodes may lead to the diagnosis of prosthetic thrombosis, otherwise obscured by the liberation of fragments of clot, which permit the normal function of the prosthesis. In these cases reoperation is indicated on an urgent basis.

Other causes - *Patient-valve mismatch* is an infrequent cause of reoperation. It may be the consequence of the implantation of a valve too small for the patient's size, especially in the case of some early, relatively inefficient prostheses, or of the growth of the patient subsequent to valve replacement. In either case, the signs are those of valve stenosis and the indications for elective replacement of the prosthesis are identical to those of stenosis of the native valves, especially in the aortic position.

This author has observed *growth of host tissue* over sewing and metal rings, another cause of prosthetic stenosis, with increasing frequency in the late follow up. The incidence of this complication may be influenced by many factors. As the tissue grows over and narrows the valve orifice, it may impair the movement of the occluder, with all of its consequences, including valve thrombosis (Fig. 6) (40). Surgery is indicated when there is evidence of increasing transvalvular gradients or of valvular dysfunction.

Although all prostheses cause a degree of *hemolysis*, this is usually subclinical. However, severe hemolysis may occur with apparently normal valves, caused either by the impact of jets of blood on sutures and the remains of the native valve tissue, or by small periprosthetic leaks of little or no hemodynamic significance (48). Finally, minor and often undetectable irregularities in the valve components may

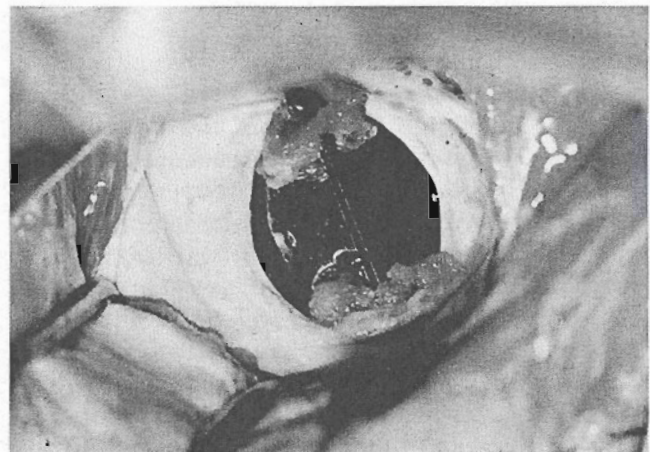


Figure 6. Thrombosed St. Jude Medical mitral valve. Note the exuberant fibrous tissue overgrowth which may have been the primary cause of thrombosis.

cause significant hemolysis. When the other causes of damage to the blood cells are excluded, surgery for replacement of the prosthesis or repair of the leak is indicated.

Technique of reoperation

It is not within the scope of this paper to elaborate on the surgical aspects of reoperation, but discussion of some of its most important aspects is nevertheless warranted. Reoperations are technically more demanding than the equivalent initial procedures, mainly because of the pericardial adhesions and the condition of the valve annulus after removal of the prosthesis. The previous operation report is of utmost importance (49). Knowledge of whether or not the pericardium had been closed after the original valve procedure facilitates planning of sternal re-entry. Other details of the report may help in deciding the extent of dissection and choice of the replacement prosthesis (50).

Sternal re-entry is one of the most difficult and potentially most dangerous steps in the procedure (50,51). Occasionally, it may be necessary to proceed with cardiopulmonary bypass instituted via the femoral vessels. Femoro-femoral bypass may also have to be used in extremis if the right ventricle and/or the aorta are entered during sternal split.

Although major accidents during re-entry are infrequent, we are convinced that a closed pericardium facilitates the procedure and decreases the number of small lacerations in the anterior ventricular and atrial walls. This confirms the experience of other surgeons and is the reason why pericardial substitutes are often advocated. Glutaraldehyde preserved bovine pericardium and expanded polytetrafluoroethylene (Goretex) have been used most frequently, the latter appearing to yield the best results (52,53). Artificial absorbable membranes were recently tested in animals with encouraging results (54). However, Loop has found no difference in the incidence of catastrophic hemorrhage between patients with open or closed pericardium after the initial operation (50).

