ORIGINAL ARTICLE – **ADULT CARDIAC**

Results of surgical aortic valve replacement and transapical transcatheter aortic valve replacement in patients with previous coronary artery bypass grafting

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Abstract

OBJECTIVES: To evaluate the results of aortic valve replacement through sternotomic approach in redo scenarios (RAVR) vs transapical transcatheter aortic valve replacement (TAVR), in patients in the eighth decade of life or older already undergone previous coronary artery bypass grafting (CABG).

METHODS: One hundred and twenty-six patients undergoing RAVR were compared with 113 patients undergoing TaTAVR in terms of 30-day mortality and Valve Academic Research Consortium-2 outcomes. The two groups were also analysed after propensity-matching.

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RESULTS: TaTAVR patients demonstrated a higher incidence of 30-day mortality ($P = 0.03$), stroke ($P = 0.04$), major bleeding ($P = 0.03$), worse 'early safety' ($P = 0.04$) and lower permanent pacemaker implantation ($P = 0.03$). TaTAVR had higher follow-up hazard in all-cause mortality [hazard ratio (HR) 3.15, 95% confidence interval (CI) 1.28–6.62; $P < 0.01$] and cardiovascular mortality (HR 1.66, 95% CI 1.02–4.88; $P = 0.04$). Propensity-matched patients showed comparable 30-day outcome in terms of survival, major morbidity and early safety, with only a lower incidence of transfusions after TaTAVR (10.7% vs RAVR: 57.1%; $P < 0.01$). A trend towards lower Acute Kidney Injury Network Classification 2/3 (3.6% vs RAVR 21.4%; $P = 0.05$) and towards a lower freedom from all-cause mortality at follow-up (TaTAVR: 44.3 ± 21.3% vs RAVR: 86.6 ± 9.3%; $P = .08$) was demonstrated after TaTAVR, although cardiovascular mortality was comparable (TaTAVR: 86.5 ± 9.7% vs RAVR: 95.2 ± 4.6%; $P = 0.52$). Follow-up freedom from stroke, acute heart failure, reintervention on AVR and thrombo-embolisms were comparable ($P = NS$). EuroSCORE II ($P = 0.02$), perioperative stroke ($P = 0.01$) and length of hospitalization ($P = 0.02$) were the determinants of all-cause mortality at follow-up, whereas perioperative stroke ($P = 0.03$) and length of hospitalization ($P = 0.04$) impacted cardiovascular mortality at follow-up.

CONCLUSIONS: Reported differences in mortality and morbidity after TaTAVR and RAVR reflect differences in baseline risk profiles. Given the lower trend for renal complications, patients at higher perioperative renal risk might be better served by TaTAVR.

Keywords: Aortic valve disease • Bioprosthesis malfunction • Aortic valve replacement • Transapical transcatheter aortic valve replacement • Redo

INTRODUCTION

Several surgical scenarios considered at increased risk of hospital mortality—such as redo surgery—have become preferential indications for transcatheter aortic valve replacement (TAVR) although conclusive data from randomized trials and multicentre registries proving the superiority of transcatheter approaches over conventional surgery are still lacking [1–5]. In particular, previous coronary artery bypass grafting (CABG) at the time of aortic valve replacement (AVR) (RAVR) represents a surgical challenge because of the risk of iatrogenic injury of patent grafts, and in view of the technical issues related to myocardial protection during aortic cross-clamping [6]. Single-centre retrospective experiences evaluating the results of TAVR in patients with prior CABG reported similar results between peripheral TAVR and RAVR [4], or alternatively a better outcome with transapical TAVR (TaTAVR) compared with RAVR [3, 7]. In contrast, the PARTNER trial subanalysis of patients with previous CABG reported the superiority of conventional RAVR over transcatheter procedures [8]. Moreover, a recent multi-centre Italian registry of TaTAVR reported excellent results in several redo scenarios [5], whereas another similar multicentre European registry demonstrated excellent early-to-mid-term outcome after RAVR in patients with previous CABG [9, 10]. In view of the contradictory results and the limitations of the existing studies, the aim of this analysis was to merge data from the two above-mentioned multicentre registries, to evaluate 'all-comers' elderly patients with an aortic stenosis and a history of previous CABG with known patent grafts and scheduled for TaTAVR or RAVR, to define the best surgical approach.

