

Tricuspid valve annuloplasty using a partial flexible ring: mid-term follow-up

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Key words:

Color Doppler echocardiography; Pulmonary hypertension; Tricuspid regurgitation; Tricuspid valve; Valvuloplasty.

Background. Tricuspid valve annuloplasty (TVA) using a complete or partial rigid or flexible ring is becoming common practice in the surgical treatment of tricuspid insufficiency (TI). This study evaluates the immediate outcome and the mid-term clinical and echocardiographic follow-up after TVA performed using the Cosgrove-Edwards partial flexible ring.

Methods. From June 1998 to March 2002, 35 consecutive adult patients with TI > 2+ underwent TVA using this annuloplasty ring. TI was secondary to right ventricular dilation and/or dysfunction (functional TI) in 32 (91.4%) patients, and due to anatomic anomalies of the tricuspid valve (organic TI) in 3 (8.6%). Pulmonary hypertension was present in 34.4% of the patients with functional TI. Thirty-two (91.4%) patients were in preoperative NYHA functional class III or IV. The mean follow-up was 28.3 ± 14.6 months.

Results. There were three (8.6%) in-hospital non-valve-related cardiac deaths, and one (3.1%) non-cardiac death during follow-up. The 3-year actuarial survival was 96.5%. TI was well controlled within grade 1+ in 30 (96.8%) survivors, but one presented residual grade 2+ TI. The NYHA functional class improved to 1.3 ± 0.5 ($p = 0.035$).

Conclusions. TVA performed using the Cosgrove-Edwards ring is a valid option for the surgical treatment of both functional and organic TI, even in case of pulmonary hypertension and at mid-term follow-up.

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Introduction

The Cosgrove-Edwards annuloplasty ring (Edwards Lifesciences, Irvine, CA, USA) is a "C"-shaped universally flexible band (partial flexible ring) that provides, in the tricuspid valve position, a measured plication of the anterior and posterior annulus whilst preserving the physiologic annulus motion. Preliminary experiences using this annuloplasty ring for the correction of tricuspid insufficiency (TI) following diseases of the left-sided heart valves produced good results^{1,2}.

In this retrospective study, we report the immediate outcome and the clinical and echocardiographic mid-term follow-up after tricuspid valve annuloplasty (TVA) performed using the Cosgrove-Edwards partial flexible ring.

Methods

From June 1998 to March 2002, 35 consecutive adult patients with TI > 2+ underwent TVA performed using the Cosgrove-Edwards annuloplasty ring at our Department. This population included 26 (74.3%)

women and 9 men (mean age 66.3 ± 11.8 years, range 42-82 years).

TI was secondary to right ventricular dilation and/or dysfunction following diseases of the left-sided heart valves (functional TI) in 32 (91.4%) patients, and due to anatomic anomalies of the tricuspid valve (organic TI) in 3 (8.6%). The two congenital organic TI were due to Ebstein's disease and to an atrioventricular canal septal defect respectively. The traumatic organic TI was caused by anterior leaflet prolapse due to chordal and anterior papillary muscle rupture (associated with annular dilation) owing to blunt chest trauma (Table I).

Ten (28.6%) patients had been previously submitted to valve operations: one prior operation in 7 patients and two prior operations in 3. These interventions included: closed or open mitral commissurotomy ($n = 4$), mitral valve or prosthesis replacement ($n = 5$), combined open mitral commissurotomy or mitral valve replacement and aortic valve replacement ($n = 3$), and combined mitral valve replacement, aortic valve replacement and tricuspid valve suture annuloplasty (De Vega's method) ($n = 1$).

Twenty-two (62.8%) patients were in NYHA functional class IV, 10 (28.6%) in

Table I. Causes of tricuspid insufficiency (TI).

