Assessing the Best Prognostic Score for Transcatheter Aortic Valve Implantation (from the RISPEVA Registry)

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The ACC/TVT score is a specific predictive model of in-hospital mortality for patients undergoing transcatheter aortic valve implantation (TAVI). The aim of this study was to test its predictive accuracy in comparison with standard surgical risk models (Logistic Euroscore, Euroscore II, and STS-PROM) in the population of TAVI patients included in the multicenter RISPEVA (Registro Italiano GISE sull'impianto di Valvola Aortica Percutanea) registry. The study cohort included 3293 patients who underwent TAVI between 2008 and 2019. The 4 risk scores were calculated for all patients. For all scores, the capability to predict 30-day mortality was assessed by means of several analyses testing calibration and discrimination. The ACC/TVT score showed moderate discrimination, with a C-statistics for 30-day mortality of 0.63, not significantly different from the standard surgical risk models. The ACC/TVT score demonstrated, in contrast, better calibration compared with the other scores, as proved by a greater correspondence between estimated probabilities and the actual observations. However, when the ACC/TVT score was tested in the subgroup of patients treated in a more contemporary period (from 2016 on), it revealed a slight tendency to lose discrimination and to overestimate mortality risk. In conclusion, in comparison with the standard surgical risk models, the ACC/TVT score demonstrated better prediction accuracy for estimation of 30-day mortality in terms of calibration. Nevertheless, its predictive reliability remained suboptimal and tended to worsen in patients treated more recently. © **2020 Published by Elsevier Inc. (Am J Cardiol 2021;144:91–99)**

Transcatheter aortic valve implantation (TAVI) has undergone widespread growth over the latest years due to the refinements in valve design and delivery systems, and improvement of operators' expertise.[1,2] Nevertheless, the selection of TAVI candidates remains challenging, mainly because the procedure has been recently extended to low-risk patients.[1] Risk stratification models have been used to aid this process: established risk scoring systems derived from surgical cohorts, such as the Logistic Euroscore, Euroscore II, Society of Thoracic Surgeons Predicted Risk of Operative Mortality (STS-PROM), have been adapted to the scope and used by Heart Teams after ''integration'' with anatomical and baseline clinical characteristics.[3] Since the prognostic accuracy of the surgical scores is arguable, data from the large STS/American College of Cardiology (ACC) Transcatheter Valve Therapy (TVT) Registry have been used to develop, in 2016, a specific predictive model of in-hospital mortality for patients undergoing TAVI: the ACC/TVT score.[4] The aim of this study was to evaluate the reliability and accuracy of the ACC/TVT score, both in absolute and relative terms as compared with the previous surgical risk models. The performance of all scores was tested in patients who underwent TAVI and were included in the large prospective real-world RISPEVA (Registro Italiano GISE sull'impianto di Valvola Aortica Percutanea) registry. Furthermore, the possible differential performance of the ACC/TVT score according to different enrolment periods (before and after 2016) was investigated.

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See page 97 for disclosure information.

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Methods

The design of the RISPEVA registry has been previously described.[5–9] In brief, the RISPEVA registry is an ongoing Italian multicenter observational registry, started in 2008, approved by the ethics committees of all participating centers (the complete list is provided in Online Supplement), with all patients providing written informed consent. The study is registered online at clinicaltrials.gov (NCT02713932). All patients in whom TAVI is attempted and willing to provide consent are included in the registry, without any additional selection criterion. Accordingly, patient selection and procedural strategy were at physician's discretion. Nonetheless, subject selection, preprocedural management, procedural technique, device choice, and subsequent management were generally guided by contemporary best practice recommendations from national and European scientific societies. In detail, a Heart Team was available in all participating centers, even though a preliminary Heart Team evaluation was not mandatory.

For the present analysis, patients treated from March 2008 to October 2019 and included in the RISPEVA registry were considered. The only exclusion criterion was lack of mortality data at 30 days (Supplementary Figure 1). The Logistic Euroscore, Euroscore II, and STS-PROM scores were prospectively calculated by study investigators at participating sites along with other baseline and procedural characteristics. The ACC/TVT score was calculated retrospectively for all included patients, as well as the Euroscore II for patients enrolled before 2011.

