# Contemporary Outcomes of Operations for Tricuspid Valve Infective Endocarditis

Murtaza Y. Dawood, MD, Faisal H. Cheema, MD, Mehrdad Ghoreishi, MD, Nathaniel W. Foster, Robert M. Villanueva, MPA, Rawn Salenger, MD, Bartley P. Griffith, MD, and James S. Gammie, MD

Division of Cardiac Surgery, University of Maryland School of Medicine, Baltimore, Maryland

*Background.* Tricuspid valve infective endocarditis (TVIE) is uncommon. Patients are traditionally treated with antibiotics alone, and indications for operation are not clearly established. We report our operative single-center experience.

*Methods.* We retrospectively reviewed 56 patients who underwent operations for TVIE between January 2002 and December 2012.

*Results.* Methicillin-resistant *Staphylococcus aureus* was present in 41% of patients, septic pulmonary emboli in 63%, moderate/severe tricuspid regurgitation in 66%, and 86% were intravenous drug abusers. Patients underwent early operation if there was concomitant left-sided endocarditis with indications for operation (n = 18), atrial septal defect (n = 6), infected pacemaker lead (n = 4), or prosthetic TVIE (n = 1). The remaining 27 patients were treated with intravenous antibiotics. Five patients completed a 6-week course of intravenous antibiotics before requiring an operation for symptomatic severe tricuspid regurgitation or persistent bacteremia. Twenty-two patients did not complete the antibiotic therapy and underwent operation for symptomatic severe tricuspid regurgitation (n = 15), persistent fevers/bacteremia (n = 3), or patient-specific factors (n = 4). Valve repair was successful in 57% of patients. Overall operative mortality was 7.1%. No operative deaths occurred in patients with isolated native TVIE. Recurrent TVIE was diagnosed in 21% (5 of 24) of the replacement group and in 0% (0 of 32) in the repair group. Use of repair was strongly protective against recurrent TVIE ($p < 0.01$).

*Conclusions.* In contrast to previously published reports of high operative mortality with TVIE, this experience demonstrates improved outcomes with low morbidity and mortality, particularly for native isolated TVIE. Future prospective comparisons between surgically and medically treated patients may help to further define indications and timing for operation for patients with TVIE.

(Ann Thorac Surg 2014;■:■–■)


Tricuspid valve infective endocarditis (TVIE) is an uncommon diagnosis, accounting for less than 15% of cases of IE [1]. Most patients with TVIE are successfully treated with antibiotics, and surgical intervention is generally reserved for patients in whom medical therapy has failed. Key differences between left-sided and right-sided IE include better tolerance of acute valvular regurgitation on the low-pressure right side of the circulation, fewer adverse sequelae of embolic episodes to the lungs compared with the systemic circulation, and a younger patient population. Whereas the global mortality rate for left-sided IE is between 20% and 30%, in-hospital mortality for right-sided IE ranges from 7% to 11% [2–7].

There are no well-defined indications for surgical intervention for TVIE [8]. Comparing outcomes of medical and surgical therapy for TVIE is difficult because of the lack of midterm and long-term follow-up of medically treated patients, many of whom are left with substantial tricuspid regurgitation (TR), and the small experience with surgical intervention for TVIE. One recent report based on a national registry found fewer than 100 operations per year were performed in North America for active TVIE [4]. Our institution admits a large population of patients with TVIE for medical and surgical treatment. The purpose of this study was to review our contemporary surgical experience to describe indications and report outcomes of operation in this population.

## Material and Methods

A total of 322 patients underwent an operation for IE at the University of Maryland Medical Center between January 2002 and December 2012. Of these, 63 had TV operations. Three patients with rheumatic valve disease and four with functional tricuspid disease were excluded. This yielded a cohort of 56 consecutive patients for analysis with active or treated TVIE, as depicted in Figure 1. Patient data were gathered from The Society of Thoracic Surgeons (STS) local database and supplemented with record reviews. All patients included in this study met the modified Duke criteria for IE [9]. Patient

Accepted for publication Aug 15, 2014.

Presented at the Fiftieth Annual Meeting of The Society of Thoracic Surgeons, Orlando, FL, Jan 25–29, 2014.

Address correspondence to Dr Dawood, Division of Cardiac Surgery, University of Maryland School of Medicine, 110 S Paca St, 7th Flr, Baltimore, MD 21201; e-mail: mdawood@smail.umaryland.edu.



0003-4975/$36.00
http://dx.doi.org/10.1016/j.athoracsur.2014.08.069

**Abbreviations and Acronyms**

ASD = atrial septal defect
ePTFE = expanded polytetrafluoroethylene
HD = hemodialysis
IE = infective endocarditis
IVDA = intravenous drug abuse
LV = left ventricular
MRSA = methicillin-resistant *Staphylococcus aureus*
MSSA = methicillin-sensitive *Staphylococcus aureus*
PFO = patent foramen ovale
POD = postoperative day
PPM = permanent pacemaker
RHF = right heart failure
RV = right ventricular
SD = standard deviation
TR = tricuspid regurgitation
TV = tricuspid valve
TVIE = tricuspid valve infective endocarditis

characteristics and outcome definitions were based on the STS Adult Cardiac Surgery Database criteria (http://www.sts.org/sites/default/files/documents/word/STSAdultCVDataSpecificationsV2_73%20with%20correction.pdf). The University of Maryland Institutional Review Board approved this review, with a waiver of consent from individual patients.