An alternative to repeat median sternotomy is right anterior thoracotomy, which is the preferred approach of some surgeons and gives excellent exposure of the mitral valve. It may very well be the alternative of choice for multiple reoperations (55).

In the author's view, complete dissection of the pericardial adhesions is unnecessary in the majority of cases. Exposure of the ascending aorta and of the right atrial appendage is sufficient to gain access to the aortic valve. Adequate exposure of the mitral valve is usually obtained by the classic approach,

through a left atrial wall incision posterior to the interatrial groove for which additional dissection of the free right atrial wall is required. The transeptal or the superior approaches may also be used. De-airing after completion of the procedure, which is often used to justify complete release of the adhesions, has not been a major problem for us in reoperations. Finally, limiting the extent of the dissection helps to keep the rate of hemorrhage to a minimum.

It should be mentioned, however, that many surgeons prefer complete division of adhesions, because it allows the use of topical cooling and facilitates exposure of the mitral valve, especially in case of small left atrium.

Hemorrhagic complications occur in a significant number of reoperations and constitute an important cause of morbidity and mortality. Careful and methodic yet limited dissection is essential in decreasing the risk of bleeding. Some patients nevertheless represent an increased risk because of the underlying severe cardiac and hepatic failure and the preoperative anticoagulation therapy. In these cases it is essential to replace the deficient clotting factors, preferably preoperatively if surgery can be delayed safely. Recently, aprotinin has been shown to decrease perioperative bleeding markedly (56) and, if the accumulating evidence confirms current experiences, it could become mandatory.

Removal of the affected prosthesis is the next important step. The native aortic valve and the circumflex artery are particularly at risk during the retrieval of mitral bioprostheses (57). These and other difficulties have led investigators to pursue the goal of the two-component, screw-in replaceable cardiac valve.

Sometimes, however, it may not be necessary to remove the prosthesis. Small bland periprosthetic leaks may be better treated by direct suture closure. Correction of larger and multiple defects is often facilitated by complete removal of the prosthesis followed by reimplantation of the same, or a new one. Other situations where removal of the prosthesis may not be required include thrombosis, which can be managed by declotting, as discussed above, and tissue overgrowth. We routinely inspect all prostheses judged to be functioning well when reoperating for another position and often remove rings of fibrous tissue from the ventricular and atrial or aortic sides of the sewing ring (Fig. 7).

The condition of the annulus has a major influence on the results of reoperation. This structure may be disrupted by the removal of the prosthesis if incorrect technique is used. It also may be affected by infective endocarditis, which is frequently marked by

the presence of annular abscesses. In either case, reimplantation is made difficult because of the lack of tissue strong enough to hold the sutures. Bovine pericardium has been used to reconstruct the anulus, but in most cases this implies the closure of a septic cavity, with all its consequences.

Finally, the surgeon is faced with the dilemma of the choice of a new prosthesis. Is it correct to use a mechanical valve to replace a degenerated bioprosthesis, assuming that the initial choice had been appropriate? Or to use a bioprosthesis to replace a thrombosed mechanical valve in an obviously non-compliant young patient? The choice must be made on an individual basis, in accordance with each sur-

geon's experience, and based on the population's characteristics and the type of pathology involved. Bioprostheses, for example, are allegedly more resistant to reinfection by prosthetic valve endocarditis (Fig. 8) (29).

As discussed above, prosthetic valve endocarditis with large and multiple annular abscesses, especially in the aortic position, represents a challenge to the surgeon (58). These cases probably constitute the best indications for the use of homograft valves, not only because they permit isolation of the abscessed areas, but also because they can easily be sutured at any level in the left ventricular outflow tract. In extreme cases, the whole aortic root may have to be replaced.

