Featured Article

Surgical outcomes of isolated tricuspid valve procedures: repair versus replacement

Julius I. Ejiofor, Robert C. Neely, Maroun Yammine, Siobhan McGurk, Tsuyoshi Kaneko, Marzia Leacche, Lawrence H. Cohn, Prem S. Shekar

Division of Cardiac Surgery, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA

Correspondence to: Prem S. Shekar, MD. Chief, Division of Cardiac Surgery, Brigham and Women's Hospital, 75 Francis St, Boston, MA 02115, USA. Email: pshekar@partners.org.

Background: Isolated tricuspid valve (ITV) operations are infrequent and the decision to operate is controversial. We report a series of ITV operations to outline the current disease status requiring this uncommon procedure with an emphasis on the results of tricuspid valve repair (TVr) versus replacement (TVR).

Methods: Using our prospective cardiac surgery database, 57 patients who underwent ITV operations between 01/02–03/14 were identified. Median follow up time was 3.5 years [interquartile range (IQR), 0.8–6.7 years].

Results: Fifty-seven patients underwent ITV surgery with a mean age of 54.4±14.9 yrs and 61% were women. Baseline characteristics were similar between patients who underwent TVr (n=18) or TVR (n=39). The etiologies of TV dysfunction were: ITV endocarditis 14/57 (25%), persistent TV regurgitation after left-sided valve surgery in 12/57 (21%), traumatic biopsies and iatrogenic injury from pacing leads in 11/57 (19%), orthotopic heart transplant 9/57 (16%), carcinoid syndrome 3/57 (5%), congenital 2/57 (5%) and idiopathic 5/57 (9%). Overall, 32/57 (56%) patients had prior heart surgery; of which 10/32 (31%) were TV procedures. Bioprosthetic prostheses were used in 34/39 (87%) patients. Of those who had repair, 11/18 (61%) had ring annuloplasty, 3/18 (17%) bicuspidization, and 3/18 (17%) De Vega annuloplasty and one had vegetectomy. Operative mortality was 5.1% (n=2) and 16.7% (n=3) for TVR and TVr groups, respectively (P=0.32), with an overall mortality rate of 8.6%. Postoperative complications included new onset renal failure in 6/39 (15%) of TVr and 2/18 (11%) of TVR (P=0.71) and there were no strokes. Overall survival rates and degree of residual RV dysfunction were similar for the two groups (both P=0.3). Five-year survival was 77% and 84% for TVr and TVR respectively (P=0.52). There was no difference in rates of recurrent tricuspid regurgitation for TVr and TVR (35.7% *vs.* 23.5%, respectively, P=0.4).

Conclusions: ITV surgery is associated with improved but still relatively high operative mortality. Mid-term outcomes for TVr and TVR are similar with regards to postoperative complications, survival, and freedom from recurrent tricuspid regurgitation.

Keywords: Tricuspid valve (TV); isolated; endocarditis; tricuspid valve repair (TVr); tricuspid valve replacement (TVR)

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Introduction

In a recent review of the Society of Thoracic Surgeons (STS) database, 86% of tricuspid valve (TV) operations were performed in conjunction with another major procedure, usually left sided valve operations, highlighting the relative rarity of isolated TV surgery (1). Indications for TV surgery have largely been placed within the context of concomitant left sided heart disease and the presence of pulmonary hypertension (PHTN). The updated American

Heart Association/American College of Cardiology 2014 guidelines for valvular heart disease recommend isolated tricuspid valve (ITV) repair for severe TR when symptomatic (Class I) or accompanied by progressive right ventricular dysfunction (Class IIb) (2). The guideline also recommend TV repair for asymptomatic severe TR or dilated tricuspid annulus when performing surgery on left-sided valves (2).

In the absence of left sided pathology, the decision to perform an ITV operation is more controversial. The literature on isolated TV operations is sparse and historically associated with high mortality rates (3,4). This is especially true in the setting of right ventricular failure (4). While some studies have questioned if TV replacement is ever indicated (5), there is increasing interest in TV pathology and interventions reflected in recent publications (1,6-8). We present our mid and long term outcomes with ITV surgery to help elucidate the indications, timing, and surgical approach for ITV repair and/or replacement.

