Tricuspid Valve Surgery and Intraoperative Echocardiography

Factors Affecting Survival, Clinical Outcome, and Echocardiographic Success

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Background. The impact of echocardiographic-guided treatment on outcome after tricuspid valve (TV) surgery is not well defined.

Objectives. The purpose of this study was to determine clinical and echocardiographic factors associated with adverse outcomes after TV surgery and determine the role of intraoperative echo (IOE) in facilitating successful outcomes after TV surgery.

Methods. Four hundred and one patients (279 females, mean age 60 years) underwent TV surgery and other concomitant cardiac surgery at a single institution and were followed clinically and by echocardiography during a 10-year period.

Results. Decreased survival after TV surgery was associated with: preoperative increased New York Heart Association (NYHA) functional classification (relative risk [RR] = 2.02), increased left ventricular dysfunction by echocardiography (RR = 1.28), and use of a TV replacement strategy (RR = 2.92). Decreased event-free survival after TV surgery was associated with concomitant coronary artery bypass grafting (RR = 2.97). Late echocardiographic failure (3 to 4+ tricuspid valve regurgitation [TR]) after TV surgery was associated with increased severity of TR on preoperative echocardiogram (odds ratio [OR] = 1.91). Decreased late echocardiographic failure after TV surgery was associated with the use of a TV annuloplasty ring with a repair strategy (OR = 0.40). The surgical plan was altered at the time of surgery to insure a successful outcome in 32 (10%) of 335 patients based on IOE findings.

Conclusions. Adverse outcomes after TV surgery can be predicted by several preoperative clinical and echocardiographic variables. IOE is useful in improving immediate, but not late, outcomes after TV surgery.

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Clinical risk factors associated with increased mortality after surgery to correct a dysfunctional tricuspid valve (TV) include: the presence of coronary artery disease (1–3), increased New York Heart Association (NYHA) functional class (1–8), a history of prior cardiac surgery (4,9), the presence of signs and symptoms of congestive heart failure (1,5,7,9), the presence of signs and symptoms of significant primary pulmonary disease (1,10), and male gender (5,7,9).

Echocardiography has developed into an indispensable adjunct to the clinical interview and physical examination for preoperative and postoperative evaluation of cardiac pathophysiology in the setting of valvular heart disease. The use of intraoperative echocardiography (IOE) is beneficial in insuring a successful immediate outcome after cardiac valvular surgery (11–19). Evidence of such benefit is most compelling with the use of IOE in the surgical repair of the dysfunctional mitral valve (20). Evidence of the benefit of the use of IOE in the surgical repair of the dysfunctional TV (12–19) is limited by a smaller number of patients evaluated in fewer studies compared with mitral valve surgery. No prior study has specifically examined what association exists, if any, between preoperative and intraoperative echocardiographic findings and the clinical and echocardiographic outcomes after TV surgery. The purpose of this study was to determine which of several preoperative and intraoperative clinical and echocardiographic factors are associated with adverse clinical and echocardiographic outcomes after TV surgery. A secondary purpose of this large cohort study was to demonstrate the benefit, if any, of the use of IOE on both the clinical and echocardiographic outcomes of TV surgery.

Methods

Study population. The study population consisted of 401 patients who underwent initial TV surgery, with and without other concomitant surgical procedures, over a 10-year period at a single tertiary referral center (The Cleveland Clinic Foundation), and had complete preoperative and follow-up echocardiograms. The study population excluded patients who...
had no preoperative or follow-up echocardiogram, and was divided into two groups for the purpose of comparison, as depicted in Figure 1. The use of IOE was based on availability of echocardiographic equipment and the individual surgeon’s preference.

Echocardiographic criteria for severity of tricuspid regurgitation. The severity of tricuspid regurgitation (TR) was assessed semi-quantitatively using pulsed-wave Doppler (21–24) and/or contrast (25–27) and/or color (18,28) Doppler flow mapping of the spatial distribution of the regurgitant jet within the right atrium. The dimensions and/or area of the regurgitant jet were compared with the right atrial dimensions and/or area in several planes, and the comparison was translated to a semi-quantitative (0 to 4+) grading scale (18,22,28–30) corresponding to no, mild, moderate, moderately severe, and severe regurgitation, respectively.

