Incidental Tricuspid Regurgitation in Adult Cardiac Surgery: Focus on Current Evidence and Management Options for the Perioperative Echocardiographer

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INCIDENTAL MODERATE tricuspid regurgitation remains common and clinically significant in adult cardiac surgical practice. Recent guidelines have classified functional tricuspid regurgitation based on anatomy, valve hemodynamics, hemodynamic consequences, and clinical symptoms. Although recent guidelines for surgical intervention in tricuspid regurgitation lack robust evidence, recent trials suggest that it is reasonable to consider surgical management of incidental significant tricuspid regurgitation at the time of cardiac surgery, including at the time of left ventricular assist device implantation. Further prospective randomized trials are required to resolve this clinical equipoise. It is likely that the advent of three-dimensional perioperative echocardiography will foster advances in surgical and transcatheter tricuspid valve therapies that may facilitate clinical intolerance for incidental moderate tricuspid regurgitation in the adult cardiac surgical patient.

INTRODUCTION

Incidental tricuspid regurgitation (TR) is common in the adult cardiac surgical population.[1,2] The classification and management options for TR have been updated recently, including updates to focused guidelines by the European Society of Cardiology (ESC), the European Association of Cardiothoracic Surgery (EACTS), the American Heart Association (AHA), and the American College of Cardiology (ACC).[2–4] The three-dimensional anatomy and echocardiographic assessment of the tricuspid valve complex already have been described comprehensively in a series of high-quality articles in the Journal.[5–8] The goal of this expert review is to detail the latest evidence and guidelines as a guide for the perioperative echocardiographer in decision-making on the management of tricuspid regurgitation in the adult cardiac surgical patient, especially when it is incidental and hemodynamically significant.[9,10]

THE CLINICAL STAGES OF TRICUSPID REGURGITATION

The etiologies of TR may be primary or secondary. Primary disorders of the tricuspid valve apparatus that may result in clinically significant TR include congenital diseases (eg, Ebstein's anomaly), rheumatic fever, endocarditis, radiation, carcinoid syndrome, trauma, endometrial biopsy, and pacing leads.[2–4] Although the primary disorders are varied, together they account only for approximately 20% of TR cases. The remaining 80% of TR cases are functional in etiology.[4] Functional TR is, therefore, approximately 4 times more common than primary TR and, thus, is the type likely to be encountered in the perioperative period. Functional TR may occur secondary to annular dilation and/or leaflet tethering from right ventricular remodeling from pressure and/or volume overload.[2–4] The tricuspid valve annulus is typically a saddle-shaped ellipse that dilates in an anterior–posterior fashion to become flat and circular in this setting.[4–8] This annular distortion may persist despite relief of the right ventricular strain. Given that functional TR is the predominant type of TR likely to be encountered as incidental in the perioperative period, this expert review will focus mainly on this subtype of TR.

The AHA/ACC recent guideline has classified functional TR into 4 stages (A, B, C, and D), with defining features divided into 4 quadrants: Valve anatomy, valve hemodynamics, hemodynamic consequences, and clinical symptoms.[4] Stage A has been defined as patients at risk for functional TR with a clinical profile of mild annular dilation, trace TR, and no hemodynamic or clinical consequences. Stage B has been defined as progressive asymptomatic TR with early annular dilation and moderate leaflet tethering with mild-to-moderate TR. Mild TR has been defined echocardiographically as a central jet area ≤ 5.0 cm^2, a soft and parabolic continuous Doppler envelope, and systolic dominance on interrogation of hepatic vein flow.[4,11] Mild TR also is associated with normal size of the right atrium, right ventricle, and inferior vena cava.

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The echocardiographic definition of moderate TR in this setting included the following criteria: A central jet area of (5-10) cm^2, a vena contracta width $\leq$0.70 cm, a dense continuous Doppler profile, and systolic blunting of hepatic vein flow.[4,11] Moderate TR typically is associated with no right ventricular enlargement, mild dilation of the right atrium and inferior vena cava, and normal right atrial pressure.[4]

Stage C functional TR has been defined as asymptomatic severe TR due to marked leaflet tethering and/or severe annular dilation as indicated by a measured diameter $\geq$40 mm or $\geq$21 mm/m^2. The echocardiographic criteria that define severe TR include the following: A central jet area $>10cm^2$, a vena contracta width $>$0.7 cm, a dense and triangular continuous wave Doppler profile with an early peak, and systolic reversal of hepatic vein flow.[4,11] In Stage C functional TR, the hemodynamic consequences typically include dilated right heart and inferior vena cava, decreased respirophasic variation of flow within the inferior vena cava, high right atrial pressure with a c-v wave, and diastolic flattening of the interventricular septum. Stage D functional TR has been defined as symptomatic severe TR with severe annular dilation and leaflet tethering.[4] The echocardiographic criteria and hemodynamic consequences for severe functional TR are the same as for stage C, except that in stage D, systolic dysfunction of the right ventricle is also a feature.[4] The presence of right heart failure automatically grades the TR as stage D, even if the remaining morphologic and hemodynamic criteria are unmet.

