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Choosing the most appropriate valve operation and prosthesis

ABSTRACT

Repairing a diseased heart valve is usually better than replacing it. However, repair is not always feasible. No valve is ideal, and patients should be informed of the risks associated with each. The decision requires close discussion among the patient, the physician, and the surgeon.

KEY POINTS

In a young patient, preserving the native valve will spare the patient years of exposure to potential complications from a prosthetic valve.

Mechanical valves are very durable but carry a higher risk of thromboembolic complications and therefore necessitate lifelong anticoagulation.

Bioprostheses are less long-lasting and may have to be replaced during the patient's lifetime. However, the risk of thrombosis is low, and anticoagulation is not usually needed.

Although bioprosthetic valves degenerate sooner in younger patients, they appear to be the preferred valves in patients who are likely to become pregnant and for whom repair is not feasible.

Survival and complication rates appear to be similar with the two types of valves, and thus the choice between them should be made on the basis of the valve's hemodynamic properties and the patient's condition and preferences.

THE CLINICIAN who manages patients with valvular heart disease faces key decisions when referring patients for surgery. First, should the valve be repaired or replaced? And for replacement, what type of prosthesis should be chosen?

Valve repair is generally preferable to valve replacement. However, repair is not always feasible. When the valve must be replaced, a choice must be made between mechanical and biological prosthetic valves. The decision is influenced by structural factors such as ventricular size and geometry, by patient age and preferences, and by concomitant medical conditions such as atrial fibrillation and bleeding diathesis.

This review focuses on how the medical physician can help in choosing the most appropriate valvular procedure for a patient.

VALVE REPAIR

Valve repair is generally preferable to valve replacement, but it can be done only for selected patients and indications. With the mitral valve, the success of repair varies with the mechanism of mitral insufficiency.[1–2] **TABLE 1** shows early Cleveland Clinic results; success rates have improved since these data were collected.

Valve repair in myxomatous disease

Myxomatous mitral valve disease is the most common indication for mitral valve surgery in the United States. In this condition, chordal and leaflet abnormalities lead to valvular insufficiency.

Often myxomatous valves are amenable to repair. Options include resection of a portion of the leaflet, chordal transfer, and placement

of an annuloplasty ring.

There have been no randomized trials comparing mitral valve repair and valve replacement. However, observational data suggest that patients undergoing repair have better results, both in the short term and the long term.[3–10]

The results in part reflect the healthier clinical status of patients in whom valve repair is feasible, but they also reflect real physiologic advantages of repair. Ventricular geometry is better preserved by repair than by replacement and by leaving subvalvular structures intact. Preserving ventricular geometry has a beneficial effect on end-systolic wall stress,[5–8] which may explain the better postoperative ejection fraction in hearts with repaired valves.[5] Exercise ejection indices are likewise higher in patients with repaired valves.[8] The subsequent risks of thromboembolism and endocarditis appear to be lower.[3,6–7]

Although the frequency of reoperation after repair is similar to the frequency after replacement, perioperative morbidity and mortality are lower after repair.[3–4]

If preoperative evaluation identifies myxomatous disease as the cause of mitral regurgitation, and valve repair seems likely, the patient should be referred to a surgical center with extensive expertise in valve repair.

TABLE 1

Success rates in mitral valve repair, by disease mechanism

MECHANISM CAUSING REGURGITATION	REPAIR SUCCESS RATE (%)
Myxomatous degeneration	
Overall	75–80
With posterior chordal rupture	90.9
With elongated chordae	81.8
With dilated annulus	67.7
With anterior chordal rupture	63.3
With anterior and posterior chordal rupture	40.7
Ischemic mitral regurgitation	65–70
Congenital etiologies	50–55
Rheumatic mitral regurgitation	45–50
Endocarditis	45–50

DATA FROM STEWART WJ. ACC HEART HOUSE LEARNING CENTER HIGHLIGHTS 1995; 10:2–7.

