When should a mechanical tricuspid valve replacement be considered?

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Background: Isolated mechanical tricuspid valve replacement (mTVR) is uncommon, early mortality is reported to be high, and little is known regarding the long-term outcome. We sought to evaluate the long-term outcome of mTVR.

Methods: From 1980 to 2007, isolated mTVR was performed in 64 patients (33 men) at our institution; the median age was 45.5 years (6-71 years). There were 2192 tricuspid valve (TV) repairs and 137 isolated bioprosthetic TV replacements during the same time interval. Valve dysfunction was caused by congenital TV abnormality in 45 patients (70%), carcinoid heart disease in 13 (20%), traumatic TV regurgitation in 3 (5%), and other reason in 3 (5%). Twenty-three patients (36%) had at least 1 previous cardiac procedure (TV repair in 8 and bioprosthetic TV replacement in 7).

Results: Mechanical prostheses used included Starr-Edwards (before 1993) in 36 patients (56%) and bileaflet prostheses in 28 (44%). Concomitant procedures included atrial septal defect closure in 28 (44%), arrhythmia surgery in 11 (17%), and pulmonary valvectomy for carcinoid disease in 10 patients (16%). Early mortality occurred in 5 patients (7.8%). Early morbidity included a permanent pacemaker in 9 (14%) and reexploration for bleeding in 2 patients (3%). Mean follow-up was 6 years (maximum 22.4 years). Five- and 10-year survival was 65% and 58%, respectively. There was no valve-related mortality. Late morbidity included valve thrombosis in 5 patients (8%); 3 were managed nonoperatively and 2 underwent TV rereplacement.

Conclusions: Isolated mTVR still leads to increased early mortality. A mechanical valve can be considered in select situations when anticoagulation is necessary and in the presence of good right ventricular function. (J Thorac Cardiovasc Surg 2014;148:603-8)

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Tricuspid valve replacement (TVR) is rarely performed compared with tricuspid valve (TV) repair. TV repair is usually the procedure of choice, and, when not possible, the decision has to be made on which type of prosthetic valve to use. When TVR is performed, it is usually as a combined procedure with other valve replacements.[1] TVR is associated with high early mortality[2] and little is known regarding long-term outcomes.

PATIENTS AND METHODS

The current study was approved by the Mayo Foundation Institutional Review Board. We retrospectively reviewed 64 patients who underwent isolated mechanical TVR (mTVR) at the Mayo Clinic, Rochester, Minnesota, between 1980 and 2007. During this period, there were 2192 TV repairs and 137 isolated bioprosthetic TVRs. TV repair was preferred if possible.

Among the 64 patients who underwent mTVR, there were 33 men (52%), ranging in age from 6 to 71 years (mean age, 43.2 ± 15 years). Congestive heart failure was the presenting symptom in 27 patients (42.2%). Moderate-severe right ventricular dysfunction was demonstrated on preoperative echocardiography in 20 patients (31%).

TVR was performed for isolated severe regurgitation in 53 patients (83%); severe TV stenosis was the main indication for TVR in 3 patients (4.7%). Severe TV regurgitation caused by Ebstein malformation of the TV was found in 45 patients (70%), carcinoid heart disease in 13 (20%), and a double outlet right ventricle in 1 patient (1.6%). Two patients (3%) had distortion of the TV by the prosthetic patch that was used for a previous ventricular septal defect closure, and 1 patient (1.6%) had moderate-severe TV regurgitation as a result of radiation-induced heart disease. One patient had lupus anticoagulant syndrome causing TV disease and requiring life-long anticoagulation.

Eight patients (12%) had previous TV repair; 5 patients (8%) had 1 previous TVR and 2 patients (3%) had 2 previous TVRs. Mechanical prostheses used were Starr-Edwards (Edwards Lifesciences, Irvine, Calif) in 36 patients (56%; all before 1993), St Jude Medical (St Jude Medical, Inc, St Paul, Minn) bileaflet in 15 (24%), and CarboMedics (Sulzer Carbomedics, Inc, Austin, Tex (division of Sulzer Medica)) bileaflet in 13 (20%) patients.

