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Mortality risk after transcatheter aortic valve implantation: analysis of the predictive accuracy of the Transcatheter Valve Therapy registry risk assessment model

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KEYWORDS

- aortic stenosis
- elderly (>75 years)
- no specific risk
- TAVI

Abstract

Aims: The risk assessment tools currently used to predict mortality in transcatheter aortic valve implantation (TAVI) were designed for patients undergoing cardiac surgery. We aimed to assess the accuracy of the TAVI dedicated risk score in predicting mortality outcomes.

Methods and results: Consecutive patients (n=1,038) undergoing TAVI at a single institution from 2014 to 2016 were included. The ACC/TVT registry mortality risk score, the STS-PROM score and the EuroSCORE II were calculated for all patients. In-hospital and 30-day all-cause mortality rates were 1.3% and 2.9%, respectively. The ACC/TVT risk stratification tool scored higher for patients who died in-hospital than for those who survived the index hospitalisation (6.4±4.6 vs. 3.5±1.6, p=0.03, respectively). The ACC/TVT score showed a high level of discrimination, C-index for in-hospital mortality 0.74, 95% CI: (0.59-0.88). There were no significant differences between the performance of the ACC/TVT registry risk score, the EuroSCORE II and the STS-PROM score for in-hospital and 30-day mortality rates.

Conclusions: The ACC/TVT registry risk model is a dedicated tool to aid in the prediction of in-hospital mortality risk after TAVI.

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Abbreviations

ACC/TVT	American College of Cardiology/Transcatheter Valve Therapy
AS	aortic stenosis
CI	confidence interval
GFR	glomerular filtration rate
LVEF	left ventricular ejection fraction
SAVR	surgical aortic valve replacement
STS-PROM	Society of Thoracic Surgeons - predicted risk of mortality
TAVI	transcatheter aortic valve implantation
VARC-2	Valve Academic Research Consortium-2

Introduction

Transcatheter aortic valve implantation (TAVI) has emerged as an option for patients with severe aortic stenosis (AS) at elevated risk for surgical aortic valve replacement (SAVR)[1-3]. In clinical practice, the Heart Team estimates risk for SAVR/TAVR utilising a combination of clinical judgement, frailty indices, and various surgical risk calculators such as the Society of Thoracic Surgeons - predicted risk of mortality (STS-PROM) score, the logistic EuroSCORE and the EuroSCORE II[4-7]. However, these risk scores, designed for surgical risk assessment, have not been validated in transcatheter interventions and their ability to predict risk for TAVI is unclear[8,9]. Recently, a dedicated TAVI risk model has been developed based on the data from the American College of Cardiology (ACC)/Transcatheter Valve Therapy (TVT) registry[10]. The aim of the present study was to compare the accuracy of the STS-PROM, EuroSCORE II, and ACC/TVT risk scores in predicting outcomes from a large population of TAVI patients.

Methods

From January 2014 to November 2016 all patients with severe AS who underwent TAVI at our institution (n=1,038) were identified. Decisions regarding risk and candidacy for TAVI were made by a dedicated Heart Team.

Severe AS was defined as a valvular orifice area <1.0 cm^2 or <0.6 cm^2/m^2 and/or mean pressure gradient >40 mmHg and/or jet velocity >4.0 m/s. Selected patients with discordant echocardiographic findings underwent dobutamine echocardiography.

Patients were assessed by echocardiography, coronary angiography, and gated cardiac computed tomography. If vascular anatomy was unsuitable for a transfemoral approach alternative accesses were considered.

The ACC/TVT risk score, the STS-PROM score, and the EuroSCORE II were calculated for all patients[11-13]. Variables and endpoints of the ACC/TVT risk prediction tool, the STS-PROM score and the EuroSCORE II are presented in **Supplementary Table 1**. Events were collected in a dedicated database during the index hospitalisation, at 30-day follow-up and at one year. Endpoints were adjudicated according to the Valve Academic Research Consortium-2 (VARC-2) definitions[14]. The Columbia University Institutional Review Board approved the retrospective chart reviews of all patients and waived individual patient consent.

STATISTICAL ANALYSIS

The primary outcomes were in-hospital and 30-day all-cause mortality. Descriptive data are presented as means and standard deviations for continuous data or frequencies and percentages for categorical data. For univariate analysis, t-tests were used to compare the continuous variables and Pearson's chi-square tests were performed for categorical variables to determine the associations between in-hospital mortality and/or 30-day mortality with baseline demographic, echocardiographic and TAVI procedural characteristics.