Echocardiographic criteria for severity of ventricular dysfunction. Global measurements of left ventricular systolic function were made using accepted systolic indices of the dimensions or volume of the left ventricular chamber (31). Global measurements of right ventricular systolic function were made using the excursion of the tricuspid annulus in systole in an apical four-chamber view (32). Less frequently, contrast echocardiography was used to obtain a measure of right ventricular ejection fraction (33,34). The obtained measurements were routinely translated to a semi-quantitative, five-category grading scale corresponding to normal, mild, moderate, moderately severe, and severe ventricular dysfunction, respectively.

Preoperative and follow-up echocardiographic assessment. Preoperative two-dimensional and Doppler flow echocardiography was performed with either a transthoracic (92%) or transesophageal (2%) transducer, or both (6%), to optimize the imaging and Doppler data obtained. Several commercially available echocardiographic systems (Hewlett-Packard; Acuson) were used during the study period. Color Doppler gain controls were adjusted to obtain a barely perceptible amount of background color “speckle” in the far field. Evaluation of TR was performed as described using multiple imaging planes. Echocardiographic studies were recorded on high-fidelity VHS tape for replay review and archival storage. Clinical interpretation reports, based on a consensus of at least two experienced echocardiographers, were generated based on findings read on the echocardiogram using real-time review or replay review, or both.

Intraoperative echocardiographic assessment. Intraoperative echocardiography was performed with either an epicardial (14.5%) or a transesophageal transducer (72%), or both (13.5%), to optimize the imaging and Doppler data obtained. Both epicardial and transesophageal echocardiograms were performed according to standard published and accepted techniques (11,12,35,36). Initial imaging was performed after endotracheal intubation and induction of general anesthesia, but before instituting cardiopulmonary bypass. Subsequent imaging was obtained during the operation as warranted and at the completion of the surgical procedure after removal of cardiopulmonary bypass support and stabilization of hemodynamics. Multiple imaging planes were used for Doppler mapping of TR, including a four-chamber view. The severity of TR was analyzed and graded online by an experienced echocardiographer with transducer in hand.

Intraoperative surgical assessment. Annuloplasty techniques not assessed with IOE were assessed using accepted surgical techniques of insufflation and/or digital exploration of the right atrial cavity to detect and grade the severity of any residual TR (37,38). Appropriate surgical adjustment could then be performed to minimize TR detected by these methods.

### Abbreviations and Acronyms
- IOE = intraoperative echocardiogram or intraoperative echocardiography
- NYHA = New York Heart Association
- OR = odds ratio
- RR = relative risk
- TR = tricuspid valve regurgitation
- TV = tricuspid valve

Figure 1. Diagram of the patient population demonstrating the use of preoperative, intraoperative, and postoperative echocardiography.
However, DeVega’s sliding annuloplasty (39) was infrequently performed. A suture annuloplasty was routinely performed based on the size of the fibrous portion of the tricuspid annulus and the size of the septal leaflet of the TV.

Echocardiographic criteria for tricuspid valve repair failure. Echocardiographic failure of TV surgery was designated as a postoperative echocardiographic study demonstrating grade 3+ or 4+ TR. If the postcardiopulmonary bypass intraoperative echocardiographic study demonstrated TV repair failure, the patient had, at the echocardiographer’s recommendation and the surgeon’s discretion, a second cardiopulmonary bypass run to correct the residual regurgitation during the same thoracotomy (Fig. 2).

Clinical data. Clinical data were abstracted from review of patient charts, regular follow-up of patients using mail surveys and telephone interviews, and communications with referring physicians. Pulmonary disease was defined in this study as the presence of any one of the following established diagnoses: chronic obstructive lung disease, other chronic lung disease, or history of pulmonary embolus.

Adverse clinical events criteria. Four adverse clinical events pertinent to the study purpose were tracked in follow-up and included: death, recurrence of any number of the constellation of symptoms that prompted the initial TV surgery, the occurrence of any number of cardiac symptoms attributed to congestive heart failure, and any combination of the above symptoms, along with an echocardiographic assessment of TV repair failure that led to a second TV surgery. Adverse clinical events were closely tracked and formally updated by patient contact on an every-other-year basis for each patient as part of the designed operation and maintenance of a surgical valve registry.

Statistics. Categorical and ordinal data were compared using a chi-square test to ascertain an overall p value, and then the two groups were compared at each level (40). Continuous variables with a normal distribution were compared using the t test. Non-normally distributed continuous data were compared using Wilcoxon rank sum test. The Kaplan-Meier method was used to compute survival statistics, and the log-rank statistic was used to compare the survival curves. The 0.05 significance level was used to determine statistical significance for all comparisons.