### *Preoperative Evaluation*

All patients underwent transthoracic or transesophageal echocardiography and a computed tomography scan of the chest and abdomen, and blood samples were cultured. Coronary catheterization was performed if risk factors for coronary artery disease were present. Triggers for immediate or early operation included left-sided IE with indications for operation [10], prosthetic TVIE, an atrial septal defect, and infected permanent pacemaker (PPM) leads. Patients initially treated medically were assessed daily and underwent interval echocardiography. Medical therapy was deemed to have failed if there were any or all of persistent vegetation, continued bacteremia, or intractable right-sided heart failure, defined as the presence of dyspnea, anasarca, lower extremity edema, or ascites.

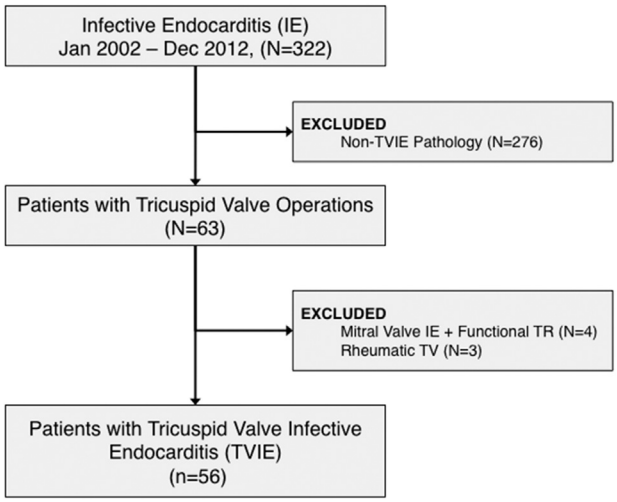


*Fig 1. Cohort diagram. (IE = infective endocarditis; TR = tricuspid regurgitation; TV = tricuspid valve; TVIE = tricuspid valve infective endocarditis.)*

### *Operative Techniques*

All patients underwent the TV operation through a median sternotomy with cardiopulmonary bypass using a bicaval venous drainage technique. Use of a cross-clamp and cardioplegic cardiac arrest was determined by surgeon preference. All efforts were made to repair the valve. Techniques used for valve repair included annuloplasty ring insertion, excision of vegetation and reconstruction using fresh autologous pericardium, leaflet bicuspidization, leaflet sliding-plasty, and expanded polytetrafluoroethylene chordal reconstruction. If a quality repair was not achievable, the valve was replaced with a tissue valve. Early in this experience we used inverted stentless porcine aortic root prostheses in the tricuspid position [11], but more recently, we have favored stented bioprosthetic valves. When TV replacement was necessary, we routinely placed a permanent epicardial pacing lead.

### *Postoperative Course*

A total of 32 patients underwent a postoperative transthoracic echocardiogram before their discharge from the hospital. All patients were discharged on daily aspirin. Patients with active endocarditis or with positive intraoperative cultures were discharged with a 6-week course of appropriate intravenous antibiotics.

### *Patient Follow-Up*

Patients were followed up in the clinic between 4 and 6 weeks. Long-term mortality was evaluated by cross-referencing the Social Security and National Death indices. Vital status follow-up was complete through May 31, 2013, and the mean duration of follow-up was 47.7 $\pm$ 42 months (range, 12 to 132 months).

### *Statistical Analysis*

In this descriptive analysis, categoric variables are summarized with frequency counts and percentages and continuous variables with mean $\pm$ standard deviation or median. Kaplan-Meier curves were used to assess the long-term survival analysis, and log-rank testing was done when comparisons were drawn based on any stratifications. Results were considered statistically significant for $p < 0.05$. Statistical analysis was performed using JMP 10.0 software (SAS Institute Inc, Cary, NC).

## Results

### *Patient Characteristics*

Patients were a mean age of 39 $\pm$ 12 years (range, 20 to 73 years), and 59% were female. A history of intravenous

drug abuse (IVDA) was present in 48 patients (86%), 35 (63%) were positive for hepatitis B or C, and 8 (14%) were seropositive for human immunodeficiency virus. Two patients (3.6%) were dialysis dependent. There were 10 patients (18%) with New York Heart Association Functional Class III or IV symptoms.

Pulmonary parenchymal septic emboli were visualized on computed tomography in 36 patients (64%). These septic emboli were more commonly visualized among patients with vegetation size exceeding 1 cm (67% [24 of 36]) compared with those with vegetation size of less than 1 cm (33% [12 of 36]; $p = 0.02$). Table 1 summarizes the preoperative echocardiographic characteristics. Severe TR was present in 32 of 56 patients (57%). An atrial septal defect/patent foramen ovale was present in 5 of 56 patients (8.9%). Overall, the mean TV vegetation size was 1.89 cm (range, 0.6 to 4.4 cm). Active endocarditis was present in 45 patients (80%) at the time of their operation, and the remaining 11 (20%) had a recent (within 3 months) history of active TVIE.

Most patients (83.9% [47 of 56]) in our cohort were diagnosed at other hospitals and transferred to our institution for evaluation and treatment. In 4 patients (7.1%), the endocarditis was associated with infected pacemaker leads, which were removed during the operation. Four patients (7.1%) had undergone previous valve operations, including 1 Ross procedure, 2 mitral valve replacements, and 1 TV replacement.

