

Long-term outcomes of tricuspid valve replacement after previous left-side heart surgery[†]

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Abstract

OBJECTIVES: To assess long-term outcomes of tricuspid valve replacement (TVR) after previous left-side heart surgery.

METHODS: We reviewed reoperative TVR after left-side heart surgery performed at our institution between March 1997 and June 2012. In-hospital data were retrieved from our institutional database or medical records; follow-up was performed through telephone call, surviving patients being asked to provide a recent (≤ 6 months) echocardiogram.

RESULTS: Reoperative TVR was performed in 117 patients. Preoperative characteristics included: mean age 63.7 years, median logistic EuroSCORE (LES) 11.8, New York Heart Association (NYHA) class >2 in 79.5% of patients, right ventricle (RV) dysfunction $>$ mild in 23.9% of patients and mean systolic pulmonary artery pressure (sPAP) 48.4 mmHg. A mechanical prosthesis was implanted in 5.1% of patients. A right thoracotomy was preferred to median sternotomy in 8.6% of cases. Isolated-TV (I-TV) was performed in 52.1% of patients, a beating-heart approach being used in 85.2% of I-TV cases. Postoperative RV failure occurred in 46.1% of patients. Median length-of-stay was 11.5 days. Thirty-day mortality was 6.0% overall and 8.2% in the I-TV group. Higher preoperative LES ($P = 0.002$), ascites ($P = 0.004$), RV dysfunction ($P = 0.033$) and sPAP ($P = 0.046$) were associated with acute mortality. No significant difference in acute outcomes was observed between beating and arrested-heart I-TV, except for postoperative median length-of-stay (9 vs 28 days, respectively, $P = 0.007$). Among survivors median follow-up time was 5.1 years. Five-year and 10-year freedom from cardiac death were 79.4 and 61.0%, freedom from tricuspid reoperation were 97.3 and 87.5%, freedom from bioprosthesis degeneration were 92.8 and 74.3%, respectively. Five-year and 10-year survival in the I-TV subgroup were respectively 74.4 and 61.6%. Higher preoperative sPAP was associated with increased follow-up mortality ($P = 0.048$). At the last follow-up, NYHA class I–II was found in 86.1% of surviving patients.

CONCLUSIONS: In selected cases, TVR is currently feasible with low acute mortality, especially if performed in the absence of ascites, significant RV dysfunction and pulmonary hypertension. Long-term mortality remains more difficult to predict, although it appeared to be also associated with higher preoperative pulmonary pressure. The global high-complexity profile of these patients is likely to impair long-term outcomes.

Keywords: Tricuspid • Reoperative • Left side • Replacement • Right ventricle

INTRODUCTION

Tricuspid valve replacement (TVR) has commonly been associated with poor acute and long-term outcomes [1–3], especially when performed as a reoperative procedure [4]. The main reason that has been advocated for such poor TVR results is late patient referral: patients usually arrive to surgery after a long-lasting cardiac disease, when other affections (such as atrial fibrillation and right ventricle (RV) dilatation/dysfunction) have had time to occur. Moreover, TVR patients are frequently reoperative cases [5, 6], which carries *per se* an intrinsic higher operative risk. Finally, they are also frequently affected by other non-cardiac comorbidities.

Recent improvements in terms of myocardial protection, technical developments and perioperative management, however, seem to have led to a global improvement in outcomes. Over the past couple of years, other groups have reported their single-centre experiences in the field of reoperative tricuspid disease including also TVR procedures, showing encouraging early results, although patient number and follow-up time remain limited [7–9].

The aim of this study was to report our own long-term experience in the setting of reoperative TVR after left-side heart surgery.

METHODS

We reviewed all TVR cases performed at our institution between March 1997 and June 2012 and selected all reoperative TVR after

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left-sided heart surgery. Redo operations after isolated right-side surgery and complex congenital disease were excluded. Patients presenting with tricuspid disease after left-side surgery who underwent tricuspid valve repair were also excluded.

From July 2000, preoperative, intraoperative and postoperative data were prospectively entered into our Department database; in-hospital data before July 2000 were retrieved from the institution records archive.

Follow-up was conducted through telephone calls using an *ad hoc* clinical questionnaire. All patients were asked to provide an echocardiogram via mail or fax, collection time being closed in August 2013: echocardiograms no more than 6 months old were considered adequate. When patient or family members were not able to provide adequate information, the referral cardiologist/basic doctor was contacted. Local municipality anagraphic services were searched for patients who were otherwise uncontactable.

The follow-up was 98.3% complete (115/117 patients). Median time from procedure was 7.4 years (4.8–10.9), ranging from 0.8 up to 16.0 years.

Ethics approval for the study was obtained from our institution ethics committee.

Surgery

Surgery was performed using standard techniques including bicaval cannulation or peripheral venous cannulation based on the surgeon's choice and mild hypothermia. TVR was performed either on the arrested heart (custodiol cold crystalloid cardioplegia) or on the beating heart (BH), using a standard median sternotomy approach or a right anterior thoracotomy. Outcomes of isolated TVR (I-TVR) were separately analysed.

Echocardiography

RV function was defined using a rough descriptive four-step scale (good function, mild-moderate-severe dysfunction) based on an integrated approach combining visual judgement and the case-by-case available quantitative methods: ejection fraction, tricuspid annular plane systolic excursion and S' peak at tissue doppler imaging.