Mitral valve repair in rheumatic disease

Repair (commissurotomy) in rheumatic mitral valve disease is technically more demanding than in myxomatous disease. Repair is often successful in younger patients with pliable valves, but it is frequently impossible in middle-aged or older patients with calcified valvular and subvalvular structures. Commissurotomy is indicated especially in young women of childbearing age who are considering becoming pregnant and for whom anticoagulation should be avoided. Valve repair in rheumatic disease is associated with a higher reoperation rate[4,11] than in myxomatous disease.

Mitral valve repair in ischemic heart disease

Mitral insufficiency that develops as a result of ischemic heart disease is also amenable to valve repair.

Left ventricular dilatation can occur as a result of prior infarcts, leading to papillary muscle displacement and incomplete leaflet coaptation.[4] In these patients, an annuloplasty ring may be sufficient to relieve the insufficiency.

Infarction or chronic ischemia can lead to elongation of the papillary muscle (usually the posteromedial muscle), preventing adequate coaptation of the leaflets. In this situation, the papillary muscle can be folded onto itself to repair the valve.[4]

Long-term outcome in patients with ischemic mitral regurgitation appears to depend on the severity of the underlying coronary disease and left ventricular function.[12]

Myxomatous valves can often be repaired

Secondary mitral insufficiency

Left ventricular dysfunction with severe secondary mitral insufficiency is a difficult clinical problem. Patients with this condition often present with severe and refractory heart failure. In patients with overwhelming mitral regurgitation, surgical correction of the mitral insufficiency (usually with an undersized annuloplasty ring alone) improves symptoms and ventricular geometry and volume.[13–14]

Valve repair in endocarditis

Selected patients with endocarditis can also undergo valvular repair. Perforations can be closed with pericardial patches, leaflets can be

partially resected with pericardial patch closure, and vegetations can be removed.[4,15] Endocarditis recurs less frequently in patients who have undergone these procedures than in those who have received prosthetic valves.

Repairing the tricuspid and aortic valves

Tricuspid insufficiency as a result of annular dilatation is not uncommon in patients with mitral valve disease. This is usually treated with placement of an annuloplasty ring at the time of mitral valvular surgery.

Repair of the aortic valve is also feasible in certain patients. Those with aortic root enlargement and secondary aortic insufficiency caused by poor coaptation of the leaflets are good candidates.[16] Patients with bicuspid aortic valves that have prolapse of the large conjoint leaflet and resultant aortic insufficiency are also candidates for repair, provided the leaflets are thin and free from significant calcification.[16–17]

Bicuspid aortic valves that are repaired tend to become stenotic, and so patients may need repeat surgery after several years. Nevertheless, in the Cleveland Clinic experience, freedom from reoperation was 84% at 7 years.[18] The only predictor of reoperation was residual post-repair aortic insufficiency. In addition, patients who present with severe aortic insufficiency are often young, and preserving the native valve will spare them years of exposure to the potential complications resulting from a prosthetic valve.

Mechanical valves are more durable than bioprostheses

VALVE REPLACEMENT

If valve repair is not feasible and replacement is needed, both mechanical prostheses and bioprostheses are available.

Mechanical prostheses include ball-and-cage valves (eg, the Starr-Edwards valve), single tilting disk valves (eg, the Björk-Shiley, Lillehei-Kaster, and Medtronic Hall models), and bileaflet tilting disk valves (eg, the St. Jude Medical and CarboMedics products). The bileaflet valves are the most commonly used mechanical prostheses today.

A variety of bioprosthetic valves are used. Porcine heterografts are porcine valves fixed with glutaraldehyde. Bovine pericardial valves are constructed from bovine pericardium, which is made into three cusps mounted in a stent. Stentless homografts are taken from cadaveric hearts.

Pulmonary autografts can be considered another class of biological valves. They are used in the Ross procedure, in which the patient's pulmonary valve is removed and used as an autograft in the aortic position. A cadaveric homograft is then implanted in the pulmonary position.

