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ORIGINAL ARTICLE

Results and factors associated with adverse outcome after tricuspid valve replacement

Paweł Litwiński[1], Piotr Kołsut[1], Tadeusz Sitko[1], Tomasz Zieliński[2], Piotr Hoffman[3], Tomasz Hryniewiecki[4], Jacek Różański[1], Mariusz Kuśmierczyk[1]

[1]Department of Cardiac Surgery and Transplantology, The Cardinal Stefan Wyszynski Institute of Cardiology, Warsaw-Anin, Poland
[2]Department of Heart Failure and Transplantology, The Cardinal Stefan Wyszynski Institute of Cardiology, Warsaw-Anin, Poland
[3]Department of Congenital Heart Diseases, The Cardinal Stefan Wyszynski Institute of Cardiology, Warsaw-Anin, Poland
[4]Department of Acquired Cardiac Defects, The Cardinal Stefan Wyszynski Institute of Cardiology, Warsaw-Anin, Poland

Abstract

Background and aim: This retrospective analysis of patients with severe tricuspid valve disease, who underwent tricuspid valve replacement (TVR) for either tricuspid regurgitation or stenosis, has been designed to determine the factors that predict poor hospital and long-term survival.

Methods: The study population comprised 86 patients, 65 women and 21 men, who underwent TVR with or without concomitant surgical procedures between 2000 and 2010 at our institution. Patients with Ebstein's or other complex congenital anomalies were excluded from the study.

Results: Average age at operation was 58.5 ± 12.5 (range 16–78) years. Fifty (58.1%) patients had undergone previous cardiac surgery. Forty-two patients were in New York Heart Association (NYHA) class III functional capacity, and 18 were in class IV. Symptoms of right heart failure (HF) were present in 66 patients, of whom 19 had ascites. Bioprosthetic tricuspid valves were implanted in 84 patients and mechanical prostheses in two. The choice to proceed to TVR instead of repair was individualised and based on the surgeon's preference. In-hospital mortality was 18 (20.9%) patients, caused mainly by multi-organ and HF, and was significantly related to NYHA class and symptoms of right HF before surgery, with no mortality in patients with NYHA class I and II, 19% mortality with NYHA class III, and 55.6% mortality with NYHA class IV. Eighteen (20.9%) patients died during postoperative follow-up. The main risk factors associated with perioperative mortality were: the presence of severe symptoms at the time of surgery, low preoperative haematocrit, postoperative complications, postoperative ventilation time longer than 72 h, and renal failure requiring dialysis. Elevated pulmonary artery pressure, preoperative symptoms of right HF, and low haematocrit unfavourably affected the long-term results.

Conclusions: Many earlier studies reported high mortality and morbidity after TVR in both early and late postoperative periods. Our main finding is that good outcomes for TVR are achievable in properly selected patients. Sixty of 86 patients in our group had preoperative NYHA functional class III and IV, which suggests that surgical timing was late in many patients. Based on our observations, we propose that surgical correction of severe tricuspid valve disease should be considered before the development of advanced HF, when patients are asymptomatic or only oligosymptomatic.

Key words: tricuspid valve, outcomes, cardiac surgery

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INTRODUCTION

Tricuspid valve disease is often found in combination with other valvular pathologies. Tricuspid regurgitation (TR), the most common tricuspid valvular condition, most frequently occurs with a structurally normal tricuspid valve (functional TR) and is usually caused by disease of the left heart, but disease of the pulmonary vasculature or the right ventricle may be responsible. Whatever the aetiology, TR has a significant impact on the clinical condition, and medium- and long-term prognosis of patients. It is also known that severe

Address for correspondence:
Paweł Litwiński, MD, PhD, Department of Cardiac Surgery and Transplantology, The Cardinal Stefan Wyszynski Institute of Cardiology, ul. Alpejska 42, 04–628 Warszawa-Anin, Poland, e-mail: open4cor@gmail.com
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TR is an independent risk factor of long-term mortality [1]. For many years it was believed that mitral valve surgery alone would allow TR to resolve. Consequently, TR was ignored. More recently, compelling data have shown that surgically untreated secondary TR can persist or even worsen despite correction of the associated left-sided lesion, warranting more aggressive therapeutic approaches toward secondary TR. Significant TR occurring late after left heart surgery is observed in up to 40% of patients, with a median survival of five years, and the prevalence of this valvular pathology in patients presenting for mitral valve surgery is in the range of 30% to 40% regardless of degenerative or ischaemic mitral regurgitation, or mitral stenosis [2, 3]. Currently, moderate to severe TR affects approximately 1.6 million patients in the United States, of whom only 8000 undergo tricuspid surgery annually [4]. This results in an extremely large number of patients with TR treated only conservatively. Unfortunately, the referral for surgical correction of TR is often delayed until patients develop advanced symptoms. Tricuspid valve surgery is typically a supplementary procedure during another major cardiac operation and is rarely performed in isolation. Tricuspid valve repair is the basis of current surgical therapy for tricuspid valve disease and aims to correct annular dilatation and restore annular geometry, resulting in improved leaflet coaptation. Still, there are circumstances when the tricuspid valve is severely functionally or organically diseased, in which case a tricuspid valve replacement (TVR) is unavoidable. In recent decades the proportion of tricuspid valve repairs has increased significantly, while the proportion of TVR has decreased [5]. Many earlier studies reported high mortality (5%–50%) and morbidity after TVR in both early and late postoperative periods [6]. According to the literature, the development of severe TR is likely to indicate right heart failure (HF) with right ventricular decompensation and dilatation [7]. The need for tricuspid valve surgery reflects an advanced stage of heart disease, frequently associated with multi-organ failure.