Severe chronic kidney disease (CKD) was defined as an estimated Glomerular Filtration Rate (eGFR) $\leq$30 ml/min calculated by means of the Cockcroft-Gault formula. New and old-generation devices were defined according to the latest literature: CoreValve (Medtronic, Medtronic Parkway, Minneapolis, Minnesota) and Sapien XT (Edwards Lifesciences, Irvine, California) were considered as old-generation prostheses.[6,10,11] Because acuity categories are not included in the RISPEVA registry variables, we derived acuity status by the setting of the procedure (elective or urgent) and the patient's hemodynamic status (cardiogenic shock). The primary endpoint was 30-day all-cause mortality. All scores were tested and compared on the basis of the discrimination and calibration power. Discrimination is the ability to distinguish patients who experience an event and those who do not, whereas calibration is the measure of the degree of correspondence between the estimated probabilities produced by a model and the actual observations.

Descriptive data are presented as means and standard deviations for continuous or frequencies and percentages for categorical variables. Multiple imputations were used for missing values; missing life status was not imputed as representing an exclusion criterion. The study population was described as a whole and divided according to the vital status at 30 days into the survivors and deceased cohorts. Baseline characteristics, procedural findings, and clinical outcomes of the study patients were compared using the Pearson Chi-square test or Fisher exact test, when appropriate, for categorical variables and the Student's *t* test for continuous variables. Accuracy of prediction models for 30-day mortality was tested by means of several analyses that provided estimates for calibration and discrimination. All the used statistical assessments and their significance are described in detail in the Online Supplement. Predictive accuracy of the ACC/TVT score was also examined in the 2 subpopulations defined by the time of treatment (before and after 2016). For all analyses, a 2-sided $p < 0.05$ was considered statistically significant. Data were analyzed by SPSS version 22 (IBM Research, Armonk, New York) and R3.5.3 (R Foundation, Wirtschaftsuniversität Wien Welthandelsplatz, Vienna, Austria).

Results

The study population comprised 3,293 patients included in the RISPEVA registry between March 2008 and October 2019. The rate of 30-day mortality was 3.0%. Table 1 summarizes the baseline clinical characteristics of patients, also divided by 30-day survival. No differences in terms of gender and mean age were detected between groups. Compared with the survivors, nonsurvivors more frequently suffered from high-degree heart failure, severe CKD, and peripheral vascular disease. Regarding baseline echocardiographic features, survivors more frequently had preserved left ventricle ejection fraction, lower pulmonary artery systolic pressure, and lower rates of coexisting severe aortic and mitral regurgitation. Despite a similar distribution of most of the comorbidities between the 3 groups, all the risk stratification tools (including the ACC/TVT score) scored significantly higher for patients who died at 30 days. Procedural features are described in Table 2.

The baseline characteristics and procedural findings of the RISPEVA population stratified according to the period of the procedure (before and after 2016) are shown in the Supplementary Tables 1 2. Patients treated after 2016 had a lower prevalence of peripheral artery disease, previous stroke/transient ischemic attack, severe CKD, and chronic obstructive pulmonary disease. They also had significantly lower predicted surgical risk as expressed by standard surgical scores. Furthermore, from 2016 on, patients underwent TAVI for less symptomatic and advanced valvular disease, as demonstrated by the lower rates of previous pulmonary edema and class NYHA III/IV, lower pulmonary artery systolic pressure and mean aortic gradient. With regard to procedural characteristics, after 2016 TAVI was performed more often under local anesthesia using a fully percutaneous approach, with less contrast volume, with new-generation devices, and through lower size sheaths.

In the RISPEVA cohort, the ACC/TVT score showed moderate discrimination, with a C-statistics for 30-day mortality of 0.63. The performance did not significantly differ from the Logistic Euroscore, Euroscore II, STS-PROM, as shown in Figure 1. None of the aforementioned risk scoring systems showed indeed high level of discrimination in predicting short-term mortality (Supplementary Figure 2).

As displayed in Table 3 and Figure 2, the ACC/TVT score demonstrated adequate accuracy in terms of calibration in predicting 30-day mortality. For ACC/TVT score, the output of the Hosmer-Lemeshow test was not significant ($p = 0.836$) and suggestive of good calibration, at variance with the other 3 tested scores. In agreement with these results, the Spiegelhalter z-test showed that the ACC/TVT

Table 1
Baseline characteristics of the entire RISPEVA population stratified according to 30-day mortality