### *Microbiologic Determination*

Table 2 describes the organisms responsible for TVIE. *Staphylococcus aureus* was the predominant etiologic organism (68% [38 of 56]), with methicillin-resistant *Staphylococcus aureus* (MRSA) present in 23 of 56 patients (41%). Four patients (7.1%) had culture-negative TVIE.

### *Indications for Operation*

Indications for operative intervention were based on clinical evaluation and echocardiographic data, as depicted in Figure 2. Patients underwent early operation if there was concomitant left-sided endocarditis with indications for operation (n = 18), atrial septal defect (n = 6), infected pacemaker lead (n = 4), or prosthetic TVIE (n = 1). The mean TV vegetation size was 1.7 ± 0.6 cm. Among the 20 patients with concomitant left-sided endocarditis, there were 10 patients with mitral valve IE and 10 with aortic valve IE. Mitral pathology included anterior (n = 4), posterior (n = 4), or bileaflet vegetations (n = 1), and prosthetic valve endocarditis (n = 1). Aortic valve pathology included root abscess (n = 2), and vegetations on the noncoronary (n = 3), left (n = 2), and right cusps (n = 3).

The remaining 27 patients with isolated, native TVIE were initially treated with intravenous antibiotics for a mean of 4.4 ± 2.5 weeks. Five patients completed a 6-week course of intravenous antibiotics before undergoing operation. Indications in this group included symptomatic severe TR (n = 2), persistent vegetation with bacteremia (n = 2), and persistent fevers with symptomatic severe TR (n = 1). Twenty-two patients did not complete the course of antibiotic therapy and underwent operation at a mean interval of 36.1 ± 36.4 days (median, 24 days) after diagnosis for persistent severe TR (n = 15), persistent fevers/bacteremia (n = 3), patient-specific factors (n = 2; noncompliance, immunosuppression), and vegetation embolization into a main pulmonary artery branch (n = 2). In this group, the mean vegetation size was 2.0 ± 0.8 cm.

The mean interval from diagnosis to operation was 38.6 ± 37.1 days (median, 25 days) in the antibiotic therapy group (n = 27) and 32.3 ± 33.1 days (median, 17 days) in the early operative group (n = 29).

*Table 1. Baseline Echocardiographic Data*

| Variables | Frequency (%) or Mean ± SD |
|---|---|
| LV ejection fraction | 0.56 ± 0.11 |
| RV dysfunction | 14 (25) |
| TR grade | |
| Trace/none | 9 (16) |
| Mild | 7 (13) |
| Moderate | 8 (14) |
| Severe | 32 (57) |
| Vegetation size, cm | 1.89 ± 0.8 |
| <1 cm | 25 (45) |
| ≥1 cm | 31 (55) |
| Native TVIE | 55 (98) |

LV = left ventricular; RV = right ventricular; SD = standard deviation; TR = tricuspid regurgitation; TVIE = tricuspid valve infective endocarditis.

*Table 2. Microbiologic Determination*

| Organism | Frequency (%) |
|---|---|
| *Staphylococcus* spp | 38 (67.9) |
| MRSA | 23 (41.1) |
| MSSA | 12 (21.4) |
| *Streptococcus* spp | 6 (10.7) |
| *Enterococcus* spp | 4 (7.1) |
| *Pseudomonas* spp | 3 (5.4) |
| *Candida* spp | 1 (1.8) |
| Negative culture | 4 (7.1) |

MRSA = methicillin-resistant *Staphylococcus aureus*; MSSA = methicillin-sensitive *Staphylococcus aureus*.

### *Operative Characteristics*

Isolated TV operations were performed in 57% (32 of 56) of patients. In the remaining patients, a concomitant procedure was performed that included mitral valve repair or replacement in 25% (14 of 56), aortic valve replacement in 16.1% (9 of 56), and a pulmonary valve replacement in 1.8% (1 of 56). Reoperative sternotomy was performed in 3 patients (5.4%). TV operations were done using cardioplegic cardiac arrest in 89% (50 of 56) and on the beating heart in 11% (6 of 56). Average perfusion times were 129 ± 54 and 91 ± 77