METHODS

The aim of the study was to identify the risk factors associated with in-hospital and long-term mortality after TVR. The study was a retrospective analysis of our experience with TVR for tricuspid valve disease. Eighty-six consecutive patients, 65 women and 21 men, who underwent TVR with or without concomitant surgical procedures between 2000 and 2010 at our institution, were included. Patients with Ebstein's or other complex congenital anomalies were excluded from the study. From 2000 to 2013, follow-up procedure for death was obtained. The completeness of the mortality data was checked with the national database on deaths, the PESEL Registry. During the study period, valve repair was the procedure of choice for all tricuspid valve diseases. Valve replacement was performed after previous prosthetic TVR, when valve repair was not possible, when the risk of TR recurrence after tricuspid valve plasty was too high due to the valve anatomy (extreme annular dilatation with concomitant retraction of the leaflets), or when attempts at repair had failed. Preoperative and in-hospital postoperative data were obtained from hospital records. A large number of baseline characteristics and demographics were examined. These included patient characteristics, valve lesion(s), physical findings (as documented in the examination of the cardiologist/cardiac surgeon) and functional class, concomitant diseases, blood tests, assessment of current medications (doses of diuretics, the use of inotropes), electrocardiogram, chest X-rays, echocardiogram, cardiac catheterisation in some cases, and the EUROSCORE II as a method of calculating predicted operative mortality for patients undergoing cardiac surgery. Baseline characteristics are shown in Table 1. The underlying diseases of the patients included among others rheumatic (n = 36, 41.9%), functional (n = 22, 25.6%), congenital (n = 2, 2.3%), endocarditis (n = 8, 9.3%), and posttraumatic (n = 1, 1.2%). The predominant lesion was a significant TR. Average age at the time of operation was 58.5 ± 12.5 (range 16–78) years, and the average body mass index was 24.77 ± 4.2 (range 17.9–40.9) kg/m^2. Fifty (58.1%) patients had undergone previous cardiac surgery and 30 of them had previous tricuspid valve surgery (repair in 10 or replacement in 20). The preoperative New York Heart Association (NYHA) functional class could be assessed in all the patients. Most of them had an advanced stage of heart valve disease. Five (5.8%) patients demonstrated NYHA class I, 21 (24.4%) patients — NYHA class II, 42 (48.8%) — NYHA class III, and 18 (20.9%) — NYHA class IV. Symptoms of right HF (peripheral oedema, hepatomegaly) were present in 66 (76.7%) patients, ascites in 19, and pulmonary hypertension in 69.8% of the patients (moderate in 51.2%, severe in 18.6%).

Operative variables (Table 2) recorded included prosthesis type, aortic cross-clamp and cardiopulmonary bypass (CPB) time, concomitant procedures, intraoperative complications, and requirement for vasopressor therapy or intra-aortic balloon pump placement during weaning from bypass. Isolated TVR was performed in 34 (39.5%) patients. Concomitant cardiac procedures were necessary in 52 (60.5%) patients. Moreover, 37 (43%) patients had undergone one previous cardiac operation, 11 (12.8%) had undergone two, and two (2.3%) patients three. We used different types of prosthesis in the tricuspid position, including 84 (97.7%) bioprostheses and two (2.3%) mechanical valves. Recorded postoperative variables included the length of stay in surgical intensive care and regular hospital care units, laboratory data, and specific complications (Table 3).

