TRICUSPID VALVE REPLACEMENT: POSTOPERATIVE AND LONG-TERM RESULTS

A series of 146 consecutive patients who underwent tricuspid valve replacement at the University Brugmann Hospital between 1967 and 1987 was reviewed. Mean age at operation was 51.4 years (± 12.1 years). Different types of prostheses were implanted including porcine and bovine pericardial bioprostheses and older and bileaflet mechanical valves. Most patients were severely disabled by their cardiac disease before operation, with 30.1% in New York Heart Association functional class III and 69.9% in class IV. Operative mortality and hospital mortality rates (30 days) were high (16.4%). Incremental risk factors for hospital death included icterus ($p < 0.005$), preoperative hepatomegaly ($p = 0.012$), and New York Heart Association functional class IV ($p = 0.013$). Multivariate analysis only selected preoperative icterus ($p < 0.01$) as being independently significantly related to hospital mortality. The hospital survivors were followed up for a median of 94 months. A complete follow-up was available for all patients except two for 30 months or more. At 30 months the only two significant parameters were the type of myocardial protection ($p = 0.024$) and the year of operation (before 1977 or after [precardioplegia era or after], $p = 0.011$). There were 70 late deaths during the entire follow-up period. The univariate (log-rank statistics) incremental risk factor for late death was the type of tricuspid prosthesis (Smeloff-Cutter and Kay-Shiley versus St. Jude Medical versus bioprosthesis) ($p = 0.04$). A trend was observed for the type of operative myocardial protection (normothermia and coronary perfusion) ($p = 0.06$) and preoperative New York Heart Association functional class IV ($p = 0.055$). Actuarial survival was 74% at 60 months and 23.4% at 180 months. Cumulative follow-up added up to 1015 patient-years. In a more detailed analysis of the effect on survival of the type of tricuspid prosthesis, a significant difference was observed between the bioprostheses and some older mechanical prostheses (Smeloff-Cutter and Kay-Shiley) ($p = 0.04$) but not between the bioprostheses and the bileaflet valves ($p = 0.15$). When the follow-up period was stratified according to less than 7 years and more than 7 years of follow-up, no difference was observed for the first period, but for the late follow-up the new mechanical prostheses did better than the bioprostheses ($p = 0.05$), suggesting a degradation of the bioprostheses after 7 years and favoring mechanical prostheses for those patients with a good long-term prognosis. (J THORAC CARDIOVASC SURG 1995;110:672-9)

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Since the start of tricuspid valve replacements in the early 1960s, nearly all types of prostheses have been used in the tricuspid position, with different results. In the absence of severe structural damage of the native valve, repair or annuloplasty should always be attempted.¹ During the period of our study 173 tricuspid valve reconstructions were done at the same hospital. Nevertheless, nearly 45% of our patients with tricuspid valve disease required

Table I. Clinical features of the 146 patients undergoing TVR

Clinical feature	N	%
NYHA class		
III	44	30.1
IV	102	69.9
Rhythm		
Atrial fibrillation	122	83.5
Sinus rhythm	22	15.1
Unknown	2	1.4
Hepatomegaly	80	54.8
Icterus	31	21.2
Peripheral edema	66	45.2
Ascites	21	14.4
Cyanosis	24	16.4
Cardiothoracic ratio >0.5	143	97.9

valve replacement, more frequently in the early years. We reviewed and analyzed the results in our 146 patients with valve replacement to establish a strategy toward the optimal valve choice. As described by McGrath and colleagues,² bioprostheses in the tricuspid position perform well up to 10 years after implantation, but can show some structural deterioration, and this finding was even more pronounced in younger patients in other series.³ Good long-term results with bileaflet mechanical valves could alter our policy of using preferentially a large bioprosthesis in the tricuspid position.