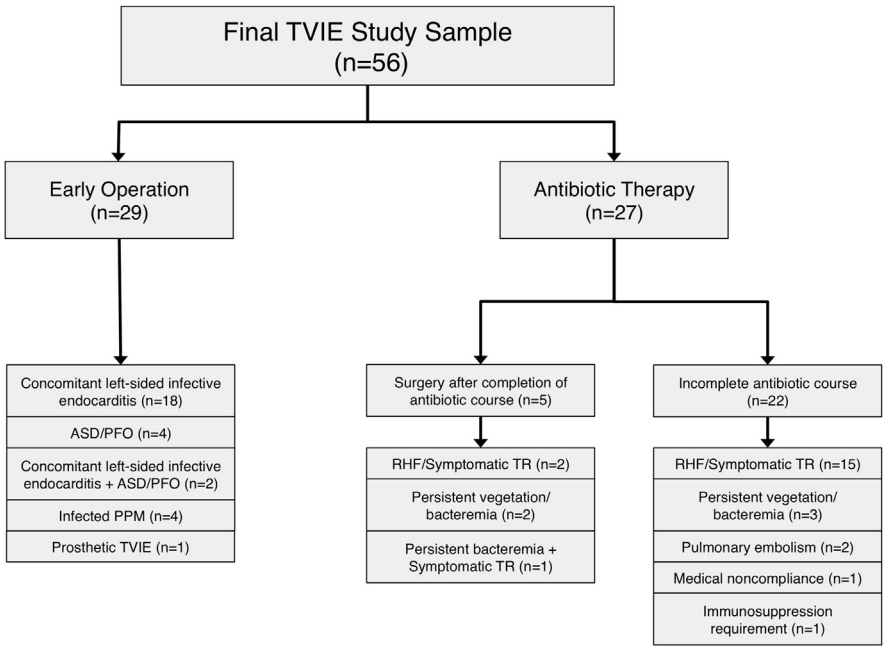


*Fig 2. Operative cohort (ASD = atrial septal defect; PFO = patent foramen ovale; PPM = permanent pacemaker; RHF = right heart failure; TR = tricuspid regurgitation; TVIE = tricuspid valve infective endocarditis.)*

minutes for the arrested and beating-heart operations, respectively. Ischemic time for the arrested group was 99 ± 53 minutes. Perfusion and ischemic times for isolated native TVIE patients were 99 ± 43 minutes and 63 ± 42 minutes, respectively.

TV repair was performed in 57% (32 of 56) of patients with primary TVIE using an array of techniques (Figure 3). Among the 20 patients in which the repair included an annuloplasty ring, a geometric rigid partial ring (MC3 Tricuspid Annuloplasty Ring; Edwards Lifesciences, Irvine, CA) was used in 14 patients, and a flexible partial annuloplasty ring (Cosgrove-Edwards; Edwards Lifesciences) was used in 6 patients. The median size used was 28 mm (range, 26 to 36) mm. Twelve patients were repaired without an annuloplasty ring.

Valve replacement was performed in 24 of 56 patients (43%). All patients received bioprosthetic TV replacements, including inverted stentless porcine aortic roots in 7 (29%), stented bovine pericardial valves in 6 (25%), and stented porcine valves in 11 (46%). The median size was 29 mm (range, 27 to 33 mm). No patients were managed with tricuspid valvulectomy.

Among the native TVIE patients, there was a trend toward TV replacement in the patients who were initially treated with antibiotics (14 of 27 [49%]) compared with the early surgical group (9 of 28 [32%], $p = 0.14$).

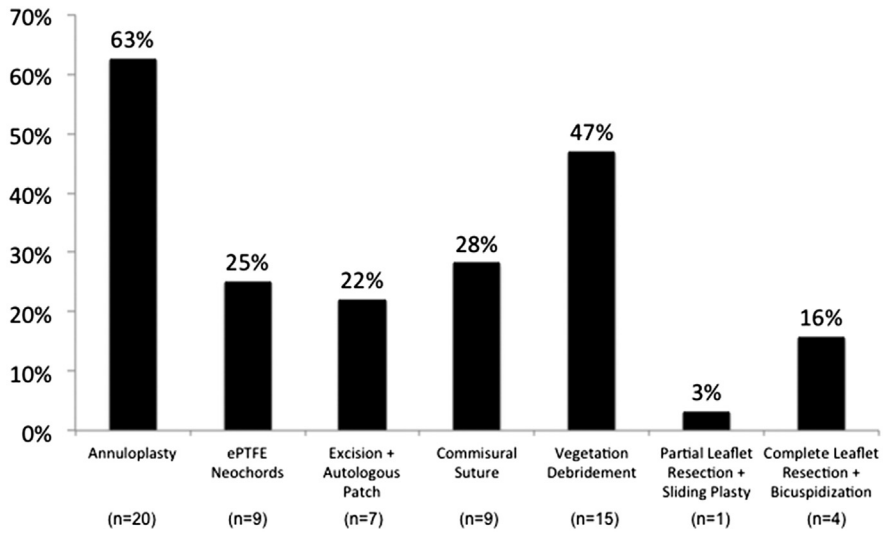


*Fig 3. Techniques used during tricuspid repairs. (ePTFE = expanded polytetrafluoroethylene.)*

### *Patient Outcomes*

The operative mortality was 7.1% (4 of 56) and was 0% (0 of 32) for the isolated native TVIE group and 16.7% (4 of 24) for the multivalve group. Table 3 summarizes postoperative morbidity and mortality. One patient sustained a postoperative iatrogenic hepatic injury during a thoracostomy tube placement in the intensive care unit that resulted in severe coagulopathy and death. Intractable right heart failure developed in 1 patient in the operating room that failed to respond to pharmacologic intervention. Overwhelming sepsis developed in the third patient, who had undergone a prior splenectomy, and the patient died while at a rehabilitation facility on postoperative day (POD)12. The fourth patient was readmitted from a rehabilitation facility for fevers and chills on POD 19. Blood cultures remained positive for MRSA, and no vegetation was seen on transthoracic echocardiography. The patient was transferred to an intensive care unit on POD 23 for hypotension. On POD 25, the patient had a cardiac arrest that failed to respond to advanced cardiovascular life support and open cardiac massage.

