The Current Status of Surgery for Acquired Valvular Disease*

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INTRODUCTION

The origins of valvular surgery lie 65 years ago but remained dormant until the 1950's when closed mitral valve surgery was "rediscovered" and the heart-lung bypass machine became available.

The first operation for acquired valvular heart disease was performed in 1923 by Cutler and Levine (1) in the United States. Their patient suffered with mitral stenosis and they unfortunately decided to resect part of the valve in the procedure. Surprisingly the result was successful in the first patient but the following patients died so the procedure was abandoned. In 1925, Souttar performed a digital valvotomy, at the London Hospital in England on a young lady with mixed mitral valve disease. Despite the fact that the regurgitation became worse she survived for several years before dying of progressive mitral valve disease. It is unfortunate that he too did not continue the operation.

No further attempts were made to treat valvular heart disease until 1948 when Harken described the first digital commissurotomy for mitral stenosis. The procedure soon gained worldwide acceptance in view of the good results obtained and the almost inevitable fatal outcome of the disease in these predominantly young patients. In 1953 Gibbon performed the first open heart operation, repairing an atrial septal defect successfully in a young woman, and so began the modern era of cardiac surgery. In spite of the advent of extracorporal pump oxygenators, closed commissurotomy remained a safer alternative because of the complications associated with cardiopulmonary bypass (CPB). A further advance was made with the development of the mitral valve dilator by Tubbs, allowing for a better commissurotomy, with much lower risk of valvular re-stenosis.

Aortic valve surgery commenced in 1952 when Bailey attempted to relieve aortic stenosis using a transventricular dilator. With the introduction of open heart surgery, attempts were made to treat aortic stenosis and regurgitation using valvotomy, debridement and reconstruction. The results were not good and it became apparent that these conservative techniques alone were unable to correct the defects totally.

About the same time attempts were being made to repair regurgitant mitral valves with poor results in many patients, and attempts were then made to find a suitable prosthetic valve to replace the diseased valves.

The modern era of valve replacement began with the ball valve prosthesis, developed by Starr and Edwards in 1961. Their work had followed the successful implantation of a ball valve by Huffnagel and Harvey in 1953, into the descending thoracic aorta of a patient with aortic regurgitation without CPB. Since then many other valves have been developed and used with varying success, initially mechanical and then bioprosthetic also.

PATHOLOGY

The basis of acquired valvular disease is valvular injury. Once injury occurs the problem is compounded by a series of events (fig. 1) which leads to further valvular injury. The commonest cause of trauma is still rheumatic fever. A history of rheumatic fever however, is frequently absent.

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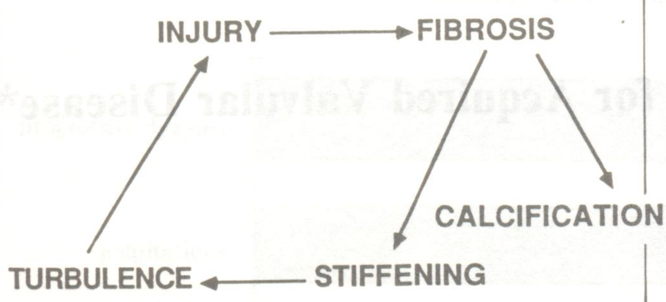

Fig 1. Pathology of acquired valvular disease

Nonetheless, despite the relatively uncommon occurrence of the disease in England nowadays. rheumatic valvular disease continues to be the main cause of valvular injury worldwide, although the rate is declining.

Valvular infection can initiate or worsen injury. Infection usually occurs in valves which are already abnormal (previous rheumatic fever, bicuspid aortic valve, etc.) but can also affect normal valves. This usually occurs with virulent organisms or in drug-abusers.

Whatever the mode of injury, healing occurs by fibrosis which causes valvular distortion, retraction and thickening (fig. 2). The leaflets become stiffer as a result of this and the reduced pliability causes turbulent blood flow across the valve and energy dissipation in the cusps. This in trun contributes to further valvular injury and may be associated with other changes such as annular dilatation or chordal fusion. As the process continues dystrophic calcification occurs in the fibrotic leaflets (fig. 3) and so the process continues.

