ADULT

Mortality after tricuspid valve procedures: A 27-year, single-center experience

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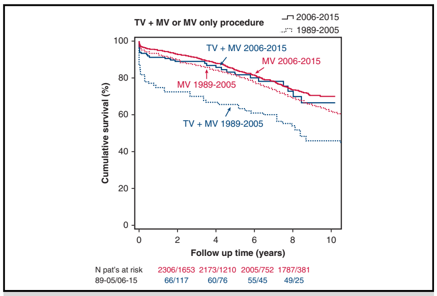
ABSTRACT

Objective: To assess mortality after tricuspid valve (TV) surgery in a large single-center patient cohort.

Methods: Data from 392 TV procedures performed between 1989 and 2015 in 388 adult patients were retrospectively reviewed. The patients were divided into groups according to the type of concomitant procedure, ie, coronary artery bypass grafting (CABG) (TV + CABG group; n = 87), other valve surgery (TV + valve group; n = 240), or an isolated TV procedure with or without another minor procedure (isolated TV group; n = 65), and the era of the operation, ie, 1989-2005 (n = 173) or 2006-2015 (n = 219). Control groups of patients who underwent other valve procedures and/or CABG during the same time periods were used for comparison.

Results: During the most recent era, the annual number of TV procedures increased 2.4-fold, mainly for TV + valve procedures (2.8-fold). Within the TV + valve group, a larger proportion of patients had mild-to-moderate tricuspid regurgitation (grade $\leq$2) compared with the first-time period (*P* = .001). The TV + CABG group had significantly greater mortality than both the other groups during both time periods, whereas isolated TV procedure had the lowest mortality rates with the exception of the TV + valve group during the most recent era (*P* = .41). Survival for patients undergoing TV + valve procedures has improved significantly during the last decade (*P* = .001) and was comparable with that for other valve operations during this period.

Conclusions: In the last decade, TV repair has been performed more frequently and at lower grades of tricuspid regurgitation compared with previously, and mortality after TV procedures has decreased. (J Thorac Cardiovasc Surg 2021;161:1239-48)



Survival after concomitant TV is now similar to other valve surgery patient groups.

Central Message

Survival for patients undergoing a tricuspid valve procedure concomitant with other valve procedures has improved significantly in recent years and is now comparable with other types of valve surgery.

Perspective

More robust scientific guidance for when to perform a tricuspid valve procedure is needed, as the level of evidence for current recommendations is low. In practice consistent with current guidelines, the procedure nowadays is performed more frequently and at lower grades of regurgitation than hitherto, and postoperative survival has improved during the period of this investigation.

See Commentary on page 1249.

Tricuspid regurgitation (TR) is a frequent clinical finding. According to the Framingham study, TR is present in 80% to 90% of healthy individuals but is of moderate or greater in severity in <1% of the population.[1] Moderate or greater TR is an independent risk factor for long-term

Scanning this QR code will take you to the table of contents to access supplementary information.

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Abbreviations and Acronyms

AV	= aortic valve
CABG	= coronary artery bypass grafting
LVEF	= left ventricular ejection fraction
MV	= mitral valve
NYHA	= New York Heart Association
PV	= pulmonary valve
Q	= quartile
SE	= standard error
TR	= tricuspid regurgitation
TV	= tricuspid valve

mortality, and the mortality rate increases with increasing severity of TR.[2] The most common cause of TR is functional TR, ie, annular dilatation due to left-sided heart disease. About 30% of patients undergoing mitral valve (MV) surgery have moderate or greater preoperative TR.[3-5]

The approach to treating TR associated with left-sided valve disease has changed rather radically during the last decade. It is now known that, for a proportion of cases with TR left untreated at the time of left-sided heart surgery, TR will not resolve and may even progress.[6] In the light of this, the former conservative strategy[7,8] is no longer recommended. Moreover, TR can develop progressively months or years after the left-sided heart surgery[3,9] and, in contrast to a first-time operation, performing a reoperation due to late TR is associated with high short- and long-term mortality.[10] Accordingly, the latest valve guidelines[11-13] have envisioned an earlier and more aggressive approach to TR. For example, it is now recommended to repair the tricuspid valve (TV) at the time of left-sided valve surgery for patients who have mild functional TR with tricuspid annular dilatation (≥40 mm or >21 mm/m^2 on echocardiography). However, the level of evidence for this recommendation is still low (level C, ie, expert opinions). Therefore, more clinical data are needed to inform recommendations regarding TV procedures.

The aims of this study were to report perioperative mortality and long-term survival after TV procedures in a series of consecutive adult patients during a 27-year period (1989-2015) and to compare outcomes during a first and second era of that period. In addition, we compared outcomes after TV surgery with those after other cardiac surgery procedures.

MATERIALS AND METHODS

Patients and Procedures

This was a retrospective, single-center cohort study based on preoperative, perioperative, and postoperative data from consecutively performed TV procedures in patients aged >18 years that took place between 1989 and 2015 at Sahlgrenska University Hospital. The study was approved by the regional ethical review board of Gothenburg. The final follow-up date regarding mortality was March 22, 2016. Exclusion criteria were congenital heart disease, concomitant aortic surgery, heart transplantation, carcinoid, and infective endocarditis. A total of 392 procedures in 388 patients were included in the study. The patients were divided into different subgroups depending on the types of concomitant procedures (Figure 1). Mortality during the most recent decade (2006-2015) was compared with that during the preceding period (1989-2005), and mortality rates were compared with those for other cardiac surgery patient groups from the same time periods. The cut-off year (2006) was chosen because the institutional treatment strategy and patient selection were changed in that year as a response to, eg, the study of Dreyfus and colleagues,[6] which suggested that a more aggressive approach to TV procedures should be performed concomitantly with left-sided heart surgery. The numbers of procedures performed over time are presented in Figure E1.

Patients undergoing TV ring annuloplasty, other repair, or replacement were divided into 3 groups: (1) isolated TV procedure or with another minor procedure (atrial septal defect/ventricular septal defect closure, antiarrhythmic procedure, myxoma extirpation; isolated TV group); (2) TV and another valve procedure (MV, aortic valve [AV], pulmonary valve [PV], or combined; TV + valve group); and (3) TV together with coronary artery bypass grafting (CABG) possibly with an additional valve procedure (TV + CABG group). The TV + valve group also was divided into subgroups according to which other valve was operated on.