MATERIALS AND METHODS

Data from ITA (**I**talian Registry of **T**rans-**A**pical Aortic Valve Implantation) Registry and RECORD (**RE**do **C**ardiac **O**perations **R**esearch **D**atabase) Registry have been already reported elsewhere [5, 9–12]. Briefly, the ITA is an independent prospective multicentre registry including all consecutive TaTAVR patients treated at 20 Italian cardiac surgery centres according to the indication of the local Heart Team since this procedure became commercially available in 2008 [3, 7]. All patients received a Sapien or Sapien XT (since mid-2010) TAVR (Edwards Lifesciences, Irvine, CA, USA) [11]. For the

purpose of this study, all patients in the eighth decade of life or over with a previous CABG and enrolled for a primary aortic valve procedure or for a valve-in-valve TaTAVR were included in the analysis (no. 113 patients, Group ITA). Overall, the ITA enrolled 774 patients during the study period, resulting in a mean number of 38 TaTAVR/centre [12].

RECORD is an independent multicentre registry including all surgical AVR performed in patients with a history of prior cardiac surgery since 2003 at 7 European centres, where alternative TaTAVR treatment was not available during the study period [8–10]. For the purpose of the study, only patients contemporary to ITA (i.e. since 2008) in the eighth decade of life with previous patent CABG were considered (no. 126, RECORD-Group). Indeed, RECORD enrolled 422 redo patients from 7 centres since 2008, resulting in a mean number of 60 RAVR/centre during the study period [9, 10].

In both registries, preoperative risk factors were defined according to the EuroSCORE II criteria (www.euroscore.org/euroscore_scoring.htm). Independent investigators evaluated patient's outcome and adverse events in light of the Valve Academic Research Consortium-2 (VARC-2) definitions [13]. The following variables were collected: (i) all-cause hospital mortality; (ii) cardiovascular hospital mortality; (iii) periprocedural acute myocardial infarction (AMI); (iv) 30-day 'disabling or non-disabling' stroke; (v) major/life threatening or disabling bleeding; (vi) acute kidney injury [defined as Class 2 or 3 of acute kidney injury network (AKIN) classification] and need for renal replacement therapy; (vii) permanent pacemaker implantation; (viii) 'early safety', defined as the cumulative end point at 30 days of all-cause mortality, all strokes, life-threatening bleedings, Class 2 or 3 AKIN, coronary artery obstruction requiring intervention, major vascular complication, valve-related dysfunction requiring repeat procedure [13]; (ix) late all-cause mortality; (x) late cardiovascular mortality; (xi) late 'disabling or non-disabling' stroke. Moreover, the following 'non-VARC-2' outcomes were considered, because of their prognostic and/or economic impact: (i) prolonged intubation, defined as ≥24 h mechanical ventilation and/or respiratory insufficiency with the need for reintubation, or need for non-invasive ventilation ≥24 h [9]; (ii) length of hospitalization; (iii) acute heart failure (AHF) during follow-up; (iv) reinterventions on the aortic prosthesis during follow-up; (v) thrombo-embolisms during follow-up; (vi) New York Heart Association (NYHA) class at last follow-up.

Hospital and follow-up outcome data were reported for the entire population and a propensity-matched subgroup of patients.

Table 1: Baseline characteristics of the two populations

Variables	RAVR (126)	TaTAVR (113)	*P*-value
Age (years)	77 (70–88)	80 (71–88)	0.01
Height (cm)	168 (152–182)	165 (150–176)	0.01
Weight (kg)	75.8 ± 13.5	69.0 ± 15.7	<0.01
Body mass index (kg/m^2)	27.1 ± 4.5	26.3 ± 13.5	0.54
EuroSCORE II	8.7 (2.4–32.7)	20.1 (4.9–29.9)	<0.01
Female gender	42 (33.3%)	46 (40.7%)	0.15
Critical state	1 (0.8%)	3 (2.7%)	0.27
NYHA class I	3 (2.4%)	2 (1.8%)	0.95
NYHA class II	24 (19.0%)	22 (19.5%)	
NYHA class III	84 (64.7%)	73 (64.6%)	
NYHA class IV	15 (11.9%)	16 (14.2%)	
Systemic hypertension	90 (71.4%)	102 (90.3%)	<0.01
Diabetes mellitus	59 (46.8%)	37 (32.7%)	0.02
Renal disease	30 (23.8%)	71 (62.8%)	<0.01
Vasculopathy	27 (21.4%)	78 (69.0%)	<0.01
Chronic obstructive pulmonary disease	29 (23.0%)	21 (18.6%)	0.25
Neurological dysfunction	24 (19.0%)	7 (6.2%)	<0.01
Pervious AMI	40 (31.7%)	7 (6.2%)	<0.01
Left ventricular ejection fraction >50%	78 (61.9%)	52 (46.0%)	0.03
Left ventricular ejection fraction 30–50%	44 (34.9%)	53 (46.9%)	
Left ventricular ejection fraction <30%	4 (3.2%)	8 (7.1%)	
Pulmonary hypertension	22 (17.5%)	63 (55.8%)	<0.01
Cognitive Impairment	7 (5.6%)	15 (13.3%)	0.03
Child-Pugh A	7 (5.6%)	12 (10.6%)	0.02
Child-Pugh B	4 (3.2%)	9 (8.0%)	
Child-Pugh C	–	4 (3.5%)	
Serum albumin <3.5 g/dl	4 (3.2%)	13 (11.5%)	0.01
Body mass index <20 kg/m^2 or weight loss >5 kg/year	8 (6.3%)	12 (10.6%)	0.23
Hostile chest	4 (3.2%)	11 (9.7%)	0.04

