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On-line risk prediction models for acute type A aortic dissection surgery: validation of the German Registry of Acute Aortic Dissection Type A score and the European System for Cardiac Operative Risk Evaluation II

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Key question

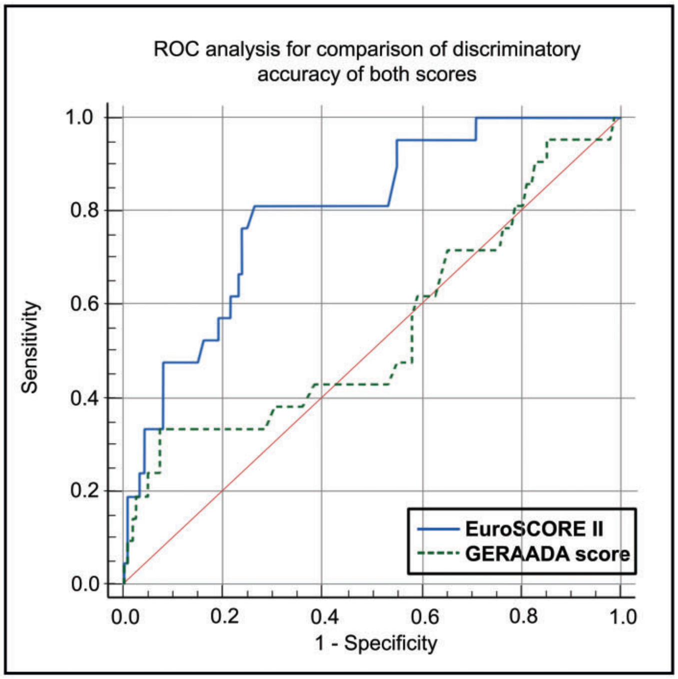
How accurate is the predictive power of on-line available risk scores for predicting early mortality in acute type A aortic dissection (ATAAD) surgery?

Key finding(s)

The C index for mortality was 0.550 for the GERAADA score and 0.799 for the EuroSCORE II. Calibration was good for both scores.

Take-home message

The EuroSCORE II showed better discriminatory power than the GERAADA score. Further validation of larger cohorts of patients undergoing ATAAD surgery is required to evaluate performances of both scores.



Abstract

OBJECTIVES: The German Registry of Acute Aortic Dissection Type A (GERAADA) on-line score calculator to predict 30-day mortality in patients undergoing surgery for acute type A aortic dissection (ATAAD) was recently launched. Using the European System for Cardiac Operative Risk Evaluation II (EuroSCORE II), it is also possible to predict operative mortality for the same type of surgery. The goal of our study was to validate the prediction accuracy of these 2 on-line risk prediction models.

METHODS: Prospectively collected data for EuroSCORE II risk factors as well as all data for GERAADA scoring were extracted from an institutional database for 147 patients who underwent surgery for ATAAD between April 2018 and April 2021. The discriminative power was assessed using area under the receiver operating characteristic curve. The calibration of the models was tested by the Hosmer–Lemeshow statistics and by using the observed-to-expected (*O/E*) mortality ratio with the 95% confidence interval.

RESULTS: The observed operative mortality was 14.3%. The mean predicted mortality rates for the GERAADA score and the EuroSCORE II were 15.6% and 10.6%, respectively. The EuroSCORE II discriminative power (area under the curve = 0.799) significantly outperformed the discriminatory power of the GERAADA score (area under the curve = 0.550). The Hosmer–Lemeshow statistics confirmed good calibration for both models (*P*-values of 0.49 and 0.29 for the GERAADA score and the EuroSCORE II, respectively). The *O/E* mortality ratio certified good calibration for both scores [GERAADA score (*O/E* ratio of 0.93, 95% confidence interval: 0.53–1.33); EuroSCORE II (*O/E* ratio of 1.35, 95% confidence interval: 0.77–1.93)].