Discriminatory abilities of the models were assessed using the C-index. The C-index ranges from 0 to 1, with higher values indicating better discrimination. A non-parametric DeLong method was used through the ROCCONTRAST option in PROC LOGISTIC (SAS Institute Inc., Cary, NC, USA) to compare two ROC curves. We examined the predictive accuracy of the ACC/TVT risk score vs. EuroSCORE II, ACC/TVT registry score vs. STS-PROM score, EuroSCORE II vs. STS-PROM score for in-hospital mortality and 30-day mortality using the DeLong method. Calibration of the models was evaluated using the Hosmer-Lemeshow χ^2 statistic goodness-of-fit test, which compares observed and predicted outcomes over deciles of risk and also the observed probability with the expected probability within each decile, with a value <0.05 indicating significant difference in expected versus observed mortality. Analyses were conducted using SAS software, version 9.4 (SAS Institute Inc.). Statistical significance was set at $p<0.05$.

Results

We analysed the outcomes of 1,038 consecutive patients (female 49.6%) treated with TAVI between January 2014 and December 2016. In-hospital and 30-day survival status was available in 100% and 99.3% of patients, respectively. In-hospital and 30-day mortality rates were 1.34% and 2.9%, respectively. Baseline characteristics of survivors in comparison to non-survivors are presented in **Table 1**. In-hospital non-survivors were more likely to present with heart failure than in-hospital survivors (14 [100%] vs. 817 [79.8%], p=0.04). They also demonstrated higher rates of prior myocardial infarction (MI) (6 [42.8%] vs. 162 [15.8%], p=0.01), atrial fibrillation (10 [71.4%] vs. 402 [39.2%], p=0.006) and chronic lung disease (7 [50%] vs. 251 [24.5%], p=0.02) than in-hospital survivors.

Baseline echocardiographic features are presented in **Table 2**. Survivors in comparison to non-survivors had higher left ventricular ejection fraction (LVEF) at baseline (55±16% vs. 42±18%; p=0.002) and at 30-day follow-up (55±15.5% vs. 45±18%; 0.001) as well as lower rates of right ventricular dysfunction (at baseline, 224 [22%] vs. 7 [50%], p=0.01, and at 30 days, 215 [22%] vs. 13 [43%], p=0.01) **(Table 2)**. Non-transfemoral access was associated with higher mortality rates (48 [4.6%] vs. 6 [42.8%], p<0.001, and

Table 1. Baseline characteristics.

	All patients (N=1,038)	In-hospital survivors (n=1,024)	In-hospital non-survivors (n=14)	*p*-value	30-day survivors (n=984)	30-day non-survivors (n=30)	*p*-value
Age, years	83.2±7.9	83.2±7.9	85.1±8.8	0.37	83.1±8.0	84.8±7.2	0.25
Female	515 (50)	509 (50)	6 (43)	0.61	488 (50)	12 (40)	0.30
Body mass index, kg/m²	26.8±5.9	26.9±5.9	26.5±5.5	0.82	26.8±5.9	26.8±4.5	0.99
ACC/TVT risk score	3.6±1.7	3.5±1.0	6.4±4.6	0.03	3.5±1.6	5.0±3.5	0.02
EuroSCORE II	6.1±5.4	6.0±5.3	13.2±10.8	0.03	6.0±5.2	11.1±9.8	0.01
STS-PROM score	6.7±4.8	6.6±4.6	14.4±12.4	0.03	6.6±4.6	11.0±9.6	0.01
CHF prior two weeks	831 (80)	817 (79.8)	14 (100)	0.04	803 (79.6)	27 (80)	0.07
Prior myocardial infarction	168 (16.2)	162 (15.8)	6 (42.8)	0.01	151 (14.9)	9 (30)	0.02
Prior PCI	306 (29.4)	301 (29.4)	5 (35.7)	0.19	302 (29.9)	8 (26.7)	0.15
Atrial fibrillation	412 (39.7)	402 (39.2)	10 (71.4)	0.006	393 (38.9)	19 (63.3)	0.004
Cerebrovascular disease	176 (16.9)	173 (17)	3 (21.4)	0.23	170 (16.8)	6 (20)	0.16
Peripheral arterial disease	163 (15.7)	160 (15.6)	3 (21.4)	0.21	160 (15.9)	6 (20)	0.15
Diabetes mellitus	316 (30.4)	309 (30.1)	7 (50)	0.06	306 (30.6)	11 (36.6)	0.11
Hypertension	961 (92.6)	947 (92.4)	14 (100)	0.33	929 (92.1)	28 (93.3)	0.28
Dyslipidaemia	846 (81.5)	834 (81.4)	12 (85.7)	0.26	812 (80.5)	24 (80)	0.17
Chronic lung disease	258 (24.9)	251 (24.5)	7 (50.0)	0.02	246 (24.4)	14 (46.6)	0.005
Glomerular filtration rate, ml/min/m²	49.4±23.9	49.5±23.8	51.2±24.6	0.41	49.2±23.9	50.3±23.5	0.37
Pre-TAVI creatinine, mg/dl	1.3±0.9	1.3±0.9	1.39±0.8	0.75	1.3±0.9	1.5±0.9	0.20
CKD stage 3	514 (49.5)	508 (49.6)	6 (43)	0.63	494 (50.2)	14 (46.6)	0.52
CKD stage 4	98 (9.4)	96 (9.4)	2 (14.2)	0.38	80 (8.1)	4 (13.3)	0.23
Renal replacement therapy	27 (2.6)	24 (2.2)	3 (21.4)	0.004	21 (2.0)	4 (13.3)	0.005