Operative techniques

All operations were performed by the same group of surgeons. The surgical techniques remained substantially constant during the study period. Operative procedures were carried

Table 1. Baseline patient data

Number of patients	86
Age [years]	58.5 ± 12.5
Sex:	
Male	21 (24.4%)
Female	65 (75.6%)
Body mass index [kg/m^2]:	
> 40	1
35–40	3
30–35	3
25–30	26
18.5–25	51
< 18.5	2
Concomitant diseases:	
Coronary artery disease	10
Atrial fibrillation	69
Hypertension	17
Diabetes mellitus	15
Chronic lung disease	10
Stroke/TIA in the past	9
Pulmonary hypertension:	
Moderate 31–55 mmHg	44 (51.2%)
Severe > 55 mmHg	16 (18.6%)
NYHA class:	
I	5 (5.8%)
II	21 (24.4%)
II	42 (48.8%)
IV	18 (20.9%)
Symptoms of right ventricular failure:	66 (76.7%)
Ascites	19 (22.1%)
Furosemide IV preoperative	24 (27.9%)
Catecholamines IV preoperative	9 (10.5%)
> 1 diuretic preoperative	60 (69.8%)
Preoperative dose of furosemide:	
mean	105 mg
max.	1200 mg
min.	0 mg
Status post pacemaker implantation	14 (16.3%)
Preoperative LVEF:	
> 50%	64 (74.4%)
31%–50%	21 (24.4%)
21%–30%	1 (1.2%)
< 20%	0 (0%)
EUROSCORE II:	
mean	8.75
max.	74.83
min.	0.56

Data are given as mean ± standard deviation or number (percentage). TIA — transient ischaemic attack; LVEF — left ventricular ejection fraction; NYHA — New York Heart Association

Table 2. Intraoperative variables

Total number of patients	86
Status post TVR	20
Status post TVPL	10
Reoperation:	50 (58.1%)
Third reoperation	2
Second reoperation	11
First reoperation	37
Primary operation	36
Type of operations:	
Isolated TVR with biological valve	33
Isolated TVR with mechanical valve	1
AVR, MVR, TVR	10
MVR, TVR	18
TVR with closure of paravalvular leak after MVR	2
MVR, TVR, CABG	4
AVR, TVR	1
AVR, TVR, removal of an electrode	1
AVR, TVR, CABG	1
Re-MVR, re-TVR	1
Re-MVR, TVR	3
AVR, MVR, TVR, implantation of an epicardial electrode	1
AVR, MVR, TVR, CABG	1
AVR, re-TVR	1
Re-TVR, resection of emphysematous bullae	1
TVR with additional, other procedure	6
Re-MVR, AVR, TVR	1
Intraoperative complications	20 (23.3%)
Time of extracorporeal circulation [min]	117.55 (41–255)
Time of aortic cross-clamp [min]	80.9 (0–212)
Intraoperative death	0

Data are given as number (percentage) or mean (minimum–maximum). TVR — tricuspid valve replacement; TVPL — tricuspid valve plasty; AVR — aortic valve replacement; MVR — mitral valve replacement; CABG — coronary artery bypass graft

out through the standard median sternotomy, on CPB with normothermia or mild hypothermia and bicaval cannulation. In three patients CPB was initiated after peripheral cannulation. In addition, antegrade blood cardioplegia was used for 83 procedures. In three patients TVR was performed on the beating heart, and in one with circulatory arrest under deep systemic hypothermia due to technical problems during reoperation. The implantation of the valves was carried out using 2-0 everted pledget-supported Ethibond sutures. Sutures at the septal leaflet were placed at the leaflet tissue to prevent

Table 3. Postoperative variables

Drainage after 12 h [mL]	526 (75–1800)
Drainage after 24 h [mL]	773 (125–2050)
Overall drainage [mL]	1528 (140–7880)
Infusion of catecholamines at the ICU:	
Adrenaline	62 (72.1%)
Dobutamine	63 (73.3%)
Dopamine	37 (43%)
Corotrop	25 (29.1%)
Infusion of furosemide at the ICU	34 (39.3%)
Hemofiltration	8 (9.3%)
Intra-aortic balloon pump	4 (4.7%)
Time on respirator [h]	53 (6–1152)
Number of RBC units transfused	4.9 (0–35)
Complications at the ICU	49 (57%)
Resternotomy	19 (22.1%)
Days at the ICU	8.15 (1–70)
Overall duration of the hospitalisation	25 (5–79)
Complications at the cardiac surgery ward	42 (48.8%)
Deaths during hospitalisation	18 (20.9%)
Deaths during follow-up	18 (20.9%)
Overall mortality	36 (41.86%)

Data are given as number (percentage) or mean (minimum–maximum).
ICU — intensive care unit; RBC — red blood cell