Concomitant procedures with TVR (Table 1) were closure of an atrial septal defect in 28 patients (44%), arrhythmia surgery in 11 (17%), pulmonary valvectomy for carcinoid heart valve disease in 10 (16%), pulmonary valvotomy in 1 (1.6%), repair of a ruptured sinus of Valsalva aneurysm in 1 (1.6%), pericardiectomy in 1 (1.6%), and coronary artery bypass grafting in 1 (1.6%). Standard median sternotomy was the approach in 63 patients (98%); 1 TVR (1.6%) was performed through a right thoracotomy. TVR was performed without aortic crossclamp in 7 patients (11%). Warfarin was used for postoperative anticoagulation in all patients.

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Abbreviations and Acronyms

INR = international normalized ratio
mTVR = mechanical tricuspid valve replacement
TV = tricuspid valve
TVR = tricuspid valve replacement

Statistical Analysis

Descriptive statistics for categorical variables are reported as the frequency and percentage; continuous variables are reported as the mean (standard deviation) or median (range) as appropriate. The differences before and after TVR were analyzed. Survival analysis and analysis of freedom from reoperation and thrombosis were performed by the Kaplan-Meier method. SAS 9.13 (SAS Institute, Inc, Cary, NC) was the software used for statistical analysis.

RESULTS

There were 5 early deaths (7.8%). There have been no early deaths since 1994. Survival at 5 and 10 years was 65% and 58%, respectively (Figure 1, *A*). Overall survival was significantly lower compared with the white population in the state of Minnesota (Figure 1, *B*). Overall survival for patients with Ebstein malformation was 81.8%, 76.4%, and 71.9% at 1, 5, and 10 years, respectively (Figure 1, *C*); survival for patients with carcinoid heart disease was 41.7% and 20.8% at 1 and 5 years, respectively (Figure 1, *D*). Survival was higher at all times in the CarboMedics and St Jude Medical groups compared with the Starr-Edwards group (88.9% and 71.4% vs 69%, respectively) (Figure 2). There were 22 late deaths; 18 occurred before 1999; the cause was unknown in 10 patients, 6 patients died of progression of their carcinoid disease with hepatic metastases; 5 patients died of heart failure, and 1 patient died of complications from embolic stroke caused by bacterial endocarditis on his native aortic and mitral valves. No valve-related mortality was reported.

Early reoperation included reexploration for bleeding in 2 patients (3%). Two patients had early anticoagulation-related bleeding; 1 patient required reexploration and the other required percutaneous echo-guided pericardiocentesis. Permanent epicardial pacemaker implantation was required in 9 patients (14%). The indications for pacemaker implantation were complete heart block in 4 patients, brady-tachy syndrome in 2, sinus node dysfunction in 1; the other 2 patients underwent a concomitant cryomaze procedure at the time of TVR and experienced high-grade atrioventricular block postoperatively.

Mean follow-up was 6 years (maximum, 22.4 years). Freedom from late reoperation at 1, 5, and 10 years was 95.1%, 92.1%, and 92.1%, respectively (Figure 3). Freedom from reoperation was higher in the CarboMedics and St Jude Medical groups at 5 and 10 years compared with the Starr-Edwards group (100%, and 90.9% vs 90.4%, respectively). Late reoperation occurred in 2 patients (3%) who required TV rereplacements for thrombosed prostheses.