Fig. 2. Mitral stenosis and regurgitation showing typical appreances

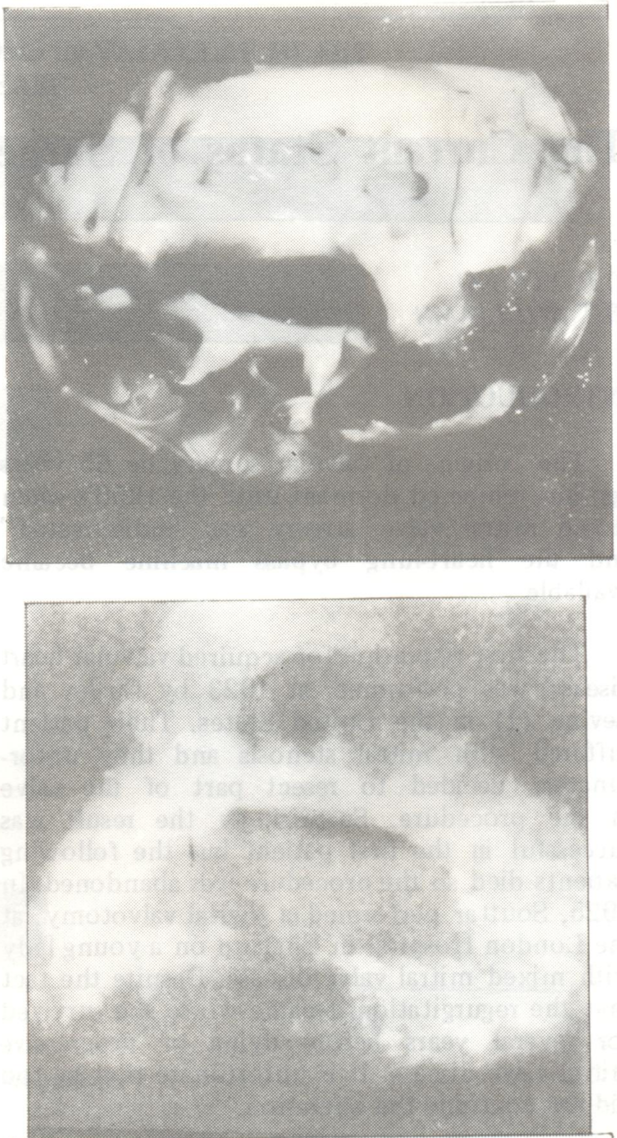

Fig. 3. A: Typically stenotic explanted mitral valve
B: X-ray of explanted valve showing heavy calcification

Other causes of valvular dysfunction occur less commonly. The presence of immature collagen in chordae tendinae predisposes to rupture. With the hereditary generalised connective tissue disorder of Marfan's syndrome valvular incompetence can occur as a result of cystic medial necrosis of the aortic wall, with aneurysmal dilatation of the aorta and the aortic valve annulus. The pathology extends further than the aortic wall and involves the valvular leaflets also.

Coronary artery disease can also indirectly cause valvular incompetence by causing ischaemic papillary muscle dysfunction or rupture.

VALVULAR REPAIRS

When valvular surgery began, repair was the only means by which to improve valve function. Due to the poor results obtained with conservative aortic surgery, these procedures were abandoned with the advent of valve replacement, apart from valve resuspension in cases of aortic dissection with annular disruption. Conservative mitral valve surgery however continued and is enjoying a revival following Carpentier's published results.

(i) COMMISSUROTOMY

As previously stated, closed mitral valvotomy opened the age of cardiac surgery, and remained the operation of choice for mitral stenosis for a long time after CPB became available. Nowadays however, it has to be regarded as second best. Open commissurotomy is both safe and effective, with a much lower incidence of re-stenosis than the closed procedure. There is also a greatly reduced incidence of cerebral embolism—a major complication of the closed operation. Performing the operation under direct vision allows for a more extensive commissurotomy, which can be performed safely in the knowledge that any regurgitation produced can be corrected also. This is important in the long-term, for although diastolic gradients can be greatly improved or abolished if the mitral valve area is increased to 2.5 cm or more; technically this still represents a stenosed valve which is likely to cause turbulent flow, continuing the cycle of injury. An open approach produces a greater valve area and hence minimises further injury and is associated with a better long-term result.