Control groups for comparing overall mortality were constructed by extracting data from the SWEDEHEART registry[13] on all cardiac surgery patients operated on at our center during the periods 1992-2005 and 2006-2015. The control patients had undergone: (1) isolated CABG (n = 15,258 and n = 5825 for 1992-2005 and 2006-2015, respectively); (2) CABG + MV/AV/PV surgery (n = 1870 and n = 1212, respectively); or (3) valve surgery on valves other than the TV (n = 2577 and n = 2199, respectively). Patients aged <40 years were excluded from the control groups.

Data Collection

Data were collected from the Swedish Cardiac Surgery Registry, which is part of the SWEDEHEART registry,[14] as well as from patient records. Data included in SWEDEHEART are registered prospectively. Only data not available in SWEDEHEART were collected from patient records. The patient characteristics included were sex, age, previous cardiac surgery, previous TV procedure, preoperative atrial fibrillation (missing data 2.6%), preoperative pacemaker (missing data 1.3%), preoperative TR grade (missing data 16.0%), left ventricular ejection fraction (LVEF; missing data 17.9%), and New York Heart Association (NYHA) functional classification (missing data 14.8%). Intraoperative factors registered were type of operation and procedures performed concomitantly with the TV procedure (CABG, valve replacement or repair of the MV, AV, PV, or combined valves, atrial septal defect or ventricular septal defect closure, antiarrhythmic surgery, pacemaker implantation, and implantation of a circulatory support device during surgery), and acuteness of the procedure (missing data 0.5%). An acute operation was defined as one that started within 24 hours of the decision to perform surgery. Outcome parameters were 30- and 90-day mortality and overall mortality (until the end of follow-up; maximum 26 years). In addition, 1- and 5-year survival rates were reported. Postdischarge mortality data were collected from the Swedish Civil Registry. The mean follow-up period was 6.4 years (standard deviation 5.8 years; range 0-25.8 years; median 5.0 years; first-to-third-quartile interval [Q1-Q3] 1.9-9.0 years) and the dataset was 99.5% complete regarding mortality. The missing patients (n = 2) were foreign citizens who had been operated on acutely when visiting Sweden.

Statistical Analyses

As no variables were normally distributed, continuous variables are presented as the median plus first and third quartile (Q1-Q3) range.

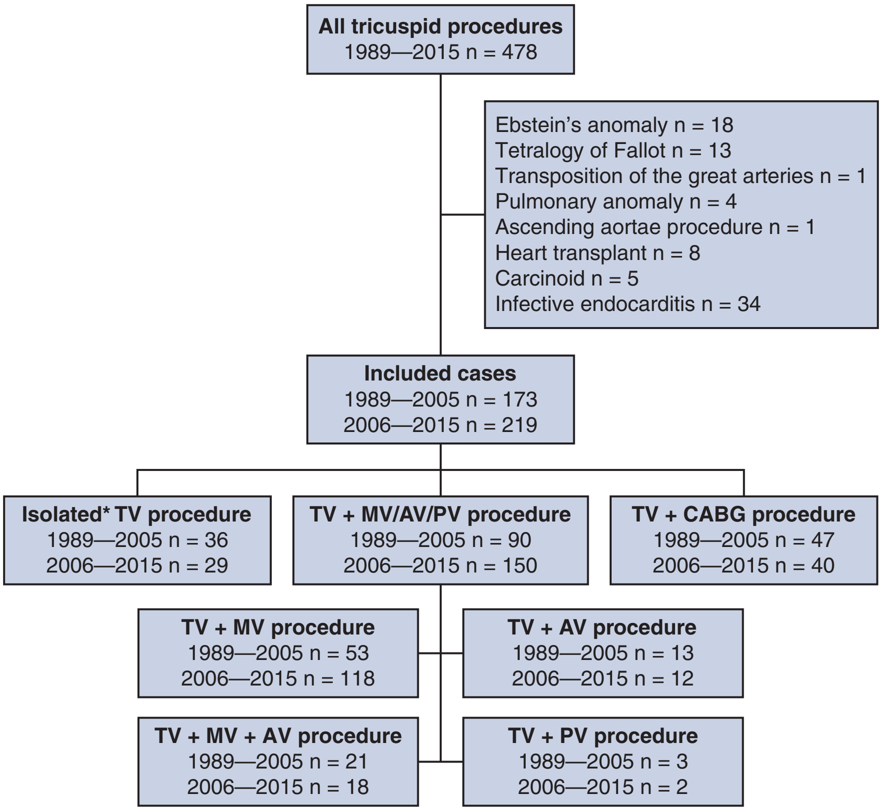


FIGURE 1. Scheme showing all procedures compiled, together with presentation of the included and excluded cases. Groups were established according to the procedure performed, and the numbers of procedures performed during the 2 time periods are displayed. *May include atrial/ventricular septal defect closure, antiarrhythmic procedure, or myxoma extirpation. *TV*, Tricuspid valve; *MV*, mitral valve; *AV*, aortic valve; *PV*, pulmonary valve; *CABG*, coronary artery bypass grafting.

The nonparametric Mann–Whitney *U* test was used to compare continuous variables between the 2 patient groups. The Fisher exact test was used for comparisons of dichotomous variables between the 2 groups. Kaplan–Meier estimates (with 95% confidence interval or standard error [SE]), together with the log-rank test, were used to present and analyze mortality for the different patient groups. If there were >90 days between 2 TV procedures for one patient within the study period, then both were included; however, in Kaplan–Meier estimates, the patient was only included once and the follow-up time was taken from the first surgical procedure. Logistic regression was used to identify factors associated with 30- and 90-day mortality, and Cox regression models were used for overall mortality. Tests of the Cox proportional hazards assumption were conducted on the basis of Schoenfeld residuals after fitting a model. For the parameters that did not meet the demands of proportional hazard assumption, 4 different time periods for time of death (0-90 days, 90 days-1 year, 1-10 years, and >10 years) were used to assess whether proportionality could be achieved. Thereafter, we tried to find suitable time periods to present as few hazard ratios as possible. Variables with a P value $< .10$ in univariable models were included in forward stepwise multivariable models. As data regarding LVEF and NYHA class were missing in a fair proportion of cases, 2 multivariable models were used for overall mortality: one with and one without those variables. All significance tests were 2-sided and conducted at the 5% significance level. IBM SPSS Statistics, version 23 (IBM Corp, Armonk, NY) and Stata Statistical Software, version 15.1 (StataCorp, College Station, Tex) were used for statistical analysis.