There were no episodes of structural valve deterioration or prosthetic valve endocarditis reported during the follow-up period. Freedom from valve-related thrombosis at 1, 5, and 10 years was 97.3%, 87%, and 87%, respectively (Figure 4, *A*). Freedom from valve-related thrombosis was higher in the St Jude Medical and CarboMedics groups than the Starr-Edwards group at 1 year (100% vs 95.2%, respectively), but at 5 years, it was higher in the St Jude Medical and Starr-Edwards groups compared with the CarboMedics group (100%, 95.2% vs 37.5%, respectively) (Figure 4, *B*). Valve thrombosis occurred in 5 patients (8%); 4 of them had a therapeutic international normalized ratio (INR), at least moderate right ventricular dysfunction, and a dilated right ventricle. Valve thrombosis occurred despite adequate anticoagulation and a therapeutic INR at the time of identification. Two patients responded to thrombolytic therapy only and 2 required TV rereplacement. For the last patient, anticoagulation had to be held because of recent spine surgery and valve thrombosis responded to thrombolytic therapy after a failed attempt at percutaneous catheter balloon thrombectomy (Figure 5, *A* and *B*); the patient did not require reoperation. No anticoagulation-related bleeding occurred during late follow-up.

DISCUSSION

TV repair is the technique preferred by many surgeons for treating moderate to severe TV regurgitation. TVR, despite becoming less attractive option in recent years,[3,4] still has a role in those patients who are not suitable for repair. A previous study from our institution[5] indicated that adverse outcomes with TVR are related to the preoperative status; however, a better outcome may be achieved if the patient undergoes surgery before the onset of advanced right heart failure. From 1980 to 2007, we have performed 2192 tricuspid repairs and 201 TVRs, which includes the cohort of 64 patients in this study who underwent isolated mTVR.

The prosthesis of choice for TVR is still a matter of debate,[6] and the concern about replacing the TV with a

TABLE 1. Concomitant procedures

Procedure	Number of patients	Percentage (%)
Atrial septal defect closure	28	44
Arrhythmias surgery	11	17
Pulmonary valvectomy	10	16
Pulmonary valvotomy	1	1.6
Repair of ruptured sinus of Valsalva aneurysm	1	1.6
Pericardiectomy	1	1.6
Coronary artery bypass graft	1	1.6