CONCLUSIONS: The EuroSCORE II has better discriminative power for predicting operative mortality in ATAAD surgery than the GERAADA score. Both scores confirmed good calibration ability.

Keywords: Acute aortic dissection • Surgery • On-line risk prediction models

ABBREVIATIONS

ATAAD	Acute type A aortic dissection
AUC	Area under the curve
CI	Confidence interval
CTA	Computed tomography angiography
EuroSCORE II	European System for Cardiac Operative Risk Evaluation II
GERAADA	German Registry of Acute Aortic Dissection Type A
LVEF	Left ventricular ejection fraction
O/E	Observed to expected

INTRODUCTION

Acute type A aortic dissection (ATAAD) is a life-threatening condition, associated with significant mortality and morbidity. Despite considerable advances in perioperative management and surgical technique, the early mortality operative rate following ATAAD surgery remains high. The latest information from high-volume cardiac/aortic dissection surgical registries reported operative mortality rates in a range from 9.5% (Japan Cardiovascular Surgery Database, 11 843 patients) [1] to 14.8% (the International Registry of Acute Aortic Dissection, 2823 patients) [2] and up to 21.5% [the German Registry for Acute Aortic Dissection Type A (GERAADA), 2537 patients] [3, 4]. To assess a patient's perioperative risk, several risk scoring systems for cardiac surgery have been developed over the past 2 decades. Of these risk score systems, on-line multivariable models, namely, that of Society of Thoracic Surgeons [5] score, and the European System for Cardiac Operative Risk Evaluation II (EuroSCORE II) [6] are the most widely used worldwide, and they have been adopted by clinical guidelines [7]. Because the Society of Thoracic Surgeons score does not cover thoracic aortic surgery, and the EuroSCORE II was designed to predict the risk of patients undergoing major cardiac surgery and not specifically ATAAD surgery, Czerny *et al.* [3] recently developed and launched the first on-line risk scoring system, the GERAADA score, specially designed for prediction of the 30-day mortality of patients undergoing ATAAD surgery. However, aside from common risk factors (age, sex, redo procedure), the EuroSCORE II contains a majority of the risk factors implemented in the GERAADA score. The GERAADA score variables: resuscitation before surgery, intubation/ventilation, and the use of catecholamines at referral are covered by the critical preoperative state and salvage surgery in the EuroSCORE II. We can match coronary and peripheral malperfusion in the GERAADA score with myocardial infarction (<90 days, actually, acute myocardial infarction) and extracardiac arteriopathy in the EuroSCORE II. Extracardiac arteriopathy can also be a substitute for extension of the dissection in supra-aortic vessels (GERAADA score). Preoperative hemiparesis (GERAADA score) has an equivalent in poor mobility secondary to neurological dysfunction (EuroSCORE II). Preoperative visceral (mesenteric) malperfusion is not recognized by EuroSCORE II, but the GERAADA score does not consider renal function impairment (EuroSCORE II does). Aortic valve regurgitation (GERRADA score) is counted as an additional major cardiac procedure (reconstruction, resuspension or replacement for grade III or IV) by the EuroSCORE II. Finally, the GERAADA score recognized the location of the primary entry tear within the aortic arch as a separate variable, whereas EuroSCORE II has a separate risk factor for surgery on the thoracic aorta, plus the emergency (urgency) status of the procedure. Therefore, our goal was to investigate, evaluate and comment on the outcomes of ATAAD surgery, comparing these 2 on-line risk prediction models.

PATIENTS AND METHODS

Ethical statement

The institutional ethical committee approved this retrospective study and waived the need for informed consent from each patient.

