Surgery for rheumatic tricuspid valve disease: A 30-year experience

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Objective: This study was undertaken to assess factors influencing short- and long-term outcomes of surgery for rheumatic disease of the tricuspid valve.

Methods: Between 1974 and 2005, a total of 328 consecutive patients (mean age 51.3 ± 13.6 years) underwent tricuspid valve surgery for rheumatic disease. There were 12 cases of isolated tricuspid lesion, 199 of triple-valve disease, 114 of tricuspid and mitral valve disease, and 3 of aortic and tricuspid valve disease. Most patients (72%) had predominantly tricuspid regurgitation. Tricuspid valve prosthetic replacement was performed in 31 cases and valve repair in 297.

Results: In-hospital mortality was 7.6%. Late mortality was 52.1%, whereas the expected mortality of the Spanish population of the same age was 24.2%. Predictors of in-hospital mortality were male sex, isolated tricuspid lesion, moderate aortic insufficiency, postclamping time, and tricuspid valve replacement. Mean follow-up was 8.7 years (range 1–31 years). Follow-up was 98.9% complete. Predictors of late mortality were age, New York Heart Association functional class IV, postclamping time, and mitral valve replacement. In total, 114 patients required valve reoperation, but only 4 (3.5%) for isolated tricuspid valve dysfunction. At 30 years, actuarial survival was $12.1\% \pm 4.4\%$, actuarial freedom from reoperation was $27.5\% \pm 5.8\%$, and actuarial freedom from valve-related complications was $2.0\% \pm 1.3\%$.

Conclusion: Organic tricuspid valve disease associated with rheumatic mitral or aortic lesions increases hospital and late mortality, but valve repair compared favorably with valve replacement. Long-term results may be considered acceptable for otherwise incurable valve disease.

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In contrast with functional tricuspid regurgitation with annular dilatation and structurally normal valves, organic tricuspid disease is a valvular dysfunction caused by primary structural pathology affecting the leaflets, the subvalvular apparatus, or both, with or without a dilated annulus. The most common cause of organic tricuspid disease worldwide is rheumatic fever. It usually affects the mitral valve and frequently affects the aortic valve concomitantly. Despite the dramatic decline of acute rheumatic fever in developed countries, significant morbidity and mortality are still associated with rheumatic heart disease in developing nations. In our country, Spain, a large population of patients with rheumatic valve disease have undergone diagnosis and treatment during the past 30 years, not only because eradication of rheumatic fever occurred later than in other developed countries but also because there has been a resurgence of the disease as a result of the influx of immigrants from countries where rheumatic fever is prevalent.¹ On the other hand, there is a paucity of studies in the literature on the long-term results of patients undergoing tricuspid valve surgery for organic tricuspid disease.^{2–4} The purpose of this study was therefore to review our experience with patients who required correction of tricuspid valve disease operated on between 1974 and 2005, with the ultimate goal of assessing long-term outcomes of rheumatic tricuspid valve surgery.

Abbreviations and Acronyms

NYHA = New York Heart Association

Materials and Methods**Study Subjects**

From 1974 to 2005, a total of 328 consecutive patients underwent surgical correction at our institution for a diagnosis of valve disease of rheumatic etiology with significant tricuspid dysfunction involving the leaflets or the subvalvular apparatus. During the study period, a total of 1106 patients required 1213 operations on the tricuspid valve for tricuspid valve disease of acquired etiology (excluding active infective endocarditis). The incidence of organic rheumatic tricuspid valve disease was thus 29.7%. Operations were performed on 189 patients between 1974 and 1988 and on the remaining 139 between 1989 and 2005. There were 57 male patients and 271 female patients (aged 51.3 ± 13.6 years, range 14–81 years). Fifty-three patients (16.2%) were in New York Heart Association (NYHA) functional class II, 203 (61.9%) in class III, and 72 (21.9%) in class IV. A total of 275 patients (83.8%) had atrial fibrillation. Previous cardiac operations had been performed in 88 cases (26.8%): 62 on the mitral valve, 6 on the aortic valve, and 20 on both mitral and aortic valves. None of the patients had previously undergone tricuspid valve surgery.