Patients and methods

All 146 patients who underwent tricuspid valve replacement (TVR) at the University Brugmann Hospital between 1967 and 1987 were included in the review. Our series included 32 male (21.9%) and 114 female (78.1%) patients with a mean age of 51.4 years (range 15 to 71 years, standard deviation 12.1). The clinical data of the patients in the TVR group are summarized in Table I. Rheumatic heart disease was the most frequent cause and was present in 102 patients (69.9%). Ebstein's anomaly occurred in 4 (2.7%), endocarditis in 3 (2.1%), and in the remaining 37 patients (25.3%) the disease process was considered to be functional. Eighty-eight (60.3%) patients had tricuspid valve regurgitation only, 4 had pure stenosis (2.7%), and 54 (37.0%) had a combination of both, as assessed clinically, echocardiographically, hemodynamically, and perioperatively. Most of our patients had an advanced stage of heart valve disease, with 44 patients (30.1%) in New York Heart Association (NYHA) functional class III and 102 patients (69.9%) in class IV or higher. Ascites was present in 21 patients (14.4%), cyanosis in 24 (16.4%), hepatomegaly in 80 (54.8%), edema in 66 (45.2%), and icterus in 31 (21.2%). Concomitant cardiac procedures were necessary in 139 patients (95.2%), as shown in Table II. Moreover, 59 patients

Table II. Associated cardiac procedures in 146 patients undergoing TVR

Procedures done	N	%
MVR	93	63.6
AVR, MVR	26	17.8
AVR	2	1.3
OMC	2	1.3
MVR, aortic valve repair	1	0.7
Thrombectomy left atrium	5	3.4
Thrombectomy right atrium	1	0.7
Mitral paravalvular leak closure	2	1.3
Aortic paravalvular leak closure	1	0.7
Atrial septum defect repair	3	2.0
Ventricular septum defect repair	1	0.7
Epicardial pacemaker	2	1.4
Total	139	95.2

MVR, Mitral valve replacement; AVR, aortic valve replacement; OMC, open mitral commissurotomy.

Table III. Previous cardiac operations in 146 patients undergoing TVR

	N	%
One procedure		
MVR	13	8.9
CMC	16	10.9
OMC	12	8.2
AVR, MVR	5	3.4
AVR	2	1.4
OMC, tricuspid valve repair	3	2.0
MVR, tricuspid valve repair	2	1.4
AVR, MVR, tricuspid valve repair	1	0.7
AVR, MVR	1	0.7
OMC, OTC	1	0.7
Tricuspid valvectomy	1	0.7
Atrial septum defect repair	1	0.7
Pericardectomy	1	0.7
Total	59	40.4
Two procedures		
First	Second	
CMC	CMC	1 0.7
CMC	AVR, MVR, tricuspid valve repair	1 0.7
AVR, MVR	AVR, MVR	1 0.7
AVR, MVR	Paravalvular leak closure	1 0.7
MVR	Paravalvular leak closure	1 0.7
VSD repair	Residual VSD closure	1 0.7
Total		6 4.1

MVR, Mitral valve replacement; CMC, closed mitral commissurotomy; OMC, open mitral commissurotomy; AVR, aortic valve replacement; OTC, open tricuspid commissurotomy; VSD, ventricular septal defect.

(40.4%) had undergone one previous cardiac operation and 6 had undergone two (4.1%), as shown in Table III.

We used different types of prostheses in the tricuspid position: 69 bioprostheses (47.3%) and 77 mechanical valves (52.7%). During the 1960s and early 1970s, only

Table IV. Univariate analysis of clinical variables related to hospital mortality