Advantages and disadvantages of mechanical valves

Mechanical valves have excellent durability and may last the patient's lifetime.[19–20] The reported rates of structural failure are very low, except for the Björk-Shiley convexoconcave valve, which is no longer in use.

Unfortunately, the advantage offered by durability is offset by the need for anticoagulation. All mechanical valves require anticoagulation because they carry a significant risk of valve thrombosis and thromboembolism.[19–20] Mechanical valves are most likely to develop thrombus when they are in the mitral and tricuspid positions, because flow velocity is lower than in the aortic valve. The cumulative risk for mechanical valves is quite high. Even with anticoagulation, the risk of thromboembolism is between 0.5% and 3% per year for valves in the aortic position, and between 0.5% and 5% per year in the mitral position.[19]

Although anticoagulation is necessary to prevent thromboembolic complications, it carries an inherent bleeding risk. This risk has been reported to be from 1% to 8.5% per patient year, and it is highest in patients over 70 years old.[19–21] In a pooled analysis, the risk of a major bleeding complication was reported to be 1.4 per 100 patient years.[20,22] The risk of intracranial and spinal hemorrhage has been estimated at 0.6% per 100 patient years.[21,23] The risk of bleeding is higher in patients who have an international normalized ratio (INR) above the therapeutic range.

Mechanical valves are especially appropriate for younger patients for whom anticoagulation is not contraindicated and for whom durability is important.

Patients whose valve disease is complicated by chronic or recurrent atrial fibrillation already require anticoagulation, and a

mechanical prosthesis may therefore be a good choice for these patients.

Pros and cons of bioprosthetic valves

Bioprosthetic valves have higher rates of structural failure, but they are associated with lower rates of thromboembolism.

Bioprosthetic valves do not themselves necessitate anticoagulation. However, concomitant medical conditions may warrant anticoagulation, but at a level lower than that required for patients with mechanical valves. The risk of thromboembolism with bioprosthetic valves has been reported at 0.2% to 3.8% per patient year for valves in the aortic position, and 0.3% to 5.1% per patient year for valves in the mitral position.[19] Thus, the risk of bioprosthetic valve thrombosis appears comparable to that of properly anticoagulated mechanical valves. The risk appears to be highest in the first few months after valve replacement.[20,24,25] This has led some to advocate anticoagulation with warfarin for the first 3 months after valve placement, but this is not our routine practice at The Cleveland Clinic.

Structural failure is the major limitation of bioprosthetic valves. The risk of failure increases linearly with time, beginning at 4 years after valve implantation.[20] Valves in the mitral position appear to degenerate faster than those in the aortic position.[20,26] Conditions of rapid calcium turnover such as chronic renal failure or Paget disease may possibly be associated with more rapid bioprosthetic degeneration.[20]

The risk of failure is inversely related to patient age at time of implantation.[21,26–29] In a series of more than 1,100 patients with Carpentier-Edwards porcine bioprostheses, only 25% of aortic valves implanted in patients over age 40 were free of degeneration at 15 years. The figure was only 7% for mitral valves (**FIGURE 1**).[29] The older the patient at the time of implantation, the lower the likelihood of structural failure at 15 years. This study and other series suggest that the yearly risk of structural failure of mitral heterografts is lowest for patients who receive the valve when older than 70 years, and the risk for aortic valves is lowest for those who receive them when older than 65.[20,27]