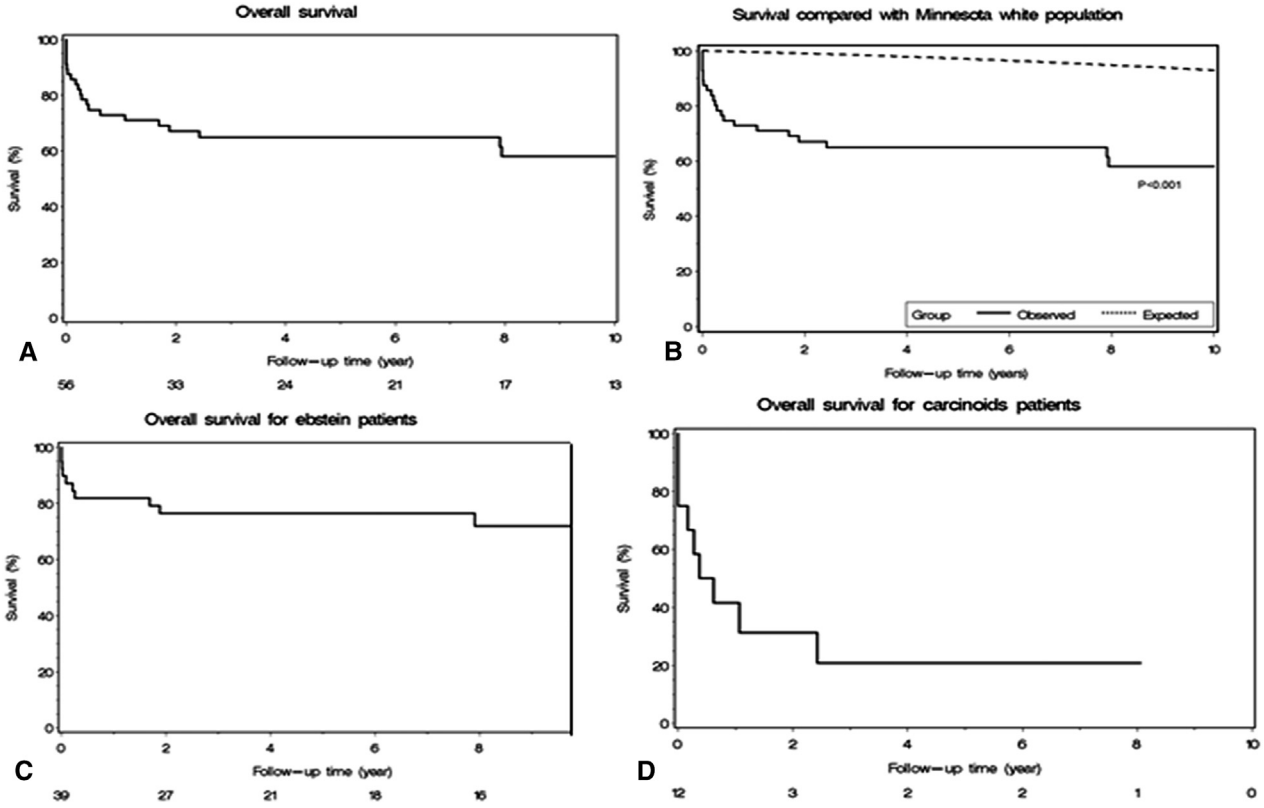

FIGURE 1. Survival curves: A, overall survival; B, survival of those who underwent isolated TVR compared with the white population of Minnesota; C, overall survival of patients with Ebstein anomaly; D, overall survival of those with carcinoid heart disease.

mechanical prosthesis relates to the increased risk of valve thrombosis as well as valve dysfunction related to pannus formation as seen in previous studies.[7] Valve selection should be based on discussion with the patient, paying special attention to the patient's lifestyle, the need for life-long warfarin therapy, and right ventricular function. In the current era, percutaneous valve technology has increased the likelihood of tissue TVR use, recognizing percutaneous replacement as a management option in those with degeneration.

The question about the type of the prosthesis in the TV position was asked by Van Nooten and colleagues[8] in their series of 146 TVRs, which included 69 bioprostheses and 77 mechanical prostheses. Their hospital mortality was

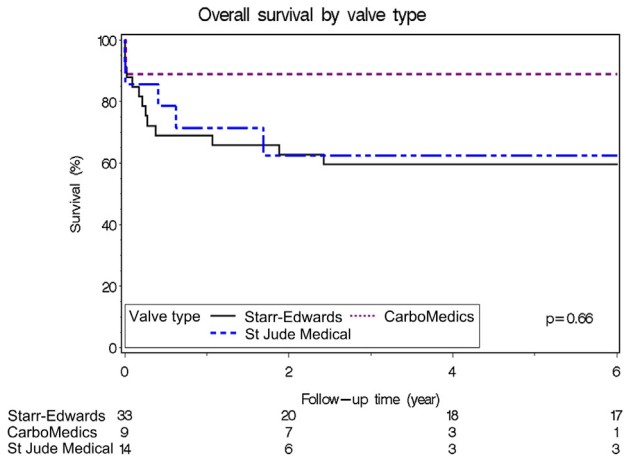

FIGURE 2. Overall survival according to the type of the prosthesis.

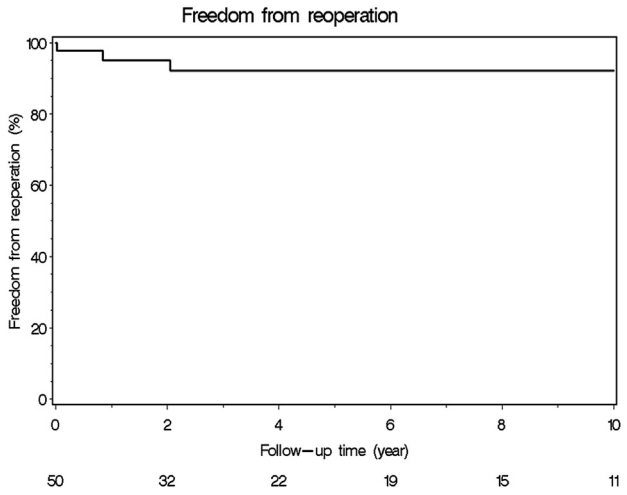

FIGURE 3. Freedom from reoperation at 1, 5, and 10 years was 95.1%, 92.1%, and 92.1%, respectively.