NYHA: New York Heart Association; AMI: acute myocardial infarction; RAVR: aortic valve replacement after previous CABG; TaTAVR: transapical TAVR.

Continuous variables are presented as mean and standard deviation, categorical variables as counts and percentages. Normally distributed continuous variables were compared using the unpaired *t*-test, whereas the Mann–Whitney *U*-test was used for non-normally distributed variables. Categorical variables were analysed using either the χ^2 test or Fisher's exact test as appropriate. Long-term overall survival and cardiovascular survival in the entire population were assessed by step-wise Cox regression analyses. A *P*-value of less than 0.05 was considered significant. To reduce the effect of selection bias and potential confounding factors, all the outcome-parameters were adjusted by propensity-matching. A propensity score model was built using a step-wise logistic regression (probability for step-wise entry *P* = 0.20, and probability for step-wise removal *P* = 0.10). Numerous factors were employed as covariates: EuroSCORE II, gender, age, preoperative NYHA class, left ventricular ejection fraction, systemic hypertension, diabetes mellitus, chronic obstructive pulmonary disease, chronic kidney disease, extracardiac vasculopathy, preoperative neurological dysfunction, previous AMI, pulmonary hypertension and previous type of cardiac surgery. Fifty-six pairs of TaTAVR and RAVR patients having the same probability score (calliper match with three digits approximation) were selected. Balance of matching was then assessed by statistical comparison, using standardized differences (with a difference >0.1 treated as significant) for continuous and Fisher's exact test for categorical variables [14]. Survival analyses were performed using the Kaplan–Meier method with log-rank test in the propensity-matched

population. The SPSS 13.0 program performed statistical analysis (SPSS, Inc., Chicago, IL, USA).

RESULTS

A total of 239 consecutive patients after previous CABG were enrolled (126–52.7% underwent RAVR, 113–47.3%, TaTAVR). The two populations differed for baseline characteristics (Table 1). Aortic cross-clamping time in RAVR was 74.3 ± 33.8 min, cardiopulmonary bypass time 119.5 ± 51.9 min. Four patients (3.5%) required cardiopulmonary bypass during TaTAVR. Among RAVR, 16 patients (12.7%) required also redo CABG. Seventeen patients (13.5%) in the RAVR cohort and 3 in the TaTAVR cohort (2.7%, *P* < 0.01) had redo for degenerated aortic bioprosthesis. Within the RAVR cohort, 40 patients (31.7%) underwent preoperative CT scan, 72 (57.1%) pre-sternotomy institution of peripheral cardiopulmonary bypass, 104 (82.5%) had patent left internal mammary artery (LIMA) graft, 85 (67.5%) underwent surgical isolation of the LIMA graft, 70 (55.6%) LIMA-graft clamping, 110 (87.3%) had patent saphenous vein graft, 112 (88.9%) received blood cardioplegia, 108 (85.7%) had antegrade + retrograde cardioplegia, 47 (37.3%) underwent cardioplegia delivery into saphenous grafts. The mean number of preoperative patent grafts was 2.3 ± 0.8. Among the above-mentioned technical factors, absence of pre-sternotomy institution of peripheral cardiopulmonary bypass (AMI without cardiopulmonary bypass: 4/4–100% vs AMI with cardiopulmonary bypass: 0/72–0%; *P* = 0.02), absence of blood cardioplegia (AMI without blood

Table 2: Hospital and 30-day outcome in the entire population and the propensity-matched subgroups