(ii) ANNULOPLASTY

Has been performed intermittently for the last 25 years. The success and long term results have been variable. Differing methods of annuloplasty were described but all have been applicable only to wholly regurgitant valves.

McGoon described a repair for ruptured chordae in an otherwise normal valve in 1960 (fig. 4). One striking point in the paper is the stress placed upon conservative surgery if possible. This was quite unusual at a time when valve replacement was beginning and the results of some valve repairs were so poor.

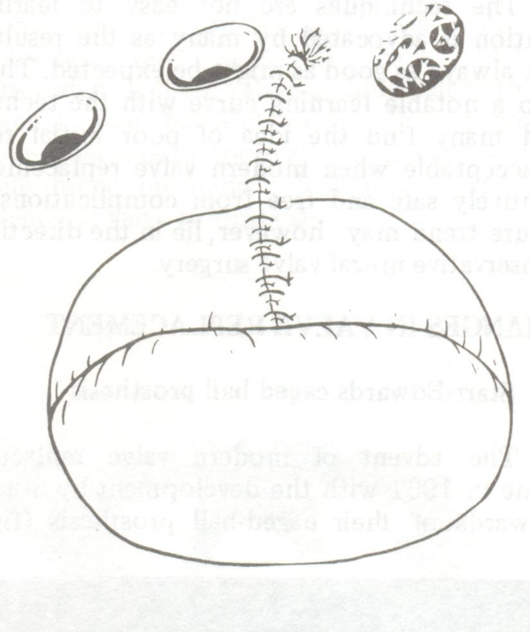

Fig. 4. McGoon repair for ruptures chordae of the cusp and annulus after excision of the redundant section

(iii) LEAFLET ADVANCEMENT

These techniques became popular around 1960. They were used for regurgitant valves with fibrotic leaflets. By detatching the leaflet from the annulus it was possible to insert a pericardial patch and partially correct the defect. With advancements in valve replacement the technique soon faded, particularly as the valve retained the fibrotic deformed leaflets and the procedure did not fully correct the anastomatic defect.

(iv) MODERN VALVE REPAIR

Interest is again being shown in conservative mitral valve surgery, thanks mainly to the pioneering work of Alain Carpentier at the Clinique Leriche in Paris. The current technique involves a functional approach to valve repair, ignoring aetiology or anatomy. Stenosis is first dealt with by commissurotomy and the leaflets assessed, as being (i) normal, (ii) prolapsed or (iii) restricted. Correction of individual leaflet motion is then performed by several means (Table 1) (chordal transfer, shortening, elongation, resection of part of a leaflet, etc.) and finally annular dilatation is corrected by the insertion of a prosthetic valve ring.

The techniques are not easy to learn and caution is advocated by many as the results are not always as good as might be expected. There is also a notable learning curve with the technique and many find the idea of poor initial results unacceptable when modern valve replacement is relatively safe and free from complications. The future trend may however, lie in the direction of conservative mitral valve surgery.

CHANGES IN VALVE REPLACEMENT

(i) Starr-Edwards caged ball prosthesis

The advent of modern valve replacement came in 1961 with the development by Starr and Edwards of their caged-ball prosthesis (fig. 5).