Table 1. Perioperative mortality (%) for patients subjected to valvular reoperation

| | Pansini ³⁴ N=183 | Antunes ^{6,7} N=472 | Husebye ²² N=617 | Bosch ⁶⁰ N=89 | Lytle ⁸ N=1000 | Cohn ³³ N=58 | Wideman ⁶¹ N=200 |
|----------------------|--------------------------------|---------------------------------|--------------------------------|-----------------------------|------------------------------|----------------------------|--------------------------------|
| 1. OVERALL | 8.7 | 10.6 | 8.7 | 21.3 | 12.1 | 14 | 5.0 |
| 2. ELECTIVE | 2.4 | 4.5 | 1.3 | 19.5 | 9 | | - |
| EMERGENCY | 20.0 | 24.1 | 45.0 | 42.9 | 37 | | - |
| 3. NYHA ≤ III | | | 4.4 | | | 0 | 3 |
| NYHA IV | | | 29.9 | | 20 | 25 | 23 |
| 4. SEX: Male | | | 7.4 | | 9 | | |
| Female | | | 12.4 | | 21 | | |
| 5. AGE > 60 | | | 16.8 | | 20 | | |
| 6. PATHOLOGY | | | | | | | |
| PVE | 16.7 | 27.9 | 24.3 | 62.5 | 26 | | 19 |
| TO | | 13.0 | | | | | |
| Deg. BIO | 9.4 | 6.0 | | | | | 5 |
| PV Leaks | 5.4 | 16.3 | 10.6 | 23.1 | 12.9 | | 0 |
| Struct. failure | | 8.2 | 9.1 | 10.3 | 4.5 | | |
| Conservative | | 2.4 | | 15.4 | 4.0 | | |
| 7. PROSTHESIS | | | | | | | |
| Mechanical | | 12.5 | | | | 23.4 | |
| Biological | | 10.2 | - | 16.0 | 10 | | |
| 8. POSITION | | | | | | | |
| Aortic | 5.5 | 8.9 | 5.9 | 35.1 | 10.9 | 15 | 5 |
| Mitral | 8.8 | 12.0 | 19.6 | 8.7 | 10 | 13 | N/A |
| 9. ASSOC. PROCEDURES | | | | | | | |
| Tricuspid valve | | 23.7 | | | 20 | | |
| Other | | | 23.8 | 20.0 | | | 5 |
| 10. 1st REOPERATION | | 9.5 | | | 10.9 | | 4 |
| 2nd REOPERATION | | 14.5 | 14.0 | | 15.0 | | 15 |
| 3 REOPERATION | | | 7.0 | | 45.0 | | |
| 11. ACT. SURVIVAL | | | | | | | |
| Global | 57(7) | | 73(5) | 55(10) | | 70(8) | |
| Reop. Free | 51(7) | | | 38(10) | | | |

1. BIO, bioprosthesis; 2. PV, perivalvular; 3. PVE, prosthetic valve endocarditis; 4. TO, thrombotic obstruction. Figures in parenthesis indicate period of follow-up in years.

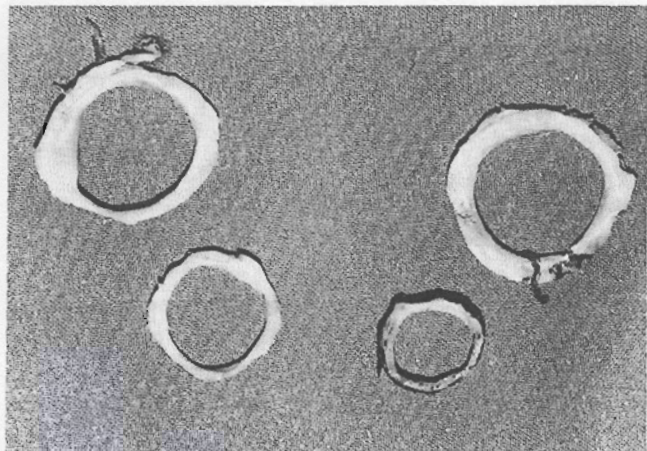


Figure 7. Fibrous rings removed intraoperatively from both sides of aortic and mitral prosthesis without signs of dysfunction other than mild transvalvular gradients.

Homograft infection is a very rare event when used in situations of non-controlled endocarditis (59).