		30 days		
Variable	Overall (n = 3,293)	Survivors (n = 3,193)	Nonsurvivors (n = 100)	p
Age (years)	82.6 ± 6.1	82.5 ± 6.1	83.6 ± 5.8	0.080
Women	1,953 (59.3%)	1,891 (59.2%)	62 (62.0%)	0.578
Body mass index (m/kg^2)	26.1 ± 4.4	26.1 ± 4.4	25.3 ± 4.7	0.072
Risk scores				
Logistic Euroscore	17.4 ± 12.5	17.2 ± 12.3	23.7 ± 17.9	<0.001
Euroscore II	5.5 ±5.0	5.4 ± 4.8	8.5 ± 9.2	<0.001
STS-PROM score	4.5 ±4.7	4.5 ± 6.5	4.6 ± 6.5	<0.001
ACC/TVT score	3.7 ± 1.8	3.7 ± 1.8	4.6 ± 2.3	<0.001
NYHA class III/IV	2,250 (68.3%)	2,168 (67.9%)	82 (82.0%)	0.003
Arterial hypertension	2,583 (78.4%)	2,505 (78.5%)	78 (78.0%)	0.914
Diabetes mellitus	784 (23.8%)	757 (23.7%)	27 (27.0%)	0.447
Current smoker	228 (6.9%)	222 (7.0%)	6 (6.0%)	0.712
Carotid artery disease	582 (17.7%)	567 (17.8%)	15 (15.0%)	0.477
Peripheral artery disease	642 (19.5%)	614 (19.2%)	28 (28.0%)	0.029
Prior stroke/transient ischemic attack	223 (6.8%)	218 (6.8%)	5 (5.0%)	0.684
Prior acute pulmonary edema	479 (14.5%)	452 (14.2%)	27 (27.0%)	<0.001
Prior coronary artery disease*	823 (25.0%)	797 (25.0%)	26 (26.0%)	0.813
Prior myocardial infarction	420 (12.8%)	403 (12.6%)	17 (17.0%)	0.196
Prior percutaneous coronary intervention	746 (22.7%)	724 (22.7%)	22 (22.0%)	0.874
Prior coronary bypass	228 (6.9%)	218 (6.8%)	10 (10.0%)	0.218
Prior cardiac surgery	443 (13.5%)	429 (13.4%)	14 (14.0%)	0.871
Prior valvuloplasty	182 (5.5%)	175 (5.5%)	7 (7.0%)	0.513
Ventricular assist device	10 (0.3%)	9 (0.3%)	1 (1.0%)	0.266
Severe chronic kidney disease	973 (29.5%)	929 (29.1%)	44 (44.0%)	0.002
Serum creatinine (mg/dl)	1.2 ± 0.7	1.2 ± 0.7	1.4 ± 0.8	0.004
eGFR (ml/min)	54.3 ± 23.9	54.4 ± 23.7	49.7 ± 30.8	0.068
Chronic obstructive pulmonary disease	619 (18.8%)	596 (18.7%)	23 (23.0%)	0.275
Chronic oxygen therapy	61 (1.9%)	58 (1.8%)	3 (3.0%)	0.387
Porcelain aorta	154 (4.7%)	146 (4.6%)	8 (8.0%)	0.110
Peak aortic gradient (mm Hg)	78.1 ± 22.6	78.3 ± 22.5	73.0 ± 25.0	0.042
Mean aortic gradient (mm Hg)	48.8 ± 15.8	49-0 ± 16.7	43.4 ± 17.7	0.001
Aortic valve area (cm^2)	0.6 ± 0.2	0.6 ± 0.2	0.6 ± 0.2	0.152
Peak aortic velocity (m/s^2)	4.4 ± 0.7	4.4 ± 0.7	4.2 ± 0.7	0.229
Left ventricular ejection fraction (%)	52.6 ± 12.5	52.7 ± 10.7	49.3 ± 12.7	0.002
Left ventricular ejection fraction <50%	883 (26.8%)	884 (26.4%)	39 (39.0%)	0.005
Left ventricular ejection fraction <30%	241 (7.3%)	226 (7.1%)	15 (15.0%)	0.003
Moderate or severe aortic calcification	1,826 (55.5%)	1,774 (55.6%)	52 (52.0%)	0.481
Moderate aortic regurgitation	551 (16.7%)	530 (16.6%)	21 (21.0%)	0.246
Severe aortic regurgitation	135 (4.1%)	125 (3.9%)	10 (10.0%)	0.003
Moderate mitral regurgitation	1,263 (38.4%)	1,226 (38.4%)	37 (37.0%)	0.777
Severe mitral regurgitation	82 (2.5%)	72 (2.3%)	10 (10.0%)	<0.001
Systolic pulmonary artery pressure (mm Hg)	41.9 ± 12.5	41.7 ± 12.4	47.3±15 .3	<0.001

CC/TVT = American College of Cardiology/Transcatheter Valve Therapy; eGFR = Estimated glomerular filtration rate; NYHA = New York Heart Association; STS-PROM = Society of Thoracic Surgeons Predicted Risk of Operative Mortality. Values are expressed as mean±standard deviation or n (%).