Methods

Patient selection

All adult patients aged over 17 years who underwent ITV surgery from January 2002 through to March 2014 at Brigham and Women's Hospital were identified from our prospective cardiac surgery database. This study was approved by the Partners Healthcare Institutional Review Board. A total of 57 patients underwent ITV surgery. At our institution, we believe that careful patient selection and preoperative optimization is paramount to excellent results. This includes patients with symptomatic, severe TV regurgitation or asymptomatic with progressive RV annular dilation (>40 mm) and/or systolic dysfunction.

Patients' demographics, perioperative characteristics, laboratory test results, and in-hospital outcomes of the index admission were extracted from the Brigham cardiac surgery database and the linked Partners Health Care Electronic System. Variables were defined and coded according to the Society for Thoracic Surgeons, Adult Cardiac Surgery database specifications, version 2.52. Follow up data was aggregated from the linked Partners Health Care System, and primary care physicians or cardiologists documentation. Of the 52 patients alive at discharge, follow up was 92% complete. Mortality data was obtained from our internal research data repository, our state's Department of Public Health and Registry of Vital Statistics, through routine patient follow-up, or by query of the Social Security Death Index. Median follow-up duration was 3.5 years [interquartile range (IQR), 0.8–6.7 years].

Statistical analysis

Categorical variables are presented as percentage (number) and were evaluated using Fisher's Exact test. Continuous variables are presented as mean ± standard deviation if normally distributed or median and IQR if non-normally distributed. Analyses of continuous variables were done using student's *t*-test with Levine's homogeneity of variance or Mann-Whitney's U test as appropriate. Survival was estimated by Kaplan-Meier analysis with the Log Rank test for significance. Comparison of post-operative echocardiograms to baseline values was performed using the paired student's *t*-test. Cox proportional hazards modeling was used to evaluate predictors of survival. SPSS 13.0 statistical software (IBM, Chicago, IL, USA) was used for data analysis and $P \leq 0.05$ was the criterion of significance.

Results

A total of 57 patients underwent ITV surgery during the study period. Mean age was 54.4±14.9 years (range 23–83 years). Congestive heart failure was present in 38.6% (22/57), and 43.9% (25/57) were NYHA in class III/IV. The estimated EuroSCORE was 4.7±6.0. One patient required an emergent operation. *Table 1* shows preoperative baseline characteristics for the entire cohort and for those who underwent repair versus replacement. Eighteen patients underwent TVr and the TV was replaced in 39 patients (68%). There was no statistical difference in baseline characteristics between the TVR and TVr groups. The majority of patients, 54% (31/57) had history of at least one prior cardiac operation with 61% [11] of the repair group and 51% [20] of the replacement group (P=0.78). Of these reoperative cases, 29% (9/31) had prior TV surgeries (5 prior TVR, 4 TVr) (*Table 1*).

Etiologies

The majority of our patients (79%, 45/57) had severe TR of whom 52% had primary TV regurgitation. The primary indications for operative intervention were isolated TV endocarditis 25% (15/57), persistent TV insufficiency after left sided surgery 21% (12/57), traumatic biopsies and iatrogenic injury from pacing leads 19% (11/57), orthotopic