Early reoperation was necessary in 3 patients (5.4%). One patient returned for bleeding on POD 1. Two patients with stentless porcine bioprostheses returned because of prosthetic valve dysfunction necessitating repeat replacement with a stented porcine bioprosthesis on POD 9 and POD 18. Dehiscence of a commissural post occurred in the first patient that resulted in severe prosthetic valve regurgitation. The second patient continued to have symptoms of right-heart failure resulting from high gradients across the tricuspid prosthesis. Both patients had repeat replacement with a stented porcine valve.

Prolonged ventilation was required in 14 patients (25%) and did not correlate with the presence of pulmonary septic emboli. New postoperative renal failure requiring hemodialysis developed in 4 patients (7%), which reversed in 2 patients before discharge. There were no instances of mediastinitis or deep-sternal wound infections. Four patients (7.1%; 3 TV replacements, 1 repair) required a new PPM postoperatively. There were no postoperative strokes.

*Table 3. Postoperative Morbidity and Mortality*

| Outcome | Frequency (%) |
|---|---|
| Operative mortality | |
| Overall | 4 (7.1) |
| Isolated native TVIE | 0 (0) |
| Morbidity | |
| Prolonged ventilation | 14 (25) |
| Renal failure requiring HD | 4 (7) |
| Early reoperation (cardiac) | |
| Postoperative bleeding | 1 (2) |
| Prosthetic valve dysfunction | 2 (4) |
| Deep sternal wound infection | 0 (0) |
| Pneumonia | 0 (0) |
| Stroke | 0 (0) |
| Permanent pacemaker | 4 (7) |

HD = hemodialysis; TVIE = tricuspid valve infective endocarditis.

A predischarge transthoracic echocardiogram was performed in 19 of 32 patients (59%) in the repair group and in 13 of 24 (54%) in the replacement group. Among the 32 repaired patients, moderate TR was present in 3 (9.4%) and severe TR in 1 (3.1%). The only patient with severe TR did not have an annuloplasty ring inserted. The median intensive care unit stay was 2.2 days (range, 0.5 to 47.9 days). The median postoperative length of stay was 9 days (range, 1 to 27 days).

Five patients in this series who had TV replacements required late reoperations for prosthetic valve endocarditis as a result of continued IVDA at a mean interval of 27.3 months (range, 9 to 67 months). One of these patients died of complications during sternal reentry. Another patient required a third operation for prosthetic valve endocarditis 9 months after the first reoperation. None of the repaired valves presented with reinfection. Aside from the patient with reoperative sternotomy injury, all patients with late reoperations were discharged and alive at the time of the latest follow-up. The reinfection rate was 21% (5 of 24) in the replacement group, which is in contrast to 0% (0 of 32) reinfections in the repair group ($p < 0.01$).

The 5-year actuarial survival was 76.1%. When stratified for various groups, there was no long-term survival difference between isolated native vs multivalve IE ($p = 0.88$), early operation vs initial antibiotic therapy ($p = 0.92$), or repair vs replacement ($p = 0.74$) groups at the 5-year follow-up (Fig 4).

## Comment

The key findings of this study include the observation that TVIE remains predominantly a disease of IVDA, MRSA is the most common etiologic organism, the TV can be fixed in most patients, TV repair is strongly protective against recurrent TV endocarditis, and operative mortality for isolated TVIE is low.

The indications for surgical management of TVIE are poorly defined. Reported operative mortality ranges from 9% to 15% for patients with isolated TVIE and is as high as 22% with concomitant left-sided endocarditis [12–14]. Nonoperative management of TVIE with antibiotics alone usually clears the bacteremia and is associated with in-hospital mortality rates of between 7% and 11% [3, 5]. Unfortunately, many patients are left with important residual TR, which has been demonstrated to compromise long-term survival [15].

Our approach to TVIE includes early operation in the presence of any of the following: concomitant left-sided endocarditis, an atrial septal defect, infected indwelling pacing wires, and prosthetic valve endocarditis. Approximately half of our patients were treated with antibiotics with close clinical follow-up. Of those, most failed to show clinical improvement and underwent operation. Most of those patients continued to show signs of symptomatic volume overload despite diuretic