Cox regression was used to determine risk factors for death, adverse clinical events, and adverse clinical events, or death. Analyzed risk factors included: age; gender; NYHA functional class; hypertension; pulmonary disease; cardiomegaly on chest x-ray; prior cardiac surgery; degree of severity of valvular regurgitation and stenosis for the mitral, aortic, and tricuspid valves; degree of left and right ventricular dysfunction; degenerative valve disease; rheumatic valve disease; concomitant aortic or mitral valvular surgery; use of valve repair or replacement strategy for the mitral, aortic, and tricuspid valves; use of an annuloplasty ring for tricuspid repair; concomitant coronary artery bypass surgery; and the use of IOE. Logistic regression was used to determine risk factors for surgical failure. Analyzed risk factors were identical to those analyzed for the Cox regression models. The multivariable models were built in a step-wise fashion with age and gender always included in each model.

Results

Preoperative demographics and echocardiographic findings. Preoperative study population demographics, frequencies of comorbidities, and echocardiographic findings as demonstrated on the preoperative echocardiogram are shown in Table 1. The frequency of moderately severe to severe mitral stenosis and moderately severe to severe aortic stenosis were greater in the group who did not undergo IOE.

Types of tricuspid valve surgery and other concomitant surgeries. The types of TV surgical procedures and other concomitant surgeries performed are shown in Table 2. Other less frequently performed TV procedures included commissurotomy, decalcification, and chordoplasty. Tricuspid valve annuloplasty with a Carpentier-Edwards ring, TV annuloplasty without an annuloplasty ring (suture annuloplasty), and mitral valve replacement occurred more frequently in the study group who did not undergo IOE. Tricuspid annuloplasty with a
Table 1. Study Population Preoperative Demographics and Echo Findings

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Intraoperative Echo (n = 335)</th>
<th>No Intraoperative Echo (n = 66)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Median (range)</td>
<td>63 (45–70)</td>
<td>66 (40–72)</td>
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<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>237 (71%)</td>
<td>42 (64%)</td>
<td>0.251</td>
</tr>
<tr>
<td>Male</td>
<td>98 (29%)</td>
<td>24 (36%)</td>
<td>0.251</td>
</tr>
<tr>
<td>Pulmonary disease</td>
<td>224 (67%)</td>
<td>43 (63%)</td>
<td>0.787</td>
</tr>
<tr>
<td>EKG</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Atrial fibrillation</td>
<td>3 (1%)</td>
<td>0 (0%)</td>
<td>0.436</td>
</tr>
<tr>
<td>L/R bundle branch block</td>
<td>35 (10%)</td>
<td>6 (9%)</td>
<td>0.739</td>
</tr>
<tr>
<td>L/R ventricular hypertrophy</td>
<td>56 (17%)</td>
<td>14 (21%)</td>
<td>0.379</td>
</tr>
<tr>
<td>Chest x-ray</td>
<td>261 (78%)</td>
<td>56 (85%)</td>
<td>0.206</td>
</tr>
<tr>
<td>NYHA Functional Class</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>0</td>
<td>8 (2%)</td>
<td>1 (2%)</td>
<td>0.604</td>
</tr>
<tr>
<td>I</td>
<td>44 (13%)</td>
<td>5 (8%)</td>
<td>0.130</td>
</tr>
<tr>
<td>II</td>
<td>152 (45%)</td>
<td>29 (44%)</td>
<td>0.783</td>
</tr>
<tr>
<td>III</td>
<td>100 (30%)</td>
<td>19 (29%)</td>
<td>0.828</td>
</tr>
<tr>
<td>IV</td>
<td>28 (8%)</td>
<td>12 (18%)</td>
<td>0.051</td>
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<td>Echo Findings</td>
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<td></td>
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<tr>
<td>Moderately-severe to severe</td>
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<td></td>
<td></td>
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<tr>
<td>(3+ to 4+)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tricuspid regurgitation</td>
<td>259 (77%)</td>
<td>52 (80%)</td>
<td>0.634</td>
</tr>
<tr>
<td>Tricuspid stenosis</td>
<td>2 (1%)</td>
<td>1 (2%)</td>
<td>0.421</td>
</tr>
<tr>
<td>Mitral regurgitation</td>
<td>188 (56%)</td>
<td>32 (48%)</td>
<td>0.212</td>
</tr>
<tr>
<td>Mitral stenosis</td>
<td>41 (12%)</td>
<td>17 (26%)</td>
<td>0.004</td>
</tr>
<tr>
<td>Aortic regurgitation</td>
<td>27 (8%)</td>
<td>7 (11%)</td>
<td>0.473</td>
</tr>
<tr>
<td>Aortic stenosis</td>
<td>20 (6%)</td>
<td>11 (17%)</td>
<td>0.003</td>
</tr>
<tr>
<td>Left ventricular dysfunction</td>
<td>18 (5%)</td>
<td>5 (8%)</td>
<td>0.558</td>
</tr>
<tr>
<td>Right ventricular dysfunction</td>
<td>17 (5%)</td>
<td>3 (5%)</td>
<td>1.000</td>
</tr>
</tbody>
</table>