Values are presented as mean±standard deviation (SD) or number (%). ACC/TVT: American College of Cardiology/Transcatheter Valve Therapy; CHF: congestive heart failure; PCI: percutaneous coronary intervention; STS-PROM: Society of Thoracic Surgeons - predicted risk of mortality; TAVI: transcatheter aortic valve implantation

44 [4.4%] vs. 10 [33.3%], p=0.04), for survivors vs. non-survivors during hospitalisation and at 30-day follow-up, respectively. Major vascular complications were significantly higher in non-survivors in comparison to survivors (4 [28.5%] vs. 20 [1.9%], p<0.001 for in hospital non-survivors vs. survivors, respectively) **(Table 3)**.

Mean ACC/TVT registry risk score and EuroSCORE II predicted a relatively high in-hospital mortality, 3.6±1.7% and 6.1±5.4%, respectively, in comparison to the 1.3% in-hospital mortality registered among our cohort of patients. Predicted 30-day mortality rates according to STS-PROM score were 6.7±4.8% in contrast to the lower actual 30-day mortality rates of 2.9%. The ACC/TVT risk stratification tool scored higher for patients who died in hospital than for those who survived (6.4±4.6 vs. 3.5±1.6, p=0.03, respectively).

The ACC/TVT registry risk score showed a high level of discrimination (C-index for in-hospital mortality area under the curve [AUC] 0.74, 95% confidence interval [CI]: 0.59-0.88) **(Figure 1A)**. The C-index statistics for in-hospital mortality of the EuroSCORE II and

Table 2. Baseline echocardiographic characteristics.

	All patients (N=1,038)	In-hospital survivors (n=1,024)	In-hospital non-survivors (n=14)	*p*-value	30-day survivors (n=984)	30-day non-survivors (n=30)	*p*-value
Left ventricular ejection fraction %	54.7±15.7	54.9±15.6	41.6±17.7	0.002	55.0±15.5	45.4±18.2	0.001
Right ventricular dysfunction	231 (22)	224 (22)	7 (50)	0.01	215 (22)	13 (43)	0.01
Mitral regurgitation ≥ moderate	246 (24)	238 (23)	8 (57)	0.01	233 (24)	13 (43)	0.01
Peak aortic valve gradient, mmHg	73.7±24.4	73.9±24.3	62.4±29.2	0.08	74.0±24.5	66.6±23.4	0.10
Mean aortic valve gradient, mmHg	40.5±14.3	40.6±14.3	33.9±16.8	0.08	40.6±14.4	36.3±13.6	0.11
Peak aortic valve velocity, m/s	4.2±0.7	4.2±0.7	3.8±1.0	0.15	4.2±0.7	4.0±0.8	0.09
Calculated aortic valve area, cm²	0.8±0.8	0.8±0.8	0.8±0.2	0.71	0.8±0.8	0.8±0.2	0.81
Low-gradient severe aortic stenosis	276 (27)	272 (27)	4 (29)	0.89	267 (27)	9 (30)	0.62

Values are presented as mean±standard deviation (SD) or number (%). Right ventricular dysfunction was defined by the overall impression of the imaging specialist based on fractional area change <35%, TAPSE <17 mm, etc.

Table 3. Transcatheter aortic valve implantation procedural characteristics.