Results

The analysis of results is made difficult by the lack of uniformity of the definition of reoperation in the published literature (vide supra). Only 28% of patients included in the series of 1000 reoperations published from the Cleveland Clinic underwent replacement of a prosthesis, and it was a significant risk factor in this series (8). As a result, the global results are improved by the inclusion of the remaining 72% of the patients. In contrast, our series of 249 mitral and 203 aortic procedures included only those cases where isolated replacement of a prosthesis or a bioprosthesis in one of these positions was performed (6,7).

Another factor affecting the analysis is the large amount of variables involved, making each series unique. Furthermore, there are obvious differences in the statistical methods used by different authors. With these limitations, an attempt will be made to give an overview of the results published over the past decade (6-8,18,22,33,34,60), since the year of operation was one of the risk factors in most series where this variable was studied, with recent procedures showing better results (Table I). Nevertheless, some large series published in the late 1970's deserve consideration and will be mentioned (62,63).

Perioperative mortality

Early surgical mortality is affected by a number of patient factors and the pathologic process involved.

Functional class and emergency – Surgical mortality

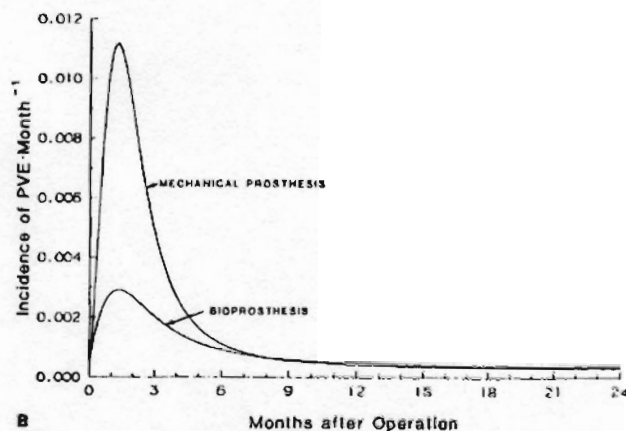
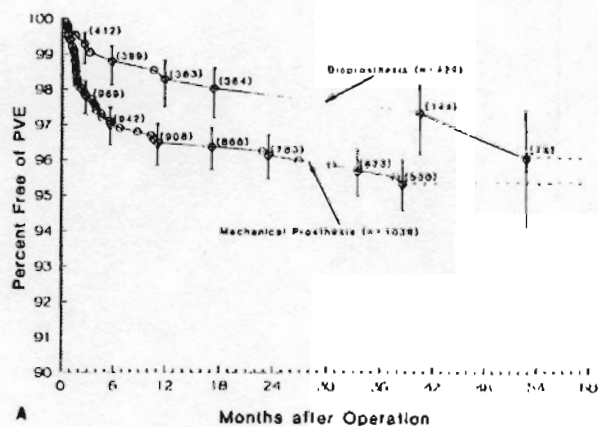


Figure 8/A. Actuarial incidence of freedom from prosthetic valve endocarditis after valve replacement with mechanical prostheses and bioprostheses (70% confidence limits)

8/B. Hazard function in the same group of patients.
(Reproduced from Ivert TSA et al. *Circulation* 1984;69:223-32, by permission of the American Heart Association, Inc.)

varied from 8.7% to 21.3%. These figures were mainly affected by the number of patients operated on an emergency basis. In effect, the mortality for elective reoperation was 1.3% in the series reported by Husebye et al. (22) from the Mayo Clinic. However, this rate was influenced by the very low mortality of 0.8% (1 of 117) in symptomless patients operated on for replacement of the Braunwald-Cutter valve "which had shown a tendency toward poppet wear and subsequent embolization".

The differences in mortality rates between elective and emergency procedures were also influenced by classification criteria. Generally, lower rates for elective reoperations go hand in hand with higher rates for emergencies, which reflects the inclusion in the latter group of all higher risk cases, especially those in a higher NYHA functional class. In the report by

Husebye et al. (22), only one of 223 patients operated upon electively was in class IV, whereas 64% of the emergency procedures were done on class IV patients. Consequently, neither of these two factors had an independent predictive value in the multivariate analysis.