Variables	Overall population			Propensity-matched cohort		
	RAVR (126)	TaTAVR (113)	*P*-value	RAVR (28)	TaTAVR (28)	*P*-value
30-day mortality	2 (1.6%)	8 (7.1%)	0.03	–	1 (3.6%)	1.0
30-day CV mortality	2 (1.6%)	5 (4.4%)	0.18	–	1 (3.6%)	1.0
Stroke	1 (0.8%)	6 (5.3%)	0.04	–	2 (7.1%)	0.49
MLD bleeding	4 (3.2%)	11 (9.7%)	0.03	1 (3.6%)	1 (3.6%)	1.0
AMI	4 (3.2%)	1 (0.9%)	0.22	1 (3.6%)	–	1.0
Prolonged intubation	14 (11.1%)	6 (5.3%)	0.08	4 (14.3%)	1 (3.6%)	0.35
AKIN 2/3	19 (15.1%)	9 (8.0%)	0.06	6 (21.4%)	1 (3.6%)	0.05
Need for dialysis	7 (5.6%)	5 (4.4%)	0.46	4 (14.3%)	1 (3.6%)	0.35
Need for pPMK	15 (11.9%)	5 (4.4%)	0.03	3 (10.7%)	–	0.23
Transfusions	75 (59.5%)	23 (20.4%)	<0.01	16 (57.1%)	3 (10.7%)	<0.01
DSWI	2 (1.6%)	–	0.89	–	–	–
Early safety	19 (15.1%)	28 (24.8%)	0.04	6 (21.4%)	6 (21.4%)	1.0
Hospitalization (days)	10 (5–19)	10 (4–20)	0.12	10.9 ± 6.7	8.9 ± 3.9	0.17

CV: cardiovascular; MLD: major/life threatening/disabling; AMI: acute myocardial infarction; AKIN: Acute Kidney Injury Network Classification; pPMK: permanent pacemaker; DSWI: deep sternal wound infection; RAVR: aortic valve replacement after previous CABG; TaTAVR: transapical TAVR; TAVR: transcatheter aortic valve replacement.

cardioplegia: 4/4–100% vs AMI with blood cardioplegia: 0/112–0%; *P* < 0.01) and absence of antegrade + retrograde cardioplegia (AMI without retrograde cardioplegia: 4/4–100% vs AMI with retrograde addition: 0/108–0%; *P* < 0.01) correlated with perioperative AMI at univariate analysis.

Within the TA-TAVR cohort, 96 patients had a patent LIMA graft (84.9%, *P* = 0.61 vs RAVR), and 94 had patent saphenous vein grafts (83.2%, *P* = 0.37 vs RAVR). The mean number of preoperative patent grafts was 2.3 ± 0.9 (*P* = 0.68 vs RAVR).

Hospital outcome demonstrated lower all-cause 30-day survival and 'early safety' after TaTAVR, associated with dissimilar technique-specific morbidity between the procedures (worse stroke, major/life-threatening/disabling bleeding after TaTAVR, higher permanent pacemaker implantation and transfusions after RAVR) (Table 2). A higher mean transprosthetic gradient (15.1 ± 2.7 vs 9.9 ± 3.5 mmHg; *P* < 0.01) and a lower residual regurgitation (none 118/126–93.8%, mild 6/118–4.6%, moderate 2/126–1.6% vs none 59/113–52.2%, mild: 46/113–40.7%, moderate 8/113–7.1%; *P* < 0.01) was found after RAVR versus TaTAVR, respectively. Mean follow-up was longer in RAVR [20.1 months, 95% confidence interval (CI) 0.2–58.7 vs TaTAVR: 12.2 months, 95% CI 0.2–30.4; *P* < 0.01]. RAVR reported a lower hazard in all-cause (Fig. 1A) and cardiovascular mortality (Fig. 1B). Causes of non-cardiovascular mortality at follow-up in TaTAVR were cancer (no. 2), hepatic insufficiency (no. 2), pneumonia (no. 2), gastrointestinal bleeding (no. 1). Cox regression analysis demonstrated that EuroSCORE II [hazard ratio (HR)1.09, 95% confidence limits (CL) 1.08–1.19; *P* = 0.02], perioperative stroke (HR 22.9, 95% CL 17.3–30.4; *P* = 0.01) and length of hospitalization (HR 1.14, 95% CL 1.02–1.26; *P* = 0.02) were significant factors determining follow-up all-cause mortality, whereas perioperative stroke (HR 5.2, 95% CL 1.6–13.2; *P* = 0.03) and length of hospitalization (HR 1.07, 95% CL 1.0–1.2; *P* = 0.04) impacted follow-up cardiovascular mortality. Freedom from stroke was higher after RAVR (98.0 ± 2.0% vs TaTAVR: 72.8 ± 21.1%; *P* = 0.02), whereas freedom from AHF (RAVR: 93.1 ± 2.8% vs TaTAVR: 81.0 ± 7.1%; *P* = 0.10) and thrombo-embolisms (RAVR: 97.0 ± 2.3% vs TaTAVR: 99.1 ± 0.9%; *P* = 0.90) were similar, with a trend towards a higher freedom from reinterventions after RAVR (98.0 ± 2.0% vs TaTAVR: 93.0 ± 5.0%; *P* = 0.06). NYHA class at last follow-up was better after RAVR (Table 3).