PeriGuard ring, and mitral valve replacement, occurred more frequently in the study group who did undergo IOE.

Immediate surgical outcome. The immediate surgical outcome as determined by the use of IOE is shown in Figure 3. Overall, 10% of preoperative surgical plans were altered based on the findings of IOE with the goal of facilitating a successful immediate surgical outcome for each patient.

Follow-up echocardiographic outcome. Findings at the time of echocardiographic follow-up are shown in Table 3. Echocardiographically defined failure of TV surgery occurred in 52 (13%) of all patients undergoing TV surgery.

Risk of clinical end points. Results of multivariable analyses of death, the occurrence of an adverse clinical event after TV surgery, and the combined end point of death or the occurrence of an adverse clinical event after TV surgery in the 401 study patients are shown in Figure 4. Increased relative risk of death after TV surgery was independently associated with a higher preoperative NYHA functional classification (relative risk [RR] 2.02, 1.39–2.95; p < 0.001), increased degree of left ventricular dysfunction on preoperative echo (RR 1.28; 1.08–1.51, p = 0.005), and with the use of a TV replacement strategy (RR 2.92, 1.46–5.84; p = 0.002). Increased RR of the occurrence of an adverse clinical event was significantly associated with coronary artery bypass surgery performed concomitantly with TV surgery (RR 2.97, 1.39–6.36; p = 0.005). Increased relative risk of death or the occurrence of an adverse clinical event was associated with a higher preoperative NYHA functional class (RR 1.91, 1.35–2.68; p < 0.001), an increased degree of left ventricular dysfunction on preoperative echo (RR 1.18, 1.01–1.39; p = 0.039), the use of a TV replacement strategy (RR 3.33, 1.77–6.26; p < 0.001), and coronary artery bypass surgery performed concomitantly with TV surgery (RR 1.52, 1.02–2.28; p = 0.042). Decreased relative risk of death or the occurrence of an adverse clinical event was significantly associated with a mitral valve replacement strategy performed concomitantly with TV surgery (RR 0.70, 0.49–0.99; p = 0.045) when both valves were sufficiently dysfunctional to require surgical correction.

Risk of echo failure of tricuspid surgery. Results of multivariable analysis of echofailure of tricuspid surgery are shown in Figure 4. Increased odds ratio of echocardiographic failure of TV surgery was significantly associated with increased severity of TR on preoperative echo (OR 1.91, 1.27–2.88; p = 0.002). A significant decreased relative risk of echocardiographic failure of TV surgery was associated with the use of a tricuspid annuloplasty ring with a repair strategy (OR 0.40, 0.21–0.76; p = 0.005).

Seven adverse clinical events occurred in the group of 52 patients that had echocardiographic failure of TV surgery: two
patients had return of original symptom(s) prompting surgery, two patients had the occurrence of heart failure symptom(s), and three patients required reoperation for symptomatic TV dysfunction. However, echocardiographic failure of TV surgery was not significantly associated with the occurrence of an adverse clinical event after TV surgery ($p = 0.296$).

**Follow-up clinical outcome.** Kaplan-Meier survival probability and event-free survival probability curves for the two study population groups are shown in Figure 5. Eight-year survival probability for the entire study population was 50%. By analyzing the follow-up clinical data for the previously specified adverse clinical events (death, recurrence of original symptom(s) prompting surgery, occurrence of heart failure symptom(s), reoperation for symptomatic TV dysfunction), event-free survival probability was determined. Eight-year event-free survival probability for the entire study population was 40%.

**Discussion**

The clinical value and prognostic implications of data obtained from preoperative and intraoperative echocardiography in the surgical management of TV dysfunction was previously less well defined. This study identifies several clinical and echocardiographic factors (NYHA functional class, left ventricular dysfunction, TV replacement strategy, and concomitant coronary artery bypass grafting) associated with an increased risk of morbidity and mortality after TV surgery. The severity of TR, determined by preoperative echocardiography, was found to be predictive of the follow-up echocardiographic outcome after TV surgery. Intraoperative echocardiography provided information relevant to ensuring a successful immediate echocardiographic outcome in 10% of TV surgical procedures utilizing IOE.