RESULTS

Patients and Procedures

Patient characteristics and the numbers of procedures performed in the 2 time periods are presented in Table 1 and Figure E1. Four patients in the isolated TV group underwent 2 TV operations during the study period; there were 3.4 months, 3.9 months, 3.1 years, and 4.2 years, respectively, between those procedures. Eighteen TV prostheses (7 mechanical, 11 biological) were implanted during the entire study period. Only 2 of these were implanted between 2006 and 2015, both in the isolated TV group. Between 1989 and 2005, 2 TV replacements were performed in the TV + valve group, 2 in the TV + CABG group, and 12 in the isolated TV group. Of the repair procedures, 356 were ring annuloplasties, 14 were ring annuloplasties performed together with other repairs, and 5 were other plasties. In the TV + CABG group, 68% of patients underwent concomitant valve replacement or repair (MV 55%, AV 9%, MV + AV 3%).

The preoperative grade of TR was significantly lower during the years 2006-2015 (median 2.5, Q1-Q3 2.5-3.5) than the years 1989-2005 (median 3.0, Q1-Q3 2.5-3.0)

TABLE 1. Patient and surgery-related characteristics

Parameters	All procedures (n = 392) 1989-2005 (n = 173)	All procedures (n = 392) 2006-2015 (n = 219)	Isolated TV procedures* (n = 65) 1989-2005 (n = 36)	Isolated TV procedures* (n = 65) 2006-2015 (n = 29)	TV + valve procedures (n = 241) 1989-2005 (n = 90)	TV + valve procedures (n = 241) 2006-2015 (n = 150)	TV + CABG procedures (n = 87) 1989-2005 (n = 47)	TV + CABG procedures (n = 87) 2006-2015 (n = 40)
Age, y, median (Q1, Q3)	69 (57, 74)	70 (60, 76)	57 (47, 70)	58 (43, 64)	69 (57, 74)	70 (62, 77)	72 (67, 77)	73 (69, 77)
Sex, male	82 (47%)	147 (67%)	13 (36%)	12 (41%)	36 (40%)	102 (68%)	33 (70%)	33 (83%)
Diabetes	14 (10%) n = 134	22 (10%) n = 217	0 n = 27	1 (4%) n = 28	6 (8%) n = 72	13 (9%) n = 149	8 (23%) n = 35	8 (20%) n = 40
Left ventricle ejection fraction	58 (45, 65) n = 106	55 (50, 60) n = 216	57 (44, 63) n = 17	60 (48, 60) n = 29	58 (48, 63) n = 58	55 (50, 60) n = 148	59 (39, 65) n = 31	55 (45, 60) n = 39
NYHA class	3 (3, 3) n = 117	3 (2, 3) n = 217	3 (2, 3.25) n = 22	3 (2, 3) n = 29	3 (3, 3) n = 66	3 (2, 3) n = 148	3 (2, 3) n = 29	3 (3, 3) n = 40
Previous cardiac surgery	61 (35%)	47 (21%)	13 (36%)	9 (31%)	37 (41%)	31 (21%)	11 (23%)	7 (18%)
Earlier TV procedure	5 (3%)	3 (1%)	4 (11%)	2 (7%)	1 (1%)	1 (0.7%)	0	0
Preoperative atrial fibrillation	92 (56%)	151 (69%)	10 (29%)	14 (48%)	54 (63%)	109 (73%)	28 (65%)	28 (70%)
Pacemaker	15 (9%)	28 (13%)	8 (22%)	6 (21%)	3 (3%)	17 (12%)	4 (9%)	5 (13%)
Surgery-related parameters								
Acute surgery	8 (5%)	10 (5%)	2 (6%)	3 (10%)	4 (4%)	3 (2%)	2 (4%)	4 (10%)
ASD/VSD closure	24 (14%)	29 (13%)	14 (39%)	9 (31%)	5 (6%)	17 (11%)	5 (11%)	3 (8%)
Antiarrhythmic procedure	5 (3%)	63 (29%)	1 (3%)	6 (21%)	2 (2%)	52 (35%)	2 (4%)	5 (13%)
Pacemaker implantation	16 (9%)	8 (4%)	10 (28%)	5 (17%)	4 (4%)	3 (2%)	2 (4%)	0
Circulation support implanted	17 (10%)	7 (3%)	1 (3%)	1 (3%)	8 (9%)	6 (4%)	8 (17%)	0
TR grade (from UCG)	(n = 139)	(n = 190)	(n = 28)	(n = 23)	(n = 69)	(n = 129)	(n = 42)	(n = 38)
Mild (<2)	12 (9%)	19 (10%)	1 (4%)	2 (9%)	7 (10%)	15 (12%)	4 (10%)	2 (5%)
Moderate (2 < 3)	45 (32%)	99 (52%)	5 (18%)	6 (26%)	21 (30%)	70 (54%)	19 (45%)	23 (61%)
Severe (3-4)	82 (59%)	72 (38%)	22 (79%)	15 (65%)	41 (59%)	44 (34%)	19 (45%)	13 (34%)

Unless stated otherwise, all values shown represent numbers of patients, with percentages in parentheses. *TV*, Tricuspid valve; *CABG*, coronary artery bypass grafting; *Q1*, first quartile; *Q3*, third quartile; *NYHA*, New York Heart Association; *ASD*, atrial septal defect; *VSD*, ventricular septal defect; *TR*, tricuspid regurgitation; *UCG*, ultracardiography. *May include ASD/VSD closure, antiarrhythmic procedure, or myxoma extirpation.

($P < .001$). The greatest difference was seen in the TV + MV group (TR grade 3-4, 52% vs 29%; data not shown in table).