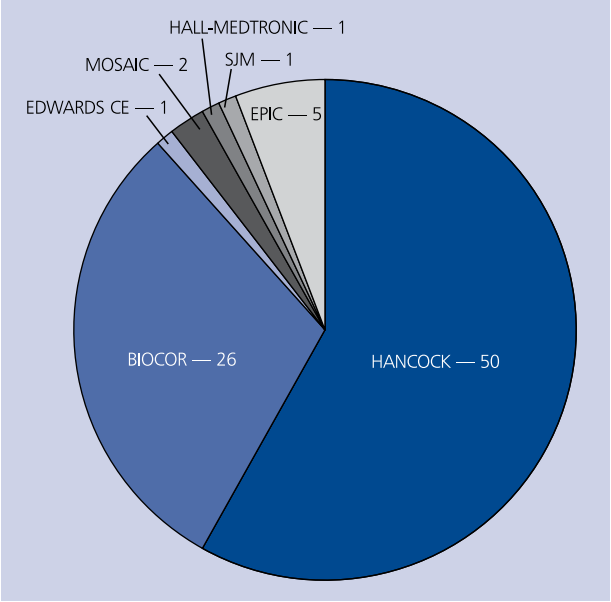

Figure 1. Types of implanted valves

heart block. Our technique involved the preservation of tricuspid valvular and subvalvular apparatus, when possible. The choice to proceed to TVR instead of repair was individualised and based on surgeon's preference. Different bioprostheses (Epic, Hancock, Biocor, Edwards CE, Mosaic) were placed in 84 patients and mechanical valves (Hall-Medtronic, SJM) in the remaining two (Fig. 1). The decision regarding tissue or mechanical prosthetic valves was based on our department policy to implant heterografts in the tricuspid position, due to their good durability and the incidence of valve thrombosis after TVR with mechanical prosthesis. In the present series the main indications for reoperation after TVR were: valve thrombosis in two cases, dysfunction of the mechanical valve in tricuspid position due to pannus formation in two cases, degeneration of the heterograft in 13 cases, and prosthetic endocarditis in one case. Ten patients developed failure of tricuspid valve repair (suture annuloplasty) due to enlargement of the tricuspid valve annulus (n = 6), progression of valve leaflet degeneration (n = 3), and dehiscence of the De Vega annuloplasty suture. In the present study reoperation was not associated with a higher mortality when compared to first operation.

Statistical analysis

Statistical analysis was performed using the statistical software package R 2.15 (R Core Team; 2012). R is a language and environment for statistical computing from the R Foundation for Statistical Computing, Vienna, Austria. All data were expressed as proportion, or mean and standard deviation. The Kaplan-Meier method was applied to study patient survival. The log-rank test was used to ascertain differences between groups. The χ^2 test and Fisher exact test were used to determine differences in categorical variables. Significant factors were entered into a multivariate proportional hazard model (Cox regression) to assess the independent impact of potential risk factors. The relationship of preoperative furosemide dose to postoperative hospital mortality was assessed by the analysis of the receiver operating characteristic (ROC) curve. Results were considered statistically significant at a value of $p < 0.05$.

RESULTS

Mean bypass time was 117.6 (range 41–255) min and cross-clamp time was 80.9 (range 0–212) min. There were no intraoperative mortalities. The main intraoperative complications were: injury to the heart and large vessels during reoperation in four patients, requirement for high-dose vasopressor therapy (n = 7) or intra-aortic balloon pump placement (n = 2) during weaning from bypass, and new onset of atrioventricular block in three patients. Eighteen patients died during hospitalisation, yielding a hospital mortality rate of 20.9%, which is comparable with those in the literature ranging from less than 10% to more than 50% for both isolated and combined TVR. The main causes of death were cardiac and multiple organ failure. Late death occurred in 18 (20.9%) patients. The cumulative overall mortality in our series was