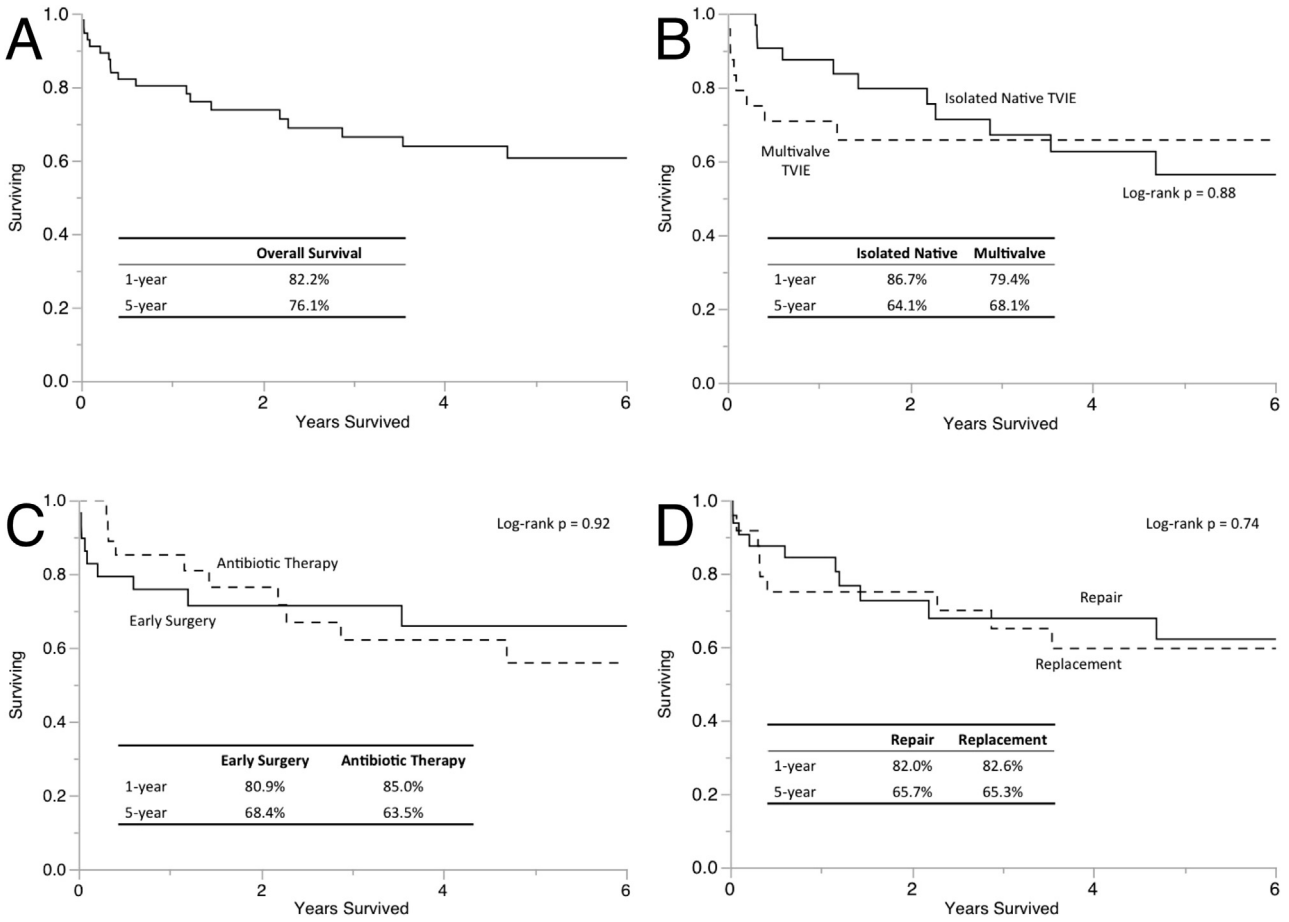


*Fig 4. Kaplan-Meier survival curves: (A) overall; (B) isolative native tricuspid valve infective endocarditis (TVIE; solid line) vs multivalve TVIE (dashed line); (C) initial antibiotic therapy (dashed line) vs early operation (solid line); and (D) tricuspid valve repair (solid line) vs tricuspid valve replacement (dashed line).*

therapy. Persistent bacteremia/fevers during antibiotic therapy was another frequent cause of failed antibiotic therapy.

The operative mortality for isolated native TVIE in our cohort was 0%. Other centers have published similar results [14, 16], with continued excellent outcomes during midterm follow-up. Early surgical intervention has an in-hospital mortality experience that is similar to or lower than antibiotic therapy alone but prevents the long-term sequelae of untreated severe TR. On the basis of our experience in this series, we now consider early operation for any patient with TVIE and severe TR.

Building on lessons learned from experience with mitral valve repair in IE [17], our goal is to repair the infected TV whenever possible. TV repairs can be accomplished in most patients using a variety of techniques, including implantation of an annuloplasty ring, expanded polytetrafluoroethylene neochords, excision and repair with a fresh autologous pericardial patch, or a combination of a number of available repair techniques. Our approach to leaflet repair included debridement of infected tissue, use of untreated autologous pericardium [10] as a patch when necessary, and placement of an undersized partial annuloplasty ring [18]. Over our review period, the reinfection rate in the repair group was 0% despite the high prevalence of IVDA in our population. However, 21% (5 of 24) of patients with TV replacements required late reoperations for prosthetic valve endocarditis secondary to recurrent IVDA ($p < 0.01$).

Patients initially treated with antibiotics tended to have a higher rate of TV replacement rather than repair compared with the early operative group. It is possible that earlier intervention may avoid ongoing destruction of leaflet tissue and increase the likelihood of TV repair.

The sole early failure in the repair group (defined as severe TR on predischarge echocardiography) may have been related to failure to use an annuloplasty ring. On the basis of our experience with repair of functional TR, we believe that an undersized (size 26 or 28) rigid geometric annuloplasty ring is an essential component of an effective, durable tricuspid repair [18], and we have never seen reinfection of a prosthetic annuloplasty ring.

The use of valvulectomy is of historical interest only [2]. This approach is associated with significant morbidity resulting from systemic venous hypertension. Right heart failure develops, and patients ultimately die or require

reoperation for refractory right heart failure with a significantly increased operative risk. We do not endorse this technique. We had initial enthusiasm for implantation of inverted stentless porcine aortic roots in the tricuspid position [11]. However, due to the complexity of fashioning and positioning the valve, as well as the early failures in the series, we have abandoned that technique, and our practice has evolved to favor stented bioprostheses when replacement is necessary.