	Alive	Dead	P Value
Age (yr, mean $\pm$ SD)	51.5 $\pm$ 12.6	52.7 $\pm$ 9.6	NS
Sex			
Female	99	15	0.04
Male	23	9	
Previous operation			
Absent	69	13	NS
Present	53	11	
Rheumatic disease			
Absent	32	12	NS
Present	88	14	
Tricuspid disease			
Regurgitation	71	17	NS
Stenosis	51	7	
NYHA class			
III	42	2	0.013
IV	80	22	
Ascites			
Absent	107	18	NS
Present	15	6	
Cyanosis			
Absent	105	17	NS
Present	17	7	
Icterus			
Absent	102	13	0.005
Present	20	11	
Hepatomegaly			
Absent	61	5	0.012
Present	61	19	
Edema			
Absent	65	15	NS
Present	57	9	

SD, Standard deviation; NS, not significant.

old-style mechanical valves (27 Smeloff-Cutter,* 14 Kay-Shiley,† and 1 DeBakey‡) were available. Before 1977, 23 Björk-Shiley† tilting-disc valves were implanted in the tricuspid position. Since 1975, porcine xenografts (31 Carpentier-Edwards§ and 25 Hancock||) have been currently used. Between 1979 and 1981, 12 St. Jude Medical¶ mechanical valves were inserted in the tricuspid position. Finally, some bovine pericardial bioprostheses (9 Carpentier-Edwards and 4 Mitroflow) were implanted between 1978 and 1983.

All operations were done through median sternotomy with the use of standard cardiopulmonary bypass (CPB). Before 1977, normothermic CPB with coronary perfusion and mild systemic hypothermia was used, whereas more

recently moderate hypothermia and cold antegrade St. Thomas' Hospital cardioplegic solution has been used. Anticoagulation therapy with warfarin (Coumadin) was started on the first postoperative day and continued life-long in patients with mechanical valves or chronic atrial fibrillation; otherwise it was stopped after 3 months. Several clinical parameters and surgical parameters were recorded retrospectively.

Statistical analysis. Continuous variables are expressed as mean and standard deviations. Variables entered into risk-factor analysis included age, gender, previous operation, rheumatic disease, tricuspid disease, NYHA functional class, ascites, cyanosis, icterus, hepatomegaly, edema, duration of aortic clamping, duration of CPBs, myocardial protection, year of operation, and type of prosthesis. For statistical power considerations the types of tricuspid prostheses were grouped into three categories: bioprostheses, old mechanical prostheses, and new mechanical prostheses. Univariate comparisons between the groups of survivors and nonsurvivors at 30 days and 30 months after operation were done by Fisher's exact test and Student's *t* test. A stepwise multivariate logistic regression was used to identify a subset of independent variables predictive of hospital and 30-month mortality (Systat 5.2 statistical program, Systat, Inc., Evanston, Ill.). The level for entrance to or removal from the model was set at 0.05. Univariate analysis of survival curves was done by the log-rank test.⁴

Results

Hospital mortality. Twenty-four patients died during hospitalization, yielding a hospital mortality rate of 16.4%. Cardiac failure was responsible in 11 patients (45.8%), bleeding in 3 (12.5%), arrhythmias in 3 (12.5%), multiple organ failure in 2 (8.3%), respiratory insufficiency in 1 (4.2%), sepsis in 1 (4.2%), and valvular thrombosis in 1 (4.2%); sudden death of unknown origin occurred in 2 patients (8.4%). Univariate analysis (Table IV) showed presence of icterus ($p = 0.005$), presence of hepatomegaly ($p = 0.012$), NYHA class IV ($p = 0.013$), and male gender ($p = 0.04$) to be associated with hospital mortality. The cause (rheumatic or not) of the tricuspid valve disease and the pathologic condition of the tricuspid valve (regurgitant or not) showed no relation with the in-hospital outcome. Among the perioperative parameters no relation was found at all with early survival (Table V).

Valve-related complications. Paravalvular leakage developed in 4 patients (3.3%). Twice the tricuspid prosthesis was concerned: once in a Smeloff-Cutter and once in a Björk-Shiley valve. The first patient died without surgical intervention and the latter underwent successful replacement of the affected prosthesis. Late endocarditis occurred in 3 patients (2.5%) 36, 54, and 96 months, respec-

* Cutter Biological, Berkeley, Calif.