The risk of bioprosthetic valve failure decreases with patient age at surgery

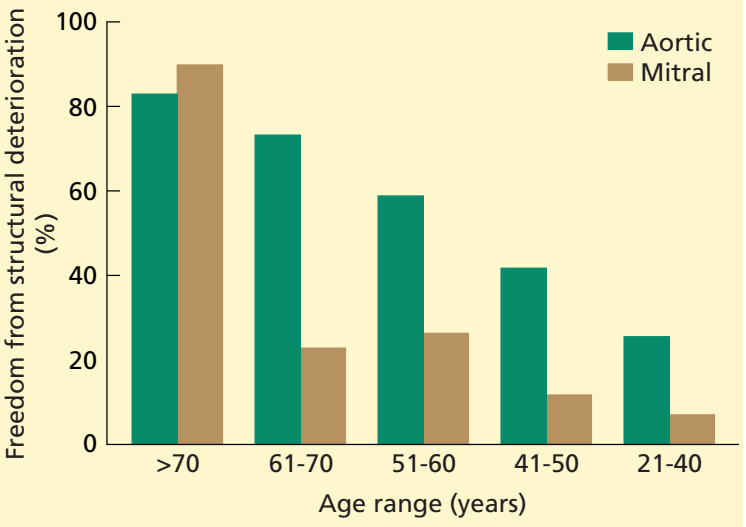

FIGURE 1. Freedom from structural deterioration at 15 years in 1,181 patients undergoing 1,198 implantations of the Carpentier-Edwards bioprosthesis by patient age and valve position.

DATA FROM JAMIESON WR, BURR LH, MUNRO AI, MIYAGISHIMA RT. CARPENTIER-EDWARDS STANDARD PORCINE BIOPROSTHESIS: A 21-YEAR EXPERIENCE. ANN THORAC SURG 1998; 66:S40–S43.

The precise mechanism whereby biological valves degenerate at a faster rate in younger patients is unknown. Potential mechanisms implicated include greater calcium turnover, greater flow and thus stress on the valve, and a stronger immune response in younger patients.

The likelihood of structural failure in pericardial valves is also dependent on age at time of implantation. For valves in the aortic position, actuarial analysis showed that 96.3% of patients who were older than age 65 at the time of implantation remained free from need for reoperation at 14 years vs 76.1% for those aged 65 or younger.[30] For valves in the mitral position, at 11 years, 100% of patients over the age of 70 were free from explantation required by valve failure, vs 89.4% for those aged 61 to 70, and 78.1% for those under age 60.[31]

A comparative study between porcine bioprostheses and bovine pericardial valves in the mitral position shows a clear advantage in valve durability at 10 years for the pericardial

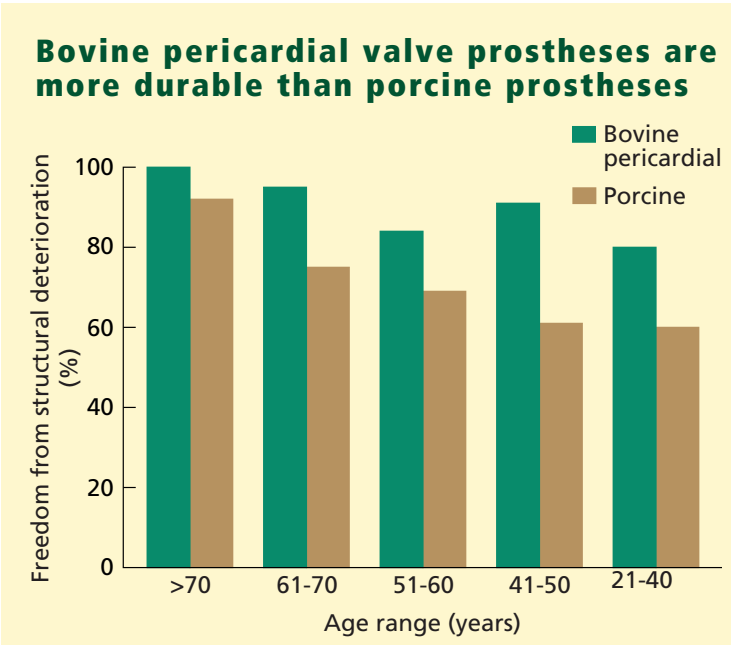

FIGURE 2. Freedom from structural deterioration at 10 years, Carpentier-Edwards porcine bioprosthesis (n = 1,266) vs Carpentier-Edwards Perimount bovine pericardial bioprosthesis (n = 429) by patient age.