* prior coronary artery disease included stable angina, unstable angina, or myocardial infarction.

score can be considered well calibrated (at $\alpha = 0.01$), whereas Logistic Euroscore, Euroscore II, and STS-PROM scores were not (p <0.001). For the ACC/TVT score, the intercept was the closest to 0 and the slope was very close to 1 (values of −0.31 and 0.97, respectively). Furthermore, the ACC/TVT score also exhibited smaller expected calibration error and maximum calibration error, as expected from the Hosmer-Lemeshow test results, and the best value of integrated calibration index. Conversely, the other risk scores (Logistic Euroscore, Euroscore II, and STS-PROM) showed suboptimal capacity to predict short-term outcome. Calibration plots with LOESS curve, showing deciles of observed versus predicted 30-day mortality for all risk models, also demonstrated that the ACC/TVT model curve is the one closer to the diagonal, as a confirmation of better prediction ability (Figure 2). However, all the analyzed scores showed a tendency to overestimate mortality risk, as indicated by an observed/expected ratio (OER) ranging from 0.17 to 0.81. The lower degree of overprediction was observed for the ACC/TVT score (Figure 3). Moreover, the ACC/TVT model reached the smallest Brier score, a consistent measure of global accuracy.

The predictive reliability of each score was examined in the 2 subpopulations defined by the period of treatment

Table 2
Procedural featuresin the entire RISPEVA population stratified according to 30-day mortality

Variable	Overall (n = 3,293)	30 days		p
		Survivors (n = 3,193)	Nonsurvivors (n = 100)	
Local anesthesia	2,391 (72.6%)	2,330 (73.0%)	61 (61.0%)	0.008
Transesophageal echocardiography	429 (13.0%)	416 (13.0%)	13 (13.0%)	0.993
Femoral access	2,831 (86.0%)	2,751 (86.2%)	80 (80.0%)	0.081
Percutaneous approach only	2,478 (75.3%)	2,408 (75.4%)	70 (70.0%)	0.217
Sheathless device	233 (7.1%)	226/7.1%)	7 (7.0%)	0.976
Sheath size(F)	16.6 ± 2.3	16.6 ± 2.3	16.6 ± 2.9	0.900
Prosthesis size(mm)	26.4 ± 2.8	26.4 ± 2.8	26.5 ± 3.0	0.907
Aortic valve gradient (mm Hg)	59.8 ± 27.1	60.0 ± 27.2	49.5 ± 23.8	0.029
Device				
Old-generation devices*	1,076 (32.7%)	1,033 (32.4%)	43 (43.0%)	0.025
CoreValve	424 (12.9%)	409 (12.8%)	15 (15.0%)	0.520
Sapien XT	608 (18.5%)	584 (18.3%)	24 (24.0%)	0.147
New-generation devices†	1,926 (58.2%)	1,881 (58.9%)	45 (45.0%)	0.005
Evolut Pro	132 (4.0%)	131 (4.1%)	1 (1.0%)	0.119
Evolut R	608 (18.5%)	593 (18.6%)	15 (15.0%)	0.365
Acurate	201 (6.1%)	197 (6.2%)	4 (4.0%)	0.372
Lotus	134 (4.1%)	130 (4.1%)	4 (4.0%)	1.000
Portico	408 (12.4%)	397 (12.4%)	11 (11.0%)	0.668
Sapien3	454 (13.8%)	444 (13.9%)	10 (10.0%)	0.265
Directflow	32 (1.0%)	30 (0.9%)	2 (2.0%)	0.287
Allegra	19 (0.6%)	19 (0.6%)	0 (0.00%)	1.000
Jena	2 (0.1%)	0 (0.0%)	2 (2.0%)	0.001
Undefined	269 (8.2%)	257 (8.0%)	12 (12.0%)	0.155
Embolic protection device	33 (1.0%)	32 (1.0%)	1 (1.0%)	1.000
Predilation	1,852 (56.2%)	1,797 (56.3%)	55 (55.0%)	0.800
Postdilation	718 (21.9%)	700 (21.9%)	18 (18.0%)	0.350
Contrast volume (ml)	163.4 ± 100.7	162.4 ± 98.8	197.4 ± 148.4	0.002
Procedural time(minutes)	106.1 ± 50.7	105 ± 49.8	133 ± 70.5	<0.001
Closure device use	1,995 (61.8%)	1,940 (61.4%)	55 (56.1%)	0.243
Proglide	951 (28.9%)	924 (28.9%)	27 (27.0%)	0.674
Prostar	1,044 (31.7%)	1,016 (31.8%)	28 (28.0%)	0.419
Device success	2,896 (87.9%)	2,822 (88.4%)	74 (74.0%)	<0.001

Values are expressed as mean±standard or n (%).
* COREVALVE, SAPIEN XT were defined as old-generation devices.
† SAPIEN3, ACURATE, EVOLUT R-PRO, PORTICO, LOTUS were defined as new-generation devices.