Cause	No. patients
TI secondary to right ventricular dilation and/or dysfunction (functional TI) following:	32
- Mitral valve rheumatic disease	16
- Mitral and aortic valve rheumatic disease	3
- Mitral prosthesis dysfunction and aortic valve rheumatic disease	1
- Mitral and aortic prosthesis dysfunction	1
- Mitral valve degenerative disease	4
- Mitral and aortic valve degenerative disease	3
- Mitral valve ischemic disease	2
- Idiopathic dilated cardiomyopathy	1
- Chronic constrictive pericarditis	1
TI due to anatomic anomalies of the tricuspid valve (organic TI) owing to:	3
- Congenital heart diseases	2
- Chest trauma	1

NYHA functional class III, and 3 (8.6%) patients in NYHA functional class II. All patients presented with symptoms of right heart failure. Only 5 (14.3%) patients were in sinus rhythm (Table II).

Preoperative right- and left-sided heart catheterization and echocardiographic examination were always performed. The severity of TI was echocardiographically graded according to a 5-point scale and on the basis of color Doppler flow images and of the flow direction in the inferior vena cava or hepatic veins: 0 = no or trivial, 1+ = mild, 2+ = moderate, 3+ = moderate-severe, and 4+ = severe³. Using color Doppler guidance, it was always possible to calculate the right ventricular systolic pressure as the sum of the right ven-

Table II. Preoperative clinical and echocardiographic data.

<i>Preoperative clinical data</i>	
NYHA functional class	3.5 ± 0.7
Symptoms of right heart failure	
Palpable hepatomegaly	28 (80.0%)
Jugular venous distension	22 (62.9%)
Pulsatile liver	18 (51.4%)
Important peripheral edema	7 (20.0%)
Ascites	4 (11.4%)
Heart rhythm	
Sinus rhythm	5 (14.3%)
Chronic atrial fibrillation*	23 (65.7%)
Recent atrial fibrillation**	3 (8.6%)
Pacemaker-induced	4 (11.4%)
<i>Preoperative echocardiographic data</i>	
Grade of TI (5-point scale 0-4)	3.5 ± 0.5
sPAP (mmHg)	49.3 ± 15.9 (range 30-95)
Left ventricular ejection fraction (%)	52.2 ± 8.9 (range 35-80)

sPAP = systolic pulmonary artery pressure; TI = tricuspid insufficiency. * occurring over 6 months before cardiac operation; ** occurring within 6 months before cardiac operation.

tricular to right atrial systolic gradient, calculated using the simplified Bernoulli's equation applied to the regurgitant jet, and the clinically estimated right atrial pressure. In case of patients without an obstruction between the right ventricle and the pulmonary artery, the right ventricular systolic pressure was taken as being equivalent to the systolic pulmonary artery pressure (sPAP)⁴. Pulmonary hypertension, defined as a sPAP > 59 mmHg, was present in 34.4% of the patients with functional TI⁵. The preoperative left ventricular ejection fraction was echocardiographically estimated soon before surgery. The preoperative echocardiographic data were similar to the heart catheterization data (Table II).

The surgical priority, graded according to the Society of Thoracic Surgeons classification, was elective in 26 (74.3%) patients, urgent in 7 (20.0%), and emergency in 2 (5.7%) patients. Twenty-nine (82.9%) patients had a EuroSCORE of ≥ 6 (95% confidence interval for expected mortality 10.9 to 11.5%)⁵.

The surgical technique for the implantation of the Cosgrove-Edwards ring at the tricuspid annulus was performed using the system described by McCarthy and Cosgrove¹. Thirty (85.7%) 32 mm-flexible rings and five 34 mm-flexible rings were used. In 34 (97.1%) patients 52 concomitant surgical procedures were performed: mitral valve procedures (n = 28), aortic valve procedures (n = 10), myocardial revascularization (n = 6), patent foramen ovale closure (n = 3), left atrial internal microwave ablation for recent atrial fibrillation (n = 2), pericardiectomy (n = 1), atrioventricular canal septal defect repair (n = 1), and artificial chordae implantation and anterior papillary muscle reconstruction (n = 1). The number of surgical procedures per patient was 2.5.

Echocardiographic evaluation performed to confirm the competence of the tricuspid valve after TVA was carried out, intraoperatively, using a transesophageal approach and, at the time of discharge and during follow-up, using a transthoracic approach. The mean clinical and echocardiographic follow-up was 28.3 ± 14.6 months or 82.5 cumulative patient-years, with a range of 8.0 to 52.2 months.