**Survival.** The clinical and echocardiographic factors, corrected for age and gender, independently associated in this study with decreased survival after TV surgery include: increased preoperative NYHA functional class, increased left ventricular dysfunction on preoperative echo, and the use of a TV replacement strategy. Previous studies have shown that increased preoperative NYHA functional class is a risk factor associated with increased mortality after TV surgery (1,2,4,6–8). Similarly, increased left ventricular dysfunction has been associated with increased mortality using invasive contrast ventriculography to evaluate left ventricular function (10). The finding that the use of a TV replacement surgical strategy was associated with an increased relative risk of death was anticipated based on several prior reports, but contradicts some previous reports (9,37). The overall 8-year survival of 50% is lower than (38,41–43), equivalent to (44–46), and less than (3,7,9,47) several previously reported values. Similar comparisons can be made with event-free survival. The overall survival and event-free survival are, to a large extent, inherent descriptors of the study population, in addition to reflecting the effects of diagnostic and therapeutic interventions.

**Event-free survival.** An increased preoperative NYHA functional class, increased left ventricular dysfunction on preoperative echo, the use of a TV replacement strategy, and performance of concomitant coronary artery bypass surgery are associated with a reduced event-free survival. These findings are in excellent agreement with previous findings in this study for death and clinical events alone, as well as previous findings of other studies (1–7,9,10). Adverse clinical events have been associated in previous studies with increased severity of TR on preoperative evaluation (1), the presence of severe mitral valve dysfunction (3), the presence of severe right ventricular dysfunction (5,7,9) and the presence of significant

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**Table 3. Study Population Postoperative Echo Findings**

<table>
<thead>
<tr>
<th></th>
<th>Intraoperative Echo (n = 335)</th>
<th>No Intraoperative Echo (n = 66)</th>
<th>Overall p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderately-Severe to Severe (3+ to 4+):</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Tricuspid regurgitation</td>
<td>43 (13%)</td>
<td>9 (14%)</td>
<td>0.825</td>
</tr>
<tr>
<td>Tricuspid stenosis</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>—</td>
</tr>
<tr>
<td>Mitral regurgitation</td>
<td>20 (6%)</td>
<td>5 (8%)</td>
<td>0.578</td>
</tr>
<tr>
<td>Mitral stenosis</td>
<td>1 (0%)</td>
<td>0 (0%)</td>
<td>1.000</td>
</tr>
<tr>
<td>Aortic regurgitation</td>
<td>0 (0%)</td>
<td>1 (1%)</td>
<td>0.162</td>
</tr>
<tr>
<td>Aortic stenosis</td>
<td>1 (0%)</td>
<td>0 (0%)</td>
<td>1.000</td>
</tr>
<tr>
<td>Left ventricular dysfunction</td>
<td>36 (11%)</td>
<td>4 (6%)</td>
<td>0.135</td>
</tr>
<tr>
<td>Right ventricular dysfunction</td>
<td>28 (8%)</td>
<td>4 (6%)</td>
<td>0.569</td>
</tr>
</tbody>
</table>
primary pulmonary disease (1). However, this study did not confirm these previous findings.

Risk of echo failure of tricuspid valve surgery. Identification by the present study of increased severity of TR on preoperative echo as a risk factor for echocardiographic failure of TV surgery represents a new finding. However, increased severity of TR as determined by cardiac catheterization was previously identified as a risk factor for increased mortality in the setting of TV replacement surgery (1).

Clinical significance of echo failure of tricuspid valve surgery. Controversy exists over the clinical significance of the demonstration of echocardiographic failure after TV surgery. One study has demonstrated that the occurrence of severe, symptomatic TR late after mitral valve replacement is associated with right ventricular failure and portends a poor prognosis (48). In addition, the surgical repair of significant TR late after mitral valve replacement did little to improve survival, and TV surgery was recommended to be performed at the time of the original mitral valve surgery, if significant TR was present (48). In our study, right ventricular function evaluated preoperatively was not significantly associated with an increased relative risk for death, adverse clinical event, or echocardiographic failure of TV surgery. Significant, grade 3+ or 4+ TR has been shown by several authors to be a negative prognostic factor if not surgically corrected (1,5,37,48,49). It appears logical that echocardiographic failure of TV surgery would be associated with an increased risk of death or the occurrence of an adverse clinical event. In our study, however, no significant association was demonstrated between the presence of echocardiographic failure of TV surgery and death after TV surgery (p = 0.183). Similarly, two previous studies (42,43) have demonstrated no relation between the presence of significant TR after TV replacement surgery and the occurrence of adverse clinical symptoms.