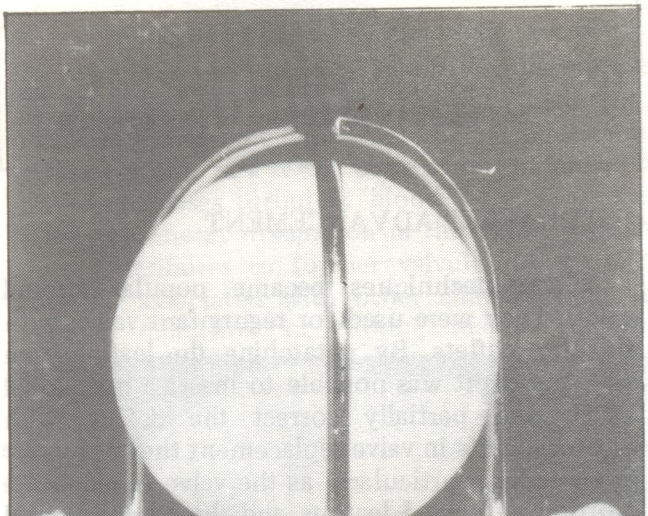

Fig. 5. Starr-Edwards caged-ball prosthesis

The initial prosthesis consisted of a silastic cage with an uncovered stainless steel housing. Initial results were excellent for that time and the valve became very popular.

Several other types of caged-ball prostheses were developed also, some as alternative valves and others to try and overcome the problem of placing a large cage into the ventricle. However, as valve technology advanced, it became apparent that with the Starr-Edwards prosthesis, cloth wear (fig. 6) and haemolysis were major long-term problems and the design reverted to a silastic ball held within a bare metal cage. Although problems were encountered with ball variance in the late 1960's the valve has remained popular worldwide. Its major advantage is that it has stood the test of time with an excellent record of durability. The haemodynamics of the valve however are far from perfect, particularly when inserted into a small aorta. The centrally placed ball causes severely turbulent flow and transvalver pressure gradients can be relatively high, particularly with smaller valves.

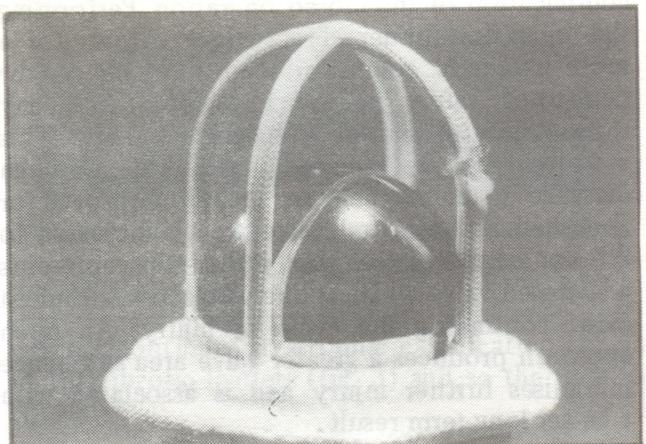

Fig. 6 Starr-Edwards mitral prosthesis showing cloth wear

(ii) Advances in Mechanical Prostheses

Despite the success of the Starr-Edwards prosthesis, research continued to improve valve haemodynamics and thromboembolic problems. One major drawback of the caged-ball prosthesis

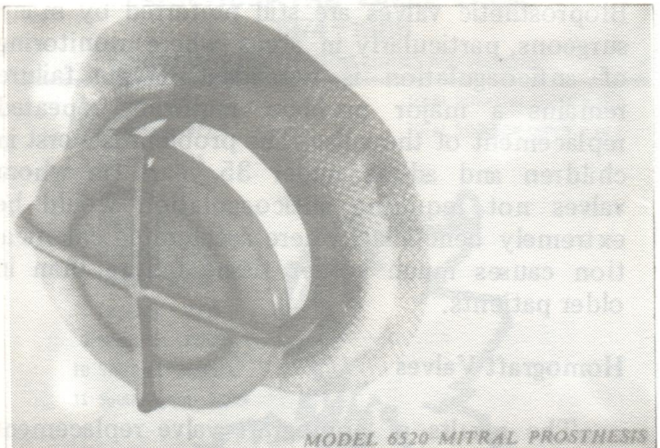

Fig. 7. Starr-Edwards caged-disc prosthesis (model 6520)

was having to insert a large cage into the ventricular cavity. This led to the development of disc valves, initially cages (fig. 7) and then with tilting mechanism. Radical changes in design led to the introduction of the popular Bjork-Shiley tilting disc prosthesis (fig. 8) in the late 1960's. Many valves were inserted before the problems of valve thrombosis and strut failure became apparent. Continued research however improved the design reducing valve complications. This was achieved firstly by improving the opening angle of the disc from 60 to 70 and also by improvements in the attachment of the strut to the frame. This was later superseded by machining the valve frame and strut from a single block, therefore eliminating joints.