Mortality

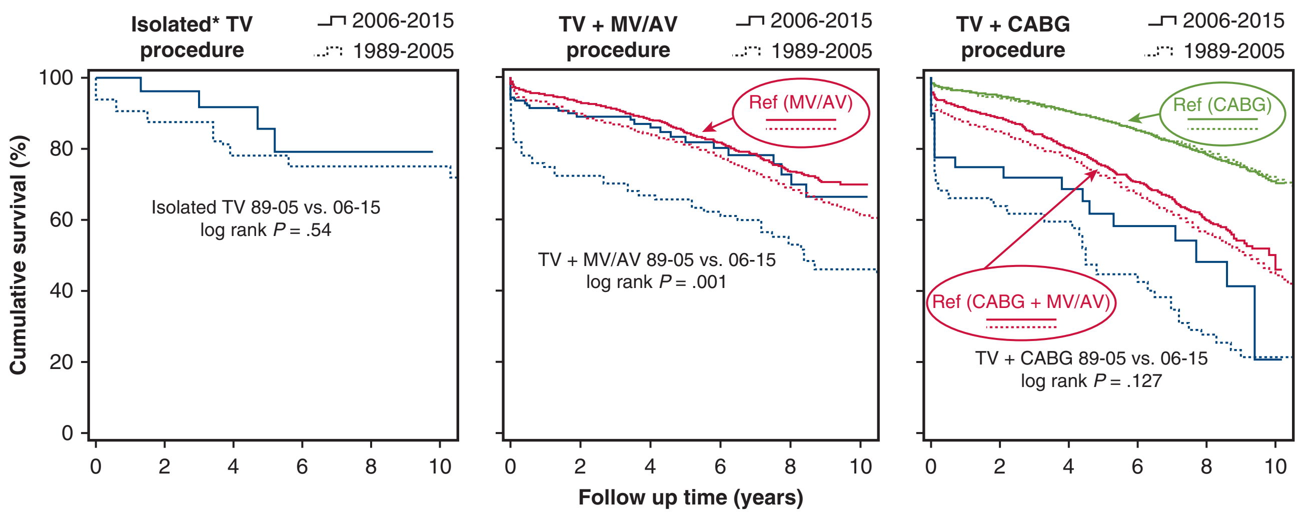
Between the first and second time periods, overall 30-day mortality declined from 16.1% to 7.3% ($P = .009$) and overall 90-day mortality from 19.6% to 8.7% ($P = .002$). One-year mortality declined from 24.4% (41/168 patients) to 11.2% (23/205 patients) ($P < .001$) and 5-year survival improved from 61% (SE 4%) to 79% (SE 3%) ($P < .001$). Significantly greater mortality was observed in the TV + CABG group than both the other groups during both time periods ($P < .001$-.013), whereas the lowest mortality rates ($P < .001$-.013) occurred in the isolated TV during 1989-2005 and in the TV + valve group during the last time period ($P = .41$) (Figure 2). TV procedures performed concomitantly with MV procedures increased 2.5-fold (mean per year) between the periods 1989-2005 and 2006-2015, whereas 30-day, 5-year, and 10-year mortality decreased by a factor of 2.4-2.9 (Tables 1 and 2).

Survival rates improved in all TV procedure groups between the 2 time periods, but a statistically significant difference in overall mortality was found only in the TV + valve group (Figures 2 and 3). Compared with the reference group of patients undergoing procedures on valves other than the TV, mortality was significantly greater for the TV + valve group during the period 1989-2005 (log-rank $P < .001$) but did not differ between the patient groups during 2006-2015 (log-rank $P = .37$; Figure 2, *B*, Table 2). The TV + CABG group experienced significantly greater mortality compared with the reference cohort of isolated CABG and CABG + MV/AV procedures during both time periods (log-rank $P < .001$/$P < .001$ and $P < .001$/$P = .022$, respectively) (Figure 2, *C*).

There were no significant differences in mortality between patients in the TV + CABG group who underwent different concomitant valve replacements or repairs (MV, AV, MV + AV; $P = .11$-.80).

Factors Associated With Mortality

Variables associated with 30- and 90-day mortality were identified from logistic regression models (Table 3). The



	Isolated TV		TV + MV/AV		MV/AV		TV + CABG		CABG		CABG + MV/AV	
	1989-2005		1989-2005		1989-2005		1989-2005		1989-2005		1989-2005	
Follow up (y)	No. at risk	Survival (95 % CI)	No. at risk	Survival (95 % CI)	No. at risk	Survival (95 % CI)	No. at risk	Survival (95 % CI)	No. at risk	Survival (95 % CI)	No. at risk	Survival (95 % CI)
1	30	96.8 (78.6-99.5)	68	87.0 (77.2-92.8)	2383	92.7 (91.7-93.7)	32	75.6 (59.4-86.1)	14651	96.5 (96.2-96.8)	1644	88.7 (87.1-90.0)
2	29	93.3 (75.9-98.3)	66	84.4 (74.2-90.8)	2306	89.7 (88.5-90.8)	31	73.2 (56.8-84.2)	14419	95.0 (94.6-95.3)	1592	85.9 (84.2-87.4)
4	26	83.3 (64.5-92.7)	60	76.6 (65.5-84.6)	2173	84.6 (83.1-85.9)	29	68.3 (51.7-80.2)	13824	91.0 (90.6-91.5)	1459	78.7 (76.8-80.5)
6	25	80.0 (60.8-90.5)	55	70.1 (58.6-79.0)	2005	78.0 (76.3-79.5)	21	48.8 (32.9-62.9)	13048	85.9 (85.4-86.5)	1265	68.3 (66.1-70.3)
8	25	80.0 (60.8-90.5)	49	62.3 (50.5-72.1)	1787	69.5 (67.7-71.3)	14	31.7 (18.3-46.0)	12046	79.3 (78.7-80.0)	1061	57.1 (54.8-59.4)
	2006-2015		2006-2015		2006-2015		2006-2015		2006-2015		2006-2015	
1	28	100	130	96.5 (91.7-98.5)	1900	95.1 (94.2-96.0)	28	83.1 (66.2-92.1)	5236	96.5 (96.0-96.9)	1037	92.2 (90.5-93.6)
2	25	96.3 (76.5-99.5)	117	94.1 (88.5-97.0)	1653	93.1 (91.9-94.1)	26	83.1 (66.2-92.1)	4703	95.1 (94.5-95.6)	916	89.6 (87.7-91.2)
4	18	91.7 (70.5-97.9)	76	90.7 (83.6-94.8)	1210	88.2 (86.7-89.7)	22	76.2 (57.7-87.4)	3623	90.7 (89.9-91.5)	632	81.0 (78.4-83.3)
6	13	79.0 (52.1-91.8)	45	84.8 (75.3-90.9)	752	81.7 (79.6-83.6)	16	64.8 (44.9-79.0)	2544	85.4 (84.2-86.4)	391	71.3 (68.0-74.3)
8	8	79.0 (52.1-91.8)	25	74.0 (59.6-83.9)	381	73.6 (70.8-76.2)	9	53.5 (31.7-71.1)	1381	78.6 (77.1-80.0)	169	60.5 (56.3-64.4)