† Shiley, Inc., Irvine, Calif.

‡ Surgitool, Inc., Pittsburgh, Pa.

§ Baxter Healthcare Corp., Edwards Division, Santa Ana, Calif.

|| Johnson & Johnson Cardiovascular, King of Prussia, Pa.

¶ St. Jude Medical, Inc., St. Paul, Minn.

tively, after operation. This involved 1 Carpentier-Edwards mitral prosthesis, 1 Kay-Shiley tricuspid prosthesis, and both mitral and tricuspid St. Jude Medical prostheses in the last patient. All patients were treated medically. The first 2 patients recovered and the latter died of a cerebrovascular accident. Major anticoagulant-related hemorrhage (necessitating hospitalization and transfusion) occurred in 13 patients (10.7%). Four cases were fatal: 2 digestive, 1 cerebral, and 1 posttraumatic.

Reoperation and valve thrombosis. Late tricuspid valve reoperation was required in 11 of the hospital survivors (9%) (Table VI). The mean interval to reoperation was 83.8 months (range 0.27 to 161 months). Three patients did not survive reoperation (27.3%); one died of cardiac failure, another of respiratory failure, and in the third patient the cause remains unknown. Prosthetic valve thrombosis occurred in 11 patients. Two cases of valve thrombosis on postoperative days 6 and 8 were fatal. Nine patients had late thrombosis from 5 to 132 months after primary TVR. The types of prosthesis involved included 4 Smeloff-Cutter valves (3 in the tricuspid and 1 in the mitral position), 3 Björk-Shiley valves (2 in the tricuspid and 1 in the mitral and tricuspid positions), and 1 St. Jude Medical valve and 1 Carpentier-Edwards valve in the tricuspid position. Of these 9 patients, 6 died before surgical intervention and the other 3 underwent successful replacement of the thrombosed prosthesis. Actuarial freedom from death and reoperation with a tricuspid valve prosthesis is shown in Fig. 1 for the different valve types.

Thirty-month mortality. A total of 120 hospital survivors were followed up for at least 30 months (this includes all patients except two, who were followed up for 27 and 29 months, respectively). An interim analysis at 30 months showed only a significant different survival for the type of myocardial protection (hypothermia, 8 of 68 versus normothermia, 13 of 43; $p = 0.024$) and the use of cardioplegia (before 1977, 18 of 65 versus after 1977, 5 of 55; $p = 0.011$). A trend was also shown for NYHA functional class before operation (class III, 4 of 41 versus class IV, 19 of 79; $p = 0.005$) (Table VII). A multivariate logistic regression at 30 months selected the absence of myocardial protection and the presence of tricuspid valve stenosis as the two factors positively and independently related to mortality ($p = 0.015$ and $p = 0.048$, respectively).

Late survival. Late death occurred in 70 of the 122 hospital survivors of the original TVR (57.4%).

Table V. Univariate analysis of perioperative variables related to hospital mortality

	Alive	Dead	<i>p</i> Value
Aortic clamp time (min)	66.2 ± 32.5	68.2 ± 36.1	NS
Duration of CPB (min)	113 ± 31.1	141.3 ± 58.5	NS
Myocardial protection			
Normothermia	43	11	0.99
Hypothermia	70	13	
Tricuspid prosthesis			
Old mechanical	33	9	0.49
New mechanical	29	6	
Bioprosthesis	60	9	

NS, Not significant.