In the series reviewed, including our own, the mortality rate for emergency procedures varied from 24.1% to 45% (4,64). It is conceivable that some benefit may be gained by improving the condition of the patient preoperatively by medical therapy, if this is possible. Indeed, this was our approach in many critical patients whom we would have previously operated on as emergencies, with the exception of those with thrombosed valves. Continued hypoxia and right ventricular failure are the commonest causes of death after cardiopulmonary bypass in patients presenting in pulmonary edema. Preoperative treatment with inotropes, diuretics and intermittent positive pressure ventilation has enhanced the overall survival rate in our hands.

Age and sex – Age was an independent risk factor in patients over 60 years of age (mortality 16.8%) and more significantly above 70 years (32.4%). This is an important fact to consider as bioprostheses are being implanted with increasing frequency in the elderly. Although the durability of these valves is much greater in this age group, a number of reoperations on patients in the eighth to tenth decades of their lives is inevitable.

Perhaps unexpectedly, in our experience, reoperation carried a higher mortality in women than in men, especially in the aortic valve group, although sex was not an independent risk factor in the multivariate analyses. Presumably this reflects the higher incidence of associated procedures in the female patient, which were shown to increase the risk to 20% and 24% respectively in the experiences of Bosch (60) and Husebye (22) and their coworkers. In the series of Lytle et al. (8), the need for concomitant coronary revascularization increased the risk slightly in aortic but not in mitral reoperations.

Pathology – The indication for reoperation affected perioperative risk distinctly, again with great variability between the series.

Prosthetic valve endocarditis always carried the highest mortality, ranging from 24.3% to 62.5%. In the experience of Lytle et al. (8), aortic prosthetic valve endocarditis carried a higher mortality (38%), but in our's the mortality associated with reoperation for endocarditis on a mitral prosthesis was higher (35%) than that for aortic procedures (23%). The early experience weighed heavily on the overall results. Recently, we were able to reoperate on a series of 15

consecutive patients with prosthetic endocarditis, including 10 early cases, without mortality (65). Cukingnam (66) and Leprot (67) and their colleagues also demonstrated the improving prognosis over recent years. In the reports reviewed, the lowest mortality rates were seen in the larger series, confirming the importance of the learning curve in the treatment of this type of pathology, where large aortic root abscesses often challenge the surgeon's experience and powers of innovation.

Degeneration of bioprostheses is probably the most common current indication for reoperation, following the widespread use of these prostheses in the past decade and a half. The mortality rate depends on the preoperative condition of the patient. Contrary to the opinion commonly expressed, patients with degenerated prostheses may die suddenly or present to operation in an extremely critical condition (68). Our mortality for re-replacement of bioprostheses was 6%, identical to that reported by Bortolotti et al. (6.1%) (18) and lower than that of Pansini et al. (9.4%) (34). Again, the experience of the surgical team plays an important role in decreasing mortality. Early, programmed substitution of prostheses known to be failing may be accomplished with low risk and is strongly recommended.

The risk associated with reoperation for bland periprosthetic leaks depends on the position and whether replacement of the prosthesis is required or suture closure is feasible. In the experience of Lytle and colleagues (8), the mortality rates for aortic prostheses were 14% and 5% respectively for replacement and repair, but this difference was reversed in the case of mitral periprosthetic leaks (10% and 22%, respectively). However, in our experience patients with periprosthetic leaks of the mitral valve treated by valve replacement had a higher mortality (22%) than did those with leaks of the aortic valve (12%).

Thrombotic obstruction, another lethal complication of mechanical prostheses, is not reported in most series of reoperation as it occurs most frequently in non-compliant populations. In my experience, mostly with this type of population (7), the mortality for reoperation (13.0%) did not differ significantly from the global mortality rate of 10.6%, which was also found by Renzulli and colleagues (40), working with a different population group. On the other hand, Martinell and associates (38) reported an operative mortality of 18% in a series of 41 patients with prosthetic valve thrombosis, but this rate was reduced to 4% in their late experience.