	All patients (N=1,038)	In-hospital survivors (n=1,024)	In-hospital non-survivors (n=14)	*p*-value	30-day survivors (n=994)	30-day non-survivors (n=30)	*p*-value
Valve-in-valve	46 (4.4)	45 (4.4)	1 (7.1)	0.34	39 (4.4)	2 (7.1)	0.23
Transfemoral access	984 (94.8)	976 (95.3)	8 (57.1)		950 (95.6)	26 (86.7)	
Non-transfemoral access	54 (5.2)	48 (4.6)	6 (42.8)	<0.001	44 (4.4)	10 (33.3)	0.04
Edwards valve devices	714 (68.8)						
Medtronic valve devices	320 (30.8)						
Minor vascular complication	411 (39.6)	406 (39.6)	5 (35.7)	0.20	391 (39.7)	10 (33.3)	0.12
Major vascular complication	24 (2.3)	20 (1.9)	4 (28.5)	<0.001	16 (1.6)	4 (13.3)	0.003
Need for permanent pacemaker	137 (13.2)	136 (13.3)	1 (7.1)	0.30	132 (13.4)	4 (13.3)	0.21
Need for renal replacement treatment	6 (0.58)	4 (0.39)	2 (14.3)	0.002	1 (0.1)	3 (10)	<0.001
Any bleeding	192 (18.5)	183 (17.9)	9 (64.3)	<0.001	161 (16)	13 (43.3)	<0.001

Values are presented as mean±standard deviation (SD) or number (%). Outcomes were adjudicated using the Valve Academic Research Consortium-2 (VARC-2) criteria.

30-day mortality of the STS-PROM score are shown in **Figure 1A** and **Figure 1B**, respectively. There were no significant differences in the predictive performances of the ACC/TVT registry risk score, the EuroSCORE II and the STS-PROM score for in-hospital and/or 30-day mortality rates. A comparison of the discriminative performance of the ACC/TVT registry risk score vs. the EuroSCORE II vs. the STS-PROM score for in-hospital and 30-day mortality is presented in **Figure 1A** and **Figure 1B**, respectively.

The calibration of the ACC/TVT risk prediction tool was accurate for in-hospital and 30-day mortality (Hosmer and Lemeshow goodness-of-fit 0.78, intercept –6.14 [–7.24, –5.04], p<0.0001 for in-hospital mortality and Hosmer and Lemeshow goodness-of-fit 0.84, intercept –4.71 [–5.45, –3.96], p<0.0001 for 30-day mortality) **(Table 4)**. The ACC/TVT registry risk score showed a calibration slope of 0.4 and 0.3 for in-hospital and 30-day mortality, respectively. The calibration slope of the EuroSCORE II was 0.1 for in-hospital mortality and 0.09 for 30-day mortality, and the calibration slope of the STS-PROM score was 0.11 and 0.09 for in-hospital and 30-day mortality, respectively. The higher calibration slope of the ACC/TVT registry provides a better sensitivity in comparison to the EuroSCORE II and the STS-PROM score **(Table 4)**. Dispersion graphs showing the correlation of the STS-PROM score and the EuroSCORE II to the ACC/TVT risk score are presented in **Figure 2A** and **Figure 2B**, respectively.

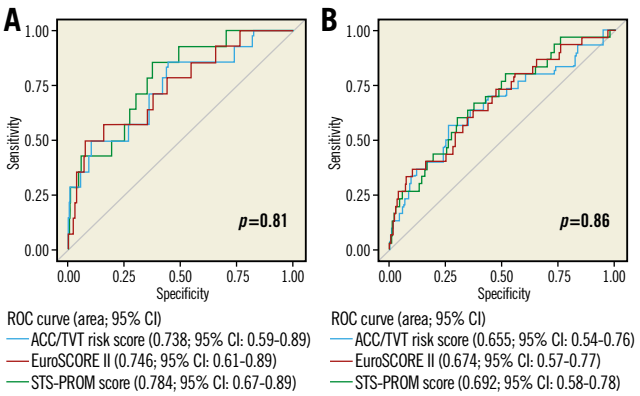

Figure 1. *Comparison of the discrimination ability of the TVT registry risk score, EuroSCORE II, and STS-PROM score. A) In-hospital mortality. B) 30-day mortality.*

Table 4. Calibration of the ACC/TVT registry model, the EuroSCORE II and the STS-PROM score.