Echodobutamine stress test was routinely used to evaluate operability in case of RV dysfunction: patients without RV function improvement after dobutamine were excluded from surgery.

Postoperative right failure was defined on an echocardiographic basis together with inotropic support need >5y dobutamine or association of two different inotropes.

Follow-up structural valve deterioration (SVD) was judged on the basis of echocardiographic presence of leaflet thickening, calcifications, reduced motion as well as increased intraprosthetic regurgitation and increased transvalvular gradients.

Statistical analyses

Statistical analyses were conducted using the SPSS Statistics software v20 (IBM Corp. Armonk, NY, USA). The distribution of variables was evaluated using the one-sample Kolmogorov–Smirnov test. Continuous variables are presented as mean \pm sample standard deviation for data with a normal distribution or as median (25th and 75th percentile limits in brackets) for data with a non-Gaussian distribution. Categorical variables are expressed as

proportions. Univariable comparisons have been performed using the un-paired *t*-test for normally distributed data. For non-normally distributed data, Wilcoxon signed-rank test was used for paired continuous and Mann–Whitney *U*-test for un-paired continuous variables. Likelihood ratio test and Fisher's exact test were used as appropriate for categorical data. Univariate logistic binary regression was used for 30-day mortality prediction. Univariate Cox hazard model was used for follow-up mortality and SVD prediction; results were tested using Wald test statistics. Odds ratio (OR) and hazard ratio (HR) of continuous variables are expressed as 'per unit', numbers in brackets denote confidence interval (CI). CI of 95% was used. Long-term survival, freedom from reoperation and freedom from structural valve disease were evaluated using the Kaplan–Meier curve. A two-sided *P*-value of <0.05 was considered statistically significant.

RESULTS

Between March 1997 and June 2012, a total of 117 patients underwent TVR as a reoperation after left-side heart surgery at our institution. Baseline major preoperative characteristics are summarized in Table 1.

The following intraoperative findings were observed on the native tricuspid valve: annular dilatation in 73 (62.4%) patients, leaflet retraction in 73 (62.4%), leaflet fibrosis in 57 (48.7%), leaflet fusion in 17 (14.5%), leaflet calcification in 4 (3.4%), pacemaker (PM) lead adhesions in 4 (3.4%) and leaflet detachment due to endocarditis in 1 (0.9%).

There were 2 (1.7%) previously implanted bioprosthesis degenerations, 33 (28.2%) previous tricuspid repair failures and 5 (4.3%) previous tricuspid commissurotomy failures. All previous procedures are shown in Fig. 1.

Tricuspid regurgitation (TR) more than moderate was present in 112 (95.7%) patients, whereas tricuspid stenosis more than mild was found in 35 (29.9%) patients. Preoperatively RV function was normal in 63 (53.9%) patients. Main echocardiographic data are shown in Table 2.

Overall, in 4 (3.4%) patients TVR was performed after a failed initial repair attempt. A mechanical prosthesis was implanted in

Table 1: Major baseline clinical characteristics

	All patients (n = 117)	I-TVR (n = 61)
Age mean, years	63.7 \pm 9.8	61.7 \pm 10.7
Male gender	29 (24.8%)	17 (27.9%)
Previous cardiac surgery >1	34 (29.1%)	17 (27.9%)
LES median, %	11.8 (8.4–17.8)	12.0 (6.1–17.4)
Atrial fibrillation	100 (85.5%)	54 (88.5%)
Permanent PM/ICD	33 (28%)	20 (32.8%)
Coronary artery disease	17 (14.5%)	10 (16.4%)
Chronic kidney disease	25 (21.4%)	12 (19.7%)
Diabetes mellitus	18 (15.4%)	9 (14.7%)
NYHA class III–IV	93 (79.5%)	48 (78.7%)
Ascites	41 (35.0%)	24 (39.3%)

Numbers following mean values report sample standard deviation and numbers in brackets following median value denote 25th and 75th percentile limits.

PM: pacemaker; ICD: implantable cardioverter defibrillator; NYHA: New York Heart Association.

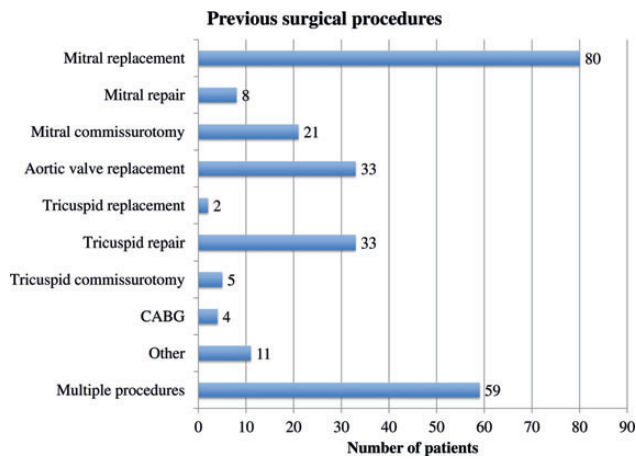


Figure 1: Previous surgical procedures.