A propensity score selected a comparable population of 56 patients (Table 4). Within the 28 RAVR patients, 5 (17.9%) required an associated CABG. There were 2 patients (7.1%) with degenerated bioprosthesis in RAVR as well as in TaTAVR cohorts (*P* = 1.0). There were no differences between RAVR and TaTAVR in 30-day outcome, with the exception of a higher transfusion rate and a trend towards higher AKIN 2/3 after RAVR (Table 2). Higher mean trans-prosthetic gradient (14.9 ± 1.9 vs 9.1 ± 2.8 mmHg; *P* < 0.01) and lower residual regurgitation (none 28/28–100% vs none 14/28–50.0%, mild: 12/28–42.9%, moderate: 2/28–7.1%; *P* < 0.01) were found in RAVR versus TaTAVR, respectively. Mean follow-up was comparable (RAVR: 19.1 ± 15.7 months vs TaTAVR: 14.1 ± 7.6 months; *P* = 0.13). There was a trend towards a lower freedom from all-cause mortality (Fig. 2A) and higher NYHA class at follow-up (Table 3) after TaTAVR although cardiovascular mortality (Fig. 2B), freedom from AHF (RAVR: 86.1 ± 7.4% vs TaTAVR: 79.5 ± 10.2%; *P* = 0.87), from stroke (RAVR: 100% vs TaTAVR: 100%), from thrombo-embolisms (RAVR: 100% vs TaTAVR: 96.4 ± 3.5%; *P* = 0.33) and from reinterventions (RAVR: 100% vs TaTAVR: 95.8 ± 4.1%; *P* = 0.41) were comparable.

DISCUSSION

The last 5 years have been characterized by the worldwide spread of TAVR practice, progressed well beyond the initial indications limited to patients at prohibitive or very high surgical risk [1], with a strong attitude to use TAVR in patients after previous cardiac surgery [15]. To date, reports on RAVR and TAVR in redo scenarios have reached contradictory conclusions, mostly related to the retrospective single-centre study design, the excessive case-mix (especially in terms of transcatheter approaches) and the baseline risk-profile of the cohorts analysed [3, 4, 7, 8]. The present study reports the results of a concurrent multicentre population of 'all-comers' with aortic valve stenosis after previous CABG, treated with either traditional RAVR or TaTAVR. The first finding of the study confirms previous literature results [3, 7] that patients undergoing TaTAVR maintain a higher preoperative risk-profile. Therefore and as expected, these patients achieve worse 30-day all-cause mortality, stroke, bleeding and
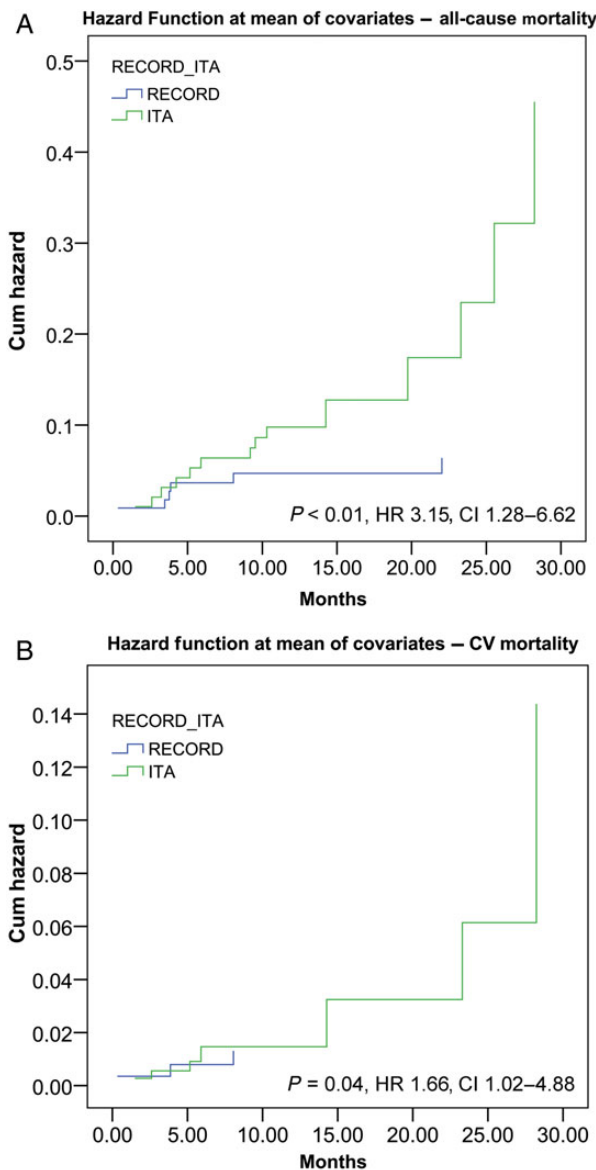
ORIGINAL ARTICLE