(before 2016 and from 2016 on). As shown in the Supplementary Figure 3, the discrimination accuracy of all scores between the 2 enrollment phases did not differ significantly. Concerning calibration ability, the ACC/TVT score, despite maintaining a good performance, revealed a slight tendency to lose predictive ability and to overestimate risk, as demonstrated by the nonsignificant Spiegelhalter z-test and the intercept value farther from 0, after 2016 (Table 4). The Logistic Euroscore, Euroscore II, and STS-PROM showed poor calibration also in patients treated after 2016. All the OER values decreased moving from before 2016 to after 2016, revealing a greater propensity to overprediction for each score in patients treated in a more contemporary period (Figure 3).

Discussion

The main findings of our study can be summarized as follows: (1) standard surgical risk models (Logistic Euroscore, Euroscore II, and STS-PROM) showed poor reliability for prediction of 30-day mortality in patients undergoing TAVI; (2) the ACC/TVT score demonstrated a better prediction accuracy in estimating 30-day mortality after TAVI relative to the Logistic Euroscore, Euroscore II, and STS-PROM in terms of calibration, whereas the discrimination performance of all scores was comparable; (3) the ACC/TVT score revealed a slight tendency to lose discrimination and to overestimate mortality risk in the subgroup of patients treated in a more contemporary period (from 2016 on).

In the absence of a dedicated risk assessment tool, the standard surgical risk scores have been employed for risk estimation and patient's selection in TAVI randomized controlled trials and are currently recommended by the European guidelines to predict the surgical risk of patients with severe aortic stenosis.[3,12–16] Nevertheless, their use in the context of TAVI is debatable since there is a large body of evidence of poor prediction performance.[17–21] In our study, the Logistic Euroscore, Euroscore II, and STS-PROM demonstrated a suboptimal discriminatory power and poor calibration in predicting early outcome after TAVI.

To improve the risk assessment process, various TAVI-specific scores have been recently developed.[22–24] The ACC/

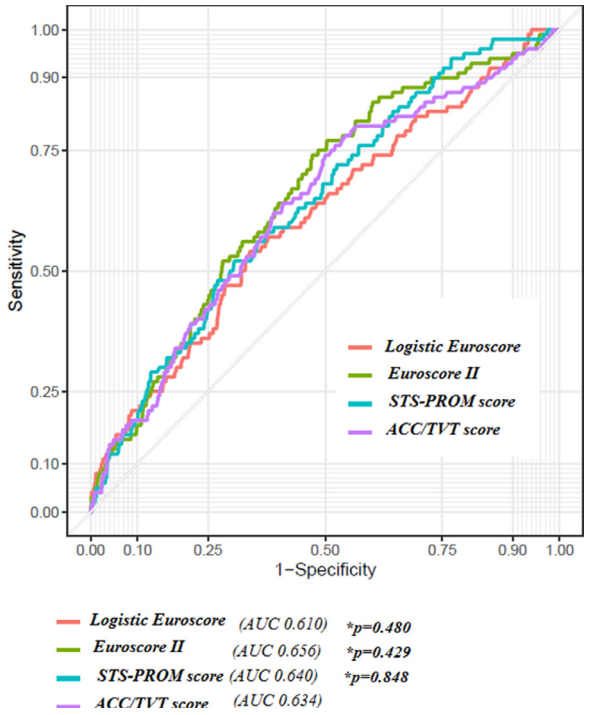

Figure 1. Receiver operating characteristic (ROC) plots showing the prognostic values of the ACC/TVT score in comparison with Logistic Euroscore, Euroscore II, and STS-PROM score for the prediction of 30-day mortality. *p = comparison of ACC/TVT score AUC with the AUC of each of the other scores (Logistic Euroscore, Euroscore II, STS-PROM). AUC = area under the ROC curve.

TVT is a predictive model created and validated in the largest cohorts of TAVI patients (13,718 and 6,868, respectively) from the STS/ACC TVT registry. With only 7 variables, the ACC/TVT score is user-friendly and the only dedicated score to consider transfemoral access among the incorporated covariates.[4] In our registry, the ACC/TVT score showed moderate discrimination and good calibration in predicting 30-day mortality. Although firstly designed to predict in-hospital mortality, in line with other recent studies,[25–27] we tested the score in a time window of 30 days, which represents a standardized time interval chosen to overcome the variability of discharge protocols among hospitals.