41.86%. Forty-nine (57%) patients experienced a complication during the postoperative period. Nineteen (22%) patients required resternotomy for bleeding or cardiac tamponade due mainly to hepatic dysfunction related to right ventricular failure secondary to tricuspid valve disease and the subsequent deficiency in clotting factors, and the complexity of the surgical procedures. Four (4.7%) patients were placed on intra-aortic balloon counterpulsation on the surgical intensive care unit and 29 (33.7%) required increased doses, new inotropes, or prolongation of vasopressor therapy. Renal insufficiency with the need for dialysis occurred in eight (9.3%), the necessity of IV furosemide infusion in 34 (39.5%), infection in seven (8.1%), and neurological events in five (5.8%) patients. Nine (10.5%) patients suffered from respiratory insufficiency (ventilator support > 72 h) leading to tracheostomy in two (2.3%). Two (2.3%) patients required pericardiocentesis, seven (8.1%) pleurocentesis, and one (1.2%) peritoneocentesis. The mean intensive care unit stay was 8.15 (range 1–70) days followed by a mean hospitalisation of 25 (range 5–79) days. Several variables were investigated to identify patients at increased risk of morbidity and mortality after TVR. Univariate analysis identified the following risk factors for in-hospital mortality (Tables 4–6): NYHA class ($p < 0.001$), preoperative presence of right HF symptoms ($p = 0.021$) and ascites ($p = 0.021$), preoperative infusion of furosemide or inotropes ($p < 0.001$), low preoperative haematocrit value ($p = 0.002$), EUROSCORE II risk score, intraoperative and postoperative complications ($p < 0.001$), ventilator support > 72 h ($p < 0.001$), and the postoperative need for dialysis ($p < 0.001$) or transfusion of more than two units of red blood cells ($p = 0.014$). Based on multivariate analysis, preoperative NYHA class > 2, preoperative inotrope infusion ($p = 0.003$) and intraoperative complications ($p = 0.021$) were identified as risk factors. Based on univariate analysis the NYHA class, preoperative symptoms of right ventricular dysfunction, preoperative treatment with furosemide and inotropes IV, the preoperative use of more than one diuretic, low preoperative haematocrit value, EUROSCORE II risk score, intraoperative complications, aortic cross-clamp time, CPB time, and the number of transfused red blood cell units were identified as risk factors for postoperative complications. Univariate analysis of the late deaths-related risk factors showed the following: pulmonary hypertension ($p = 0.044$), preoperative presence of right HF symptoms ($p = 0.009$) and ascites ($p = 0.004$), low preoperative haematocrit (< 42% in men, < 37% in women; $p = 0.003$), ventilator support > 72 h ($p = 0.044$), and postoperative need for dialysis ($p = 0.048$). Based on multivariate analysis, the only identified predictors of late death were preoperative symptoms of right ventricular dysfunction ($p = 0.005$) and ventilator support > 72 h ($p = 0.082$).

Kaplan-Meier survival curves for factors affecting long-term mortality are presented in Figure 2. The relationship between preoperative furosemide dose and postoperative hospital mortality assessed by the analysis of the ROC curve identified the preoperative furosemide dose of 200 mg as the point of maximal sum of the sensitivity (33.3%) and specificity (97.1%) for the postoperative in-hospital mortality. The area under the curve was 0.687 (Fig. 3).

DISCUSSION

Tricuspid valve surgery is performed less often than surgery on the mitral or aortic valves, although there has been a dramatic increase in tricuspid interventions over time. According to the Nationwide Inpatient Sample (NIS) database [4], procedures involving the tricuspid valve more than doubled over the 10-year period (1712 cases in 1999 vs. 4072 cases in 2008). Mirroring similar trends in the mitral valve surgery, the number of tricuspid replacements dropped while the rate of tricuspid repairs increased significantly [5]. Isolated or concomitant TVR constitutes 0.4%–5.0% of all valvular procedures and 0.1%–1.8% of all cardiac surgical interventions performed at our institution, resulting in 1–17 cases of TVR per year (Fig. 4). Tricuspid valve surgery is typically concomitant with other cardiac procedures and rarely performed isolated. A better understanding of tricuspid valve pathologies, their weighty role in right ventricular failure, and the independence of the severity of left ventricular insufficiency in the clinical outcome has increased the interest in tricuspid valve surgery. Tricuspid valve regurgitation is not a benign pathology. The presence of TR in the setting of right ventricular failure is associated with a poor prognosis [1]. The strong relationship between TR and mortality is not entirely clear, although echocardiography has confirmed that TR is likely to be a better indicator of right ventricular function than its visual inspection alone [7]. The prevalence of severe TR in patients with mitral valve disease is high (> 30%). Ruel et al. [8] reported the risk factors for HF and death in 708 patients after mitral valve replacement. Moderate-to-severe TR on echocardiography during follow-up was an independent predictor of NYHA functional class III or IV HF, HF-related death, and even all-cause mortality during five years of follow-up. Significant TR requiring tricuspid valve surgery predicts poor survival in patients undergoing valve surgery [9, 10], and poor outcome in those undergoing balloon mitral valvulotomy for mitral stenosis [11]. In the mid-1960s Braunwald et al. [12] stated that in most patients, mitral valve replacement alone leads to resolution of TR, which is typically secondary, and therefore it was considered unnecessary to be addressed surgically during cardiac operations, in particular if the left-sided cardiac lesions were to be corrected. This remained the dominant clinical view and dominant practice for at least two decades. The opposing view of routine valve repair for functional TR, first advanced by Carpentier et al. in the 1970s [13], was almost universally ignored. The rationale for surgical correction of functional TR at the time of concomitant cardiac procedures stems from the observa-