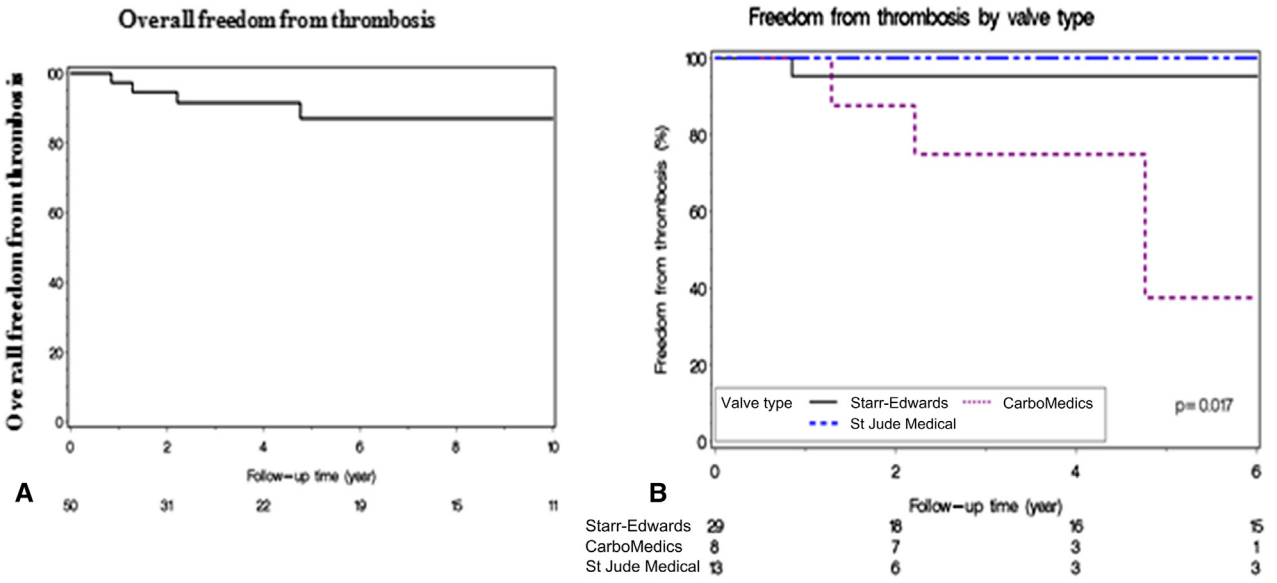

FIGURE 4. Freedom from prosthetic mechanical thrombosis: A, overall; and B, based on the type of prosthesis.

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16.1%. The investigators concluded that the outcome of TVR is influenced by preoperative and perioperative variables such as preoperative functional class, hepatomegaly, ascites, icterus, and increased cardiothoracic ratio. They indicated their preference for a large-size bioprosthesis in view of its initial good durability and low-risk of valve-related events. However, in those with good life expectancy, an acceptable alternative is a bileaflet mechanical prosthesis.

Historically, there has been increased mortality with TVR compared with other types of valve replacement surgery. The early mortality in our patients was 9.4%, which was mainly in the early years of the series (1980-1994), compared with early mortality of 0% for the latter years (1995-2007). This compares favorably with other series reported.

Mangoni and colleagues[9] reported the outcome of isolated TVR in 15 consecutive patients, 20% of whom died within 30 days after surgery and 40% died within 3 months. The study by Filsoufi and colleagues[10] reported on 81 patients (mean age, 61 years), including 25 patients with isolated TVR; the early mortality in this series was 22% and 47 patients had undergone TVR with a mechanical prostheses. The investigators identified the following as risk factors for mortality: urgency of the operation, age more than 50 years, functional tricuspid regurgitation, and pulmonary hypertension. In the series reported by Tokunaga and colleagues,[11] there were 31 cases