Prospectively collected data for the EuroSCORE II (on-line calculator available at Web application http://www.euroscore.org that also includes definitions of all EuroSCORE II variables) risk factors were extracted from the institutional database for 151 consecutive adult (≥18 years of age) patients undergoing ATAAD surgery during the last 3 years (between 1 April 2018 and 1 April 2021). All data required for GERAADA scoring (https://www.dgthg.de/de/GERAADA_Score) for the same sample were also collected from the institutional database. However, preoperative computed tomography angiography (CTA) scans, a mandatory requirement for GERAADA scoring, were retrospectively available for 147 patients due to missing CTA data for 4 cases of iatrogenic aortic dissection that occurred during major cardiac procedures [4/5738 operations (0.07%) performed over the study period]. Therefore, 147 patients were included in the final processing. The primary end-point for the study was operative mortality, which was defined as all-cause mortality occurring during the index surgical admission (EuroSCORE II definition) or after discharge but within 30 days of the surgical procedure (GERAADA score definition). Two patients with confirmed coronavirus disease 2019 were transferred to another facility that cared for patients with coronavirus disease 2019 and were alive and in stable condition 30 day after surgery. Although all patients classified as operative deaths died during the index hospitalization prior to 30 days, these patients fulfilled the criteria for operative mortality of both scores. Discharged patients were checked during regular postoperative checkups (30 days after discharge) or by phone interview 30 days after the surgical intervention. All relevant data are within the manuscript and in its supporting information files.

Definitions

ATAAD (Stanford classification) includes all cases in which the ascending aorta is involved in the dissection, with or without involvement of the arch or the descending aorta [8, 9]. An expert consensus document of thoracic aortic diseases recommended use of the term 'acute' for any aortic dissection between the onset of symptoms and 14 days, 'subacute' between 15 days and 90 days and 'chronic' thereafter [9].

The EuroSCORE II on-line risk score calculator contains a precise definition for each of the numerous risk factors. However, precise inclusion criteria/definitions for coronary, visceral (mesenteric) and peripheral malperfusion were not described either in the original manuscript [3] or in the on-line GERAADA calculator. Therefore, to define malperfusion, we used signs and symptoms of compromised blood flow by utilizing a combination of clinical history, physical examination, CTA findings and laboratory data. Thus, for cardiac (coronary) malperfusion, we looked for CTA confirmation of coronary flow obstruction associated with indicators of cardiac ischaemia [echocardiographic (regional wall motion abnormality), ischaemic electrocardiographic changes and blood test abnormalities (elevation of creatine kinase MB or troponin levels)]. Visceral (mesenteric) malperfusion was determined via a combination of clinical and laboratory data (elevated levels of lactate, liver enzymes, metabolic acidosis) and radiographic factors, including CTA evidence of flow obstruction with clinical evidence of bowel ischaemia (abdominal pain, tenderness to palpation, bloody diarrhoea). For limb malperfusion, a pulse deficit and available radiographic evidence were used to support the clinical (pain, pallor, paraesthesia, loss of motor function) and laboratory (elevated creatine kinase level) findings.

The urgency of surgical intervention was defined according to the EuroSCORE II definition: emergency—operation performed before the beginning of the next working day after the decision to operate; urgent—patients who required surgery during the current admission [6].

Statistical analyses

Continuous variables are expressed as mean ± standard deviation, and categorical variables are expressed as percentages. A variety of methods and metrics can be used to estimate the performance of prediction models. Traditional measures for binary and survival outcomes include the Brier score to indicate overall model performance, the concordance (*C*) statistic for discriminatory ability (for a binary outcome, *C* is identical to the area under the receiver operating characteristic curve) and the goodness-of-fit statistics for calibration [10]. The Brier [10, 11] score is a quadratic scoring rule, where the squared difference between predictions (*p*) and actual binary outcomes is calculated. The Brier score [10] can range from 0 (perfect prediction) to 0.25 for a non-informative model (50% incidence of the outcome). Discrimination measures the capacity of the model to differentiate low-risk from high-risk patients, namely, to distinguish between patients who will develop an event (in this case perioperative death) from those who will not. Discrimination can be assessed by the area under the receiver operative characteristic curve (AUC). The AUC is a percentage of randomly drawn pairs (meaning 1 death and 1 survivor patient-pair) for which it is true that a patient who died had a higher risk score than a patient who survived. The discriminative power is excellent if the AUC is >0.80, very good if >0.75 and good (acceptable) if >0.70 [12]. The statistical significance of the difference between both (EuroSCORE II and GERAADA score) AUCs was tested using the Hanley–McNeil test [13].