	Hosmer and Lemeshow goodness-of-fit test Pr >chi²	Intercept	*p*-value	Slope	*p*-value
ACC/TVT registry model					
In-hospital mortality	0.78	–6.14 (–7.24, –5.04)	<0.0001	0.41 (0.24, 0.58)	<0.0001
30-day mortality	0.84	–4.71 (–5.45, –3.96)	<0.0001	0.30 (0.16, 0.43)	<0.0001
EuroSCORE II					
In-hospital mortality	0.81	–5.16 (–6.04, –4.44)	<0.0001	0.10 (0.05, 0.15)	<0.0001
30-day mortality	0.97	–4.19 (–4.74, –3.65)	<0.0001	0.09 (0.05, 0.13)	<0.0001
STS-PROM score					
In-hospital mortality	0.24	–5.33 (–6.14, –4.52)	<0.0001	0.11 (0.06, 0.16)	<0.0001
30-day mortality	0.65	–4.22 (–4.78, –3.67)	<0.0001	0.09 (0.05, 0.13)	<0.0001

Values are presented as mean±standard deviation (SD) or number (%). ACC/TVT: American College of Cardiology/Transcatheter Valve Therapy; Pr: Pearson's; STS-PROM: Society of Thoracic Surgeons - predicted risk of mortality

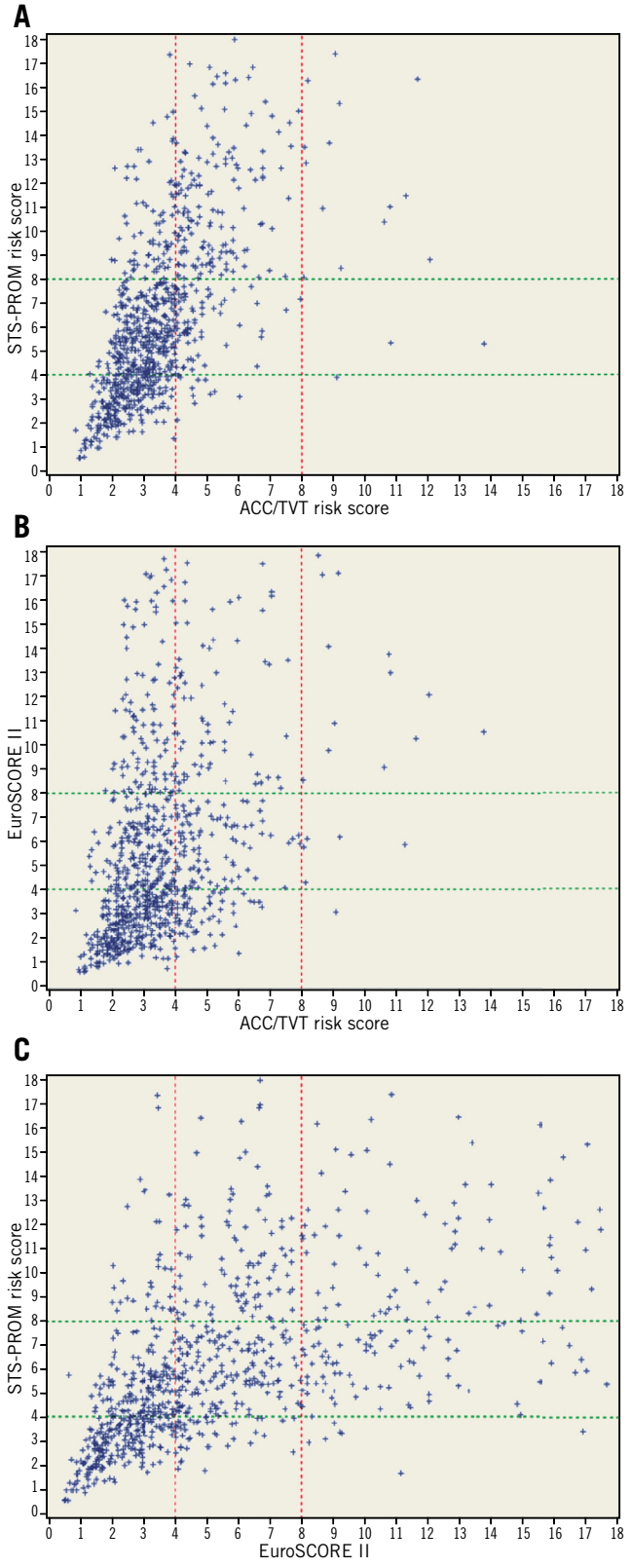

Figure 2. *Comparison of the TVT registry risk score, EuroSCORE II, and STS-PROM risk score's calculated expected mortality. Panels A and B show that the EuroSCORE II and STS-PROM models' expected mortality was higher than that of the TVT registry model. Panel C shows that the EuroSCORE II and STS-PROM scores were more correlated.*

The correlation of the STS-PROM score to the EuroSCORE II is presented in **Figure 2C**.