Table 2: Major baseline echocardiographic data

	All patients (n = 117)	I-TVR (n = 61)
Tricuspid regurgitation		
1+	1 (0.9%)	0 (0%)
2+	3 (2.6%)	2 (3.3%)
3+	13 (11.1%)	3 (4.9%)
4+	99 (84.6%)	55 (90.2%)
Tricuspid stenosis		
Mild	3 (2.6%)	1 (1.6%)
Moderate	29 (24.8%)	11 (18.0%)
Severe	6 (5.1%)	4 (6.6%)
LVEF mean, %	54.6 ± 8.8	54.4 ± 8.3
RV dysfunction		
Mild	26 (22.2%)	13 (21.3%)
Moderate	24 (20.5%)	12 (19.7%)
Severe	4 (3.4%)	0 (0%)
sPAP mean, mmHg	48.4 ± 14.1	45.3 ± 8.9

Numbers following mean values report sample standard deviation. LVEF: left ventricle ejection fraction; RV: right ventricle; sPAP: systolic pulmonary artery pressure.

6 (5.1%) patients. Among the remaining biological prostheses, 61 (55.0%) were bovine pericardial, whereas 50 (45.0%) were porcine prostheses.

Isolated-TVR procedures

TVR was performed as an isolated procedure (I-TVR) in 61 (52.1%) patients. A standard median sternotomy was preferred in 52 (85.2%) patients and a right thoracotomy in 9 (14.8%). Valve replacement was conducted on the BH without cross-clamping and cardioplegic arrest in 52 (85.2%) of I-TVR patients, with a mean cardiopulmonary bypass (CPB) time of 48.8 ± 10.0 min. Mean CPB and cross-clamp time in arrested-heart I-TVR were, respectively, 47.6 ± 4.0 and 32 ± 6.2 min.

No statistically significant preoperative difference was observed between BH (n = 52) and arrested-heart (n = 9) patients, although a trend towards a higher risk profile of BH patients was observed: median LES 12.1 (6.4–17.1) vs 8.2 (5.2–20.6) for BH vs arrested-heart, respectively (P = 0.258).

Table 3: Acute 30-day postoperative outcomes

	All patients (n = 117)	I-TVR (n = 61)
In-hospital length of stay median, days	11.5 (7–17)	11 (6.5–16)
Reoperation for bleeding	16 (13.7%)	9 (14.7%)
New acute renal failure	41 (35.0%)	18 (29.5%)
New PM implantation	17 (14.5%)	9 (14.7%)
Neurological deficit	5 (4.3%)	3 (4.9%)
Transient	4 (3.4%)	2 (3.3%)
Permanent	1 (0.9%)	1 (1.6%)
RV failure	54 (46.1%)	25 (40.9%)
Death	7 (6.0%)	5 (8.2%)

Numbers in brackets following median value denote 25th and 75th percentile limits.

PM: pacemaker; RV: right ventricle.

Combined-TVR procedures

TVR was performed as a combined procedure (C-TVR) in 56 (47.9%) patients. At time of intervention C-TVR patients showed TR degree as follows: 4+ in 44 (78.6%), 3+ in 10 (18%) and ≤2+ in 2 (3.5%) patients, whereas tricuspid stenosis was severe in 2 (3.5%), moderate in 18 (32%) and mild in 2 (3.5%) patients. The most frequent combined procedures were mitral valve replacement (51.8%), aortic valve replacement (32.1%), mitral paravalvular leak closure (25%) and atrial fibrillation radiofrequency ablation (5.4%). Median sternotomy was used in 55 (98.2%) and right thoracotomy in only 1 (1.8%) patient. Surgery was performed BH in 5 (8.9%) of C-TVR patients, with a mean CPB time of 77.3 ± 38.6 min. Mean CPB and cross-clamp time for arrested-heart C-TVR were, respectively, 102.9 ± 24.3 and 74.8 ± 21.2 min.

Early results

Complete acute 30-day postoperative outcomes for the whole cohort and the I-TVR subgroup are summarized in Table 3.

Overall 30-day mortality was 6.0% (7/117). Preoperative higher LES (P = 0.002), presence of ascites (0.004), RV dysfunction ≥ moderate (P = 0.033) and higher sPAP (P = 0.046) were associated with increased acute 30-day mortality (Table 4).

Acute postoperative mortality was also associated with older time-frame of the procedure (P = 0.042), 4 of the total 7 deaths being located in the first-time from procedure quartile, from March 1997 to March 2002.

No statistically significant difference was observed in acute mortality regarding I-TVR vs C-TVR procedures (P = 0.292). In the I-TVR sub-group, moreover, no significant difference in mortality (P = 0.331) nor postoperative complications (all P > 0.05) between the BH vs arrested-heart approach was observed, except for the postoperative median length of stay: 9 (6–15) vs 28 (17.5–43.5) for BH vs arrested-heart, respectively (P = 0.007).