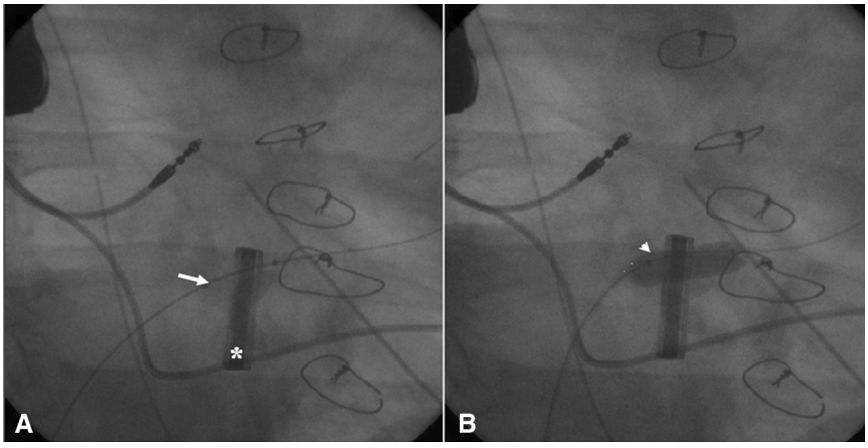

FIGURE 5. A and B, Cardiac catheterization images showing the technique of percutaneous balloon valvuloplasty with thrombectomy for a thrombosed mechanical tricuspid valve (*). This procedure was performed in a patient who underwent spine surgery and his anticoagulation had to be held perioperatively, which resulted in thrombosis of the tricuspid valve prosthesis. A, *White arrow* indicates the catheter extending across the mechanical tricuspid valve (*); B, *white arrowhead* indicates balloon thrombectomy.

of isolated TVR including only 4 patients who had mechanical prostheses; the hospital mortality was 6.5%.

The largest series was reported by Ratnatunga and colleagues.[12] They reported on their experience from the United Kingdom Heart Valve Registry comparing midterm outcomes between mechanical and biological prostheses in the TV position. A total of 425 patients underwent TVR; 225 patients (52.9%) received biological prostheses and 200 received mechanical prostheses. The early mortality in this study was 17.3%; 1-, 5-, and 10-year survival rates were 72.2%, 59.9%, and 42.9%, respectively. Predictors of overall survival included the year of the operation, age, and the number of valves implanted. Early mortality, although not statistically significant, was higher with the biological valves compared with the mechanical valves (18.8% vs 15.6%). Survival rates at 1, 5, and 10 years were 70.5%, 61.5%, and 47.7% for biological valves and 74.0%, 57.9%, and 33.9% for mechanical valves. In the study reported by Chang and colleagues,[13] the long-term outcomes of biological and mechanical prostheses were similar in 138 TVRs (35 biological, 103 mechanical) performed in 125 patients. Early mortality in that study was 17.6% and late mortality was 10.4%. The surgical mortality in that study for biological valves was higher than for mechanical valves, although this was not significant. The investigators identified 11 episodes of thromboembolism in the mechanical group with freedom from thromboembolism at 5 and 10 years of 90.2 $\pm$ 0.6% and 87.8 $\pm$ 0.7%, respectively.

Valve-related thrombosis at 1, 5, and 10 years in this study was 97.3%, 87%, and 87%, respectively, and it was significantly higher for the Starr-Edwards and St Jude Medical bileaflet prosthesis. In our 64 cases of mTVR, there were only 5 cases of valve thrombosis more than a year after valve replacement. Three of these patients had moderate or greater right ventricular systolic dysfunction. All patients reported therapeutic anticoagulation, and levels were in the appropriate range at the time of TVR thrombosis identification.