Almost all patients underwent preoperative investigation by means of echocardiography in different modes according to the year of the study, although echocardiographic findings did not contribute to the indication for surgery until the appearance of 2-dimensional mode. In this respect, hemodynamic studies to complement echocardiographic examination or coronary angiographic studies were indicated in 265 cases (80.8%). Results of hemodynamic studies are shown in Table 1.

After completion of echocardiographic and hemodynamic studies, 12 patients were found to have an isolated tricuspid lesion, 199 triple valve disease, 114 tricuspid and mitral valve disease, and 3 aortic and tricuspid valve disease. Predominant tricuspid insufficiency was present in 236 patients (72.0%), and the remaining 92 patients were considered to have predominant tricuspid stenosis. Grades of tricuspid regurgitation were 1+ in 16 patients, 2+ in 55, 3+ in 113, and 4+ in 123. All patients had organic tricuspid lesions documented at surgery by the attending surgeon. Criteria for organic tricuspid lesion included morphologic changes in the leaflets or subvalvular apparatus. The most frequent findings consisted of retraction of the free edge, thickening and appearance of calcified foci, and some degree of fusion of the commissures.⁵

In 88 patients with previous valve surgery, reoperation was indicated. Reasons were structural progression of rheumatic valve disease in 53 patients, structural deterioration of bioprosthesis in 30, early failure of valve repair in 4, and dehiscence of a prosthesis in 1. The remaining 240 patients underwent primary valve surgery for rheumatic heart disease.

Surgical Procedure

Preoperative informed consent was obtained from all patients. Operations were performed through median sternotomies with cardiopulmonary bypass. Myocardial protection was achieved with crystalloid cardioplegia in patients operated on until 1993 and with antegrade or retrograde blood cardioplegia after that. The dura-

TABLE 1. Preoperative hemodynamic studies

Variable	N	Mean $\pm$ SD	Range
Pulmonary capillary pressure (mm Hg)	216	22.4 ± 8.4	6–75
Pulmonary artery systolic pressure (mm Hg)	254	48.8 ± 17.7	16–105
Left ventricular ejection fraction (%)	239	55.2 ± 10.8	22–87
Cardiac index ($L \cdot min^{-1} \cdot m^{-2}$)	205	2.28 ± 0.76	1.06–8.9
Aortic valve gradient (mm Hg)	61	39.9 ± 27.9	1–130
Mitral valve gradient (mm Hg)	178	14.7 ± 6.7	2–30
Tricuspid valve gradient (mm Hg)	35	5.3 ± 2.8	1–11
Left ventricular end-diastolic pressure (mm Hg)	123	5.8 ± 3.7	2–13
Right ventricular systolic pressure (mm Hg)	123	51.3 ± 23.0	20–85
Total pulmonary vascular resistance ($dyne \cdot s \cdot cm^{-5}$)	146	853 ± 378	363–1231
Pulmonary alveolar resistance ($dyne \cdot s \cdot cm^{-5}$)	146	259 ± 205	103–528

tion of myocardial ischemia was 66.5 ± 34.2 minutes, that of cardiopulmonary bypass was 107.4 ± 43.6 minutes, and postclamping time was 36.7 ± 25.4 minutes. Postclamping time was defined as the interval between the release of aortic clamps and the end of cardiopulmonary bypass.⁶ Repair of the tricuspid valve was performed on an ischemic heart in 322 patients and with the heart beating in the remaining 6. An intra-aortic counterpulsation balloon was implanted in 11 patients.

Decisions regarding type of surgical procedure (replacement or repair) and type of repair (prosthetic or suture annuloplasty) were left to the discretion of the attending surgeon. Thirty-one patients (9.4%) underwent prosthetic tricuspid valve replacement (mechanical prosthesis in 13 and bioprosthesis in 18). Repair of the tricuspid valve was performed in 297 cases (90.5%). Types of repair were as follows: Duran Flexible Annuloplasty Ring (Medtronic, Inc, Minneapolis, Minn) in 79 patients, Duran Flexible Annuloplasty Ring and tricuspid commissurotomy in 72 patients, De Vega or segmental annuloplasty⁷ in 108 patients, suture annuloplasty and tricuspid commissurotomy in 21 patients, isolated tricuspid commissurotomy in 13 patients, and other procedures in 4 patients (edge-to-edge tricuspid valve repair in 3). A total of 106 patients (32.3%) underwent tricuspid commissurotomy.