Table 1 Preoperative characteristics

Demographics	All patients (N=57)	Repair (N=18)	Replace (N=39)	P value
Age (yrs), mean (SD)	54.4 (14.9)	55.2 (16.5)	54.4 (14.4)	0.856
Females, n (%)	35 (61.4)	10 (55.6)	25 (64.1)	0.570
BMI (kg/m^2), mean (SD)	27.3 (5.7)	24.7 (4.1)	28.4 (6.1)	0.063
Diabetes, n (%)	8 (14.0)	3 (16.7)	5 (12.8)	0.698
Renal insufficiency, n (%)	6 (10.5)	2 (10.5)	4 (10.5)	1.000
Preop creatinine (mg/dL), mean (SD)	1.3 (0.8)	1.5 (1.3)	1.1 (0.5)	0.269
Atrial fibrillation, n (%)	6 (10.6)	2 (11.1)	4 (10.3)	1.000
Congestive heart failure, n (%)	22 (38.6)	9 (50.0)	13 (33.3)	0.256
NYHA class, n (%)				
I	9 (15.8)	3 (16.7)	6 (15.4)	1.000
II	23 (40.4)	9 (50.0)	14 (35.9)	0.388
III/IV	25 (43.8)	6 (33.3)	19 (48.7)	0.391
Endocarditis, n (%)	16 (28.1)	5 (27.8)	11 (28.2)	1.000
Liver function tests, mean (SD)				
Total bilirubin (mg/dL)	0.98 (0.81)	1.11 (0.79)	0.91 (0.82)	0.392
AST (U/L)	29.5 (31.5)	27.6 (16.1)	30.8 (37.0)	0.716
ALT(U/L)	22.0 (13.6)	21.8 (10.4)	22.1 (15.0)	0.935
Albumin(g/dl)	3.8 (0.9)	3.7 (1.0)	3.8 (0.8)	0.695
INR	1.30 (0.34)	1.38 (0.50)	1.26 (0.23)	0.333
Echographic data				
Ejection fraction (%), mean (SD)	56.8 (11.2)	56.8 (14.0)	56.8 (10.9)	0.983
Tricuspid regurgitation, n (%)				
Mild	1 (1.8)	0 (0.0)	1 (2.6)	1.000
Moderate	5 (8.3)	5 (26.3)	0 (0.0)	0.478
Severe	45 (79.1)	13 (73.7)	32 (81.6)	0.509
Emergent procedure, n (%)	1 (1.8)	0 (0.0)	1 (2.6)	1.000
Previous surgery, n (%)	31 (54.4)	11 (61.1)	20 (51.3)	0.775
OHT	9 (15.8)	2 (11.1)	7 (17.9)	0.704
AVR	2 (3.5)	1 (5.6)	1 (2.6)	1.000
ASD	1 (1.8)	1 (5.6)	0 (0.0)	0.316
CABG	3 (5.3)	1 (5.6)	2 (5.1)	1.000
MVR	11 (19.3)	5 (27.8)	6 (15.4)	0.297
TVR + other	5 (8.8)	1 (5.6)	4 (10.3)	1.000
Estimated euroSCORE, mean (SD)	4.7 (6.0)	5.3 (5.6)	4.6 (6.3)	0.663

NYHA, New York Heart Association, OHT, orthotopic heart transplant; AVR, aortic valve replacement; ASD, atrial septal defects; CABG, coronary artery bypass graft; MVR, mitral valve replacement; TVR, tricuspid valve replacement; SD, standard deviation.

Table 2 Etiologies of TV regurgitation

Etiologies of TV regurgitation	N=57
Primary	30
Endocarditis	15
Pacing wires/biopsies	6
Blunt chest trauma	5
Carcinoid disease	3
Ebstein anomaly	1
Secondary	27
Left heart disease (with/out prior surgery)	13
RV failure (infarction, pericarditis, ASD)	5
Orthotopic heart transplant	9

TV, tricuspid valve; RV, right ventricle; ASD, atrial septal defect.

heart transplant (OHT) in 16% (9/57), carcinoid syndrome 5% (3/57), congenital malformations 5% (2/57), and idiopathic TV insufficiency in 9% (5/57). The remaining 48% had secondary or functional TR as a result of left sided heart failure and pulmonary hypertension (*Table 2*).