Discussion

This study sought to validate the STS/ACC TVT registry risk model for predicting in-hospital mortality in 1,038 patients who underwent TAVI between January 2014 and December 2016, and to compare the performance of this risk model to the performances of the STS-PROM and EuroSCORE II risk models for predicting mortality.

The primary findings are as follows. 1) The ACC/TVT performed as well as the STS-PROM score and EuroSCORE II, and there were no significant differences in the performance metrics of these models. 2) The ACC/TVT, STS-PROM and EuroSCORE II risk assessment tools predicted higher than the actual mortality rates. 3) Calibration was accurate for the three evaluated models with a higher calibration slope registered for the ACC/TVT. 4) Dispersion graphs demonstrated good correlation between the STS-PROM and the EuroSCORE II models but, when compared to the ACC/TVT registry model, both surgical models tended to place patients at higher risk than the ACC/TVT risk model. 5) Non-survivors had higher rates of LV dysfunction, right ventricular dysfunction, chronic lung disease, congestive heart failure, prior MI, atrial fibrillation and non-transfemoral access as well as higher rates of bleeding and major vascular complications.

This study demonstrated that the ACC/TVT registry risk model is equivalent to the STS-PROM score for predicting in-hospital mortality. The ACC/TVT registry model showed good calibration along with numerically (not statistically significant) higher discrimination than the STS-PROM model. However, as the ACC/TVT registry model predicts in-hospital and the STS-PROM model predicts 30-day mortality, the two scores predict different parameters of the risk-benefit analysis. The EuroSCORE II, which is validated to predict in-hospital mortality, did not differ significantly from the ACC/TVT model.

Previous TAVI risk models have been developed[15-18]. Although reported to have good discrimination, they are limited by their small derivation cohorts. The ACC/TVT registry derived and validated its risk model in a population of 13,718 and 6,868, respectively[10].

Herein, patients underwent TAVI from January 2014 to November 2016, while the TVT database included procedures from January 2011 to February 2014. Therefore, our cohort of patients does not significantly overlap with the ACC/TVT registry. Patients treated recently probably received newer-generation devices and delivery catheters and were treated by operators with greater experience.

Shorter hospital stays in contemporary patients (as against derivation) may also affect in-hospital mortality figures. Future models should be called to look at mortality at specific time points (i.e., 30 days, one year, etc.).

In accordance with our findings, other studies also predicted higher than the actual mortality rates. In the PARTNER B trial, the average STS-PROM score for patients undergoing TAVI was 11.2%,

while actual in-hospital mortality was 1.7% and 30-day mortality was 6.4%[1]. This was also noted in the PARTNER A and in the more recent PARTNER 2 and SURTAVI trials studying patients at intermediate risk[2,3,19]. In our cohort, the average STS-PROM score and EuroSCORE II were 6.7 and 6.1%, respectively, while actual mortality rates were 1.3% (in-hospital) and 2.9% (30 days). The ability of any risk score to predict mortality accurately in patients undergoing TAVI remains limited as the field rapidly evolves and mortality rates continue to decline. Our study showed that the ACC/TVT registry risk model, the STS-PROM score and the EuroSCORE II may already be dated.

The strength of the ACC/TVT risk model lies in the fact that it was derived and validated utilising patients undergoing TAVI, whereas the STS-PROM score and EuroSCORE II were developed using outcomes in patients undergoing cardiothoracic surgery[4-7]. Another strength of the model is its easy clinical applicability with only seven variables[11]. However, its limitations include absence of measurements of frailty; it is currently used to predict in-hospital mortality. A 30-day risk calculator is being developed and this will allow direct comparison between the STS-PROM and the ACC/TVT risk scores[20].

This study also included dispersion graphs to provide a visual aid to assess the correlation among the three risk models. Patients located in the superior left and inferior right parts of the graphs showed poor correlation. The dispersion graphs show a correlation between the STS-PROM score and EuroSCORE II for most patients. When either of these is compared to the ACC/TVT registry risk model, the STS-PROM score and EuroSCORE II tend to score higher, and far more patients are located in the superior left part of the graph, indicating a higher score than by using the ACC/TVT registry risk score. These differences can be explained by the presence of certain variables in the surgical risk scores that are not included in the ACC/TVT registry risk model. Previous cardiothoracic surgery is of importance when considering surgical AVR and is included in the STS-PROM and EusoSCORE II calculators; however, patients undergoing TAVI do not face the same risk, as the procedure is minimally invasive, hence this variable is not included in the ACC/TVT registry risk calculator. Moreover, LVEF %, peripheral artery disease, active endocarditis and other parameters are included in both surgically derived risk prediction tools but not included in the ACC/TVT registry risk model[11-13].