The risk of mTVR thrombosis was reported to be high in the early literature, varying between 4% and 20%.[14] This seems to be related to a reduced flow rate and lower pressure on the right side of the heart.[15] The risk of TVR thrombosis seems to increase in the presence of right ventricular dysfunction, even in the presence of adequate anticoagulation, as was found in 3 of our patients in this series. Anticoagulation regimens have also changed over time,[16] and in the current era, anticoagulant and antiplatelet agents are recommended for all patients with mechanical prostheses.[17]

We have noticed a lower thrombosis rate with the Starr-Edwards prosthesis and 1 explanation is the presence of a larger washing jet in this valve compared with other mechanical prostheses. That may be of value in the tricuspid position where the risk of mechanical thrombosis is higher compared with left-sided prostheses. The difference between CarboMedics and St Jude Medical valves is not clear. However, the same observation has been reported before in the aortic position by Kandemir and colleagues.[18] The investigators reviewed the long-term results between St Jude Medical and CarboMedics mechanical heart valves in the aortic position in 174 patients. The freedom from thromboembolism was 87.7% for the St Jude Medical group versus 83% for the CarboMedics group. This was not statistically significant and the investigators attributed the difference to patient-specific characteristics and the method of anticoagulation. Others have noticed a higher thrombosis rate for CarboMedics valves in the mitral position as well.[19] Rosengart and colleagues[19] evaluated 245 consecutive patients who underwent mechanical valve replacement. There were 5 thrombosed valves in the CarboMedics group and none in the St Jude Medical group ($P = .04$), and all thrombosed valves were in the mitral position. The investigators explained that some of the design features of the CarboMedics valve could enhance thromboembolic potentials; for example, the biocompatible sewing ring may encourage pannus formation and a valve opening profile may affect washout of stagnant flow areas where thrombus might form.

The use of bileaflet, especially St Jude Medical, prostheses has been associated with a low rate of thrombosis (freedom from thromboembolism was 92.6% $\pm$ 6.9%).[20] The high rate of mechanical valve thrombosis reported previously was mainly in the early era of caged ball and tilting disc prostheses,[21] and before aspirin therapy was routinely recommended for patients with a mechanical valve on warfarin.

Thrombosed mechanical TVRs can occasionally be salvaged by thrombolysis, however reoperation may be required in the presence of a large clot burden, marked prosthetic dysfunction, or contraindications to lytic therapy.

Five thrombosed mechanical prostheses were identified in our series. Three patients underwent successful thrombolytic therapy, including 1 patient after failed percutaneous thrombectomy; reoperation was performed in the other 2. The optimal way to manage thrombosed TVR remains controversial.

Thrombolytic therapy was first reported in 1971 by Luluaga and colleagues[22] who used streptokinase to treat thrombosed Starr-Edwards TV prostheses. This approach has been associated with lower morbidity and mortality and is usually the recommended first step for thrombosed right-sided prostheses.[23] Repeated thrombolysis was described in a 49-year-old woman with Ebstein anomaly who was treated with mTVR. She had 7 episodes of prosthetic thrombosis and all were managed with thrombolysis; she continued to be symptom free for 5 years after her last thrombotic event.[24] In addition, in our study, no patient had any valve-related mortality or structural valve failure that required reoperation.

Evaluation of right ventricular function is critical when TVR is considered. In the meantime, its complex geometry makes this evaluation a challenge. In our study, echocardiography was the only available method of evaluation, especially in the early era; however, magnetic resonance imaging is now used more frequently to evaluate right ventricular function preoperatively. The following are some of the proposed markers of right ventricular dysfunction: right ventricular ejection fraction, the presence of right ventricular dilatation, tricuspid annular velocity or excursion, right ventricular index of myocardial performance, TV regurgitation, and pressure-volume or pressure-area loops.[25]

In conclusion, TVR with a mechanical prosthesis still has its place and indications. The long-term outcome is satisfactory, with good durability and excellent freedom from reoperation. Based on our experience, we recommend considering use of a mechanical valve in the tricuspid position in patients who require warfarin anticoagulation, those with good right ventricular function, and less than moderate right ventricular dilatation. Our preference is a low-profile bileaflet mechanical prosthesis. To achieve a good surgical outcome, patients may need to be referred earlier to surgery before the development of frank end-stage right ventricular dysfunction with associated right heart failure.

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