Recent external validations of the ACC/TVT score in single-center medium-size cohorts of patients undergone TAVI between 2013 and 2016 demonstrated good reliability in predicting 30-day mortality.[26,27] Nonetheless, the aforementioned studies failed to fully demonstrate significant differences in terms of performance metrics between the ACC/TVT score and the previous surgical risk scores (specifically the STS-PROM and Euroscore II). Conversely, our results support a comparable discrimination between all scores, but a better performance in terms of calibration of the ACC/TVT score compared with the Logistic Euroscore, Euroscore II, and STS-PROM. To mention, the over-performance in terms of calibration of the ACC/TVT score should be valued in view of a larger and more heterogeneous population, compared with most previous reports.[26,27] It is noteworthy that our results in terms of calibration are in line with the recent report by Pilgrim et al[25] from the large cohort of the Swiss TAVI national registry, despite in the latter the comparison was limited to the ACC/TVT and STS-PROM scores. In contrast, the suboptimal discrimination of all currently available models including the ACC/TVT was also confirmed by a recent meta-analysis.[28]

The ACC/TVT score was developed in a group of patients who underwent TAVI between 2011 and 2014, whereas the internal validation cohort included patients treated in 2014. So far, all the external validation cohorts have included patients treated before 2016. Since our registry covered a long enrollment time, we sought to specifically test the comparative performance of the ACC/TVT score in the more contemporary cohort of patients treated from 2016 on. The rationale is the improvement of the short- and long-term prognosis after TAVI in recent years[10–16,29,30] due to the introduction of newer-generation devices, the prevalent transfemoral access, and the growing operators' expertise.[6,9,30–33] In addition, as in a virtuous circle, the refinement in device technology along with the better early prognosis have led to the extension of TAVI to intermediate/low-risk patients, further contributing to the improvement of short-term prognosis. In line with this tendency, patients included in our registry after 2016 showed lower comorbidities, less advanced valvular disease, and were more often treated with last generation devices implanted through lower size sheaths. All these differences may explain the progressive reduction of the mortality rate: 2.6% after versus 3.6% before 2016. After splitting our cohort in 2 subgroups using 2016 as the cut-off timepoint, we confirmed the suboptimal reliability of the standard

Table 3
Model statistics for prediction of 30-days mortality after TAVI

	Logistic Euroscore	Euroscore II	STS-PROM score	ACC/TVT score
Intercept	−2.062	−0.635	−0.439	−0.21
Slope	0.497	0.671	0.580	0.967
Hosmer-Lemeshow test, p value	603.45, <0.001	47.67, <0.001	28.87, <0.001	4.23, 0.836
The Spiegelhalter z-test, p value	−17.425, <0.001	−5.708, <0.001	−3.481, <0.001	−2.049, <0.020
ECE	0.144	0.025	0.017	0.008
MCE	0.393	0.115	0.088	0.024
ICI	0.144	0.024	0.015	0.008
Brier score	0.062	0.031	0.031	0.029

ACC/TVT = American College of Cardiology/Transcatheter Valve Therapy; ECE = expected calibration error; ICI = integrated calibration index; MCE = maximum calibration error; TAVI = transcatheter aortic valve implantation; STS-PROM = Society of Thoracic Surgeons Predicted Risk of Operative Mortality.