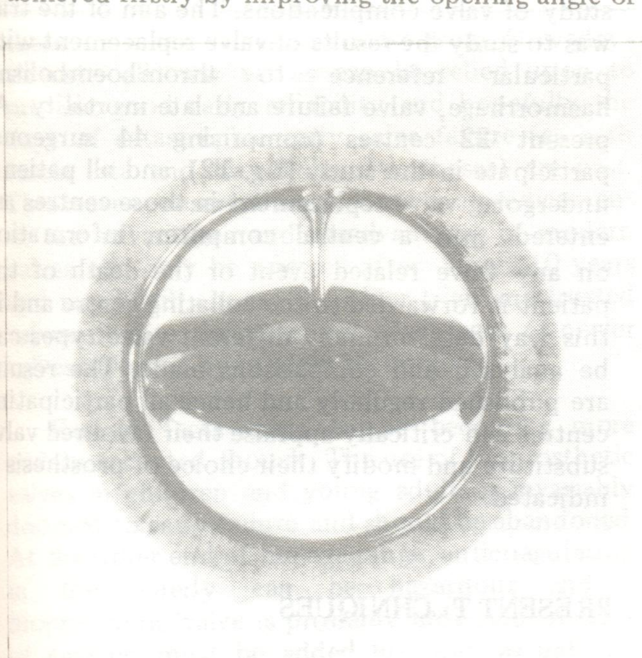

Fig. 8. Bjork-Shiley monostrut prosthesis

Progress in valve design in the 1970's led to the development of bileaflet valves, initially with the St. Jude prosthesis and later with the Duromedics valve (fig. 9). New features incorporated in these valves included all pyrolytic problems. The bileaflet valves allowed greater opening, decreasing transvalvular gradients and a mobile hinge mechanism helped to reduce the incidence of valve thrombosis.

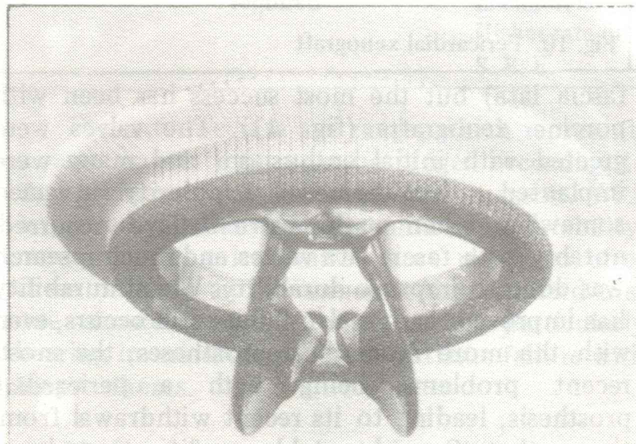

Fig. 9 Duromedics bileaflet prosthesis

Modern technology has allowed the development of better valves worth lower transvalvular gradients, improved thromboembolic rates and a lower incidence of valve failure. The most durable valve to date remains the Starr-Edwards prosthesis. Despite its shortcomings, both real and theoretical, it still remains a popular valve and its place will only be taken by newer valves as long-term evidence of durability becomes available.

(iii) Biological Valves

Because of the thromboembolic complications of mechanical valves and the risks associated with life-long anticoagulation, research was performed into constructing suitable biological valve substitutes. Early results were good for many valves but durability proved a major problem. Several tissues were used to construct prostheses (porcine valves, pericardium (fig. 10), dura mater,