Operative characteristics

Operative data for the two groups are summarized in *Table 3*. Cardiopulmonary bypass time and aortic cross-clamp time were similar for both TVr and TVR groups. Of the 39 patients undergoing replacement, 34 (86.1%) received bioprosthetic valves and 5 (13.9%) received mechanical valves. In the repair group, 61% (11/18) had ring annuloplasty alone, 17% (3/18) patients had bicuspidization of the TV and 17% (3/18) had De Vega type repair. One

Table 3 Operative data and postoperative outcomes

Variables	All patients (N=57)	Repair (N=18)	Replace (N=39)	P≤ A *vs.* B P values
Operative data				
Perfusion time (min), median (IQR)	125 (82, 167)	125 (55, 161)	126 (89, 183)	0.559
Cross-clamp time (min), median (IQR)	60 (45, 82)	56 (33, 79)	64 (47, 83)	0.500
Replacement, n (%)				
Bioprosthetic			34 (86.1)	
Mechanical			5 (13.9)	
Repair, n (%)				
Ring annuloplasty		11 (61.0)		
Bicuspidization		3 (17.0)		
De Vega annuloplasty		3 (17.0)		
Vegetectomy		1 (5.0)		
Postoperative complications				
Reoperation for bleed, n (%)	1 (1.8)	1 (5.6)	0 (0.0)	0.316
Stroke, n (%)	0 (0.0)	0 (0.0)	0 (0.0)	–
Deep Sternal Wound Infection, n (%)	1 (1.8)	1 (5.6)	0 (0.0)	0.316
Sepsis, n (%)	2 (3.5)	0 (0.0)	2 (5.1)	1.000
New onset renal insufficiency, n (%)	8 (14.0)	2 (11.1)	6 (15.4)	1.000
ICU stay (hrs), median (IQR)	53 (40, 117)	50 (45, 103)	69 (29, 127)	0.885
Postop LOS (days), median (IQR)	9 (6, 17)	9 (6, 16)	12 (6, 19)	0.770
Operative mortality, n (%)	5 (8.8)	3 (16.7)	2 (5.1)	0.312

ICU, intensive care unit; LOS, length of stay.

Table 4 Surgical approach

Approach	n
Surgical approach [no prior surgery (N=25)/reoperations (N=32)]	
Sternotomy	21/26
Mini-sternotomy	2/1
Mini-thoracotomy	2/4
Transcatheter	0/1
Cannulation technique (N=57)	
Ao/SVC-IVC	26
FA/SVC-FV	12
Ao/SVC-FV	10
Right axillary A/SVC-FV	3
Right axillary A/SVC-IVC	2
FA/FV-IJ	2
FA/FV (advanced to SVC)	2

Ao, aorta; SVC, superior vena cava; IVC, inferior vena cava; FV, femoral vein; FA, femoral artery; IJ, internal jugular vein.

patient with a history of intravenous drug use presented with active endocarditis had vegetectomy on the septal leaflet and chordae of the anterior leaflet, leaving the valve with very mild regurgitation.

Surgical approach

Surgical approaches and cannulation techniques are outlined in *Table 4*. Midline sternotomy was the most common approach in patients with and without prior surgery, 81.3% (26/32) and 84% (21/25), respectively. Access to the right atrium was obtained through mini right thoracotomy and lower mini sternotomy in two patients undergoing first time heart surgery versus four mini right thoracotomies, one lower mini sternotomy, and one transcatheter approach in a reoperative patient. Standard aortic and bicaval cannulation was used in 43% (25/57). It was also favored in first time operations 68% (17/25). For patients deemed to be high-risk reoperative candidates, cannulation through femoral vessels was used. A total of 50.9% (29/57) of the operations were performed on the beating heart without aortic cross clamp.