Table 4. Preoperative factors influencing the risk of in-hospital death

Variable	Value	In-hospital death — no	In-hospital death — yes	p
Age group [years]	0–45	9 (90.0%)	1 (10.0%)	0.94
	45–55	11 (78.6%)	3 (21.4%)	
	55–65	30 (76.9%)	9 (23.1%)	
	65–100	18 (78.3%)	5 (21.7%)	
Infective endocarditis	0	64 (82.1%)	14 (17.9%)	0.06
	1	4 (50.0%)	4 (50.0%)	
Pulmonary hypertension	0	22 (84.6%)	4 (15.4%)	0.59)
	1	46 (76.7%)	14 (23.3%)	
NYHA class	1	5 (100.0%)	0 (0.0%)	< 0.001
	2	21 (100.0%)	0 (0.0%)	
	3	34 (81.0%)	8 (19.0%)	
	4	8 (44.4%)	10 (55.6%)	
Symptoms of RVF[1]	0	19 (95.0%)	1 (5.0%)	0.021
	1	38 (80.9%)	9 (19.1%)	
	2	11 (57.9%)	8 (42.1%)	
Ascites	0	57 (85.1%)	10 (14.9%)	0.021
	1	11 (57.9%)	8 (42.1%)	
Furosemide IV before operation	0	53 (85.5%)	9 (14.5%)	0.04
	1	15 (62.5%)	9 (37.5%)	
Dopamine IV before operation	0	66 (85.7%)	11 (14.3%)	< 0.001
	1	2 (22.2%)	7 (77.8%)	
> 1 diuretic before operation	0	23 (88.5%)	3 (11.5%)	0.26
	1	45 (75.0%)	15 (25.0%)	
Renal efficiency[2]	1	16 (80.0%)	4 (20.0%)	0.23
	2	35 (85.4%)	6 (14.6%)	
	3	16 (66.7%)	8 (33.3%)	
Low preoperative HT[3]	0	45 (91.8%)	4 (8.2%)	0.002
	1	22 (61.1%)	14 (38.9%)	
High preoperative AST	0	41 (83.7%)	8 (16.3%)	0.28
	1	22 (71.0%)	9 (29.0%)	
High preoperative ALT	0	52 (80.0%)	13 (20.0%)	0.73
	1	11 (73.3%)	4 (26.7%)	
EUROSCORE II	0–3	27 (93.1%)	2 (6.9%)	0.027
	3–5	15 (83.3%)	3 (16.7%)	
	5–75	26 (66.7%)	13 (33.3%)	

Data are given as number (percentage). Differences were calculated using the χ^2 or Fisher tests as appropriate. NYHA — New York Heart Association, RVF — right ventricular failure, HT — haematocrit, AST — aspartate aminotransferase, ALT — alanine aminotransferase; [1]Symptoms of RVF: 0 — absent, 1 — signs of RVF without ascites, 2 — signs of RVF with ascites; [2]Renal efficiency: 1 — normal renal function with creatinine clearance > 85 mL/min, 2 — moderate renal impairment with creatinine clearance 50–85 mL/min, 3 — severe renal impairment with creatinine clearance < 50 mL/min; [3]Low preoperative HT: < 42% in men, < 37% in women

tions that, first, in the absence of TVR, up to 40% of patients undergoing isolated left sided valve surgery will develop significant TR during long-term follow-up [14], secondly, that TR is associated with increased early and late mortality and decreased functional outcome [1, 15], and finally that tricuspid annuloplasty is a safe and effective treatment for functional TR and appears to be associated with an improvement in both functional status and survival. Many previous studies reported considerably high mortality between 15% and 25% [16, 17] and morbidity after TVR in both early and late postoperative periods. Our results compare well with most series published in the literature. In-hospital mortality was significantly related to NYHA class and symptoms of right HF before surgery, with no mortality in patients with NYHA class I and II, contrasting

Table 5. Intraoperative factors influencing the risk of in-hospital death

Variable	Value	In-hospital death — no	In-hospital death — yes	p
Number of valves treated	1	34 (79.1%)	9 (20.9%)	1.0)
	2	24 (80.0%)	6 (20.0%)	
	3	10 (76.9%)	3 (23.1%)	
Coronary artery bypass graft	0	62 (78.5%)	17 (21.5%)	1.0
	1	6 (85.7%)	1 (14.3%)	
Reoperation	0	30 (83.3%)	6 (16.7%)	0.58
	1	38 (76.0%)	12 (24.0%)	
Intraoperative complications	0	56 (84.8%)	10 (15.2%)	0.03
	1	12 (60.0%)	8 (40.0%)	
Duration of aortic cross-clamp [min]	0–50	15 (78.9%0	4 (21.1%)	0.26
	50–100	29 (87.9%)	4 (12.1%)	
	100–250	17 (70.8%)	7 (29.2%)	
Duration of extracorporeal circulation [min]	0–50	4 (80.0%)	1 (20.0%)	0.32
	50–100	28 (87.5%)	4 (12.5%)	
	100–250	31 (73.8%)	11 (26.2%)	

Data are given as number (percentage). Differences were calculated using the χ^2 of Fischer tests as appropriate.