Deaths and complications were defined according to the published guidelines of the Society of Thoracic Surgeons and the American Association for Thoracic Surgery⁶.

Statistical analysis. Values are expressed as the mean ± SD, or as percentages. Continuous variables were compared using the Student's t-test, and categorical variables were compared using the χ^2 test. Statistical significance was assumed for a p value of < 0.05. Non-parametric estimates of survival and of freedom from postoperative TI > 1+ were obtained by the method of Kaplan and Meier. Statistical analysis was performed using MINITAB release 13 statistical software (MINITAB Inc., State College, PA, USA).

Results

In-hospital mortality. Three patients (8.6%) died within 30 days of surgery, and the cause of death was a low cardiac output syndrome not related to valve surgery. The first patient was a 64-year-old woman, in NYHA functional class IV, with mitral valve rheumatic disease causing moderate left ventricular dysfunction (left ventricular ejection fraction 37%), an increase in sPAP (48 mmHg) and severe functional TI, undergoing urgent mitral valve replacement and TVA. The second patient was a 77-year-old woman, in NYHA functional class IV and cardiac cachexia, with mitral prosthesis dysfunction and aortic valve rheumatic disease causing left ventricular failure (left ventricular ejection fraction 30%), pulmonary hypertension (sPAP 65 mmHg) and severe functional TI, undergoing emergency mitral prosthesis replacement, aortic valve replacement, and TVA (third cardiac operation). The third patient was a 69-year-old woman, in NYHA functional class IV, with mitral prosthesis dysfunction causing moderate left ventricular dysfunction (left ventricular ejection fraction 45%), pulmonary hypertension (sPAP 62 mmHg), and severe functional TI, undergoing urgent mitral prosthesis replacement and TVA.

Clinical follow-up. The 3-year actuarial survival was 96.5% (95% confidence interval 89.7 to 100%). During follow-up, 1 (3.1%) patient died of massive internal bleeding after extensive colon resection for diverticulitis, 10.4 months after cardiac surgery. In this patient, echocardiographic examination performed 6 months following discharge confirmed trivial residual TI. In all survivors, no other irreversible complications were recorded.

A clearly improved NYHA functional class was observed at the time of discharge (NYHA functional class 1.5 ± 0.7 , $p = 0.0029$) and at follow-up (NYHA functional class 1.3 ± 0.5 , $p = 0.035$). An improvement in the symptoms of right heart failure was also observed: palpable hepatomegaly was present in 6 (19.4%, $p = 0.0097$) patients, a pulsatile liver in 4 (12.9%, $p = 0.00076$), jugular venous distension in 3 (9.7%, $p = 0.00096$), significant peripheral edema in 2 (6.5%, $p = 0.045$), and ascites in 1 (3.2%, $p = \text{NS}$) patient. Ascites and significant peripheral edema persisted in 1 patient with hepatitis C virus positive cirrhosis.

Postoperatively, the heart rhythm in the survivors with preoperative sinus rhythm and chronic atrial fibrillation remained unmodified. In the 2 patients with preoperative recent atrial fibrillation undergoing left atrial internal microwave ablation, sinus rhythm persisted at follow-up.

Echocardiographic follow-up. TI was significantly reduced at the time of hospital discharge (TI 0.6 ± 0.6 , $p = 0.0013$) and at follow-up (TI 0.3 ± 0.5 , $p = 0.00010$). The further improvement in TI observed dur-

ing the time interval from the time of discharge to the most recent echocardiographic evaluation was almost significant ($p = 0.052$). TI was well controlled within grade 1+ in 30 (96.8%) survivors, but in the patient with traumatic rupture of the tricuspid valve residual grade 2+ TI persisted. The 3-year actuarial rate of survival free from postoperative TI more severe than grade 1+ was 97.0% (95% confidence interval 90.9 to 100%).