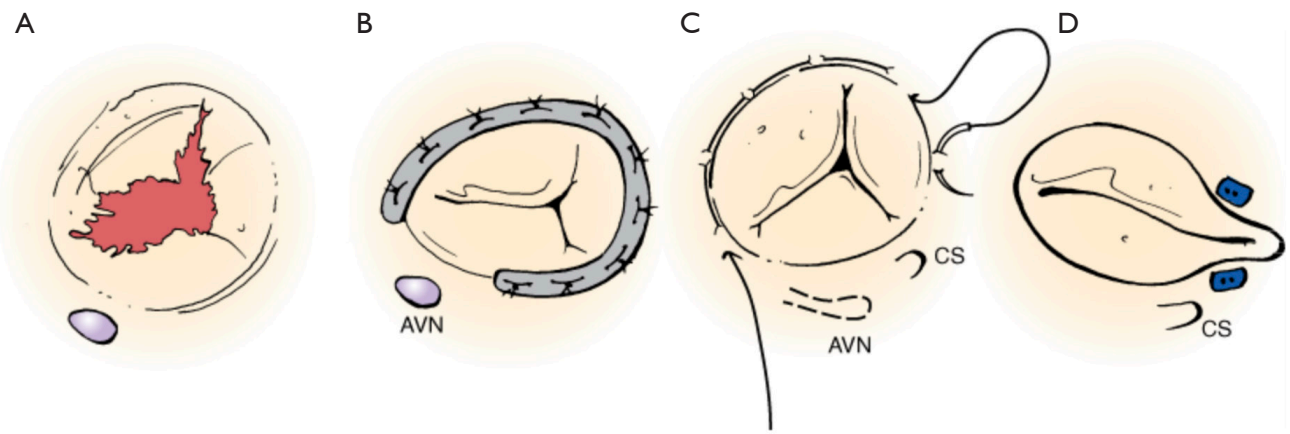

Figure 1 Predominant surgical repair techniques for functional tricuspid regurgitation (TR) in the presence of a dilated annulus. (A) Dilated tricuspid annulus with abnormal circular shape, failure of leaflet coaptation, and resultant TR; (B) rigid or flexible annuloplasty bands are used to restore a more normal annular size and shape (ovoid), thereby reducing or eliminating TR. The open rings spares the atrioventricular node (AVN), reducing the incidence of heart block; (C) DeVega suture annuloplasty partially plicate the annulus reducing annular circumference and diameter; (D) suture bicuspidalization is performed by placement of a mattress suture from the anteroposterior to the posteroseptal commissure along the posterior annulus. CS, coronary sinus. From: Shemin RJ. Chapter 46. Tricuspid Valve Disease. In: Cohn LH. editor. Cardiac Surgery in the Adult, 4e. New York, NY: McGraw-Hill, 2012. With permission from McGraw-Hill.

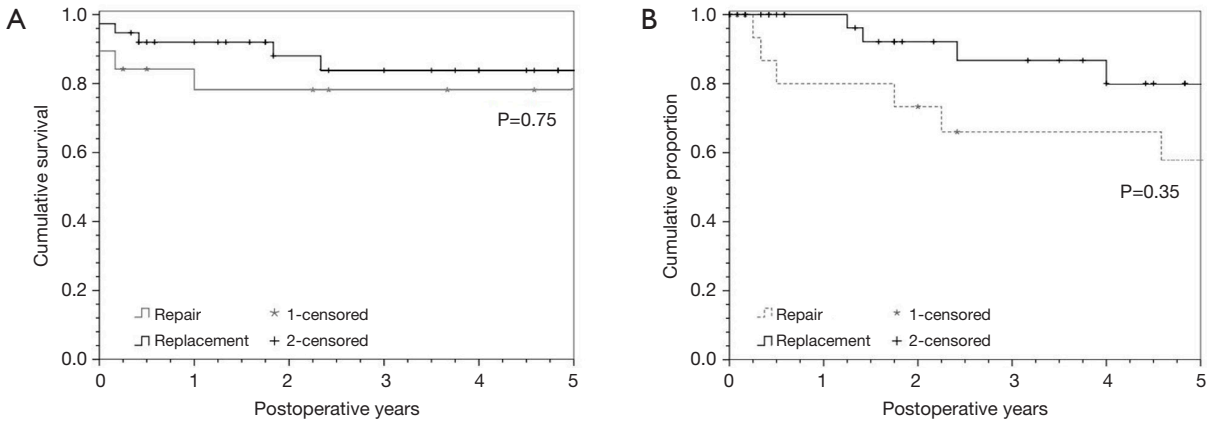

Figure 2 Survival curves for the entire cohort. (A) Showing overall postoperative survival between isolated tricuspid valve repair and replacement; (B) composite proportion of patients without return of moderate/severe TR/RH failure or TV reoperation.

Figure 1 illustrates the types of TVr techniques utilized.