A B C

FIGURE 2. Cumulative survival presented using Kaplan–Meier estimates and the log-rank test to compare survival between TV operations performed during the different time periods. TV + valve and TV + CABG procedures are plotted together with data for a reference group of patients operated on at the same clinic during the same time periods. A-C, The table included presents the numbers of patients at risk at different time points as well as Kaplan–Meier estimates with 95% CIs. *May include atrial/ventricular septal defect closure, antiarrhythmic procedure, or myxoma extirpation. *TV*, Tricuspid valve; *MV*, mitral valve; *AV*, aortic valve; *CABG*, coronary artery bypass grafting; *CI*, confidence interval.

grade of TR was an independent predictor of 90-day mortality, with an odds ratio of 1.7 per grade of TR derived from echocardiography. Figure 4 presents the predicted probability of 90-day mortality based on grade of TR, era of operation, and TV procedure group; predicted probabilities increased more than 2-fold for 90-day mortality if the TR grade was 3-4 compared with 1-2. As there was no occurrence of 90-day mortality during the most recent decade and only 2 occurrences during the first time period in the isolated TV group, the predicted probability was low. The 2 patients who died within 90 days had TR grades of 3 and 4, respectively. In addition, acute surgery, time period, and combined surgery (TV + CABG or TV + valve) versus isolated TV surgery were independently associated with 90-day mortality.

Finally, Cox regression analyses were performed to reveal variables associated with overall mortality (Table 4). Age, previous atrial fibrillation, and TR grade did not meet the demands of proportional hazard assumption and are therefore reported with hazard ratios for different time periods for time of death. TR grade, age, time period, and combined surgery (TV + CABG or TV + valve) versus isolated TV were independently associated with overall mortality (Table 4). When LVEF and NYHA class were included in the multivariable model, NYHA class also remained in the final model.

DISCUSSION

The main result of this study is that survival after TV procedures has improved significantly during 2006-2015 compared with the preceding time period. More TV procedures were performed during the later decade and at lower preoperative TR grades. Survival for patients undergoing TV procedures concomitant with other valve procedures is now comparable with that for other valve surgery patient groups.

In the literature, early mortality after TV surgery is considerable,[15,16] ranging from 4.0% to 13.9% in various studies.[16-18] From our data, we identified a significant

TABLE 2. Mortality rates or Kaplan–Meier estimates with SEs after the various TV procedures and other valve and CABG procedures

	30-day mortality		1-year survival		5-year survival	
	1989-2005	2006-2015	1989-2005	2006-2015	1989-2005	2006-2015
Isolated* TV (n = 32/28)	2 (6%)	0	89 ± 5%	100%	74 ± 7%	86 ± 8%
TV + MV/AV/PV (n = 89/150)	15 (17%)	8 (5%)	75 ± 5%	91 ± 2%	64 ± 5%	82 ± 4%
MV/AV/PV (n = 2577/2199)	111 (4%)	57 (3%)	92 ± 1%	95 ± 1%	82 ± 1%	84 ± 1%
TV + MV (n = 53/118)	10 (19%)	4 (3%)	72 ± 6%	92 ± 3%	59 ± 7%	84 ± 4%
MV (n = 451/520)	36 (8%)	22 (4%)	90 ± 1%	93 ± 1%	83 ± 2%	87 ± 1%
TV + AV (n = 13/12)	0	2 (17%)	92 ± 7%	83 ± 11%	85 ± 10%	83 ± 11%
AV (n = 1359/1575)	46 (3%)	30 (2%)	94 ± 1%	96 ± 1%	82 ± 1%	84 ± 1%
TV + MV + AV (n = 20/18)	5 (25%)	2 (11%)	71 ± 10%	89 ± 7%	67 ± 10%	65 ± 13%
MV + AV (n = 122/70)	11 (9%)	5 (7%)	89 ± 3%	86 ± 4%	71 ± 4%	79 ± 5%
TV + PV (n = 3/2)	0	0	100%	100%	67 ± 27%	–
TV + CABG (n = 47/40)	10 (21%)	8 (20%)	66 ± 7%	75 ± 7%	45 ± 7%	62 ± 8%
CABG (n = 15,258/5825)	330 (2%)	101 (2%)	96 ± 0.2%	96 ± 0.3%	88 ± 0.3%	88 ± 1%
CABG + MV/AV (n = 1870/1212)	127 (7%)	61 (5%)	88 ± 1%	91 ± 1%	73 ± 1%	75 ± 1%
Total TV procedures	27 (16%)	16 (7%)	76 ± 3%	89 ± 2%	61 ± 4%	79 ± 3%

Values shown within parentheses in the left-hand column represent patients during the early and late time periods, respectively. *TV*, Tricuspid valve; *MV*, mitral valve; *AV*, aortic valve; *PV*, pulmonary valve; *CABG*, coronary artery bypass grafting. *May include atrial/ventricular septal defect closure, antiarrhythmic procedure, or myxoma extirpation.