Modes included cardiac failure in 25 patients (35.7%), sudden death in 10 (14.3%), neurologic events in 5 (7.1%), valvular thrombosis in 5 (7.1%), anticoagulant-related bleeding in 4 (5.7%), valvular prosthesis dysfunction in 3 (4.3%), infective endocarditis in 2 (2.8%), arrhythmia in 1 (1.4%), noncardiac causes in 8 (11.4%), and unknown causes in 7 (10.0%). Cumulative follow-up added up to 1015 patient/years and the median survival time for hospital survivors was 116 months. Two patients were lost to follow-up (98.4% complete). The actuarial survival at 60 months remained 74.0% and decreased at 180 months to 23.4% (Fig. 2). Of the 52 long-term survivors, 11 (21.2%) are in NYHA functional class I, 32 (61.5%) in class II, 6 (11.5%) in class III, and the remaining 3 (5.8%) in class IV. Thirty-nine patients (75%) have atrial fibrillation, 7 have regular sinus rhythm (13.5%), 5 had a pacemaker implanted (9.6%), and in 1 patient the rhythm remains uncertain (1.9%). Univariate analysis (log-rank statistics) revealed the type of tricuspid prosthesis (Smeloff-Cutter and Kay-Shiley versus St. Jude Medical and bioprosthesis) ($p = 0.04$) as an incremental risk factor for late death. A trend was observed for the type of operative myocardial protection (normothermia and coronary perfusion) ($p = 0.06$) and preoperative NYHA functional class IV ($p < 0.06$). A more detailed analysis of the effect on survival of the type of tricuspid prosthesis showed a significant difference between the bioprosthesis and the older mechanical prostheses (Smeloff-Cutter and Kay-Shiley) ($p = 0.04$) but not between the bioprosthesis and the new prosthesis ($p = 0.15$) (Fig. 1). When the follow-up period was stratified according to less than 7 years and 7 or more years of follow-up, no significant difference

Bio	60	55	53	40	34	24	15	4
New	29	24	21	19	18	17	12	9
Old	33	25	23	20	17	12	9	5

Fig. 1. Actuarial freedom from death and reoperation with tricuspid prosthesis for different valve types.
Bio, Bioprosthesis.

Table VI. Reoperations

Original valve	Reason for malfunction	Interval to reoperation	Reoperation procedure	New tricuspid prosthesis	Status
Smeloff-Cutter	Pannus	83 mo	TVR	St. Jude Medical	Alive
	Pannus	89 mo	TVR	St. Jude Medical	Alive
	Thrombus	96 mo	TVR	Carpentier-Edwards	Died
Björk-Shiley	Thrombus	16 mo	TVR	Smeloff-Cutter	Alive
	Pannus	161 mo	TVR	Carpentier-Edwards	Alive
	Thrombus	25 mo	TVR, MVR	Smeloff-Cutter	Alive
	Thrombus	8 days	TVR	Smeloff-Cutter	Died
Kay-Shiley	Pannus	45 mo	TVR	Smeloff-Cutter	Alive
Carpentier-Edwards	PVF	133 mo	TVR	Carpentier-Edwards	Alive
	PVF	142 mo	TVR	None	Died
	Thrombus	132 mo	TVR, MVR, AVR	Carpentier-Edwards	Alive

MVR, Mitral valve replacement; PVF, primary valve failure; AVR, aortic valve replacement.

was observed for the first period but for the late follow-up the new mechanical prosthesis did better than the bioprosthesis ($p = 0.05$). A stepwise multiple logistic regression test selected the presence of icterus as the sole independent predictor of late death ($p < 0.01$).

Discussion

The operative mortality rate of 16.4% in our series is comparable with those in literature reports, which range from less than 10% to more than 50% for both isolated and combined TVR.⁵⁻¹⁹ A reduction in mortality rate in the more recent era was also observed by Livi and colleagues²⁰ and related to improvement of perioperative myocardial protec-

tion and postoperative management. Almost half of our early deaths were caused by cardiac failure related to severe depression of myocardial function, which was especially noticed in the precardioplegia group as reported in most series.^{6-8, 11, 14, 16, 18-21}