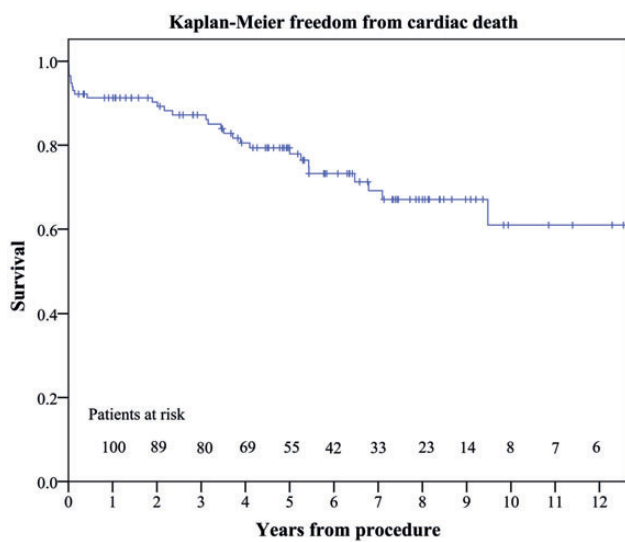
Late results

One hundred and ten patients survived the 30-day period. After that, 2 patients were lost to follow-up. In surviving patients, time

Table 4: Preoperative predictors of 30-day mortality

	Alive (n = 110)	Dead (n = 7)	P-value	OR (95% CI)
Age mean, years	62.8 ± 9.7	58.4 ± 10.9	0.255	0.96 (0.89–1.03)
LES median, %	11.6 (8.1–16.0)	38.7 (13.3–45.9)	0.002*	1.16 (1.06–1.27)
Ascites	35 (31.9%)	6 (85.7%)	0.004*	12.86 (1.49–110.89)
Number of previous operations >1	30 (27.3%)	4 (57.1%)	0.091	3.56 (0.75–16.83)
I-TVR	56 (50.9%)	5 (71.4%)	0.292	2.41 (0.45–12.96)
LVEF mean, %	54.9 ± 8.5	46.2 ± 11.8	0.072	0.92 (0.84–1.01)
RV dysfunction ≥moderate	24 (21.8%)	4 (57.1%)	0.033*	4.78 (1.00–22.82)
sPAP mean, mmHg	47.5 ± 12.9	63.7 ± 24.9	0.046*	1.05 (1.00–1.11)

Numbers following mean values report sample standard deviation and numbers in brackets following median value denote 25th and 75th percentile limits. LVEF: left ventricle ejection fraction; RV: right ventricle; sPAP: systolic pulmonary artery pressure; OR: odds ratio; CI: confidence interval; NPV: negative predictive value; PPV: positive predictive value; Sens: sensitivity; Spec: specificity.

**Figure 2:** Kaplan–Meier freedom from cardiac death in the whole study population.

from procedure to the last follow-up ranged from 0.1 to 14.0 years, with a median of 5.1 years (2.8–7.5). A total of 38 (35.2%) deaths occurred after the first 30-day period, for an overall survival at 5 and 10 years of $72.9 \pm 4.3\%$ and $42.9 \pm 7.2\%$, respectively. Twenty-two (20.4%) deaths were cardiac related. Kaplan–Meier cumulative 5- and 10-year freedom from cardiac death were $79.4 \pm 4.1\%$ and $61.0 \pm 7.7\%$ respectively (Fig. 2), whereas in the I-TVR subgroup they were $74.4 \pm 6.2\%$ and $61.6 \pm 8.6\%$, respectively. sPAP was found to be significantly associated with increased late cardiac mortality ($P = 0.048$) (Table 5).

Five- and 10-year Kaplan–Meier freedom from tricuspid valve-related reoperation were $97.3 \pm 1.9\%$ and $87.5 \pm 9.4\%$, respectively (Fig. 3). SVD was overall observed in 8 (7.4%) patients, 3 of them requiring reoperation 3.9, 9.5 and 14.0 years after the index treatment. SVD occurred at a median follow-up time of 6.7 years (4.5–8.6), range 2.9–11.9 years. Five- and 10-year Kaplan–Meier freedom from SVD in patients who survived the 30-day period were $92.8 \pm 3.5\%$ and $74.3 \pm 9.9\%$, respectively. At the last follow-up, an adequate echocardiogram was available in 43 (61.4%) of 70 surviving patients; mean and maximum trans-prosthetic gradient were 4.0 ± 1.5 and 7.2 ± 3.1 mmHg, respectively; intraprosthetic TR $\geq 2+$ was observed in 6 (13.9%) patients. At Cox regression model,

no statistically significant association was observed between age ($P = 0.682$), bioprostheses size ($P = 0.124$) nor pericardial/porcine type of bioprostheses ($P = 0.157$) and follow-up SVD, although pericardial prostheses were present in 7/8 (87.5%) cases of SVD.

At the last follow-up, NYHA class I–IV was found in 43.1–43.1–12.3–1.5% of surviving patients, respectively.

Five patients were eligible for 15-year follow-up. All of them were biological I-TVR. One died acutely in-hospital, 1 died of heart-failure (2.2 years after the procedure), 1 died of non-cardiac-cause (5.2 years after the procedure), 1 had been reoperated on (3.9 years after the procedure) due to prosthesis degeneration and 1 was lost to the follow-up.

DISCUSSION

We reported our single-centre long-term experience with reoperative TVR after previous left-side heart surgery. This study was since the beginning focused only on TVR, although we acknowledge tricuspid disease after previous left-side heart surgery is a wider topic that includes also patients submitted to tricuspid valve repair and patients left in medical therapy. We decided to focus on TVR since this is, in our opinion, the highest risk and highest complexity surgical patient population. Indeed TVR is usually performed when repair is not possible, due to leaflet structural alterations or excessive leaflet tethering in the context of a long-lasting disease. Moreover, in our experience TVR patients represented the majority of patients referred for tricuspid disease as the main clinical problem after previous left-side surgery, although we acknowledge that this may appear to be different from the experiences of other groups in Europe.