We do not use mechanical prostheses in the tricuspid position. We have observed excellent durability of tissue valves in the low-pressure right-sided circulation and have been reluctant to implant a thrombogenic mechanical prosthesis with the associated requirement for lifetime warfarin anticoagulation in the TVIE population, in whom IVDA is predominant.

An important concern with TV operations, particularly with valve replacement, is injury to the conduction system. Vassileva and colleagues [19] reviewed 28,726 admissions for TV operations in the United States and reported an overall PPM implantation rate of 11.6% (9.5% in the repair group). In contrast, the PPM rate was 3% in our experience with TV repair for functional TR [18]. In the present series, 4 patients (7%) required placement of a new postoperative PPM before discharge, with rates of 12.5% (3 of 24) in the replacement group and 3.1% (1 of 32) in the repair group.

Placement of a permanent endocardial pacing wiring across a bioprosthesis can result in early failure of the bioprosthesis. Transvalvular pacing wires can result in leaflet perforation, valve damage, and valve dysfunction [20]. A fibrotic response results from contact of the lead against leaflet tissue and the subvalvular apparatus [21]. In bioprosthetic valves, this fibrosis can distort the leaflet geometry and result in TR or stenosis, or both. To avoid this, our practice is to place permanent epicardial pacing wires at the time of the operation for all TV replacements but not for repairs.

All of the limitations of a study design that is retrospective in nature apply to this report. This study did not account for patients who were admitted to the hospital, medically managed, treated successfully, and discharged. This led to a restricted analysis, and direct comparisons between the medical and surgical treatment strategies could not be made. In addition, midterm and long-term echocardiographic follow-up was not available due to the unreliability of our patient population; however, Gottardi and colleagues [16] reinforced the durability of complex TV repairs. The causes of death for long-term survival analyses could not be ascertained.

In conclusion, MRSA was the predominant microorganism in this large contemporary experience of operations for TVIE. Multivalve endocarditis is common, and a thorough evaluation of the mitral, aortic, and pulmonary valves is mandatory. IVDA was documented in most patients. Although there is often reluctance to operate on this population, midterm survival is reasonable and recidivism is not universal. Pulmonary septic emboli should not be considered a contraindication to operation.

Valve repair can be performed in most patients using a variety of techniques with good results and should always include an undersized rigid annuloplasty ring. The use of repair was strongly protective against recurrent TV endocarditis vs valve replacement. If replacement is warranted, a stented bioprosthesis is preferred. No operative deaths occurred in the isolated native endocarditis group.

In contrast to historical reports of high mortality rates, these results show that TVIE operations can be performed with low morbidity and excellent survival and support reconsidering the threshold for operation in TVIE. Future prospective comparisons between surgically and medically treated patients may help clarify indications for operation in this patient population.

## References

1. Murdoch DR, Corey GR, Hoen B, et al. Clinical presentation, etiology, and outcome of infective endocarditis in the 21st century: the International Collaboration on Endocarditis-Prospective Cohort Study. Arch Intern Med 2009;169:463–73.
2. Arbulu A, Holmes RJ, Asfaw I. Surgical treatment of intractable right-sided infective endocarditis in drug addicts: 25 years experience. J Heart Valve Dis 1993;2:129–37; discussion 138–9.
3. Chambers HF, Miller RT, Newman MD. Right-sided Staphylococcus aureus endocarditis in intravenous drug abusers: two-week combination therapy. Ann Intern Med 1988;109:619–24.
4. Gaca JG, Sheng S, Daneshmand M, et al. Current outcomes for tricuspid valve infective endocarditis surgery in North America. Ann Thorac Surg 2013;96:1374–81.
5. Hecht SR, Berger M. Right-sided endocarditis in intravenous drug users. Prognostic features in 102 episodes. Ann Intern Med 1992;117:560–6.
6. Moss R, Munt B. Injection drug use and right sided endocarditis. Heart 2003;89:577–81.
7. Singh SK, Tang GH, Maganti MD, et al. Midterm outcomes of tricuspid valve repair versus replacement for organic tricuspid disease. Ann Thorac Surg 2006;82:1735–41; discussion 1741.
8. Gammie JS. Invited commentary. An outstanding series of tricuspid valve operations for infective endocarditis. Ann Thorac Surg 2007;84:1949.
9. Durack DT, Lukes AS, Bright DK. New criteria for diagnosis of infective endocarditis: utilization of specific echocardiographic findings. Duke Endocarditis Service. Am J Med 1994;96:200–9.
10. Evans CF, DeFilippi CR, Shang E, Griffith BP, Gammie JS. Fresh autologous pericardium for leaflet perforation repair in mitral valve infective endocarditis. J Heart Valve Dis 2013;22:560–6.
11. Cardarelli MG, Gammie JS, Brown JM, Poston RS, Pierson RN 3rd, Griffith BP. A novel approach to tricuspid valve replacement: the upside down stentless aortic bioprosthesis. Ann Thorac Surg 2005;80:507–10.
12. Baraki H, Saito S, Al Ahmad A, et al. Surgical treatment for isolated tricuspid valve endocarditis-long-term follow-up at a single institution. Circ J 2013;77:2032–7.
13. Musci M, Hübler M, Amiri A, et al. Repair for active infective atrioventricular valve endocarditis: 23-year single center experience. Clin Res Cardiol 2011;100:993–1002.
14. Musci M, Siniawski H, Pasic M, et al. Surgical treatment of right-sided active infective endocarditis with or without involvement of the left heart: 20-year single center experience. Eur J Cardiothorac Surg 2007;32:118–25.
15. Nath J, Foster E, Heidenreich PA. Impact of tricuspid regurgitation on long-term survival. J Am Coll Cardiol 2004;43:405–9.