This was also confirmed indirectly in our series by the significant relation between the year of intervention and the survival (before 1977 versus after 1977). A number of preoperative variables were identified as univariate predictors of high risk for hospital death after TVR: male gender, NYHA functional class IV, hepatomegaly, and icterus. Poor survival in men, also detected by other authors, remains unexplained.^{19, 22} The increased early risk for TVR in patients with advanced functional disability has been

Bio	60	59	54	41	36	30	20	9
New	29	28	23	20	19	18	12	9
Old	33	32	24	22	19	13	9	6

Fig. 2. Actuarial survival curves according to type of prosthesis. *Bio*, Bioprosthesis.

documented in some reports.^{9, 18-20, 22} Preoperative hepatomegaly and icterus likely represent hepatic congestion resulting from severe failure of the right side of the heart and have been associated with high early mortality rates.^{19, 22}

Late death occurred in 57% of the hospital survivors of the original TVR. More than one third of these patients died of cardiac failure, which suggests progression of cardiomyopathy despite successful surgical valve replacement.^{9, 17, 18} Significant univariate risk factors for late death were the use of a Smeloff-Cutter or Kay-Shiley tricuspid prosthesis, myocardial protection by normothermia and coronary perfusion, and preoperative NYHA functional class IV. Intraoperative myocardial protection has been reported to influence operative mortality, but not late death.²¹ Advanced functional disability seems to have an ominous influence not only on early but also on long-term results of TVR.^{9, 19, 21} The higher prevalence of tricuspid valve thrombosis in older mechanical valves has been confirmed by several authors.^{6, 9, 16, 21, 23} Likewise, a low prevalence of valve-related thromboembolism with the St. Jude Medical valve in patients with correctly regulated anticoagulation therapy has been reported.²⁴⁻²⁶ The long-term results, 14 years after implantation of the bileaflet valve, equal at approximately 8 years the good score of the bioprosthesis, to improve the late results, but this requires further follow-up. On the other hand, degeneration of the bioprosthesis in the tricuspid position is exceptional during the first 10 years and becomes more pro-

Table VII. Univariate analysis of variables related to 30-month mortality

	Alive	Dead	<i>p</i> Value
Age (yr, mean $\pm$ SD)	50.8 $\pm$ 11.9	52.2 $\pm$ 15.0	NS
Sex			
Female	79	18	NS
Male	18	5	
Rheumatic disease			
Absent	16	3	NS
Present	80	19	
NYHA			
III	37	4	0.05
IV	60	19	
Ascites			
Absent	85	21	NS
Present	12	2	
Cyanosis			
Absent	84	20	NS
Present	13	3	
Icterus			
Absent	83	18	NS
Present	14	5	
Hepatomegaly			
Absent	48	12	NS
Present	49	11	
Year of operation			
Before 1977	47	18	0.01
After 1977	51	5	
Myocardial protection			
Normothermia	60	13	0.02
Hypothermia	30	8	
Tricuspid prosthesis			
Old mechanical	24	9	NS
New mechanical	22	7	
Bioprosthesis	51	7	

SD, Standard deviation; NS, not significant.

nounced more than 10 years after initial implantation, especially in children.^{2, 3, 27, 28} In our series, two cases of primary valve failure necessitated replacement, both more than 10 years after initial implantation. Other valve-related complications such as endocarditis and paravalvular leakage were rare, regardless of the type of tricuspid prosthesis.

In conclusion, TVR carries a high operative risk and low likelihood of long-term survival, both influenced by preoperative and perioperative variables. Mechanical disc or ball valves in the tricuspid position are prone to dysfunction by pannus formation or thrombosis.^{22, 29, 30} Moreover, Smeloff-Cutter and Kay-Shiley prostheses are incremental risk factors for late death. Because bioprostheses in the tricuspid position have a low risk of valve-related events, we preferred a large-sized bioprosthesis when TVR was mandatory, although the confirmation of better long-term results (14 years) of the St. Jude Medical valves altered our valve choice in some particular young patients with a good long-term prognosis.

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