Notably, almost half of the patients submitted to TVR required also contemporary associated procedures (most frequently mitral interventions) and this reflects the high complexity level of these patients. Comparison between I-TVR and C-TVR was not an objective of this study. We know that patients with isolated tricuspid disease after previous left-side surgery are different from patients presenting with predominant left-side valve disease who undergo concomitant tricuspid procedure and pathological relevance of the two different components should be defined. In our series, we cannot state that tricuspid disease was the primary, 'culprit' indication in all combined patients because symptoms and clinical status of the patients are difficult to retrospectively assess to determine the respective role of tricuspid and concomitant left-side

Table 5: Preoperative predictors of late cardiac mortality

	Not cardiac death (n = 86)	Cardiac death (n = 22)	P-value (Wald test)	HR (95% CI)
Age mean, years	62.7 ± 10.0	62.9 ± 8.8	0.515	1.02 (0.97–1.10)
LES median, %	11.3 (7.2–15.4)	14.3 (9.7–22–6)	0.145	1.05 (0.98–1.13)
Ascites	28 (32.6%)	6 (27.3%)	0.770	1.15 (0.45–2.95)
Number of previous operations >1	21 (24.4%)	9 (40.9%)	0.137	1.93 (0.81–4.59)
I-TVR	42 (48.8%)	12 (54.5%)	0.479	1.35 (0.58–3.14)
LVEF mean, %	55.0 ± 8.8	54.8 ± 7.3	0.906	1.00 (0.94–1.06)
RV dysfunction ≥moderate	17 (19.8%)	7 (31.8%)	0.269	1.67 (0.67–4.14)
sPAP mean, mmHg	46.0 ± 11.3	58.1 ± 19.4	0.048*	1.04 (1.00–1.08)

Numbers following mean values report sample standard deviation and numbers in brackets following median value report 25th and 75th percentile limits. LES: logistic EuroSCORE; LVEF: left ventricle ejection fraction; RV: right ventricle; sPAP: systolic pulmonary artery pressure; HR: hazard ratio; CI: confidence interval.

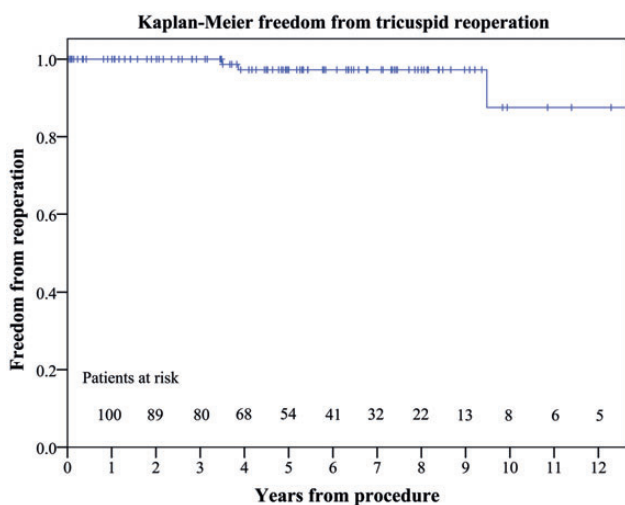


Figure 3: Kaplan–Meier freedom from tricuspid-related reoperation in the whole study population.

pathology, although we know that ascites due to venous congestion was present in 17/56 (30.4%) of C-TVR. Severe echocardiographic tricuspid valve pathology, however, regurgitation or stenosis, was observed in all patients. Moreover, we must also point out that in our institution patients undergoing primary left-side surgery and concomitant tricuspid operation (tricuspid not primary indication to surgery) usually receive a repair, since the valve disease is not so advanced (even if TR is severe). Given the historically poor outcomes previously reported with TVR, in our experience patients requiring TV replacement were the ones in whom we could not do differently (neither repair nor leave the patient as he was). So need for tricuspid intervention can be considered to be, not the only one, but certainly a major indication in all these patients. We decided to include also C-TVR patients in the study because we were surprised that I-TVR were so few and that so many patients also required left-side surgery at the same time as well: in our experience, tricuspid disease after previous left-side surgery frequently is not an isolated problem and we thought it had to be pointed out. I-TVR subgroup was separately evaluated in any case.

A significant number of patients submitted to reoperative TVR arrived to surgery in an advanced stage, when symptoms had already become heavily invalidating and could not be tolerated anymore (35% of patients with confirmed ascites, 80% in New York

Heart Association (NYHA) class III–IV). At this stage 24% of our patients showed also a moderate-to-severe degree of RV dysfunction.

Reoperative tricuspid operations have been traditionally associated with a high mortality rate, between 9 and 37% [3, 4, 10, 11]. Recently, better and promising results have been reported, with an acute mortality reduced to 2–15% [8, 9]. In our series, we could confirm a low acute mortality (6% overall) which was significantly associated with older year of the operation ($P = 0.042$). Acute mortality was also significantly associated with advance stage of the disease in terms of presence of ascites, RV dysfunction and higher sPAP. As a matter of fact, mortality was only 1/76 (1.3%) in patients without preoperative ascites vs 6/41 (14.6%) in patient with ascites ($P = 0.004$). We want to point out that the low mortality rate observed in our series, however (down to 0% during the last 3 years), may also be explained by a sort of patient selection bias: indeed patients with severe RV dysfunction who did not show signs of contractile reserve at preoperative echodopamine examination were denied surgery. We currently recommend echodopamine test to be a routine and fundamental step of preoperative patient selection pathway when RV dysfunction is present.