DATA FROM JAMIESON WR, MARCHAND MA, PELLETIER CL, ET AL. STRUCTURAL VALVE DETERIORATION IN MITRAL REPLACEMENT SURGERY: COMPARISON OF CARPENTIER-EDWARDS SUPRA-ANNULAR PORCINE AND PERIMOUNT PERICARDIAL BIOPROSTHESES. J THORAC CARDIOVASC SURG 1999; 118:297–304.

valve (FIGURE 2).[32] The Carpentier-Edwards Perimount pericardial valve (manufactured by Baxter Healthcare) has recently been approved for implantation in the United States, after extensive experience in Europe. Given its durability, its use should become widespread.

Thus, bioprosthetic valves are often indicated in older patients and in those who have contraindications to anticoagulation.

Cadaveric homografts

Cadaveric homografts are generally used in the aortic position. Aortic homografts are technically more demanding to insert than are mechanical or bioprosthetic valves because the coronary arteries must be reimplanted. The procedure has become easier with the introduction of the "mini-root" technique.[33] In this technique, the tissue above and below the valve is harvested. This sleeve of tissue encompassing the valve makes it easier to get a proper fit in the recipient heart.

One drawback to homografts is that they tend to calcify over time. In some series, fewer than 10% of homografts in the aortic position have required reoperation at 10 years,[20,34–35] but other studies have suggested that they are no more durable than heterografts.[36] Another drawback is that reoperation is more difficult in patients with homografts.

Homografts are the preferred choice in certain conditions. In patients with endocarditis, homografts appear to be less likely to become reinfected.[33] Homografts are also indicated in the setting of abscess or fistula formation, and they have a low risk of thromboembolism.[19,20,33] Also, homografts are the only valves that have a valve opening that is similar to that of the native valve.[20]

Mitral homografts have been developed, but implantation is technically very demanding because of the mitral valve's complex structure, which involves chordae and papillary muscles as well as the valve leaflets. Long-term follow-up on patients with mitral homografts is still pending.

The Ross procedure

The Ross procedure is the autograft replacement of a diseased aortic valve with the patient's own pulmonary valve, followed by the implantation of a cadaveric pulmonary homograft.

The major advantages of this procedure are durability and the potential of the autograft valve to grow with the patient. Therefore, the procedure is indicated in adolescents, children, and infants, and excellent results have been obtained in these populations.[37]

The major disadvantage with this procedure is that it turns single-valve disease into dual-valve disease. It has had variable results in adults,[38,39] with a significant likelihood of pulmonary valve problems and of aortic regurgitation when the aortic root is very dilated.

Stentless valves

Porcine valves without stents have also been developed. They may offer better hemodynamic characteristics. Five-year follow-up is only now becoming available, and recommendations about more widespread use of these valves must await longer-term follow-up.[40]

Comparing mechanical and bioprosthetic valves

Mechanical valves have the advantage of excellent durability, which is offset by the need for lifelong anticoagulation and its associated risk of hemorrhage. Bioprosthetic valves generally do not need prolonged anticoagulation but are limited by the likelihood of structural failure. Important questions remain about whether either type offers a survival advantage or a reduced risk of other valve-related complications such as endocarditis.

Data from randomized trials are limited. The Edinburgh Heart Valve Trial and the Veterans Affairs Cooperative Study have shown that in-hospital mortality and complication rates are similar for mechanical and bioprosthetic valves.[41,42] Also comparable are the rates of subsequent complications, such as endocarditis and embolization (when anticoagulation for mechanical valves is appropriate).[20] No significant difference in survival was seen during 11 to 12 years of follow-up.[41,42]

SPECIAL CONSIDERATIONS

Mitral and tricuspid mechanical valves carry the highest risk of thrombosis

Hemodynamic characteristics of various valves

All prosthetic valves except for homografts are inherently stenotic because they have opening areas smaller than those of the native valves.[20] The size difference results from the profile of the suture ring, the valve struts in bioprosthetic valves, and the occluders in mechanical valves.