Figure 4. Relative risk of death, adverse clinical event, death or adverse clinical event, and odds ratio of echocardiographic failure after tricuspid valve surgery.
Type of tricuspid valve surgery. In this study TV repair strategies predominated, and the use of an annuloplasty ring with a repair strategy was associated with a significant decreased relative risk of echocardiographic failure of TV surgery. This leads us to conclude, along with previous authors (8,50), that an annuloplasty ring with a repair strategy is a preferable method of correcting TV dysfunction, when technically feasible.

Concomitant coronary artery bypass grafting. The performance of concomitant coronary artery bypass grafting was identified as an independent risk factor for decreased event-free survival associated with TV surgery. A previous study (2) had identified the presence of coronary artery disease as an independent risk factor for death in TV replacement with a CarboMedics prosthetic valve. Other authors have shown that combined valve operations and coronary artery bypass grafting have a higher risk of death than either procedure performed alone (51–53).

Concomitant mitral valve surgery. Interestingly, a mitral valve replacement strategy to correct significant mitral valve dysfunction used concomitantly with TV surgery to correct significant TV dysfunction was independently associated with a decreased relative risk of the combined endpoint of death or the occurrence of an adverse clinical event after TV surgery. In contrast, mitral valve surgery in general, or a mitral valve repair strategy in specific, performed concomitantly with TV surgery when both were indicated to correct significant valvular dysfunction, were not significantly associated with a decreased or increased relative risk of the combined endpoint of death or the occurrence of an adverse clinical event after TV surgery. When both the mitral and tricuspid valves are sufficiently dysfunctional to both require surgery, replacement of the mitral valve and repair of the TV with the use of an annuloplasty ring is the surgical strategy associated with the most favorable outcome.

Benefit of intraoperative echo. This study demonstrated an objective benefit of the use of IOE on the immediate outcome of TV and other cardiac valvular surgery. The use of IOE in TV and other cardiac valve surgery prevented a significant number of patients from leaving the operating room with either undiscovered or inadequately corrected valve dysfunction that could have translated to an increased postoperative morbidity and mortality (48).

Our study failed to demonstrate a significant association of either benefit or detriment with the use of IOE and the observed outcome of TV surgery with respect to mortality, echocardiographic failure of TV surgery, the occurrence of an adverse clinical event, or the combined end point of death or the occurrence of an adverse clinical event. This may be due to an inadequate sample size to detect such an association, or that comorbidities such as left ventricular dysfunction, coronary artery disease, and the progression of underlying valvular pathology are the dominant determinants of long-term outcomes.

Limitations. A surgical bias existed against the use of intraoperative echo in the setting of significant concomitant mitral or aortic stenosis when a valve replacement strategy was frequently planned. A second surgical bias favored the use of intraoperative echo in the setting of a mitral valve repair strategy. The limitations of this study include the surgical bias and the inherent bias and limitations associated with a cohort study. Conclusive demonstration of an association of significant benefit or detriment with the use of IOE and outcomes of TV or other cardiac valvular surgery would require a large longitudinal randomized, controlled trial. In the absence of such a trial, cohort studies with large patient numbers, such as this one, provide limited surrogate information toward demonstrating the benefit of the use of IOE in facilitating successful outcomes after TV surgery.

Conclusions. This study identified clinical and echocardiographic factors associated with adverse clinical and echocardiographic outcomes after TV surgery. The use of a TV annuloplasty ring with a repair strategy was associated with the most favorable clinical and echocardiographic outcomes. This study was unable to determine whether changes in the surgical plan made based on data from IOE conferred any advantage to the patient in terms of clinical or echocardiographic outcomes beyond the time of surgery. However, the benefit of IOE on the outcome of TV surgery was in identifying previously unrecognized TV dysfunction requiring surgery and in identifying an unsatisfactory first attempt at surgical correction of a...
dysfunctional TV in order to facilitate the patient leaving the operating room with the best possible surgical corrective procedure.

We thank the employees of the Cleveland Clinic Foundation Cardiovascular Information Registry (CVIR) for their diligent work in abstracting charts and performing follow-up interviews, which were invaluable to the completion of this study.

References

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