In the 20 survivors with trivial, mild, or moderate residual TI at the time of discharge, sPAP decreased from 50.6 ± 18.2 mmHg preoperatively to 35.1 ± 5.0 mmHg ($p = 0.00095$). In the 11 survivors with trivial, mild, or moderate residual TI at follow-up, sPAP continued to decrease from the time of hospital discharge through follow-up, but the difference was not significant. Of the 8 (72.7%) survivors with preoperative pulmonary hypertension, 5 had no residual TI (for this reason the echocardiographic estimate of sPAP was impossible), and 3 had trivial residual TI but not pulmonary hypertension.

The left ventricular ejection fraction increased to $54.6 \pm 6.0\%$, but this variation was not statistically significant.

Discussion

At present, tricuspid valve suture annuloplasty is routinely used for the surgical treatment of important functional TI. Although Kay's⁷ and De Vega's⁸ methods are simple and reproducible, and offer good early results, at long-term follow-up (5 years) the residual or recurrent TI among hospital survivors was rated as moderate to severe in 16.2 to 33.8% and about 10% of surviving patients required tricuspid valve reoperation^{9,10}. Generally, when tricuspid valve reoperation is performed after failure of a previous tricuspid valve suture annuloplasty, the annuloplasty suture is found to be intact. Nevertheless, the tricuspid annulus and right ventricle appear dilated. This right ventricular dilation (and dysfunction) is usually due to the progression of disease of the left-sided heart valves and persisting high pulmonary artery resistance, or to independent progression of pulmonary hypertension. *De novo* organic lesions of the tricuspid valve cause recurrent TI less frequently¹⁰.

The ring annuloplasty, introduced for the treatment of mitral insufficiency by Carpentier, remodels the atrioventricular annulus, decreases tension on the suture lines, increases leaflet coaptation and prevents recurrent annular dilation¹¹.

TVA performed using a rigid ring is an excellent option for the correction of functional TI, even in the long term (8 years) and in patients with pulmonary hypertension¹². Clinical and echocardiographic studies comparing suture annuloplasty (De Vega's method) with TVA performed using a rigid ring in the prevention of TI recurrence showed ring annuloplasty to be superior

to suture annuloplasty in patients with functional TI¹³. The Achilles tendon of TVA performed using a rigid ring is the loss of tricuspid annular contraction. In effect, the tricuspid annulus is a complex dynamic structure (involved in right ventricular function) undergoing periodic and constant changes in size and shape during the cardiac cycle. Otherwise, TVA performed using a flexible ring could preserve the tricuspid annular contraction and right ventricular function¹⁴. However, these attractive notions will remain largely speculative until the publication of comparative echocardiographic reports indicates a relationship between the right ventricular function and the implantation of a rigid or flexible annuloplasty ring in the tricuspid position. Anyway, the non-standard echocardiographic evaluation of the right ventricular performance is demanding. Besides, left-sided heart procedures and the left heart conditions have an important effect on right ventricular function.

The partial annuloplasty ring provides, at the tricuspid valve, a measured plication exclusively of the anterior and posterior tricuspid annulus. Because no sutures are placed along the septal annulus, a partial ring could be superior to a complete ring in avoiding the risk of injury to the conduction system.

In this study, we analyzed our experience with the Cosgrove-Edwards partial flexible ring for the treatment of both functional and organic important TI. The in-hospital mortality was acceptable and the cause of death was not related to TVA. The single death occurring during follow-up was a non-cardiac death. No patient underwent cardiac reoperation. The freedom from postoperative TI > 1+ was very good, comparing favorably both with suture annuloplasty as well as with the complete rigid ring annuloplasty. Preoperative pulmonary hypertension did not prevent the complete postoperative control of TI. The significant decrease in the sPAP values and in the NYHA functional class confirmed good surgical correction of the diseases of the left-sided heart valves. Significant improvements in the symptoms of right heart failure were proof of a better right ventricular performance at follow-up. Arrhythmias due to injury to the conduction system were not observed.

The Cosgrove-Edwards annuloplasty ring also effectively corrected organic TI. In the patient with traumatic disruption of the tricuspid valve and severe TI, tricuspid valve repair was very demanding, but the residual TI was only moderate.

TVA performed using the Cosgrove-Edwards partial flexible ring is a valid and durable option for the surgical treatment of both functional and organic TI. It is particularly advisable in the presence of pulmonary hypertension.

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