Concomitant intracardiac procedures included mitral valve replacement in 159 patients (mechanical prosthesis in 103 and bioprosthesis in 56), mitral commissurotomy in 25 patients, Duran Flexible Annuloplasty Ring in 22 patients, and Duran Flexible Annuloplasty Ring and mitral commissurotomy in 107 patients. Fifty patients underwent concomitant repair of the subvalvular apparatus. Aortic valve operations included valve replacement in 84 patients (mechanical prosthesis in 47 and bioprosthesis in 37) and aortic valve repair with previously described techniques⁸ in 33 patients.

Follow-up

The follow-up data for this study were procured in a 6-month period (July 2006–December 2006). The patients were followed up

TABLE 2. Univariate significant predictors of in-hospital mortality

Variable	Deaths		P value
	No.	%	
Sex			.01
Male	271	15.8	
Female	57	5.9	
Valve disease			.021
Isolated tricuspid valve disease	12	25.0	
Polyvalvular disease	316	6.7	
Aortic valve disease			<.005
Predominant aortic regurgitation	48	14.6	
Predominant aortic stenosis	69	1.4	
Grade of aortic regurgitation			.048
1–2+	74	12.1	
3–4+	43	2.3	
Previous valve surgery			<.005
Yes	88	15.3	
No	240	5.3	
Tricuspid valve surgical procedure			<.005
Valve replacement	31	19.3	
Valve repair	297	6.4	
Aortic valve surgical procedure			.029
Valve repair	33	18.2	
Valve replacement	84	4.8	
Use of intra-aortic counterpulsation			<.005
Yes	11	45.5	
No	317	6.5	
Duration of cardiopulmonary bypass			<.005
>120 min	96	15.6	
≤120 min	232	4.3	

through visits in our outpatient clinic ($n = 99$), direct contact at home ($n = 185$), or direct contact with their cardiologists ($n = 12$). When follow-up was not possible, information on vital status (alive or dead) and cause of death if applicable was obtained through the Social Security database ($n = 7$). Of a possible maximum follow-up of 45,053 months, 44,557 months were obtained. Follow-up was 98.9% complete, with a mean follow-up of 16.2 ± 8.7 years (median 7 years, range 1–31 years, 25th–75th interquartile range 2.5–13 years). The follow-up was incomplete for 4 patients who were unavailable after 11.4, 11.5, 16.6, and 18.5 years of follow-up.

Statistical Methods

The Patient Analysis and Tracking System database, version 06.02.03 (Dendrite Clinical System, Inc, Portland, Ore) was used. Values are expressed as mean $\pm$ SD. The Student t test was used for the comparison of quantitative variables. Factors influencing in-hospital mortality (death before 30 days after surgery) were analyzed with multiple logistic regression; the results are expressed as odds ratios. Survival curves were obtained by actuarial method. Cox proportional hazards regression was used to study the influence of covariates on mortality and reoperation; we present the results as hazard ratios. Multivariate analysis was performed with the Stata Intercooled, release Stata 8/SE computer program (Stata Corporation,

TABLE 3. Predictors of mortality in multivariate analysis

Variable	Odds or hazard ratio	95%	<i>P</i> value
		Confidence interval	
Hospital mortality (odds ratio)			
Male sex	1.91	0.79–4.66	NS
Cardiopulmonary bypass >120 min	1.80	0.83–3.93	NS
Postclamping time (each 10 min)	1.26	1.12–1.43	<.005
Late mortality (hazard ratio)			
Age (each 1 y)	1.04	1.02–1.06	<.005
NYHA functional class IV	1.57	0.99–2.49	.056
Severe postoperative complications	1.43	0.92–2.21	.111
Mitral valve replacement vs repair	1.50	0.95–2.37	.080
Postclamping time (each 10 min)	1.11	1.01–1.23	.025
Reoperation (hazard ratio)			
Age >40 y	0.68	0.46–1.01	.058

NYHA, New York Heart Association.