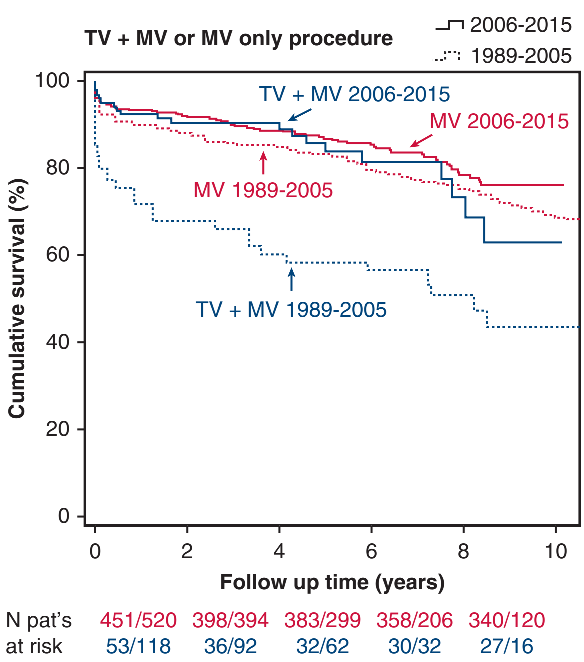


FIGURE 3. Cumulative survival presented using Kaplan–Meier estimates for the TV + MV procedure as well as for a reference group of patients who underwent a MV procedure only during the different time periods. There was a significant difference in survival between patients undergoing a TV + MV procedure and a MV procedure only (log-rank $P < .0001$) during the first time period but not during the most recent time period (log-rank $P = .35$). Survival was greater for patients undergoing TV + MV surgery during the most recent time period compared with previously (log-rank $P = .001$). *TV*, Tricuspid valve; *MV*, mitral valve.

decline in early mortality during the most recent decade, which is in agreement with the findings of other recent studies.[15,16,19] Although the cause of this improvement cannot be determined in a retrospective study, it is conceivable that earlier surgery (indicated in this cohort by lower grades of TR in the later era), better patient selection, and improvements in intensive and medical care in general have resulted in better outcomes. Interestingly, mortality did not differ between the 2 time periods for the control groups (MV and/or AV surgery and CABG patients; Figure 2), which implies that patient selection and the timing of the TV procedure probably had a greater impact than improved intensive and medical care. Surgery before the onset of severe right-sided heart failure is probably advantageous, as right-sided heart failure has been identified as a risk factor for worse outcomes[11] and always constitutes a high risk during whatever surgical procedure and with general anesthesia.[20,21] Furthermore, in the present study, there were no significant differences in mortality during the most recent decade between patients undergoing a TV procedure with or without another valve procedure and the reference cohorts of MV and/or AV surgery patients. The same applies to the subgroup of patients undergoing a TV procedure concomitant with MV surgery compared with patients undergoing an MV procedure only (Figure 4). Badhwar and colleagues[22] also concluded from a large study of patients from the Society of Thoracic Surgeons database who underwent surgery between 2011 and 2014 that concomitant TV repair was not associated with a risk-adjusted increase in mortality compared with

TABLE 3. Factors associated with 30- and 90-day mortality

	30-day mortality (n = 43)		90-day mortality (n = 52)	
	Univariable models OR (95% CI), *P* value	Final multivariable model OR (95% CI), *P* value	Univariable models OR (95% CI), *P* value	Final multivariable model OR (95% CI), *P* value
TR grade	1.6 per grade (1.0-2.6), .067		**1.6 per grade (1.0-2.6), .037**	**1.7 per grade (1.0-2.8), .046**
Age	**1.4 per 10 y (1.0-1.9), .026**		**1.5 per 10 y (1.1-2.0), .006**	
Male sex	1.0 (0.5-1.9), 1.0		1.2 (0.6-2.2), .59	
LVEF (n = 322, 82%)	0.8 per 10% (0.6-1.1), .131	(Not included)	0.8 per 10% (0.6-1.0), .079	(Not included)
NYHA class I (n = 333, 85%)	1.0	(Not included)	1.0	(Not included)
vs NYHA class II	1.4 (0.2-12.6), .76		1.0 (0.2-5.0), .96	
vs NYHA class III	2.0 (0.3-16.1), .50		1.2 (0.3-5.7), .79	
vs NYHA class IV	7.6 (0.9-62.2), .059		4.4 (0.9-21.3), .065	
Earlier heart surgery	1.3 (0.7-2.6), .44		1.3 (0.7-2.5), .38	
Preoperative atrial fibrillation	0.9 (0.5-1.8), .83		1.3 (0.7-2.5), .41	
Preoperative pacemaker	0.8 (0.3-2.5), .77		0.7 (0.2-2.0), .48	
Acute surgery	**4.5 (1.6-12.7), .004**	**8.4 (2.4-29.1), .001**	**3.5 (1.3-9.9), .016**	**6.6 (1.8-23.5), .004**
1989-2005 vs 2006-2015	**2.5 (1.2-4.9), .009**	**2.4 (1.1-5.2), .023**	**2.8 (1.6-4.8), <.001**	**2.3 (1.1-4.8), .022**
Isolated* TV	1.0	1.0	1.0	1.0
vs TV + CABG	**9.2 (2.0-42.5), .005**	**8.0 (1.6-39.4), .011**	**6.4 (2.1-19.4), .001**	**14.3 (2.9-70.9), .001**
vs TV + MV/AV/PV	4.4 (1.0-19.8), .054	3.8 (0.8-18.8), .099	2.6 (0.9-7.5), .086	**5.2 (1.0-25.9), .044**

Values shown are odds ratios, with 95% confidence intervals in parentheses. Variables in bold were found to be statistically significant. *OR*, Odds ratio; *CI*, confidence interval; *TR*, tricuspid regurgitation; *LVEF*, left ventricular ejection fraction; *NYHA*, New York Heart Association; *TV*, tricuspid valve; *CABG*, coronary artery bypass grafting, *MV*, mitral valve; *AV*, aortic valve; *PV*, pulmonary valve. *May include atrial/ventricular septal defect closure, antiarrhythmic procedure, or myxoma extirpation.

MV repair or replacement only. A recent meta-analysis reached a similar conclusion.[23]

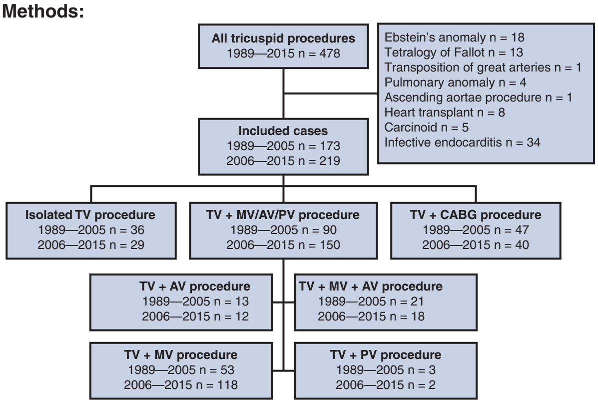
In the present study, patients who underwent a TV procedure concomitantly with CABG had the worse prognosis during both time periods compared with both other TV procedures and other CABG patient groups, whereas patients who underwent an isolated TV procedure, or with a concomitant minor procedure, had a lower mortality rate during the most recent decade, with no deaths occurring during the first postoperative year and a 5-year survival rate of 86% (Table 2). When evaluating endovascular or open-heart surgery approaches for TR intervention, it is important that current-era data are used; survival has improved compared with earlier eras and the level of evidence for treatment strategies is stronger (although still rather low at level C or, in one instance, level B). Which patients may be considered high-risk for open heart surgery is a clinical consideration.