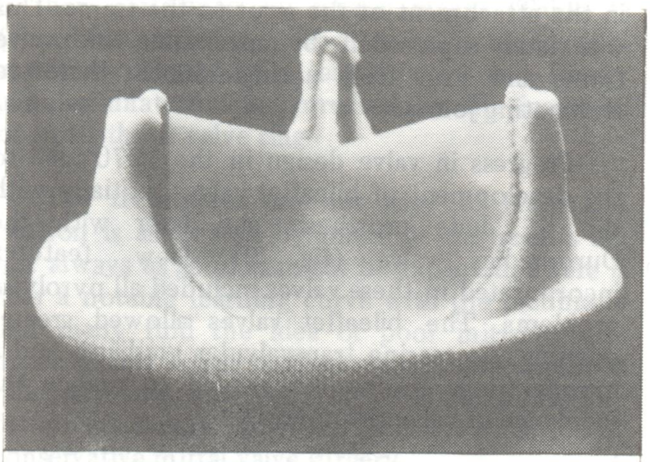

Fig. 10. Pericardial xenograft

fascia lata) but the most success has been with porcine xenografts (fig. 11). The valves were greeted with initial enthusiasm and many were implanted worldwide. Popularity waned somewhat when early valve failure occurred, notably with fascia lata valves and much research was done to improve durability. Whilst durability has improved, early valve failure still occurs, even with the more modern bioprostheses, the most recent problems being with a pericardial prosthesis, leading to its recent withdrawal from the market. Several notable modifications have been made over the last 18 years though, which have improved the overall durability. The first occurred in 1969 with the introduction of low pressure glutaraldehyde fixation techniques. Secondly, earlier harvesting of porcine valves with better preservation prior to fixation improved valvular durability. The next notable step was the introduction of a flexible stent in the Carpentier-Edwards xenograft and finally the supravalvular positioning of the prosthesis increased

Fig. 11. Carpentier-Edwards aortic bioprosthesis

valvular area and decreased transvalvular gradients. Bioprosthetic valves are still preferred by many surgeons, particularly in areas where monitoring of anticoagulation is not ideal. Tissue failure remains a major problem requiring repeated replacement of the valve. The problem is worst in children and adults under 35 years (in whom valves not requiring anticoagulation would be extremely beneficial) where accelerated calcification causes much earlier tissue failure than in older patients.

Homograft Valves

The results of homograft valve replacement are variable. Some centres (notably Ross in London) have reported good results, but the results of others have been much less encouraging. The major drawback is their limited availability world-wide. They are also expensive requiring a substantial back up service of technicians and staff to harvest and prepare the grafts. Clearly many homografts need to be inserted regularly to recoup such an outlay.

MULTICENTRE VALVE TRIAL

The U.K. Multicentre Valve Trial was begun in 1974 to provide a prospective longitudinal study of valve complications. The aim of the trial was to study the results of valve replacement with particular reference to thromboembolism, haemorrhage, valve failure and late mortality. At present 22 centres (comprising 44 surgeons) participate in the study (fig. 12), and all patients undergoing valve replacement in those centres are entered into a central computer, information on any valve related event or the death of the patient is forwarded to the collating centre and in this way data on many different valve types can be analysed and comparisons made. The results are published regularly and hence all participating centres can critically appraise their favoured valve substitute and modify their choice of prosthesis if indicated.

PRESENT TECHNIQUES

Despite all the advances in valve technology, the ideal valve sitll does not exist. The debate continues as to the merits of mechanical versus biological valve replacement and in both camps