A

B

Figure 1: Multivariable Cox survival plotted at the mean of covariates for 'all-cause mortality' (**A**) and cardiovascular mortality (**B**) in the entire population ITA: Italian Registry of Trans-Apical Aortic Valve Implantation; CV: cardiovascular; HR: hazard ratio; CI: confidence interval; RECORD: REdo Cardiac Operations Research Database.

Table 3: NYHA class in the entire population and in the propensity-matched subgroups at last follow-up

	NYHA I	NYHA II	NYHA III	NYHA IV	P-value
Entire population					
RAVR	72 (61.0%)	38 (32.2%)	8 (6.8%)	–	<0.01
TaTAVR	63 (69.2%)	12 (13.2%)	9 (9.9%)	7 (7.7%)	
Propensity-matched patients					
RAVR	14 (53.8%)	10 (38.5%)	2 (7.7%)	–	0.09
TaTAVR	14 (63.6%)	3 (13.6%)	2 (9.1%)	3 (13.6%)	

NYHA: New York Heart Association; RAVR: aortic valve replacement after previous CABG; TaTAVR: transapical TAVR; TAVR: transcatheter aortic valve replacement.

Table 4: Baseline characteristics of the propensity-matched sub-populations

Variables	RAVR (28)	TaTAVR (28)	P-value
Age (years)	77.4 ± 6.8	78.8 ± 6.5	0.44
Height (cm)	166.6 ± 9.7	164.7 ± 7.6	0.43
Weight (kg)	71.9 ± 13.7	71.1 ± 15.6	0.83
Body mass index (kg/m^2)	25.8 ± 3.9	26.0 ± 4.5	0.86
EuroSCORE II	16.3 ± 11.9	14.3 ± 6.5	0.45
Female gender	11 (39.3%)	7 (25.0%)	0.39
Critical state	1 (3.6%)	-	1.0
NYHA class I	1 (3.6%)	1 (3.6%)	0.97
NYHA class II	4 (14.3%)	5 (17.9%)	
NYHA class III	17 (60.7%)	17 (60.7%)	
NYHA class IV	6 (21.4%)	5 (17.9%)	
Systemic hypertension	23 (82.1%)	23 (82.1%)	1.0
Diabetes mellitus	12 (42.9%)	10 (35.7%)	0.78
Renal disease	11 (39.3%)	14 (50.0%)	0.59
Vasculopathy	17 (60.7%)	12 (42.9%)	0.28
Chronic obstructive pulmonary disease	7 (25.0%)	7 (25.0%)	1.0
Neurological dysfunction	5 (17.9%)	2 (7.1%)	0.42
Pervious AMI	4 (14.3%)	4 (14.3%)	1.0
Left ventricular ejection fraction >50%	15 (53.6%)	19 (67.9%)	0.26
Left ventricular ejection fraction 30–50%	13 (46.4%)	8 (28.6%)	
Left ventricular ejection fraction <30%	–	1 (3.6%)	
Pulmonary hypertension	7 (25.0%)	7 (25.0%)	1.0
Cognitive impairment	4 (14.3%)	6 (21.4%)	0.36
Child-Pugh A	5 (17.9%)	6 (21.4%)	0.69
Child-Pugh B	4 (14.3%)	5 (17.9%)	
Child-Pugh C	–	1 (3.6%)	
Serum albumin <3.5 g/dl	4 (14.3%)	4 (14.3%)	1.0
Body mass index <20 kg/m^2 or weight loss >5 kg/year	5 (17.9%)	6 (21.4%)	0.74
Hostile chest	4 (14.3%)	7 (25.0%)	0.25