In our experience, late cardiac mortality remains high (survival was 79.4 and 61.0% at 5 and 10 years, respectively) and we failed to demonstrate any protective or predictive preoperative factor with the exception of higher preoperative sPAP, which appeared significantly associated with increased cardiac mortality ($P = 0.048$). A deeper analysis, however, assessing the relative weight of pulmonary vascular resistances, RV function and left-side disease causing pulmonary pressure overload (valvulopathies or left ventricle dysfunction) will be required to better define the role played by pulmonary hypertension in both acute surgical risk and long-term prognosis in these patients.

Association with late survival was actually difficult to assess in our series, since the patient population was very heterogeneous and, besides being I-TVR or C-TVR, basically all patients also had other important cardiac factors that could significantly influence long-term outcomes, such as atrial fibrillation or previously implanted left-side prostheses: indeed many patients received ‘only’ an I-TVR as index procedure because they had already undergone a mitral and/or aortic replacement. In such a complex situation, it is difficult to determine the specific role of TVR in long-term mortality and morbidity, which are likely to be heavily influenced by the whole individual complex patient profile.

Recently, the Leipzig group showed similar outcomes in patients submitted to isolated BH or arrested-heart tricuspid operations [12].

In our reoperative I-TRV series, no clear significant difference was observed in acute mortality between the BH and the arrested-heart group. This may be due to the very small number of cases (only 5 deaths in the I-TRV group) and possibly to the fact that BH patients had a higher, although not statistically significant, surgical risk (median LES 12.1 vs 8.2 for BH vs arrested-heart respectively, $P = 0.258$). Postoperative morbidity was also not significantly different between the two groups. However, postoperative LOS was much longer in arrested-heart patients (9 vs 28 days, $P = 0.007$), indicating a somehow more complicated postoperative course in those patients. Therefore, we continue to endorse the BH approach in reoperative TVR setting which is faster and reduces heart damage, peripheral venous cannulation and thoracotomy access being particularly useful in avoiding extensive tissue dissection.

We acknowledge the excellent acute results reported by Pfannmüller *et al.* [13] with minimally invasive approach in the setting of isolated tricuspid reoperations. Besides avoiding the risks of median sternotomy, the authors suggest that right mini-thoracotomy might be useful in preventing postoperative dilatation and consequent dysfunction of the right side of the heart by avoiding adhesions removal. Indeed, this surrounding tissue might play a role mechanically supporting the thin right chambers of the heart. In the present series, a right thoracotomy access (not minimally invasive) was used only in 10 (8.6%) patients; however, this is currently becoming an increasingly used approach in our daily practice, and we feel this is actually a useful technique particularly when multiple sternotomies have been previously performed.

The rate of tricuspid-related reoperation was very low in our series, as confirmed by the 87.5% freedom from this event at 10 years. However, reoperation rate should be considered carefully when used as an efficacy and durability indicator of this kind of procedure, since surgeons are usually not very keen on performing a new reintervention in this setting and a significant number of patients die before a reoperation might become necessary.

Although debate still exist about prosthesis choice in tricuspid position [7], given the results of previous experiences with mechanical and biological prostheses [14, 15] and according to current guidelines [16], the vast majority of patients in our series received a bioprosthesis (94.9%) regardless of age or previously implanted left-side prostheses. SVD was reported in a low number of patients although the median time to this event was rather short (6.7 years) with a range down to 2.9 years in a female patient aged 57 years old at the time of operation. No evident association could be found between SVD and age, prosthesis size and prosthesis type; however, 7 (87.5%) of the total 8 ascertained SVD occurred in patients who received a pericardial prosthesis. It has been speculated that while porcine leaflets are thin and pliable, pericardial leaflets are relatively thicker and stiffer, leading to a suboptimal opening and closing under the low pressure gradients of the right side of the heart and being associated with intrinsic higher gradients, even in the absence of a real valve tissue degeneration [17]. Unfortunately, no definite conclusion regarding the best prosthesis choice in tricuspid position could yet be drawn from our study.

Given the high risk and complexity of this kind of patients, innovative transcatheter techniques are emerging as an alternative treatment option [18], but at the moment they must be reserved to inoperable symptomatic cases.

Reoperative TVR patients still represent challenging cases, since they are often affected by a long-lasting disease, heart dysfunction and multiple comorbidities. They should be, therefore, referred to experienced centres where adequate patient selection, in particular regarding RV function, and a Heart-Team multidisciplinary

approach should be routinely adopted in order to offer them the most patient-tailored therapeutic option.

Limitations of the study

Besides its single-centre, retrospective nature, we think our study has two major limitations. The first is the wide heterogeneity of the patient population: the study included basically all-comers TVR patients with different valvular aetiologies that could not be always discerned; patients with isolated tricuspid disease and combined left-side disease; patients with and without RV dysfunction.

The other major limitation is that some echocardiographic data that would be of interest, such as RV dimensions and tricuspid valve tethering, were not available and were not taken into account and that a certain heterogeneity was also present in echocardiographic data (especially RV function) due to the different time frames, techniques and operators that performed the echocardiograms. In addition, follow-up echocardiographic data (non-available for all patients) were provided by different local cardiologists and not from a centralized core-lab.