Calibration refers to the agreement between observed events and the predicted probability of the occurrence of these events. The Hosmer–Lemeshow goodness-of-fit test measures the differences between observed and expected outcomes over deciles of risk. A well-calibrated model gives a corresponding *P*-value >0.05 [14]. We have also evaluated calibration using the observed-to-expected (*O/E*) mortality ratio. Ideally, this ratio equals 1 (the observed mortality equals the expected mortality; thus the predictive model is perfectly calibrated). A value above 1 means that the model underestimates mortality, a value below 1 means that the model overestimates mortality. If the 95% confidence interval (CI) of the *O/E* mortality ratio includes the value of 1.0, the model is well calibrated [14]. Data processing was done using statistical software SPSS 25.0 for Windows 10 (IBM-SPSS Inc., Armonk, NY, USA) and MDCalc (MDCalc, New York, NY, USA).

RESULTS

In the final processing, our study included 147 consecutive adult patients [110 men, 37 women (25.2%), average age of 59.1 (standard deviation: 10.3) years] undergoing ATAAD surgery at our institution between 1 April 2018 and 1 April 2021. There were no missing data referring to variables necessary for EuroSCORE II or GERAADA score models risk calculation. Preoperative patient characteristics, prevalence of risk factors and the operative details required for EuroSCORE II calculation are presented in Table 1. GERAADA score-requested preoperative risk factors are shown in Table 2. The types of operations performed are reported in Tables 3 and 4.

The perioperative mortality observed in our sample was 14.3% (21/147). The mean values of mortality rates predicted by the GERAADA score and the EuroSCORE II were 15.6 (standard deviation: 9.5)% and 10.6 (standard deviation: 11.8)%, respectively. Overall performances of both models were acceptable (Brier scores of 0.1079 and 0.0917 for the GERAADA score and the EuroSCORE II, respectively). The discriminative power of the GERAADA score was poor, with an AUC of 0.550 (95% CI: 0.402–0.698; Figs. 1 and 2), whereas the discriminative power of the EuroSCORE II was very good, with an AUC of 0.799 (95% CI: 0.701–0.896; Figs. 1 and 3). The comparison among the AUCs (Hanley–McNeil test) showed a significant difference between the EuroSCORE II and the GERAADA score (*z* statistic—3.113; $P = 0.002$). The Hosmer–Lemeshow statistics confirmed good calibration for both models (GERAADA score Hosmer–Lemeshow, $P = 0.49$; EuroSCORE II Hosmer–Lemeshow, $P = 0.29$). The *O/E* mortality ratio certified good calibration for the GERAADA score

Table 1: Patient characteristics and operative details (European System for Cardiac Operative Risk Evaluation II risk factors) of the study population

Variable	Number of patients (%)	Variable	Number of patients (%)
Age, years, mean (SD)	**59.1** (**10.3**)	Left ventricle function	
Gender (female)	37 (**25.2**)	• Good (>50%)	101 (**68.7**)
Renal impairment (CC)		• Moderate (31–50%)	41 (**27.9**)
• Normal (>85 ml/min)	76 (**51.7**)	• Poor (21–30%)	3 (**2.0**)
• Moderate (50–85)	50 (**34.0**)	• Very poor (≤20%)	2 (**1.4**)
• Severe (<50 ml/min)	21 (**14.3**)	Recent myocardial infarction	7 (**4.8**)
• Dialysis	0	Pulmonary hypertension	
Extracardiac arteriopathy	32 (**21.8**)	• Moderate (31–55)	21 (**14.3**)
Poor mobility[a]	4 (**2.7**)	• Severe(>55mmHg)	3 (**2.0**)
Previous cardiac surgery	2 (**1.4**)	Urgency	
Chronic lung disease	4 (**2.7**)	• Elective	/
Active endocarditis	0	• Urgent	8 (**5.4**)
Critical preoperative state	12 (**8.2**)	• Emergency	136 (**92.5**)
Diabetic on insulin	0	• Salvage	3 (**2.0**)
NYHA functional class		Weight of the intervention	
• I	21 (**14.3**)	• Isolated CABG	/
• II	96 (**65.3**)	• Single non-CABG	43 (**29.3**)
• III	19 (**12.9**)	• Two procedures	50 (**34.0**)
• IV	11 (**7.5**)	• Three procedures	54 (**36.7**)
CCS class IV	0	Surgery on thoracic aorta	**147** (**100.0**)