College Station, Tex). We compared survival in our series with an age- and sex-matched Spanish population for which survival probabilities were estimated with the Gompertz function.⁸

Results

In-Hospital Mortality

The in-hospital mortality (30-day, or within first admission) was 7.6% (25 patients). Causes of death were cardiac in 80% of cases, bleeding in 16%, and neurologic in 4%.

Statistically significant variables in the univariate analysis in relation to hospital mortality are shown in Table 2. On the other hand, mean postclamping time was 62.5 ± 30.9 minutes for deceased patients and 26.5 ± 6.3 minutes for survivors ($P < .005$).

With the multiple regression model, male sex and duration of cardiopulmonary bypass did not reach statistical significance. Postclamping time was the only significant risk factor for in-hospital mortality (odds ratio 1.26 for each 10 minutes, $P < .005$; Table 3). The area under the receiver operating characteristic curve was 0.665.

Late Deaths

There were 171 late deaths among 303 perioperative survivors (late mortality 52.1%). Causes of death were cardiac in 122 patients and successive reoperations in 34 patients. The other 15 deaths were from noncardiac causes. The actuarial survivals were $61.8\% \pm 2.8\%$ at 10 years, $38.4\% \pm 3.1\%$ at 20 years, and $12.1\% \pm 4.4\%$ at 30 years (Figure 1). We estimated survivorship in a cohort of Spanish people of the same age and sex distribution by assuming a Gompertz model of mortality. Overall survivals were 96.3%, 89.0%, and 75.8% at 10, 20, and 30 years, respectively (Figure 1). In the univariate analysis, operation before 1989 and NYHA functional class IV were significant predictors of late death. Mortality was 65.7% among patients who

Figure 1. Actuarial survival curve for all causes of death (*thin solid line*) with 95% confidence interval (*dashed lines*). *Thick solid line* represents expected survival curve for cohort of Spanish population with same age and sex distribution. Number of patients at risk are displayed every 5 years.

underwent operation before 1989 and 32% among those who underwent operation after 1989 ($P < .005$). Mortality was 63.3% among patients in NYHA class IV and 46.1% among patients in NYHA class II or III ($P = .017$). On the other hand, patients undergoing tricuspid prosthetic implantation showed similar mortality to those undergoing tricuspid valve repair (52.2% vs 51.4%). Mortality was higher for mitral bioprosthesis implantation (68.7%) than for mechanical mitral valve replacement (34.0%), but the cause of this higher mortality was related to cardiac reasons rather than to successive reoperations for structural deterioration of the bioprosthesis.

In the multivariate analysis, age (hazard ratio 1.04 for each year), NYHA class IV (hazard ratio 1.57), postclamping time (hazard ratio 1.11 for each 10 minutes), and mitral valve replacement compared with mitral valve repair (hazard ratio 1.50) were predictive factors for late death (Table 3).

Reoperations

Of the 303 patients who survived the operation, 114 (37.6%) required reoperation because of isolated mitral dysfunction ($n = 23$), isolated tricuspid dysfunction ($n = 4$), isolated aortic dysfunction ($n = 4$), mitral and aortic dysfunction ($n = 12$), mitral and tricuspid dysfunction ($n = 36$), aortic and tricuspid dysfunction ($n = 2$), and mitral, aortic, and tricuspid dysfunction ($n = 33$). Indications for surgery included structural deterioration of mitral, tricuspid, or aortic bioprosthesis in 37 patients, progression of rheumatic valve disease in 49, prosthetic endocarditis in 6, dehiscence of a prosthesis in 12, and early failure of valve repair in 10. There were 27 deaths among 114 patients undergoing reoperation (mortality

23.7%). Twenty-four patients required a second reoperation, and 7 required a third reoperation.