Postoperative outcomes

Overall operative mortality was 8.8% (5/57). Operative mortality was 5.1% (n=2) and 16.7% (n=3) in the TVR and TVr groups, respectively (P=0.312). There were no strokes. Eight (14%) patients developed new onset renal failure but only two required permanent dialysis. Median ICU stay was 53 hrs (IQR 40–117 hrs) and median postoperative length of stay (LOS) was nine days (IQR 6–17 days) (*Table 3*). There were no statistical differences in outcomes between the TVr and TVR groups. One patient returned to the operating room on post-operative day one for a right hemothorax but no source of bleeding was identified. One patient with a history of chest radiation for Hodgkin's lymphoma undergoing TV bicuspidization developed a deep sternal wound infection (DSWI) and subsequent multisystem organ failure.

Of the 52 surviving patients, echocardiographic data was available for 48 (92%) with a median time to echo of 2.2 years (IQR 0.5–5.1 years). Recurrent moderate or severe TR occurred in 35.7% (5/14) TVr patients and 17.6% (6/34) TVR patients (P=0.34). Among patients with severe TR at baseline, more patients undergoing repair had severe TR at follow-up, compared to those undergoing replacement (61.5%, 8/13 *vs.* 14.8%, 4/27 respectively, P<0.008).

Postoperative survival

Median actuarial survival for the entire cohort was 9.5 years (IQR 8–10.9 yrs). TVr survival at one and three years was 83% and 77% respectively and 91% and 88% in the TVR group (*Figure 2A*, P=0.75). Due to the small numbers of patients that required reoperations or had recurrent TV insufficiency, a composite event-free outcome was defined. Event-free survival was defined as survival without recurrent TV regurgitation, reoperation, or RH failure *Figure 2B*. While the replacement group appeared to have better event-free outcomes, this difference was not statistically significant (P=0.35).

Cox proportional hazards analysis was performed to identify predictors of poor survival for isolated TV surgery. Predictors of worse postoperative survival included NYHA class IV (HR 16.393; 95% CI, 13.593–19.194, P<0.001), prior cardiac surgery (HR =9.838; 95% CI, 7.790–11.886, P=0.029), and total bilirubin (HR =2.134; 95% CI, 1.681–2.587, P<0.001). Age, ascites, preoperative diuretic use, renal insufficiency, and RV dysfunction were found to be non-contributory, as was valve repair versus replacement (P=0.75).

Discussion

Patients undergoing ITV operations are at relatively higher operative risk because of high rates of previous cardiac operations, NYHA class ≥ III, and the etiologies requiring TV interventions, including prior left sided valve surgery and iatrogenic causes such as pacemaker lead damage or endomyocardial biopsies.

Eighty-six percent of TV operations are performed in conjunction with another major procedure, usually left sided valve operations, highlighting the relative rarity

of isolated TV surgery (1). Indications to intervene for isolated TV disease remain poorly defined, and reported outcomes are limited. According to the 2014 ACC/AHA recommendations, indications for isolated TV procedures includes patients with symptomatic, severe TV regurgitation or asymptomatic with progressive RV annular dilation (>40 mm) and/or systolic dysfunction (2). Symptoms generally include dyspnea due to congestive heart failure, tachyarrhythmia intractable to other therapy, progressive cardiomegaly, and other associated cardiac pathology. Timing of surgery for TV regurgitation is dependent on the etiology of TV disease, which can be divided into two main categories of primary and secondary TR, and degree of RV dysfunction. For patients with symptomatic primary TV regurgitation unresponsive to medical therapy, TV surgery is generally recommended before the onset of significant RV dysfunction (2). Due to extent and severity of the underlying pathology, we generally replace the TV in patients with carcinoid and Ebstein's anomaly.

The incidence of tricuspid regurgitation after OHT has been estimated to range from 19 to 84%. Nine of our patients had previous OHT. Two underwent TV repair, while seven underwent TV replacement (*Table 1*). The exact etiology of TV regurgitation after OHT is unknown. Anastomotic technique, donor/recipient size characteristics, number of cellular rejections, and iatrogenic injury during endomyocardial biopsies have all been implicated (9). TR at the time of OHT has been shown to predict poor late survival, though it is unclear if TV interventions at the time of OHT will improve long-term outcomes (10). In our series, there was a 33% (3/9) mortality in the OHT group at follow up.