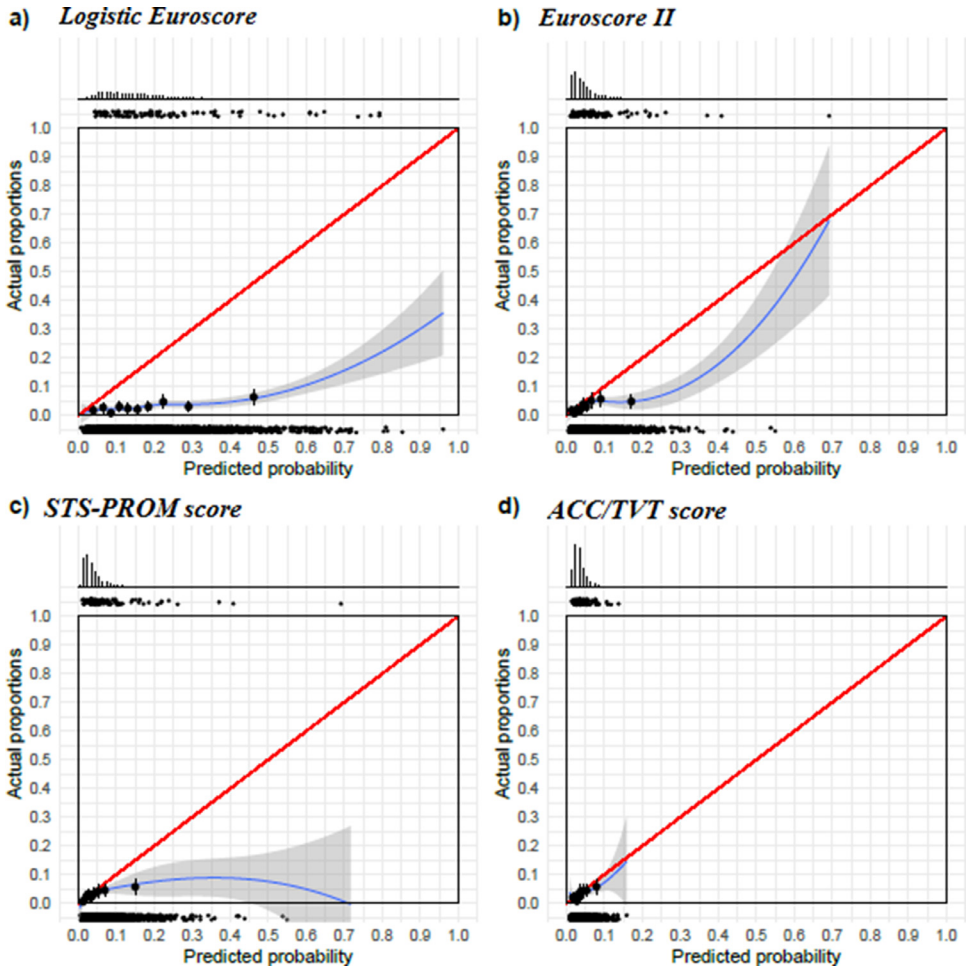

Figure 2. Plots of observed-versus-predicted mortality generated for each risk scoring system, using LOESS curve. The plots show ideal lines (red), LOESS calibration lines (blue), actual (30-day) mortality proportions versus mean predicted probability in each decile interval (points) with 95% CI. LOESS = Locally Estimated Scatterplot Smoothing; CI = confidence intervals. (Color version of figure is available online.)

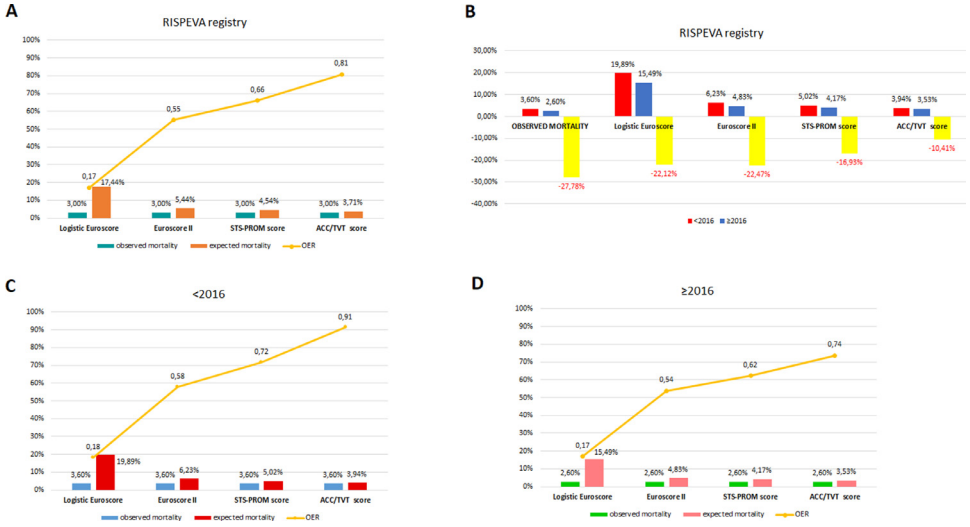

Figure 3. Thirty-day mortality rates and observed/expected ratio (OER) according to ACC/TVT score, Logistic Euroscore, Euroscore II, and STS-PROM score in the entire RISPEVA registry population *(A)*; rate reduction of observed and predicted 30-day mortality rates for each risk scoring system *(B)*; 30-day mortality rates and observed/expected ratio according to ACC/TVT score, Logistic Euroscore, Euroscore II, and STS-PROM score in the subpopulations treated before *(C)* and from 2016 *(D)*.