Normal native mitral valves open to an area of at least 4 cm^2, and similar aortic valves open to at least 3 cm^2.

For Starr-Edwards valves, the available sizes provide effective orifice areas of 1.4 to 2.9 cm^2 for the mitral position and 1.2 to 1.6 cm^2 for the aortic position.[20,43,44] The bileaflet tilting disk valves have better hemodynamic characteristics, producing effective orifice areas of 2.1 to 3.9 cm^2 for mitral valves and 1.3 to 2.5 cm^2 for aortic prostheses.[20] The effective areas for bioprostheses vary from 1.4 to 2.5 cm^2 for mitral valves and 0.9 to 1.8 cm^2 for aortic valves.[20] The new stentless heterografts allow for larger opening areas.

The valve opening or effective orifice area becomes an important issue when a patient has a small annulus, which limits the size of valve that can be implanted. It is also important in younger patients with an active lifestyle. In a patient with a small aortic annulus, for whom the largest possible prosthesis would be 19 mm, a bileaflet mechanical valve would provide a better hemodynamic profile than would a heterograft of the same size. A homograft would provide an even larger orifice area. A stentless heterograft might be an option as well.

The struts of bioprosthetic valves at the mitral position may protrude into the left ventricle. In patients with small left ventricular chambers, this can result in outflow tract obstruction. In such patients, a mechanical bileaflet tilting disk valve may be the best option.

Pregnancy

If possible, valve surgery should be deferred until after pregnancy. Regurgitant valve lesions are generally well tolerated during pregnancy.[45] If surgery is necessary, repair is preferred to replacement, because prosthetic valves increase both maternal and fetal risk. Percutaneous balloon valvuloplasty is an option for mitral stenosis that can markedly improve hemodynamics.

Although bioprosthetic valves degenerate sooner in younger patients,[46] they appear to be the preferred valves in patients who are likely to become pregnant and for whom repair is not feasible. In part, this is because managing anticoagulation during pregnancy can be very difficult and carries significant fetal and maternal risk.[47]

Right-sided valvular lesions

As mentioned earlier, tricuspid regurgitation may accompany mitral valve disease and can be repaired with an annuloplasty ring at the time of mitral valve surgery or by other procedures. However, in certain circumstances of congenital or acquired disease, tricuspid valve replacement may be necessary.

Replacing the tricuspid presents special problems. The tricuspid annulus is larger than either the mitral or aortic annulus and hence requires a larger prosthesis. Because of the larger prosthesis, and because pressures are typically lower in the right side than in the left, flow velocity is lower and the risk of thrombosis is higher.

TABLE 2

Comparison of repair and replacement for mitral and aortic valves

VALVE POSITION	REPAIR	REPLACEMENT
MITRAL		
Indications	Myxomatous degeneration Ischemic disease Perforations Rheumatic disease (if valves are pliable)	Calcified valvular or subvalvular structures Tissue loss
Operative mortality	Low	Higher than for repair
Durability	Excellent for myxomatous valves Lower in rheumatic disease	High, especially for mechanical valves
AORTIC		
Indications	Dilated aortic root with relatively normal leaflets Bicuspid valve with leaflet prolapse and minimal calcification Tricuspid valve with single leaflet prolapse or perforation	Calcified, rheumatic, or stenotic valves
Operative mortality	Low for prolapse	Higher than for repair
Durability	May be lower than with replacements	Excellent, especially for mechanical valves and for patients over age 65 with bioprostheses

Thus, bioprosthetic valves are generally preferable in the tricuspid position, even though degenerative calcification appears to progress more rapidly in these valves than in valves in the mitral position.[48–52] Durability appears to be comparable with that of mechanical valves.[49] Stentless tricuspid valves have been used, but rarely.[51]

Disorders of the pulmonary valve are most often treated in childhood. The valve may be repaired alone or, more often, as part of treatment for complex congenital heart disease. Percutaneous valvuloplasty is the preferred treatment for valvular pulmonic stenosis. If a prosthetic valve is needed, bioprostheses or homografts are generally used.[20]

SELECTING A PROSTHETIC VALVE

No prosthetic valve is ideal. Therefore, the selection of a valve must take into account the relative advantages and disadvantages of a particular prosthesis and how they apply to the patient's risk profile.