Limitations

This is a single-centre study so generalisability is a limitation. Although we were able to include 1,038 patients, our population was still small compared to the original risk model derivation and validation cohort populations. In addition, the number of events was relatively low. Therefore, our ability to show differences among scores may be limited. However, our population was diverse and large enough to demonstrate good discrimination and to reassure that no significant differences exist among the risk models. Another limitation of our study was the exclusion of the frailty index. While the risk-benefit assessment for TAVI is still evolving, we should keep in mind that a sizeable group of patients does not fully benefit from the intervention in terms of quality-of-life measures. Future prediction scores should also focus on and facilitate identifying patients who would gain quality-of-life benefits from TAVI[21].

Although we were able to show that the ACC/TVT registry risk model has slightly better discrimination than the STS-PROM risk model, this conclusion is limited because clinical practice includes both the STS-PROM risk score and frailty index in the risk-benefit analysis discussion. Lastly, our population was at intermediate risk (average STS-PROM 6.7%). As TAVI indications expand to include lower-risk populations, further iterative derivation/validation processes and studies will be required to validate the ACC/TVT registry risk model, as well as other models.

Conclusions

In a large, diverse population, the validation of the ACC/TVT registry risk model demonstrated good discrimination for the prediction of in-hospital mortality and was not significantly different from the STS-PROM risk score for 30-day mortality. Therefore, the ACC/TVT registry risk model should be considered as an alternative to the STS-PROM risk model to guide future risk-benefit analysis discussions in patients eligible for TAVI.

Impact on daily practice

As TAVI indications expand towards intermediate- and low-risk patients, a reliable and easy to use risk stratification tool, dedicated and validated for TAVI patients, is of major importance in order to inform patients, discuss expectations of treatment and report results. In our study, we compared the predictive accuracy of the ACC/TVT risk score to the surgical EuroSCORE II and STS-PROM score. From the analysis of our large and diverse population of patients, the ACC/TVT registry risk model demonstrated good discrimination for the prediction of in-hospital mortality and was not significantly different from the STS-PROM risk score for 30-day mortality.

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Conflict of interest statement

The authors have no conflicts of interest to declare.

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Supplementary data

Supplementary Table 1. Variables and endpoints of the ACC/TVT registry risk score, the STS-PROM risk score and the EuroSCORE II.

The supplementary data are published online at: http://www.pcronline.com/eurointervention/137th_issue/72

Supplementary data

Supplementary Table 1. Variables and endpoints of the ACC/TVT registry risk score, the STS-PROM risk score and the EuroSCORE II.

TVT registry risk score - variables	STS-PROM risk score - variables	EuroSCORE II - variables
Patient demographics: Age / sex / race: American Indian or Alaska native, Asian, Black or African American, Hispanic, Native Hawaiian or White.	**Procedure type:** Coronary artery bypass only / AV replacement / MV replacement / MV repair / AV replacement + coronary artery bypass / MV replacement + coronary artery bypass / MV repair + coronary artery bypass.	**Patient-related factors:** Age / gender / renal impairment (a GFR <85 ml/min is considered impaired renal function) / Extracardiac arteriopathy: Yes vs. No / Poor mobility: Yes vs. No / Previous cardiac surgery: Yes vs. No / Chronic lung disease: Yes vs. No / Active endocarditis: Yes vs. No / Critical preoperative state: Yes vs. No / Diabetes on insulin: Yes vs. No
	Patient: age / sex / height (cm) / weight (kg)	
Patient preprocedural characteristics: Serum creatinine in mg/dl / Currently on dialysis / Procedure access site: transfemoral vs. non-transfemoral / NYHA Class IV: Yes vs. No / Severe chronic lung disease: Yes vs. No.	**Haemodynamic data** - EF done: Yes vs. No / if yes: EF (%) / Heart failure within 2 weeks: Yes vs. No vs. Unknown.	**Cardiac-related factors:** NYHA: I, II, III or IV / CCS class 4 angina: Yes vs. No / LV function: Good vs. moderate vs. poor vs. very poor / Recent MI: Yes vs. No / Pulmonary hypertension: no vs. moderate vs. severe
	Race - Documented: Yes vs. No vs. Decline to disclose / if yes: Black / African American Hispanic or Latino / Asian	
Acuity status: Procedure status: Elective vs. urgent vs. emergent vs. salvage / Prior cardiac arrest: Yes vs. No / Pre-procedure inotropes: Yes vs. No / Prior cardiogenic shock: Yes vs. No / Mechanical assist device: Yes vs. No.	**Renal failure** - Dialysis: Yes vs. No vs. Unknown / Last creat level: mg/dl	**Operation-related factors:** Urgency: elective vs. urgency vs. emergency vs. salvage / Weight of the intervention: isolated CABG vs. single non-CABG vs. 2 procedures vs. 3 procedures / Surgery on thoracic aorta: Yes vs. No.
	Cardiac presentation symptoms: At time of this admission: Stable angina / Unstable angina / Angina equivalent / Non-ST-elevation MI /ST-elevation MI / Other / No symptoms.	
	Cardiac symptoms - At time of surgery: Stable angina / Unstable angina / Angina equivalent / Non-ST-elevation MI /ST-elevation MI / Other / No symptoms.	