The echocardiographic evaluation of TR is not uncomplicated and the grade of TR is subject to potential variations over time due to respiratory influences and loading conditions.[24] As a result, the echocardiographic variables evaluated in TR are less robust than in, for example, MV regurgitation; echocardiography is nevertheless still the best technique to use.[11] It has been suggested that TV procedures should be performed based on annular dilatation (≥40 mm or >21 mm/m^2 on echocardiography) regardless of the grade of TR,[6] but most publications nowadays recommend that TV procedures should be performed at the same grade of dilatation but that a moderate or mild TR should also be present.[6,25-27] The European Society of Cardiology and American Heart Association/American College of Cardiology guidelines give a Class I recommendation for TV surgery in patients with severe TR undergoing left-sided valve surgery. Their recommendations have been expanded toward consideration of TV surgery "for patients with mild or moderate secondary TR with dilated annulus (≥40 mm or >21 mm/m^2) undergoing left-sided valve surgery" and "for patients with mild, moderate, or functional TR at the time of left-sided valve surgery with either annular dilatation or prior evidence of right heart failure," respectively (both Class IIa indications, level of evidence C).[11,12] In an earlier study,[6] the difficulties involved in accurately assessing TR with echocardiography and the clinical conditions relating to the TV were shown, as the majority of patients (130/148) with an annular dilatation of >70 mm presented with a TR grade of zero or one. However, increasing annular dilatation will eventually result in TR with a physiological impact. Unfortunately, we do not have the detailed echocardiographic data to enable us to perform similar analyses in this study. Reoperation due to TR is a high-risk procedure, with a hospital mortality rate of up to 37%,[17] although other studies have reported lower rates (13.2%[28]-17%[29]). Our results would appear to add to

Objective:

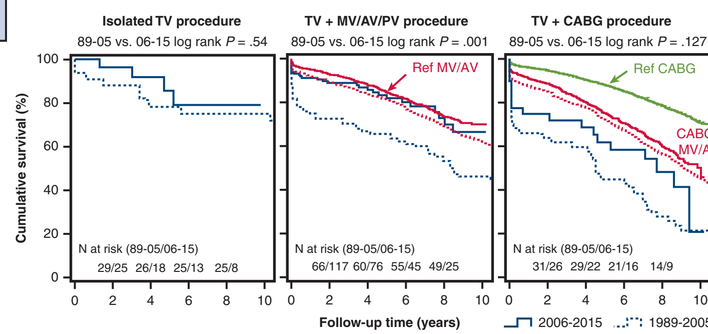
The level of evidence regarding current recommendations for tricuspid value (TV) procedure is low. We assessed mortality after TV procedure in a large single-center cohort.

Methods:



Results:

	Isolated TV procedure		TV + MV/AV/PV procedure		TV + CABG procedure	
	1989-2005	2006-2015	1989-2005	2006-2015	1989-2005	2006-2015
Age, years; median (Q1, Q3)	57 (47, 70)	58 (43, 64)	69 (57, 74)	70 (62, 77)	72 (67, 77)	73 (69, 77)
Diabetes mellitus	*0*	*4%*	*8%*	*9%*	*23%*	*20%*
LVEF; median (Q1, Q3)	*57 (44, 63)*	*60 (48, 60)*	*58 (48, 63)*	*55 (50, 60)*	*59 (39, 65)*	*55 (45, 60)*
Previous cardiac surgery	13 (36%)	9 (31%)	37 (41%)	31 (21%)	11 (23%)	7 (18%)
TR grade (from UCG)	(n = 28)	(n = 23)	(n = 69)	(n = 129)	(n = 42)	(n = 38)
Mild (<2)	1 (4%)	2 (9%)	7 (10%)	15 (12%)	4 (10%)	2 (5%)
Moderate (2<3)	5 (18%)	6 (26%)	21 (30%)	70 (54%)	19 (45%)	23 (61%)
Severe (3 to 4)	22 (79%)	15 (65%)	41 (59%)	44 (34%)	19 (45%)	13 (34%)



Conclusion:

Postoperative mortality decreased in the later time period when TV procedures were performed according to current guidelines and more frequently at lower grades of TV regurgitation.

FIGURE 4. Survival after concomitant TV procedures is now similar to that for other valve surgery patient groups (log-rank $P = .37$). Previously, survival was poorer for patients undergoing concomitant TV procedures compared with left-sided valve surgery only (log-rank $P < .001$). *TV*, Tricuspid valve; *MV*, mitral valve.

the earlier findings and suggest that it is advantageous to perform the TV procedure at earlier and milder stages of regurgitation, and under circumstances that do not necessitate acute surgery, as this was an independent risk factor for 30- and 90-day mortality. However, in our study, previous cardiac surgery was not a risk factor for early or overall mortality and, in the isolated TV group, in which there were low postoperative mortality rates, about one-third of patients had undergone previous cardiac surgery.

Although all TV procedures were compiled and presented together, TV ring annuloplasty constituted 91% of all procedures and the results mainly reflect these patients. Over the years, surgical methods used to treat TV disease have tended toward an increase in TV repairs; furthermore, valve replacement has resulted in worse short- and long-term outcomes than valve repair.[15,16] Among the different annuloplasty techniques, the use of a prosthetic ring is currently the most popular strategy, and several studies have reported better performance with ring prostheses compared with suture annuloplasty or other annuloplasty techniques regarding residual and recurrent TR as well as survival,[17,18,30] although using a ring prosthesis does not protect the patient against residual or recurrent TR.[17]

The limitations of the present study are the general ones associated with retrospective studies and include selection bias and unregistered confounders. Detailed echocardiographic data, as well as other variables assumed to have an impact on the outcome (eg, diabetes, right ventricular failure, high pulmonary artery pressure, and signs of congestive hepatopathy), could not be included in the models since a significant amount of data was missing from the first time period. Furthermore, low numbers of deaths within 30 and 90 days limited the number of variables included in the multivariable models. There was also a significant amount of missing data regarding the cause of death. The reference materials derived from SWEDEHEART were not matched with the study population, and we did not have all the appropriate variables to perform an adjusted analysis; however, we still believe that it is of clinical value to present this material and to reflect on the advances and changes in outcomes after surgical procedures on the TV.