In conclusion, the study population was very heterogeneous and complex and would have required different *ad hoc* subgroup analyses, especially regarding tricuspid disease aetiology, isolated and combined procedure and RV dysfunction. Unfortunately, the combination of the lack of all required parameters and the small number of patients, and therefore events (few acute and long-term deaths), made these analyses not possible at the moment.

CONCLUSION

Patients undergoing reoperative TVR are usually in an advanced stage of the disease. In selected cases, however, TVR is currently feasible with low acute mortality, especially if performed in the absence of ascites, significant RV dysfunction and pulmonary hypertension. Long-term mortality remains more difficult to predict, although it appeared to be associated also with higher preoperative pulmonary pressure. The global high complexity profile of these patients is also likely to impair long-term outcomes and warrants a preoperative Heart-Team approach.

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REFERENCES

- [1] Van Nooten GJ, Caes F, Taeymans Y, Van Belleghem Y, Francois K, De Bacquer D *et al.* Tricuspid valve replacement: postoperative and long-term results. *J Thorac Cardiovasc Surg* 1995;110:672-9.
- [2] Filsoufi F, Anyanwu AC, Salzberg SP, Frankel T, Cohn LH, Adams DH. Long-term outcomes of tricuspid valve replacement in the current era. *Ann Thorac Surg* 2005;80:845-50.
- [3] Bernal JM, Morales D, Revuelta C, Llorca J, Gutierrez-Morlote J, Revuelta JM. Reoperations after tricuspid valve repair. *J Thorac Cardiovasc Surg* 2005; 130:498-503.

- [4] Staab ME, Nishimura RA, Dearani JA. Isolated tricuspid valve surgery for severe tricuspid regurgitation following prior left heart valve surgery: analysis of outcome in 34 patients. *J Heart Valve Dis* 1999;8:567-74.
- [5] Fukuda S, Gillinov AM, McCarthy PM, Stewart WJ, Song JM, Kihara T *et al.* Determinants of recurrent or residual functional tricuspid regurgitation after tricuspid annuloplasty. *Circulation* 2006;114:1582-7.
- [6] Kim JB, Lee JW. Mild-to-moderate functional tricuspid regurgitation in patients undergoing valve replacement for rheumatic mitral disease: the influence of tricuspid valve repair on clinical and echocardiographic outcomes reply. *Heart* 2012;98:1181-82.
- [7] Garatti A, Nano G, Bruschi G, Canziani A, Colombo T, Frigiola A *et al.* Twenty-five year outcomes of tricuspid valve replacement comparing mechanical and biologic prostheses. *Ann Thorac Surg* 2012;93:1146-53.
- [8] Pfanmuller B, Moz M, Misfeld M, Borger MA, Funkat AK, Garbade J *et al.* Isolated tricuspid valve surgery in patients with previous cardiac surgery. *J Thorac Cardiovasc Surg* 2013;146:841-7.
- [9] Jeong DS, Park PW, Mwambu TP, Sung K, Kim WS, Lee YT *et al.* Tricuspid reoperation after left-sided rheumatic valve operations. *Ann Thorac Surg* 2013;95:2007-13.
- [10] McCarthy PM, Bhudia SK, Rajeswaran J, Hoercher KJ, Lytle BW, Cosgrove DM *et al.* Tricuspid valve repair: durability and risk factors for failure. *J Thorac Cardiovasc Surg* 2004;127:674-85.
- [11] King RM, Schaff HV, Danielson GK, Gersh BJ, Orszulak TA, Piehler JM *et al.* Surgery for tricuspid regurgitation late after mitral valve replacement. *Circulation* 1984;70:1193-7.
- [12] Pfanmuller B, Davierwala P, Misfeld M, Borger MA, Garbade J, Mohr FW. Postoperative outcome of isolated tricuspid valve operation using arrested-heart or beating-heart technique. *Ann Thorac Surg* 2012;94:1218-22.
- [13] Pfanmuller B, Misfeld M, Borger MA, Etz CD, Funkat AK, Garbade J *et al.* Isolated reoperative minimally invasive tricuspid valve operations. *Ann Thorac Surg* 2012;94:2005-10.
- [14] Chang BC, Lim SH, Yi G, Hong YS, Lee S, Yoo KJ *et al.* Long-term clinical results of tricuspid valve replacement. *Ann Thorac Surg* 2006;81:1317-23; discussion 23-4.
- [15] Hwang HY, Kim KH, Kim KB, Ahn H. Mechanical tricuspid valve replacement is not superior in patients younger than 65 years who need long-term anticoagulation. *Ann Thorac Surg* 2012;93:1154-60.
- [16] Vahanian A, Alfieri O, Andreotti F, Antunes MJ, Baron-Esquivias G, Baumgartner H *et al.* Guidelines on the management of valvular heart disease (version 2012): The joint task force on the management of valvular heart disease of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS). *Eur J Cardiothorac Surg* 2012; 42:S1-44.
- [17] Dearani JA. Lessons learned with tricuspid valve replacement. *Eur J Cardiothorac Surg* 2014;45:90-1.
- [18] Cheung A, Soon JL, Webb JG, Ye J. Transatrial transcatheter tricuspid valve-in-valve technique. *J Card Surg* 2012;27:196-8.