Table 6. Postoperative factors influencing the risk of in-hospital death

Variable	Value	In-hospital death — no	In-hospital death — yes	P
Number of transfused RBC units > 2	0	35 (92.1%)	3 (7.9%)	0.014
	1	29 (67.4%)	14 (32.6%)	
Haemofiltration at the ICU	0	67 (85.9%)	11 (14.1%	< 0.001
	1	1 (12.5%)	7 (87.5%)	
Intra-aortic balloon pump	0	66 (80.5%)	16 (19.5%)	0.19
	1	2 (50.0%)	2 (50.0%)	
Respirator > 72 h	0	64 (87.7%)	9 (12.3%)	< 0.001
	1	1 (11.1%)	8 (88.9%)	
Complication at the ICU	0	37 (100.0%)	0 (0.0%)	< 0.001
	1	31 (63.3%)	18 (36.7%)	

Data are given as number (percentage). Differences were calculated using the χ^2 of Fischer tests as appropriate. RBC — red blood cell; ICU — intensive care unit

to 19% mortality with NYHA class III and 55.6% mortality with NYHA class IV (Fig. 5). Our main finding is that good outcomes for TVR are achievable in properly selected patients. Sixty of 86 patients in our group had preoperative NYHA functional class III and IV, which suggests that surgical timing was late in many patients. Based on our observations, we propose that surgical correction of severe tricuspid valve disease should be considered before the onset of advanced HF when patients show no or only mild symptoms. Early surgical correction of the TR will provide a significantly lower operative risk. If TR is significant and surgery is postponed, right ventricular failure can develop, dramatically increasing morbidity and mortality. We agree with Chikwe et al. [18], who concluded that surgeons should systematically inspect the tricuspid valve during most mitral operations and keep a low threshold for correcting annular dilatation if present. The choice of valve prosthesis for TVR is a subject of ongoing debate. Similarly to other authors [17, 19], we advocate the use of bioprostheses based on their good durability in the tricuspid position, probably related to the lower pressures and stress in the right heart, the possibility of percutaneous interventions (valve-in-valve implantation) in the future in case of valve degeneration, the probability of anticoagulation-related complications with mechanical valves, and the higher rate of valve thrombosis compared to left heart implants. However, the application of heterografts for TVR leads to an increased rate of reoperation after 7–10 years [20]. Many of the patients who underwent tissue valve TVR require also anticoagulation therapy for other

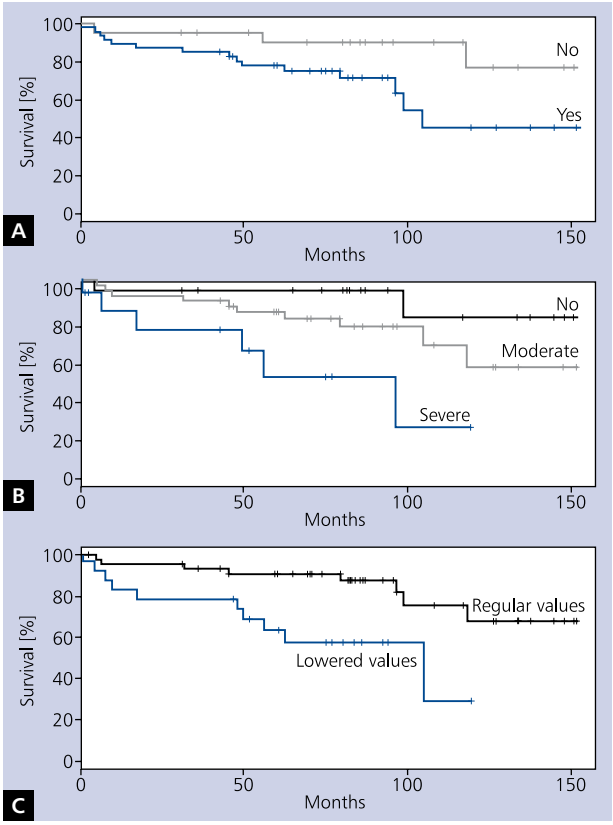

Figure 2. Kaplan-Meier survival curves for factors affecting long-term mortality; **A**. Pulmonary hypertension; **B**. Symptoms of right ventricular failure (moderate signs of right ventricular failure exclude ascites whereas severe sings of right ventricular failure include ascites); **C**. Preoperative haematocrit values