Trauma is a rare but well described etiology of TV incompetence (11,12). TV pathology after blunt trauma is less common than aortic valve injury (12) and medical management is possible if TR is well tolerated. Indeed, post-traumatic median time to operation was 14.5 years (range, 5 months–36 years) for four patients.

Carcinoid valvular disease was present in 5% (3/57) of our patients. One of these patients died, reflecting the known high mortality associated with this disease process. Carcinoid disease of the TV occurs in about 40–50% of patients with carcinoid tumors (13,14) and large reviews have shown risk reduction with tricuspid valve replacement (TVR) (15). Each of our patients with carcinoid valvular disease underwent valve replacement. Death occurred in an extremely high risk patient with metastatic carcinoid syndrome with liver involvement and ascites, who had a prolonged post-operative course but died from complications related to cancer four months post-operatively.

Comparison of outcomes

At follow up, five patients in the repair group had failures of the repair with recurrent moderate/severe TR. Of these five patients, two had bicuspidization and three had ring annuloplasty. Published results are mixed regarding the superiority of different repair techniques for the TV, but a review of the literature suggest that ring annuloplasty and De Vega annuloplasty are superior to bicuspidization (16-21). Residual RV dysfunction was also more common in the repair group, 14.3% *vs.* 5.9% in the replacement group (P=0.57). These differences in residual TR and RV dysfunction did not translate into a mortality difference between the two groups, likely due to small numbers. Also, patients who underwent TV repair had a higher incidence of postoperative residual TV regurgitation compared to the replacement group. While our 17.6% rate of residual TV regurgitation in the replacement group is relatively high, it is within range of the few studies in the literature that report this information. Buzzatti *et al.* and Pfannmuller *et al.* reported residual TV regurgitation in 13.9% and 17% respectively after TV replacement (3,6). The reasons for this are unclear and could be due to failure or improper remodeling of the RV geometry after TV replacement. Right ventricular geometry remodeling and function has been shown to improve after TV surgery (22).

Others have reported on the results of isolated TV operations infrequently. Oh *et al.* (23) in a series of 72 isolated TV operations spanning from 1965–2011 reported an overall early mortality of 12.5%; with a mortality rate of 7.9% for repair *vs.* 17.6% for replacement. While Raikhelkar *et al.* (24) in a series of 56 patients reported an overall in-hospital mortality rate of 14.2% with 13.8% *vs.* 14.8% for repair and replacement respectively. In our series, the overall early mortality was 8.8% with 16.7% and 5.1% in the repair and replacement groups respectively. Although our overall mortality for isolated TV is lower, like these two prior studies, there was no statistically significant difference when TV repair was compared to replacement. This is likely the result of small numbers, and a meta-analysis of all these studies might show superiority of either repair or replacement.

In the review by Kilic *et al.* (1), operative mortality for TV surgery had declined from 10.6% in 2000 to 8.2% in

2010 in both unadjusted and risk adjusted analyses. This large study, which included concomitant procedures, showed this trend toward decreased mortality despite increasing patient co-morbidities (1). Our series spans a decade of experience and represents evolving approaches and techniques. We believe our relative low operative mortality of 8.8% (5/57) is the result of careful patient preparation including pre-operative medical optimization.

Study limitations

The limitations to our study include those inherent to retrospective analyses. As a large referral center our patient population and resources may not apply to all facilities. Also, the heterogeneity of patients who present with TV failure, which is seen in general, make comparisons of TV repair and replacement difficult. However, in our study the preoperative characteristics between the two groups did not significantly differ from each other. Yet our approach of patient selection, use of minimally invasive incisions when appropriate, and conservative cannulation strategies for re-operations are widely applicable in experienced hands and do not require extensive resource utilization. The small size of our series represents the infrequency of this operation but we presented the breadth of etiologies for comparison.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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