	Prior MI: Yes vs. No vs. Unknown / if yes: ≤6 hrs / >6 hrs but <24 hrs / 1 to 7 days / 8 to 21 days / >21 days	
	Cardiac arrhythmia: Yes vs. No vs. Unknown / Atrial fibrillation: Paroxysmal / Persistent / None.	
	Chronic lung disease: Mild / Moderate / Severe / Severity unknown / No / Unknown	
	Cerebrovascular disease: Yes vs. No vs. Unknown / if yes, prior CVA: Yes vs. No vs. Unknown.	
	Peripheral arterial disease: Yes vs. No vs. Unknown.	
	Diabetes: Yes vs. No vs. Unknown / if yes, Diabetes control: Diet only / Oral / Insulin / Other / Other subcutaneous medication / None / unknown.	
	Hypertension: Yes vs. No vs. Unknown.	
	Immunocompromise: Yes vs. No vs. Unknown.	
	Endocarditis: Yes vs. No / if yes, Infect endocarditis type: Treated vs. Active	
	Coronary anatomy: Known: Yes vs. No. / if yes, number of diseased vessels: One, two, three or none / Percent native artery stenosis, Known: Yes vs. No / Percent stenosis - left main: %	
	Status: Elective vs. urgent vs. emergent vs. salvage	
	Resuscitation: Yes, within 1 hour of the start of the procedure / No / Yes >1 hr <24 hrs.	
	Cardiogenic shock: Yes, at the time of the procedure vs. no vs. yes, not at the time of the procedure but within prior 24 hours.	
	Classification: NYHA: I, II, III or IV.	
	IABP: Yes vs. No / if yes, IABP - when inserted: Preoperative vs. intraoperative vs. postoperative.	
	Meds-inotropes: Yes vs. No	
	Previous cardiac intervention: Yes vs. No vs. Unknown	
	Previous PCI: Yes vs. No / if yes, previous PCI-interval: ≤6 hours vs. >6 hours.	
	Mitral disease: Yes vs. No / if yes, stenosis-mitral: Yes vs. No	
	Aortic disease: Yes vs. No / if yes, stenosis-aortic: Yes vs. No	
	Insufficiency - Mitral: Trivial / Mild / Moderate / Severe / None / Not documented	
	Insufficiency - Tricuspid: Trivial / Mild / Moderate / Severe / None / Not documented	
	Insufficiency - Aortic: Trivial / Mild / Moderate / Severe / None / Not documented	
	Incidence: First cardiovascular surgery / first re-op cardiovascular surgery / second re-op cardiovascular surgery / third re-op cardiovascular surgery / fourth or more re-op	

	cardiovascular surgery	
	Previous coronary artery bypass: Yes vs. No	
	Previous valve surgery: Yes vs. No.	

Endpoints:

Risk of in-hospital mortality	**Risk of in-hospital and 30-day mortality**	**Risk of in-hospital mortality**
	Morbidity or mortality: composite endpoint defined as in-hospital or 30-day mortality, deep sternal wound infection, permanent stroke, prolonged ventilation, renal failure and/or reoperation.	
	Deep sternal wound infection: in-hospital and at 30 days.	
	Permanent stroke: any confirmed neurological deficit of abrupt onset caused by a disturbance in blood supply to the brain that did not resolve within 24 hours.	
	Prolonged ventilation: >24 hours.	
	Renal failure: increase of serum creatinine to ≥4.0 with an increase of at least 0.5 mg/dl or 3x most recent preoperative creatinine level. **A new requirement for dialysis postoperatively.**	
	Reoperation for any reason	
	Long length of stay: >14 days post procedure.	
	Short length of stay: discharged within 5 days of surgery.	