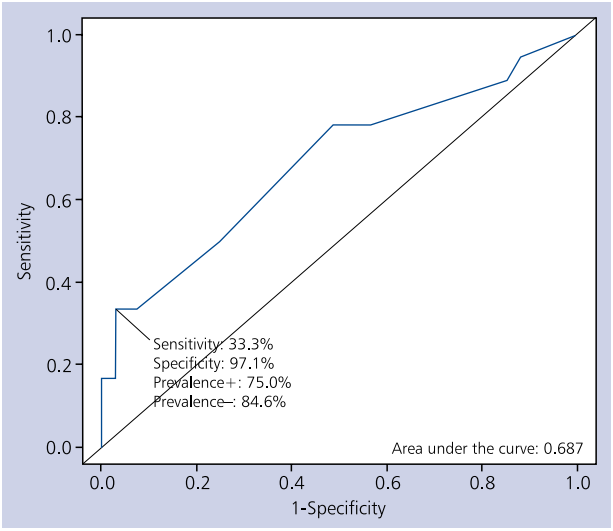

Figure 3. The relationship between preoperative furosemide dose and postoperative hospital mortality assessed by the receiver operating characteristic curves

reasons such as atrial fibrillation (80.2% in our group), thus losing the potential advantage of the bioprosthesis.

The primary limitations of this study are its retrospective nature and extended enrollment period. Consistent, accurate echocardiographic data were not available, and neither was preoperative assessment of right ventricular function, such as magnetic resonance imaging. This study included a relatively small number of cases. Patients who require TVR are a very heterogeneous group. Many of these have undergone previous cardiac surgery and in the majority tricuspid valve surgery was associated with concomitant procedures. The diversity of them is also likely to influence our study. The choice to proceed to TVR instead of repair was individualised and based on surgeon preferences.

In conclusion, our results are in accordance with other studies reporting high mortality and morbidity after TVR. The surgical correction of severe tricuspid valve disease should be considered before the development of advanced HF when patients are asymptomatic or mildly symptomatic, following the clinical trend that has emerged in recent years toward earlier and more aggressive TR intervention [21]. Further

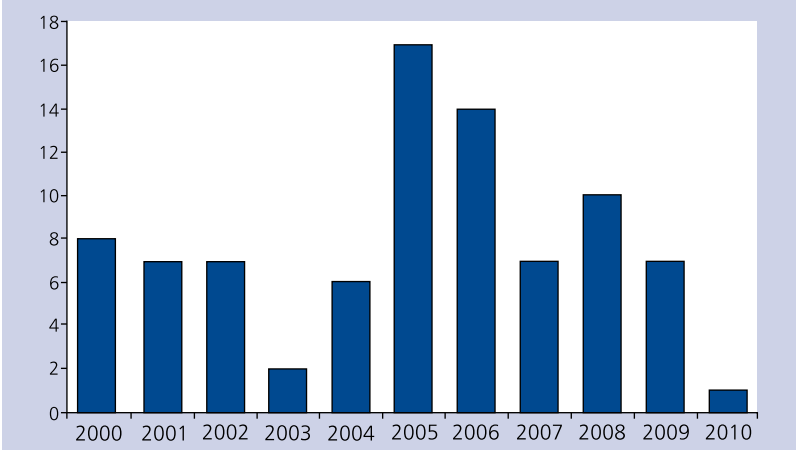

Figure 4. Number of tricuspid valve replacement procedures per year

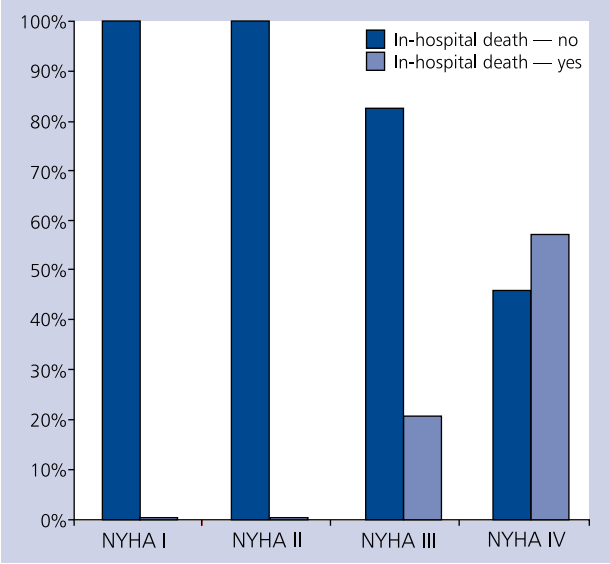

Figure 5. Occurrence of in-hospital deaths (%) and the New York Heart Association (NYHA) class

randomised trials are required to upgrade this recommendation. It is obvious that right ventricular function plays a leading role in both preoperative clinical status and postoperative results. However, discriminating between right ventricles that are capable of recovery and those that will not cope with surgical correction remains difficult because, among other things, the assessment of right ventricular function is still problematic.

Conflict of interest: *none declared*

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