APPENDIX. CONFERENCE DISCUSSION

Dr G. Dreyfus (Monte Carlo, Monaco): Basically you are reporting a retrospective study covering a 15-year period of selected tricuspid valve replacement after left-sided surgery in 117 patients. Your preoperative assessment was mainly based upon echo dobutamine to decide whether or not to operate. Fifty-two per cent of your patients underwent isolated tricuspid valve replacement, and 48% underwent a combined left-sided surgery. You showed a 6% in-hospital mortality, which I think is remarkably low and for which you are to be congratulated, as well as a complete follow-up, nearly 98%. You have identified four main risk factors: EuroSCORE, ascites, RV dysfunction, and high pulmonary artery pressure.

I have a few comments and some questions to ask you. Your main criterion in deciding whether or not to operate was stress dobutamine echo, but you never did tell us precisely what you considered as a positive 'contractile reserve' or a negative one. Can you please tell us? Moreover, you underlined that 80% of your cohort were in class III or IV of the New York Heart Association, but at the same time you mentioned in your manuscript that preoperatively 63 patients, which is 54% of your patients, had normal RV function. So are we not mixing up the inclusion criteria? Those patients in class III and IV of the NYHA

classification had severe valvular left-sided dysfunction and not really an RV dysfunction. Can you please comment on this discrepancy?

You are most likely aware that poor RV function does not predict its recovery, especially in the presence of pulmonary hypertension. Would you agree that you would be more worried by a failing right ventricle with low pulmonary pressure and low cardiac index rather than a failing RV that is able to pump again 60 mmHg in the pulmonary artery? Can you please give us your thoughts on this, because it is usually well accepted that you have an RV dysfunction which is related to pulmonary hypertension, which I personally think is wrong. The best predictor we think in a failing RV is the forward RV stroke volume measured in the RV outflow tract. Do you have any data available about that and do you think it will be useful?

Why did you not show any catheterization data, as they are very relevant in such patients to provide end-diastolic pressure of the right ventricle, which is also a very important sign of RV dysfunction, cardiac index, and also to segregate patients with pulmonary hypertension related to LV dysfunction with high wedge pressure, or those with precapillary disease and a high transpulmonary gradient. Do you have these data? And if not, why did you indicate such high risk surgery without catheterization? I understand there are some patients from 15 years ago, but I would be interested in your comment.

You do agree that basically patients with high PA pressure reflect the sickest LV and not RV. This is critical for decision-making. You will agree with me that in your table 4 you show clearly that patients with high PA pressure also had the worst LV function, which has nothing to do with RV dysfunction. Do you agree? And if you do, what is the clinical relevance of RV dysfunction and how do you set up the limit, because this is very important, I think, for the whole surgical community.

With regard to ascites, I cannot agree more with you. This is most likely the highest negative risk factor. But I am surprised that you do not mention creatinine and creatinine clearance levels, as well as bilirubin. These biological markers are directly linked to severe RV dysfunction and, when present, to higher mortality after tricuspid valve surgery, especially in redo patients. Again, do you agree? It would be interesting to give us a more structured risk assessment in order for all of us to know which patients can be safely operated on and those who cannot.

Finally, you are probably aware, as you have 62% of leaflet tethering, that some repair options have been described by others, including your team, such as the clover technique. Why do you not discuss this issue, especially in the light of bioprosthetic valve failure as early as three years?

Your publication shows that redo surgery for tricuspid valve regurgitation carries a rather acceptable mortality, which I think is a very good message and very important, and that the risk is much more due to LV function than to RV dysfunction, at least in my eyes. It is also a plea for early surgery rather than waiting for ascites and further worsening of LV function.

Dr Buzzatti: As a general answer I can maybe start saying that, unfortunately, I was also disappointed at not having as much data. You lack lots of important data, as you said, for example bilirubin, liver enzymes, creatinine, etc. Actually, we have them but not for all patients and not in a way we were confident to use them, so I had to cut them. As for the first question, it was?

Dr Casselman (Aalst, Belgium): When not to operate is an important question.

Dr Dreyfus: Pulmonary artery pressure, you see that in every paper on RV dysfunction and tricuspid valve. And let me just remind the audience that if you have an Eisenmenger complex and a congenital heart defect, sometimes you have super-systemic pulmonary pressures and no tricuspid regurgitation because the right ventricle has adapted to that. So pulmonary hypertension is not a direct link to tricuspid regurgitation. Pulmonary hypertension is always related to LV dysfunction, and basically your mortality is, of course, related a lot to the LV dysfunction as well as the pulmonary pressure. This is what I wanted to emphasize, because I think it is important.

And I also think that RV dysfunction is very difficult to determine. When Professor Antunes said 'what is your criteria for repeated surgery?' we don't already have criteria for first-time and we don't have criteria for second time. We notice it when it's too late; as you said, ascites and other criteria.

You know there is a liver surgery index which is called MELD based on INR, bilirubin and creatinine, and when this index is superior to 15, they all die. Basically we should, as cardiac surgeons, at least know that we should have some parameters before putting back a patient for tricuspid regurgitation.

Dr Casselman: I suggest, Professor Dreyfus, that you give him all your questions that you wrote down, that he provides an answer and that they publish it, and I am sure everybody in the room is going to read them.