Dysfunction of mechanical valves is generally not associated with increased risk, with reoperative mortality rates varying from 4.5% to 10.3%, if the reopera-

tions were performed electively. However, the risk depends on the type of malfunction. Mayo Clinic surgeons (22) were able to replace 117 aortic Braunwald-Cutter prostheses electively with only one death (0.8%), an experience similar to that of the University of Alabama at Birmingham (1 death in 65 patients; 1.5%). On the other hand, emergency reoperations for replacement of convexo-concave Bjork-Shiley prostheses with strut fracture and disc embolization carried a much higher mortality (69).

Reoperation for failure of conservative procedures carries a much lower risk than reoperation for replacement of a prosthesis (2.4% vs. 10.6% in our experience (6)). Lytle et al. (8), at the Cleveland Clinic, registered a mortality rate of 4.0% for reoperation after valvuloplasty which, in their mind, supports the continued use of these operations when appropriate. The absence of the "annular factor", discussed above, is the most likely explanation for the significantly decreased mortality.

In conclusion, perioperative and early mortality after reoperation is only slightly higher than that following primary valve replacement in most institutions with a considerable experience of these procedures. The risk is slightly lower for aortic than for mitral reoperations (5.9%-10.9% vs. 8.7%-19.6%). In contrast, Bosch and colleagues (60) recorded a much higher mortality for aortic (35.1%) than mitral (8.7%) procedures. Multiple reoperations still carry an increased risk, especially when the tricuspid valve is involved. Our combined mortality for second, third and fourth reoperations was only 14.2% (62), similar to those of Husebye et al. (22) for second reoperations (14.0%) and of Wideman and coworkers (61) for second and third reoperations (15.7%). In the experience of Lytle et al. (8), the rates for second and for third to fifth reoperations were 15.0% and 45%, respectively.

Finally, it is clear that the risk has decreased with time (33,61). The introduction of cardioplegia has probably been the most important single technical advance, but this could not be proved because other variables have also changed. As the experience has increased, new technical details have been introduced which have contributed to the much better recent results.

Perioperative morbidity

Non-fatal complications occur more frequently after reoperations than after primary valve procedures. Sternal re-entry problems, which occurred in 3.6% of the patients in Lytle et al (8) with a mortality of 36%, are characteristic. Similar experiences were reported by Bortolotti et al. (18) (incidence 2.6%; no

mortality) and Husebye et al. (22) (4%;8.7%). We had three cases of laceration of the right ventricle among 452 mitral and aortic valvular patients (0.7%; no mortality). Grunwald (70) also had no deaths using a direct vision technique for sternal re-entry. However, a survey made by Dobell and Jain (71) among American surgeons identified 144 cases of severe hemorrhage with 37% mortality. They resulted from damage to the right atrium, right ventricle, innominate vein, aorta, coronary arteries, pulmonary artery and vena cavae. Lesions of these structures also occur commonly during dissection of the pericardial adhesions but are usually much less serious and can be adequately repaired without significant morbidity.

Postoperative bleeding during the first few hours in the intensive care unit is another important cause of morbidity and may occasionally cause the death of the patient. Husebye et al. (22) and Pansini et al. (34) found no difference either in the amounts of blood drained after reoperation and after a first valve procedure or in the respective incidence of reintervention for bleeding and/or cardiac tamponade. Although complete data for the incidence of this complication in our experience is not available, the need for re-exploration of the mediastinum was also not different from that of primary procedures. In contrast, Lytle et al. (8) found that reintervention for postoperative hemorrhage was required in 10.4% of their patients, of whom 2.4% died. Reoperated patients required greater amounts of blood, but the usage of blood has decreased in their more recent experience. Second and subsequent reoperations did not represent an increased risk of bleeding when compared with first reoperations. Specific bleeding sites are usually not found during re-exploration and the large amounts of clots, which must be removed, originate from diffuse oozing. In general, reintervention is curative, but intensive replacement of clotting factors may be necessary in several patients. Current experience suggests that the use of Aprotinin reduces the risk of non-surgical bleeding, thereby offering itself as a valuable tool for re-interventions.