In the univariate analysis, need for reoperation was significantly higher among patients younger than 40 years (60.98%) than among patients older than 40 years (27.3%; $P = .005$), among patients with sinus rhythm (53.3%) preoperatively than among patients with atrial fibrillation (34.8%; $P = .019$), among patients with mitral valve repair (45.1%) than among patients with mitral valve replacement (32.4%; $P = .027$), among patients with mitral valve bioprostheses (69.4%) than among patients with mechanical prostheses (14.1%; $P < .005$), among patients with aortic valve bioprostheses (62.8%) than among patients with mechanical prostheses (15.6%; $P < .005$), and among patients with tricuspid valve stenosis (50.6%) than among patients with nonstenotic tricuspid valve lesions (28.6%; $P < .005$). In the multivariate analysis, younger patients had higher risk for reoperation (hazard ratio 0.88 for each 10 years of age); age older than 40 years was a significant protective factor for reoperation (hazard ratio 0.68). The actuarial curve values for freedom from reoperation were $68.7\% \pm 3.1\%$ at 10 years, $40.4\% \pm 4.2\%$ at 20 years, and $27.5\% \pm 5.8\%$ at 30 years (Figure 2).

During the follow-up, 10 patients had infective endocarditis; 4 were treated medically and 6 required reoperation. Thromboembolic episodes were recorded in 66 patients (central without sequelae in 28, central with sequelae in 26, and peripheral in 12). Major bleeding episodes related to anticoagulation were recorded in 44 patients. The actuarial curve values for freedom from valve-related complications were $42.0\% \pm 2.9\%$ at 10 years, $18.7\% \pm 2.6\%$ at 20 years, and $2.0\% \pm 4.3\%$ at 30 years.

Figure 2. Actuarial curve for freedom from reoperation (*thick solid line*) with 95% confidence interval (*dashed lines*). Number of patients at risk are displayed every 5 years.

At the follow-up closing date, 104 survivors (81.2%) were in NYHA functional class I or II, 23 (18%) were in class III, and 1 (0.8%) was in class IV.

Discussion

This study presents a 30-year experience at a university center with a homogeneous clinical series of consecutive patients with rheumatic heart disease involving the tricuspid valve. Long-term results of tricuspid valve lesions of rheumatic origin were published in the literature 10 to 20 years ago,⁹ coinciding with eradication of rheumatic fever in most industrialized countries.^{10,11} In our country, the eradication of rheumatic fever occurred later, and for this reason rheumatic tricuspid valve lesions have been seen frequently in the recent past. On the other hand, follow-up of patients even 30 years after cardiac surgery is relatively easy to obtain,^{12,13} because the Spanish health care system provides full coverage for 100% of the population. In this respect, our findings add evidence of the natural history of surgical treatment of rheumatic heart disease, in particular involving the tricuspid valve. Recently, McCarthy and colleagues¹⁴ reported the long-term results of tricuspid valve repair in 790 patients with functional tricuspid valve dysfunction.

In our overall experience (1974–2005) with 328 consecutive patients with significant tricuspid dysfunction in the context of polyvalvular rheumatic disease, in-hospital mortality was relatively low (7.6%), although slightly greater than in patients with isolated mitral valve surgery.¹⁵ Previous valve surgery, duration of cardiopulmonary bypass longer than 120 minutes, and tricuspid valve replacement rather than repair were significant predictors of in-hospital mortality. Tricuspid valve replacement is associated with high in-hospital mortality (19.3%), reaching 37% in our overall experience.¹⁶ These results may be explained by taking into account that only 9% of patients with tricuspid valve disease need valve replacement operations, compared with 91% treated with valve repair procedure.