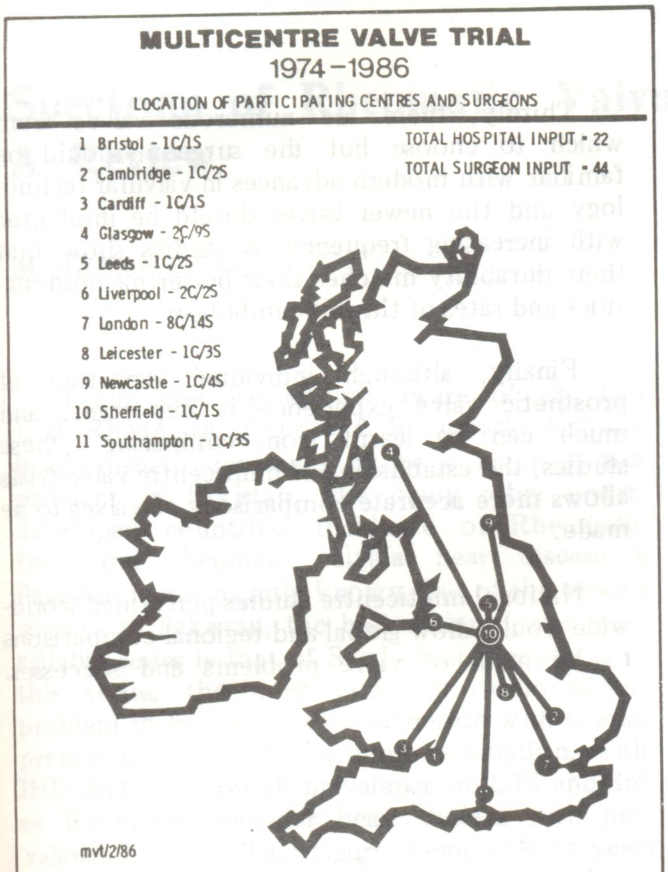

Fig. 12. U.K. Multicentre Valve Trial - Location of participating centres and surgeons

there are many valves to choose from. Nowadays almost all new valves can be relied upon to provide good early reliability and hopefully the days of catastrophic early valve failure (as with fascia lata and Kay-Shiley Prostheses) are past. This leaves conservative surgeons in a predicament as the advantages and disadvantages of modern valves can only be assessed after about 10 years and many still choose the older tried and trusted valves despite the potential advantages of newer valves afforded by modern technology.

Certain facts seem to be becoming more widely accepted though. The use of bioprosthetic valves in children and young adults is invariably doomed to early failure and should be abandoned. At the other end of the age range, anticoagulation in the elderly can be hazardous and a bioprosthetic valve is probably indicated. A note of caution must be added however; as patients live longer, so some of them are returning over the age of 70 with bioprosthetic valve failure. Clearly therefore no dogmatic rules exist.

TABLE I

CHOICE OF VALVE SUBSTITUTE

	Advantages	Disadvantages
Mechanical Valve	Excellent haemodynamics Proven durability	Anticoagulant required
Biological Valve	Satisfactory haemodynamics Anticoagulant not required	Significant failure rate after 5 years Calcification in children Higher rate of S. B. E.

The intermediate age range, which represents a large population, must be judged according to the preference of the individual surgeon. With improved valvular haemodynamics and durability, modern mechanical valves have much to offer these patients and it is against this standard that one should compare other valves, particularly bearing in mind the problem of tissue failure with bioprostheses.

Modern valve repair techniques have improved tremendously and the adage that "the patient's own valve is the best" is still true. Conservative mitral valve surgery is very challenging and may well prove to be durable. Whilst conservative aortic valve surgery is generally associated with poor results, some centres (notably Carpentier in Paris) are still attempting to improve techniques to provide a lasting repair.

TABLE II

PRINCIPLES OF MITRAL VALVE REPAIR (Carpentier)

Functional Anomaly	Treatment
Leaflet Prolapse	Extensive rectangular resection Plastic repair of chordae
Restricted Leaflet Motion	Commissurotomy Resection secondary chordae. Fenestration of chordae.

CONCLUSION

Although there are many arguments for and against the type of valve substitute, when to repair valves, etc., certain conclusions can be drawn regarding the treatment of acquired valvular heart disease. Firstly with the safety of modern surgery operations should be performed early. There is no place for waiting until deterioration occurs as complications ensue and operative mortality rises.

The next is to be conservative when possible. Although the number of valve replacements still far exceeds the number of valve repairs, it is the duty of the surgeon to consider valve repair in each case. At present the techniques are limited to the mitral and tricuspid valves, but it is hoped that successful conservative aortic surgery will be possible in the future.

Thirdly, there are numerous valves from which to choose but the surgeon should be familiar with modern advances in valvular technology and the newer valves should be implanted with increasing frequency as studies show that their durability matches their better haemodynamics and rates of thromboembolism.

Finally, although individual reporting of prosthetic valve experience is important, and much can be learnt from comparing these studies, the establishing of multicentre valve trials allows more accurate comparisons of valves to be made.

National multicentre studies performed worldwide would allow global and regional comparisons to be made of valve problems and successes.