NYHA: New York Heart Association; AMI: acute myocardial infarction; RAVR: aortic valve replacement after previous CABG; CABG: coronary artery bypass grafting; TaTAVR: transapical TAVR; TAVR: transcatheter aortic valve replacement.

cumulative end-point of 'early safety', the latter also related to the recognized learning-curve effect [16], linked with the ITA which encompasses all patients treated with Edwards Sapien valves since their initial availability. Interestingly, among perioperative complications, stroke proved to play a leading role in determining unfavourable follow-up survival in TaTAVR-patients. This issue deserves future investigations, also in light of the reported higher freedom from stroke after RAVR in our experience. Another interesting information is the extremely low incidence of major/life-threatening/disabling bleeding after RAVR, possibly explained by the extremely low incidence of iatrogenic complications at re-entry, the implemented blood conservation strategies and anticoagulation management of surgical patients together with an improved accuracy during haemostatic manoeuvres in redo surgery [17]. Finally, a cumulative effect of higher EuroSCORE II and frailty, with worse comorbidities and left ventricular ejection fraction in TaTAVR cohort may also explain the higher mid-term mortality and stroke rates reported in this subgroup. In this perspective can also be interpreted the results of the Cox regression analysis, demonstrating in both populations a critical role on long-term survival to be played by preoperative EuroSCORE II and prolonged hospitalization.
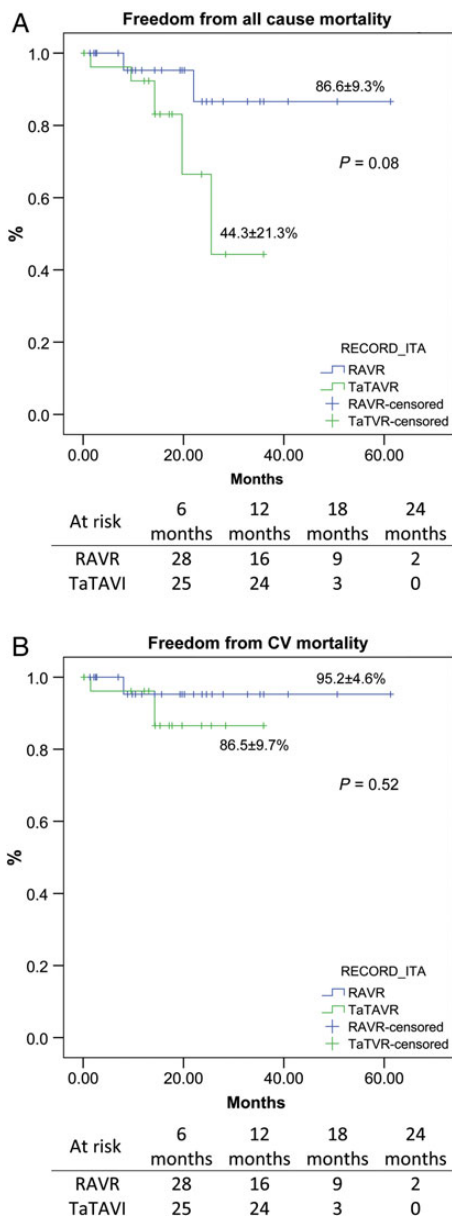
Figure 2: Freedom from 'all-cause mortality' (**A**) and cardiovascular mortality (**B**) in the propensity-matched population. ITA: Italian Registry of Trans-Apical Aortic Valve Implantation; CV: cardiovascular; RAVR: aortic valve replacement after previous CABG; TaTAVR: transapical TAVR; RECORD: REdo Cardiac Operations Research Database.

On the other hand, a lower need for permanent pacemaker implantation was documented after TaTAVR, a finding explained by the exclusive use of Edwards Sapien transcatheter valves in this experience, with their documented low impact on the conduction system [18], as well as by the protective effect of the rigid sewing ring of failed bioprostheses in those patients undergoing a valve-in-valve deployment [19]. Similarly and as previously described, a significantly lower need for transfusions was reported after TaTAVR, directly related to the less invasive nature of the procedure, [2–4]. Despite this, the higher transfusion rate of RAVR cohort—confirmed also in propensity-matched subanalysis—did not impact postoperative respiratory and renal function, or survival. On the other hand, this variable might impact on the hospital costs of RAVR, as recently demonstrated by Nguyen *et al.* [7], a matter that certainly deserves future revision.