On the other hand, in-hospital mortality was associated with clinical and surgical characteristics of the aortic lesion. Patients with moderate aortic regurgitation (2+–3+) had a significantly higher mortality (12.1%) than did patients with severe aortic dysfunction (4+, 5.3%), which may be explained by the use of repair procedures in patients with moderate aortic dysfunction during the initial period of our experience (1974–1988). In a previous study, long-term functional results of reparative procedures for nonsevere aortic valve disease in patients with predominant rheumatic mitral valve disease have been inadequate at 22 years of follow-up.⁸ Conservative operations for rheumatic aortic valve disease are associated with poorer outcome than are conservative operations for rheumatic disease of the mitral valve.^{8,13,17}

In agreement with a previous study of long-term performance of the Top Hat valve (CarboMedics Inc, Austin,

Tex) in a modern series of patients undergoing aortic valve replacement,⁶ postclamping time was a significant predictor of in-hospital mortality in both univariate and multivariate analyses (the risk for a fatal outcome increased by 1.26 for each 10 minutes of postclamping time). Prolonged postclamping time indicates that some intraoperative problems had occurred, leaving little margin for therapeutic maneuver, as factors affecting postclamping time are hardly modifiable. It is reasonable to consider that severe intraoperative complications, such as perioperative myocardial infarction or ventricular dysfunction, would be associated with a higher postoperative morbidity (respiratory distress, renal failure, and other) that could influence long-term results. We therefore suggest that postclamping time represents an omnibus risk factor that acts as a surrogate for a number of complications in the perioperative period.

The area under the receiving operating characteristic curve for the in-hospital mortality model was 0.665, reflecting relatively low discrimination. It is possible that other risk factors for in-hospital death remain unidentified in this study.

In this series with complete follow-up in 98.9% of cases, late mortality during the 30-year study period was high (52.1%). As might be expected for a group of young patients (mean age 51 years) with chronic rheumatic heart disease, the main cause of death was cardiac, related to the need for reoperation or terminal heart failure. The actuarial survival at 30 years was 12%. This figure dramatically contrasts with the 75.8% survivorship at 30 years of a cohort of Spanish people of the same age and sex distribution, although it should be noted that survivorship of Spanish women is the second highest worldwide after Japan, and women accounted for 82.6% of our series.

Other predictive factors for late death included such classic risk factors as age, NYHA class IV, and mitral valve replacement as opposed to repair. In line with the natural aging process, patients who underwent operation before 1989 showed a higher mortality than did those operated on more recently.

Surgery for rheumatic valve lesions is palliative. In this study, the actuarial curve value for freedom from reoperation was 27.5% at 30 years. There are two remarkable findings: high mortality associated with reoperation (23.7%), which is consistent with other studies,¹⁸ and reappearance of left-sided valve dysfunction as the main reason for reoperation (95.6% of cases). Isolated tricuspid valve dysfunction was the cause of reoperation in only 4 of 114 cases (3.5%). On the other hand, patients with stenosis of the tricuspid valve showed a greater probability of reoperation than did those with tricuspid regurgitation.

Results of tricuspid valve repair surgery for organic disease are less favorable than are repair procedures for functional tricuspid disease. Some authors advocate modern repair techniques, such as edge-to-edge valvuloplasty, as

effective adjuvants to annuloplasty or commissurotomy.¹⁹ In our experience, the Alfieri procedure was used in 3 patients, with acceptable functional results. Tricuspid valve replacement in advanced rheumatic heart disease is a high-risk procedure. Other authors have reported a very high mortality rate of 26%, with a survival of 37% at 10 years.² Preliminary data have shown that the mitral homograft could be an alternative to replacement of the tricuspid valve.²⁰

Although this clinical study presents a 30-year experience, from 1974 to 2005, in the course of which important clinical, diagnostic, and surgical advances took place, short-term, midterm, and long-term results are in accordance with recently published data. The mortality associated with tricuspid valve repair surgery is slightly higher than that associated with isolated mitral valve surgery, and according to different authors varies from 8% to 13%.^{3,4} Results at 10 years showed survivals of 59% and 61%,^{3,4} coinciding amazingly well with our actuarial survival of 61.8% at 10 years. The limited experience with rheumatic tricuspid valve surgery recently published in the literature^{2,11,21} is consistent with our findings of poor outcomes after prosthetic tricuspid valve replacement.

In conclusion, rheumatic tricuspid valve disease aggravates the prognosis of rheumatic heart disease, particularly in the long term. Clinical results are more favorable after tricuspid valve repair than after prosthetic replacement of the tricuspid valve.

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