Other complications, such as complete atrioventricular block requiring implantation of a permanent pacemaker, and neurologic deficits, were either not recorded or did not represent an increased risk over that of primary operations.

Late results

Prosthetic valve endocarditis and bland prosthetic leaks, both usually requiring a new reoperation, are the factors that most commonly affect late results. Additionally myocardial dysfunction, the

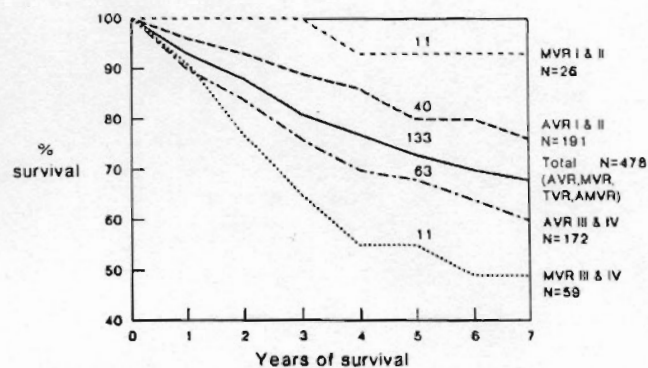


Figure 9. Relation of survival for patients after first reoperation to operative class. Patients in classes I and II had a much higher survival rate than did patients in classes III and IV. The difference was greatest in patients undergoing mitral valve reoperations (MVR). AMVR: double (aortic and mitral) valve reoperation, AVR: aortic valve reoperation, TVR: tricuspid valve reoperation. (Reproduced from Husebye DG et al. *J Thorac Cardiovasc Surg* 1983;86:543-52, with permission)

consequence of a long cardiopulmonary bypass or inadequate myocardial protection, may be an important cause of late mortality.

Complications - Prosthetic valve endocarditis may represent new infection or reinfection after replacement of an infected prosthesis. The latter, a true complication of the reoperation, occurred in three of 37 cases (8.1%) in the experience of Husebye et al (22). Prosthetic valve endocarditis was the most common cause of multiple reoperations in our patients. However, this pathology appears to have affected only the mortality of the first reoperation, probably because the infection was effectively controlled by prosthetic replacement and antibiotics. Subsequent procedures were required mostly for correction of leaks with or without minor foci of infection. However, in the experience of Blackstone and Kirklin (2), the actuarial freedom from prosthetic valve endocarditis and periprosthetic leakage was lower after reoperations than after the original procedures.

Bland periprosthetic leaks, on the other hand, may be more frequent after reoperation than after the initial procedure, presumably because of the irregularities in the annulus after removal of the prosthesis. It may also recur after repair of another leak. The incidence of this complication varies from 0.8% to 3.0% and may be more frequent in the mitral than in the aortic position.

Functional status and survival - As for primary valve procedures, NYHA functional class improves considerably after reoperation, most patients remaining in classes I and II postoperatively. Long term survival after reoperation is affected by the preoperative func-

tional class in each of the mitral and aortic groups. As there is a much higher percentage of patients undergoing reoperation in class IV, the global figures for survival after reoperation are lower than those observed for primary operations. In the experience of Husebye et al. (22), the global 7-year survival was 68% and varied between 76% for aortic and 93% for mitral patients in classes I and II, and between 49% for mitral and 60% for aortic patients in classes III and IV (Fig. 9). However, the survival of patients matched by functional class is identical after the primary and secondary operations.

Conclusion

Valvular reoperations, in some categories, may be performed electively at no greater risk than primary valve procedures. However, a much greater mortality accompanies emergency reoperations performed on patients in NYHA class IV and in some subsets of pathology, such as prosthetic valve endocarditis. Consequently, repeat surgery for prosthetic valve complications not treatable medically should be performed early, immediately after the diagnosis and preferably before significant symptoms ensue. Also, antibiotic prophylaxis of prosthetic valve endocarditis should be carried out scrupulously in all patients at risk.

Strict adherence to basic surgical principles contributes to the lowering of operative mortality. Whenever possible, reoperations should be performed by the same surgical team that performed the initial operation and in each particular team by surgeons who have the most experience with this type of procedure.

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