Table 4
Model statistics for prediction of 30-days mortality before and after 2016

	Logistic Euroscore		Euroscore II		STS-PROM score		ACC/TVT score	
	<2016	≥2016	<2016	≥2016	<2016	≥2016	<2016	≥2016
Intercept	−2.031	−2.096	−0.589	−0684	−0.360	−0.517	-0.083	−0.335
Slope	0.595	0.355	0.679	0.631	0.464	0.735	0.934	0.931
Hosmer-Lemeshow test, p value	309.09, <0.001	295.87, <0.001	23.02, 0.003	26.78, 0.001	16.51, 0.036	16.12, 0.040	0.47, 0.999	5.421, 0.712
Spiegelhalter z-test, p value	−12.30, <0.001	−12.40, <0.001	−3.81, <0.001	−4.26, <0.001	−1.50, 0.066	−3.329, <0.001	−0.563, 0.287	−2.27, 0.012
ECE	0.163	0.130	0.027	0.023	0.022	0.017	0.013	0.011
MCE	0.422	0.374	0.120	0.100	0.095	0.068	0.023	0.022
ICI	0.422	0.374	0.120	0.100	0.095	0.068	0.01	0.01
Brier score	0.161	0.130	0.026	0.024	0.021	0.013	0.035	0.025

ACC/TVT = American College of Cardiology/Transcatheter Valve Therapy; ECE = expected calibration error; ICI = integrated calibration index; MCE = maximum calibration error; STS-PROM = Society of Thoracic Surgeons Predicted Risk of Operative Mortality.

surgical risk models in patients enrolled more recently. The ACC/TVT score, albeit the better global predictive performance compared with the other scores, revealed a slight loss in discrimination and calibration ability in patients treated after 2016. Surprisingly, the degree of risk overestimation was proportionally higher for the ACC/TVT score, compared with the other surgical scores. Indeed, in view of an actual reduction of the mortality rate of 27.8%, the Logistic Euroscore, Euroscore II, and STS-PROM showed a drop of the predicted mortality ranging from 22.5% to 16.9% (Figure 3). Although the OER values for all the analyzed scores after 2016 were lower, the biggest decrease was observed for the ACC/TVT score (0.74 vs 0.91). Indeed, against a near 30% reduction of the actual mortality rate, the predicted mortality for the ACC/TVT score dropped about 10% only. Despite specifically designed for TAVI, our data raise concern on the contemporary accuracy of the ACC/TVT score. Overall, the preprocedural clinical scores appear to poorly adapting to the rapidly evolving field of TAVI, which sees continuous improvement of patient prognosis and would require constant update of such risk assessment tools. To date, the combination of the TAVI score (despite not "flawless'') with an accurate evaluation of the functional/frailty status and of the specific anatomic features of the patient by an experienced Heart Team seems the best possible approach. Nevertheless, the need for more updated scoring systems obtained from more contemporary TAVI populations is undoubtedly felt.

The present analysis could not avoid certain limitations. First, although we included a large contemporary TAVI population with systematic documentation of baseline and follow-up status, the ACC/TVT score was calculated in a retrospective manner. Second, in our dataset some data were missing and some requested parameters to assess the performance of other TAVI dedicated risk scores were absent. Third, given the nonrandomized nature of the registry, the choice of device type, procedural strategy, and periprocedural management were left to the physician's discretion.

In conclusion, Logistic Euroscore, Euroscore II, and STS-PROM showed poor reliability for prediction of 30-day mortality in patients undergoing TAVI included in the RISPEVA registry. In comparison with the standard surgical risk models, the ACC/TVT score demonstrated better prediction accuracy for estimation of 30-day mortality in terms of calibration. Nevertheless, the ACC/TVT score revealed a slight tendency to lose discrimination and to overestimate mortality risk in the subgroup of patients treated in a more contemporary time frame (from 2016 on).

Disclosures

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Authors' Contributions

Martino Pepe: Conceptualization, Methodology, Writing- Original draft preparation; **Nicola Corcione**: Investigation; **Anna Sonia Petronio**: Investigation; **Sergio Berti**: Investigation, Supervision; **Alessandro Iadanza**: Investigation; **Alberto Morello**: Investigation; **Palma Luisa Nestola**: Writing- Original draft preparation, Visualization; **Gianluigi Napoli**: Formal analysis; **Paolo Ferraro:** Investigation; **Michele Cimmino**: Investigation; **Antonio L. Bartorelli**: Investigation, Supervision; **Francesco Bedogni**: Investigation, Supervision; **Giulio G. Stefanini**: Investigation; **Carlo Trani**: Investigation, Supervision; **Marcello De Giosa**: Formal analysis; **Giuseppe Biondi-Zoccai**: Conceptualization, Validation; **Arturo Giordano**: Supervision, Project administration.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amjcard.2020.12.068.

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