With this study, we wanted to obtain a long-term perspective of TV procedures and to focus on the difference in mortality between 2 time periods in which somewhat-different approaches were taken regarding the procedure (especially when it was performed concomitantly with left-sided heart surgery). Another article focusing on predictors of certain outcomes is in preparation.

In conclusion, survival after TV procedures has improved significantly during the more recent time period (2006-2015) examined in this research, in conformity with the introduction of treatment strategies in which a more aggressive approach to TR (consistent with current guidelines) has been adopted. Survival after TV procedures is now comparable with that for other valve surgery patient groups.

TABLE 4. Factors associated with overall mortality

	Overall mortality (n = 180)		
	Univariable models	Final multivariable model (not including LVEF or NYHA class)	Final multivariable model (including LVEF or NYHA class)
	HR (95% CI), *P* value	HR (95% CI), *P* value	HR (95% CI), *P* value
TR grade*			
TR (0-90 d)	**1.6 per grade (1.0-2.4), .034**	**1.6 per grade (1.0-2.6), .033**	1.5 per grade (0.9-2.3), .101
TR (90 d-1 y)	**3.2 per grade (1.3-7.8), .011**	**3.7 per grade (1.4-9.7), .007**	**3.3 per grade (1.4-8.2), .008**
TR (>1 y)	1.0 per grade (0.8-1.2), .82	1.1 per grade (0.8-1.3), .66	1.1 per grade (0.8-1.5), .46
Age*			
Age (0-10 y)	**1.4 per 10 y (1.2-1.7), <.001**	**1.4 per 10 y (1.1-1.7), .002**	**1.4 per 10 y (1.1-1.8), .002**
Age (>10 y)	**1.9 per 10 y (1.4-2.6), <.001**	**1.7 per 10 y (1.2-2.4), .003**	1.4 per 10 y (0.9-2.1), .126
Male sex	1.3 (1.0-1.7), .091		
LVEF (n = 322, 82%)	0.9 per 10% (0.8-1.0), .013		
NYHA class I (n = 333, 85%)	1.0		1.0
vs NYHA class II	1.2 (0.5-3.0), .68		0.8 (0.3-2.0), .63
vs NYHA class III	1.8 (0.8-4.0), .183		0.9 (0.4-2.1), .77
vs NYHA class IV	**3.5 (1.5-8.7), .006**		**3.0 (1.2-7.6), .018**
Earlier heart surgery	1.2 (0.9-1.6), .32		
Preoperative AF*			
AF (0-10 y)	1.1 (0.8-1.6), .50		
AF (>10 y)	**2.7 (1.3-5.5), .008**		
Preoperative pacemaker	1.4 (0.9-2.2), .155		
Acute surgery	1.6 (0.8-3.0), .147		
1989-2005 vs 2006-2015	**1.9 (1.3-2.7), <.001**	**1.7 (1.2-2.5), .006**	**2.2 (1.4-3.5), <.001**
Isolated† TV	1.0	1.0	1.0
vs TV + CABG	**4.8 (2.9-8.0), <.001**	**3.8 (2.1-7.0), <.001**	**4.1 (2.0-8.5), <.001**
vs TV + MV/AV/PV	**2.1 (1.3-3.4), .003**	**1.9 (1.1-3.3), .028**	1.9 (1.0-3.7), .061

Values shown are HRs, with 95% CIs in parentheses. Variables in bold were found to be statistically significant. *LVEF*, Left ventricular ejection fraction; *NYHA*, New York Heart Association; *HR*, hazard ratio; *CI*, confidence interval; *TR*, tricuspid regurgitation; *AF*, atrial fibrillation; *TV*, tricuspid valve; *CABG*, coronary artery bypass grafting; *MV*, mitral valve; *AV*, aortic valve; *PV*, pulmonary valve. *Parameters did not meet the demands of proportional hazards assumption and were treated using HRs for different time periods of death occurrence. †May include atrial/ventricular septal defect closure, antiarrhythmic procedure, or myxoma extirpation.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

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Key Words: tricuspid valve, tricuspid regurgitation, cardiac surgery, valve procedure, concomitant procedures

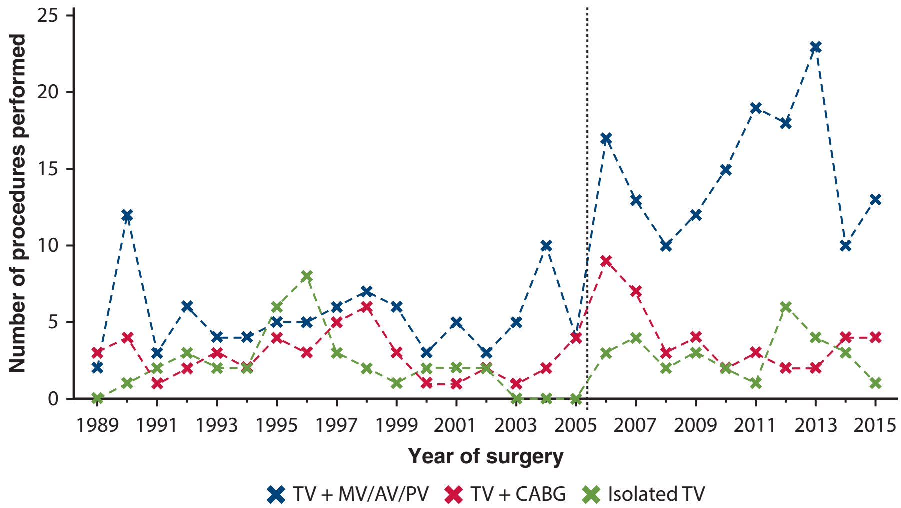

FIGURE E1. Numbers of procedures performed per year during the 2 study periods. *TV*, Tricuspid valve; *MV*, mitral valve; *AV*, aortic valve; *PV*, pulmonary valve; *CABG*, coronary artery bypass grafting.