[a]Poor mobility is defined as severe impairment of mobility secondary to neurological dysfunction or musculoskeletal disorder.

CABG: coronary artery bypass graft; CC: creatinine clearance (ml/min); CCS: Canadian Cardiovascular Society; NYHA: New York Heart Association; SD: standard deviation.

(*O/E* ratio of 0.93, 95% CI: 0.53–1.33; non-significant overestimation of mortality), as well as for the EuroSCORE II model (*O/E* ratio of 1.35, 95% CI: 0.77–1.93; non-significant underestimation of mortality).

DISCUSSION

The surgically untreated ATAAD reaches a mortality of ∼1% per h (for first 48 h) after symptom onset, with up to 90% of patients succumbing within 30 days [15]. Although risk models are commonly used to predict periprocedural mortality rates after cardiac surgery, some so-called bedside models (simple risk models) for risk prediction in ATAAD surgery [16–18] preceded the aforementioned on-line models. All 3 bedside ATAAD risk prediction models created an easy-to-use scorecard to predict in-hospital mortality rate. However, the risk prediction model [16] of the International Registry of Acute Aortic Dissection (derived retrospectively from 682 patients undergoing ATAAD surgery from 1996 to 2003) was validated on the developmental database (testing the same patients used to develop the risk score); therefore, their results should be considered with caution, because with such an approach the results might be misleading [19]. In the other 2 manuscripts, all available data were used for model development, with internal model validation using the bootstrap method [17, 18]. Both presented models [17, 18] showed satisfactory discrimination and calibration.

Our study was designed to compare the prognostic utility of modern, on-line available risk scores (GERAADA score and EuroSCORE II) for predicting death for patients undergoing ATAAD surgery. Both scores showed good overall performances (Brier score of 0.0917 for the EuroSCORE II and 0.1079 for the GERAADA score). Although the observed mortality was 14.3% (21/147 patients), both scores confirmed good calibration ability [GERAADA score Hosmer–Lemeshow, $P = 0.49$; EuroSCORE II Hosmer–Lemeshow, $P = 0.29$; GERAADA score *O/E* ratio of 0.93 (95% CI: 0.53–1.33, non-significant overestimation of mortality); EuroSCORE II model *O/E* ratio of 1.35 (95% CI: 0.77–1.93, non-significant underestimation of mortality)]. The discriminative power of the GERAADA score was disappointing, with an AUC of only 0.550 (95% CI: 0.402–0.698). The first external validation of the GERAADA score (Luehr *et al.* [20], a retrospective analysis of 371 patients who were operated on between 2010 and 2020) showed the unsatisfactory discriminatory power of the GERAADA score (AUC of 0.67 with 95% CI: 0.60–0.75). The calibration ability of the score [20] was good (observed mortality of 15.1%, predicted mortality by the GERAADA score, was 15.7%). Although the discriminative power of the GERAADA score was low in the manuscript of Luehr *et al.* [20], more prospective clinical trials are required to further externally validate the accuracy of the GERAADA score. It is well known that when discrimination of the model is good but the calibration is not, the model can be made more accurate by recalibration. However, the opposite is not possible [10]. In our study, the EuroSCORE II showed very good discriminative power with an AUC of 0.799 (95% CI: 0.701–0.896). The comparison among the AUCs (Hanley–McNeil test) showed a significant difference between the EuroSCORE II and the GERAADA score (*z*-statistic−0.113; $P = 0.002$). With very good discriminative power and good calibration ability confirmed in our study, the EuroSCORE II presented itself as an extremely useful tool for predicting perioperative mortality for patients undergoing ATAAD surgery. Luehr *et al.* [20] stated that advanced age ($P = 0.042$), preoperative resuscitation ($P < 0.001$) and other/unknown malperfusion ($P = 0.032$) were independent predictors of a poor outcome in ATAAD surgery. Although Czerny and Feisst [21] emphasized that the category 'other/unknown malperfusion' was complemented into the Webcalculator for practical reasons, it is difficult to accept that a preoperative risk factor with a logistic model coefficient of 0 [21] can be an independent risk factor for predicting 30-day mortality.