16. Gottardi R, Bialy J, Devyatko E, et al. Midterm follow-up of tricuspid valve reconstruction due to active infective endocarditis. Ann Thorac Surg 2007;84:1943–8.
17. Shang E, Forrest GN, Chizmar T, et al. Mitral valve infective endocarditis: benefit of early operation and aggressive use of repair. Ann Thorac Surg 2009;87:1728–33; discussion 1734.
18. Ghoreishi M, Brown JM, Stauffer CE, et al. Undersized tricuspid annuloplasty rings optimally treat functional tricuspid regurgitation. Ann Thorac Surg 2011;92:89–95; discussion 96.
19. Vassileva CM, Shabosky J, Boley T, Markwell S, Hazelrigg S. Tricuspid valve surgery: the past 10 years from the Nationwide Inpatient Sample (NIS) database. J Thorac Cardiovasc Surg 2012;143:1043–9.
20. Lopez JA, Lufschanowski R. A novel approach to transvenous dual-chamber pacing lead placement and cardiac defibrillator implantation after tricuspid valve replacement. J Cardiovasc Electrophysiol 2008;19:873–5.
21. Krishnan A, Moulick A, Sinha P, et al. Severe tricuspid valve stenosis secondary to pacemaker leads presenting as ascites and liver dysfunction: a complex problem requiring a multidisciplinary therapeutic approach. J Interv Card Electrophysiol 2009;24:71–5.

## DISCUSSION

**DR SIMON MALTAIS** (Nashville, TN): I have two questions. This is, of course, your historical experience. How many patients were approached through a right thoracotomy, because in our center, this is the preferred approach for isolated tricuspid surgery. And then the other question is: 5% mortality is an awesome result. Are you more proactive in intervening on these people early? And if so, can you comment on the indications for surgery itself, because reported literature says there is more than a 15% to 20% range of mortality.

**DR DAWOOD:** To answer the first question, all of our operations were performed through a median sternotomy using bicaval drainage. The second question, regarding how aggressive we are with our patient selection, I think we tend to be pretty aggressive. The main indications for us operating are whether or not they are symptomatic in terms of their degree of tricuspid valve regurgitation. Most patients usually get treated with antibiotics, and then what we tend to do is evaluate them with an echocardiogram to see if there is any progression of their vegetation size or their symptoms, and if there is, then we take them to surgery earlier rather than later.

**DR OZ SHAPIRA** (Jerusalem, Israel): My question is in regard to the choice of valve prosthesis. Many patients in this series were quite young. Why did you invariably select to use bioprostheses?

**DR DAWOOD:** There are two main rationales for using a bioprosthesis. One, our patient population is predominantly intravenous drug abusers. I am assuming your question is why use a bioprosthesis vs a mechanical valve. Using a mechanical valve in a patient population who is generally unreliable can lead to potentially higher complications in terms of anticoagulation or thrombosis of the valves. So for that main reason is why we use bioprostheses.

**DR AHMED EL KERDANY** (Cairo, Egypt): I have two quick questions. First, what was the incidence of recurrence of endocarditis in the drug abuser after surgery? We have a very high incidence of recurrence. Second question: We have problems with high gradients with the pericardial valve postoperatively. We noticed this. Do you have the same experience?

**DR DAWOOD:** The first question, in terms of how often do we have reinfection of the replacement valves in our cohort, there were seven redo operations for prosthetic valve endocarditis and two of those were the same patient, who had continued using intravenous drugs and reinfected their valves. In the repair groups, none of those patients re-presented with a reinfection of their valves.

In terms of gradients across the bioprostheses, in our practice we have transitioned from a porcine valve to a bovine pericardial valve, and what we have noticed is that these valves tend to last a little bit longer. I do not know if it is inherent with the valves, but that is something that we have noticed.

**DR ERNESTO R. SOLTERO** (Ponce, Puerto Rico): Congratulations, excellent results. Do you have any data on your long-term intravenous drug abusers? What percentage of your patients actually recur with drug abuse?

**DR DAWOOD:** Yes. Similar to the question, of the 62 operations, 3 of those were done for repeat infections in the prosthetic valve group, and of the repair groups, none of them have recurred.

**DR SOLTERO:** Did they continue to use drugs? Do you have long-term data on their drug abuse?

**DR DAWOOD:** No.

**DR S. RUSSELL VESTER** (Cincinnati, OH): Two questions. A third of the patients were dead at 5 years. What did they die of? The second question: In your series of patients, how often and in what patients do you place a permanent epicardial pacing lead at the time of surgery?

**DR DAWOOD:** In terms of the long-term outcomes at 5 years, we do not have the cause of death in those patients that died. We have seen transvenous ventricular pacer leads result in premature stenosis of the prosthetic valves. Our practice is whenever we replace the valve, we put 2 permanent epicardial leads for a potential pacemaker to avoid that problem.