THE OUTCOME SIGNIFICANCE OF MODERATE-TO-SEVERE TRICUSPID REGURGITATION

Moderate or severe TR significantly affects clinical outcome. In a large single-center trial (n = 5,223: 66.5 $\pm$ 12.8 years), moderate or severe TR significantly increased mortality regardless of pulmonary artery systolic pressure (PASP) (hazard ratio 1.31, 95% confidence interval 1.16-1.49 for PASP $>$40 mmHg; hazard ratio 1.32, 95% confidence interval 1.05-1.2 for PASP $\leq$40 mmHg).[12] This mortality risk also persisted independent of left ventricular ejection fraction (hazard ratio 1.49, 95% confidence interval 1.34-1.66 for ejection fraction $<$50% and hazard ratio 1.54, 95% confidence interval 1.37-1.71 for ejection fraction $\geq$50%).[12] Even after careful adjustment for age and biventricular function, mortality was increased in the setting of moderate TR (hazard ratio 1.17, 95% confidence interval 0.96-1.42) and severe TR (hazard ratio 1.31, 95% confidence interval 1.05-1.66).[12]

Given that moderate-to-severe TR significantly affects long-term survival, it is no surprise that a clinical trend has emerged toward earlier and more aggressive TR intervention.[13] Although pulmonary hypertension is an independent predictor of functional TR, there are multiple predictors such as age, right atrial size, and right ventricular size.[14] Further clinical trials have demonstrated that moderate–to-severe TR significantly worsened clinical survival in diverse clinical settings such as pulmonary hypertension, left ventricular systolic dysfunction, cardiac rhythm management devices, and heart transplantation.[15–18]

RECOMMENDATIONS FOR INTERVENTION IN TRICUSPID REGURGITATION

Expert Opinion

The AHA/ACC guidelines recommend diuretic therapy for severe TR associated with right-sided heart failure (stage D: Class IIa Recommendation; Level of Evidence C).[4] Furthermore, because pulmonary hypertension remains an independent predictor for progression of TR, medical pulmonary vasodilator therapy has been recommended for severe functional TR (stages C and D: Class IIb Recommendation; Level of Evidence C).[4] In the event that symptoms from severe TR prove refractory to aggressive medical therapy, tricuspid valve surgery may be beneficial (Stage D: Class IIa Recommendation; Level of Evidence C).[4] In the setting of minimally symptomatic severe primary TR (stage C), surgical intervention is a reasonable consideration when serial assessment demonstrates progressive right ventricular dilation and/or systolic dysfunction (Class IIb Recommendation; Level of Evidence C).[4]

Functional TR is common in patients presenting for left-sided valve surgery. The prevalence of significant functional TR in patients presenting for mitral valve surgery is in the range of 30% to 40% whether degenerative mitral regurgitation, ischemic mitral regurgitation, or mitral stenosis.[19–21] Tricuspid valve surgery also has been recommended for severe TR (stages C and D) in the setting of left-sided valve surgery (Class I Recommendation; Level of Evidence C).[4] Tricuspid valve repair is a reasonable consideration at the time of left-sided valve surgery in the setting of moderate functional TR (stage B) associated with pulmonary artery hypertension (Class IIb Recommendation; Level of Evidence C).[4] Reoperation for isolated symptomatic severe TR in the setting of previous left-sided heart valve surgery is a reasonable option in the absence of severe pulmonary hypertension or advanced right ventricular systolic dysfunction (Class IIb Recommendation; Level of Evidence C).[4]

Surgical Intervention: Evidence From Recent Studies

Furthermore, tricuspid valve repair has been recommended as a reasonable option in the setting of mild-to-moderate functional TR (stage B) at the time of left-sided valve surgery in the setting of tricuspid annular dilation and/or right heart failure (Class IIa Recommendation; Level of Evidence B).[4] There is an extensive evidence base that has developed to support this reasonable recommendation for additional surgical intervention.

In a prospective single-center observational trial (n = 311, 1989-2001) of patients undergoing surgical intervention for severe mitral regurgitation, the effect of tricuspid annuloplasty was examined based on intraoperative determination of tricuspid annular size.[22] In this trial, patients with tricuspid annular diameter $>$70 mm (n = 163 of the 311, 41.8%) also underwent tricuspid valve repair. Tricuspid annuloplasty significantly improved the degree of postoperative functional TR (grade 0.4 $\pm$ 0.6 *v* grade 2.1 $\pm$ 1.0; $p < 0.001$).[22] Despite this significant improvement in freedom from significant TR postoperatively, there was no demonstrable difference in 10-year

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