The proof that the apparently better outcome of RAVR patients in the entire population was linked to the better preoperative risk-profile was confirmed by the results of the propensity-matched population, showing a similar 30-day outcome with the two techniques. This finding confirms those of Wilbring *et al.* [2] and Stortecky *et al.* [4], both reporting overall equipoise in single-centre comparisons of RAVR and TAVR. Indeed, the only difference between the two propensity-matched subgroups at 30 days was the higher transfusion requirement, and the trend towards a higher incidence of AKIN 2/3 after RAVR. These findings confirmed data from Papadopoulos *et al.*, showing a higher transfusion rate after RAVR [3]. On the other hand, the slightly worse renal effect of RAVR versus TaTAVR is quite a new finding compared with the available literature reporting similar renal outcome, implying a higher injurious effect of transfusions and cardiopulmonary bypass on the one hand, compared with that of contrast medium administration on the other [20].

When mid-term outcome was considered, propensity-matched analysis demonstrated comparable results between RAVR and TaTAVR in contrast to the overall examined population, substantiating a direct dependence from baseline risk-profile. Therefore, our data demonstrate that in high-risk elderly patients with previous CABG, TaTAVR and RAVR can be considered complementary techniques. These data confirm the recent study by Nguyen *et al.*, reporting similar risk-adjusted mid-term survival between TAVR and RAVR in previous CABG [7]. Certainly other factors not captured by current risk-profiles (e.g. multimorbidity interactions, disability, frailty and cognition) may help to explain the contrast between the trend for higher all-cause mortality and the comparable cardiovascular mortality of our propensity-matched subanalysis [21, 22]. Similarly, a combination of baseline risk-profile, 'frailty items' and 'cognitive functions' can help to explain the apparent discrepancy between the better NYHA class at follow-up in overall RAVR population and the presence of only a trend towards a better NYHA after RAVR in the propensity-matched population [21, 22].

Finally, when valve performance was considered, we reported higher transprosthetic gradients after RAVR and higher residual regurgitation after TaTAVR in the entire and the propensity-matched populations. The higher residual aortic regurgitation after TaTAVR certainly relates to the first-generation nature of TaTAVR of the present study [23, 24] and the low prevalence of valve-in-valve procedure of our 'transcatheter' cohort [25]. We cannot exclude that these data might have impacted also NYHA class at follow-up. Furthermore, the low prevalence of valve-in-valve procedures in TaTAVR cohort and the stentless nature of TaTAVR, compared with the predominant stented structure of RAVR implanted in our population, explain the higher gradients reported after traditional surgery [2–4, 25]. It is noteworthy that the higher gradients reported in RAVR did not impact survival, functional class and AHF episodes at follow-up.

The main limitation of the study is related to the retrospective nature of the data-analysis. The second limitation is related to the fact that the present comparison does not adhere to any of the primary purposes according to which the two source registries have been conceptualized. The third limitation stems from the absence of a 'cost-effective' analysis between RAVR and TaTAVR in this high-risk population. Another limitation is related to the fact that the contemporary availability of RAVR in the 20 ITA-contributor centres might have led to a 'selection bias' of sicker patients towards TaTAVR, regardless of the similar risk factors captured by the EuroSCORE II, and thus potentially unmatchable despite propensity analysis. Nevertheless, some other VARC-2 risk factors not captured by EuroSCORE II (e.g. hepatic function, cognition and nutritional

status) have been analysed, according to which TaTAVR patients still reported a higher baseline risk-profile compared with RAVR patients, thus requiring propensity-matching for an acceptable comparison. The last limitation is related to the restricted number of propensity-matched patients selected in the study, associated to the employed propensity analysis, which considered quite several factors as covariates potentially influencing treatment-group allocation.

However, the above-mentioned limitations stem from the observational nature of the two registries, which on the opposite represent a 'real world' picture of concurrent RAVR and TaTAVR in 'all-comers' to redo procedures after CABG at different European institutions. Moreover, the main strengths are related to the multi-centre nature and the contemporaneity of the two registries. Finally, this is the only study besides that of Nguyen et al. [7] comparing TaTAVR and RAVR complying with VARC-2 definitions of end-points.

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