No patient with an absolute contraindication to anticoagulation can receive a mechanical valve. On the other hand, mechanical valves may be appropriate for patients who require anticoagulation for other reasons (such as chronic atrial fibrillation or history of thromboembolism). Mechanical valves may also be preferred for the hemodynamic advantages they offer to patients with small annuli or small left ventricular chambers. Aortic homografts may be suitable alternatives in these patients, although the long-term durability of these prostheses is still unknown.

Because younger patients have a substantial risk of bioprosthetic valve failure during their expected life span, mechanical valves are generally preferred. Mechanical valves have generally been recommended for patients with renal failure, which increases the likelihood of bioprosthetic degeneration. However, any decision must take into account the anticipated survival of these patients. Our

Bioprosthetic valves are often indicated in older patients and in those who cannot take warfarin

TABLE 3

Characteristics of prosthetic valve types

CHARACTERISTIC	MECHANICAL	BIOPROSTHETIC	HOMOGRAFT	AUTOGRAFT (ROSS PROCEDURE)
Feasibility	All valve positions	All valve positions	Aortic and pulmonic Perhaps mitral	Aortic
Durability	Excellent (> 20 years)	< 20 years Durability rises with age at implantation	25%–30% break down at 15 years	25% reoperation rate at 20 years
Indications	Younger age Small annulus Low hemodynamic profile needed Expected life > 10 years	Older age, especially > 70 years for mitral, > 65 years for aortic Warfarin contraindicated	Active endocarditis, especially accompanied by abscess or fistula Associated aortic root disease Need for high cardiac output (athlete)	Adolescents, children, infants, because autografts can grow Need for high cardiac output (athlete)
Contraindications	Warfarin contraindicated (especially if elderly) Noncompliance with medication	Younger age without contraindications to warfarin	Center inexperienced with or cannot provide homograft surgery	Significant disparity in aortic and pulmonary annulus size Inexperienced center Possibly, dilated aortic root
Anticoagulation	Required lifelong	Not needed, although some advocate for short term	Not needed	Not needed

experience with patients on dialysis at The Cleveland Clinic Foundation suggests that bioprosthetic valves may be considered in this population.[53]

Bioprosthetic valve integrity at 10 to 15 years is excellent for patients over the age of 65 at implantation with aortic prostheses, and for those over age 70 with mitral prostheses. In older patients, who are also at increased risk for bleeding complications, bioprosthetic valves should be considered first. Bioprosthetic valves should also be considered for patients of any age with a life expectancy of less than 10 years.

The low rate of recurrent endocarditis associated with homografts makes them an attractive option for patients with active endocarditis. However, homografts are technically more difficult to implant and are not widely available.

Patients who are likely to become pregnant after valve replacement should probably receive bioprosthetic valves, with the understanding that they will need another operation.

Patient preference must also play an important role in the selection of a prosthetic valve. Some patients may be willing to accept the risk of bioprosthetic failure and repeat surgery if it allows them to avoid taking anticoagulants. Other patients may have the opposite preference. The effect of anticoagulant therapy on the patient's lifestyle must be considered. Patient adherence to therapy needs to be considered as well; only meticulous control of the anticoagulation therapy will lower the complication rate.

Homografts and stentless heterografts are being used increasingly frequently because of their excellent hemodynamic profile. As longer-term data become available on these valves, decisions about valve selection may become easier.

TABLE 2 and **TABLE 3** summarize the indications for valve repair and valve replacement, and factors that would lead to selection of one prosthetic valve type over another.

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