Although the authors of the GERAADA score [3] should be commended for their efforts to develop the first on-line calculator for predicting 30-day mortality in patients undergoing ATAAD surgery, they have to improve the calculator's abilities, specifically, to add parameters to define organ malperfusion. Namely, the authors of 2 recent manuscripts [22, 23] emphasized that malperfusion alone should be defined as inadequate blood flow to the end organs because of dissection-related obstruction of the aorta and its branches, whereas a malperfusion syndrome is defined as tissue/organ necrosis and dysfunction due to inadequate blood flow and requires both clinical and laboratory features (abdominal pain, bloody diarrhoea, tenderness to palpation, elevated levels of lactate, troponins liver enzymes and metabolic acidosis) in addition to radiographic demonstration of decreased or absent blood flow to a vascular territory (e.g. coronary, bowel, extremities). Furthermore, Cho *et al.* [24] reported (in 268 patients undergoing ATAAD surgery from 1998 to 2012) that malperfusion without organ failure is not a risk factor for poor outcome in ATAAD surgery. Clinical malperfusion syndrome was identified by signs or symptoms of organ dysfunction (36 patients with confirmed laboratory evidence of organ hypoperfusion plus positive imaging findings). Subclinical malperfusion (malperfusion alone) was defined as laboratory evidence of organ hypoperfusion or imaging findings without signs or symptoms (40 patients). Early mortality in the malperfusion syndrome group (25%) was worse than that in the subclinical (8%; $P = 0.026$) and no-malperfusion (5%; $P < 0.001$) groups. Survival rates in the subclinical and no-malperfusion groups did not differ ($P = 0.48$). In conclusion, they emphasized that mortality was not increased in asymptomatic patients with malperfusion identified by laboratory or imaging findings [24]. Therefore, in our opinion, the authors of the GERAADA score should clarify whether 'clinical malperfusion' or 'subclinical malperfusion' should be entered in the GERAADA score calculator, because precise inclusion criteria/definitions for coronary, visceral (mesenteric) and peripheral malperfusion were not described in the original manuscript [3] nor are they available in the on-line GERAADA calculator. Czerny and Feisst [4] emphasized that a preoperative risk score should provide the interested physician with the information necessary to anticipate risk before surgery rather than after surgery, thus explaining why no intraoperative risk factors were included in the GERAADA score calculator. However, some studies [2, 25–27] have confirmed that prolonged intraoperative times (Huckaby *et al.* [2]: 2823 patients, total cardiopulmonary bypass time, $P < 0.001$; Thurau *et al.* [25]: longer cardiopulmonary bypass time, $P < 0.001$; Wen *et al.* [26]: 264 patients, aortic cross-clamping time >120 min, $P = 0.032$) were independent predictors of early perioperative mortality in ATAAD surgery. Moreover, Conzelmann *et al.* [27] [2137 consecutive patients enrolled in the same GERAADA database who underwent ATAAD surgery between

Table 2: Patient preoperative characteristics (German Registry of Acute Aortic Dissection Type A score risk factors)—study population

Variable	Number of patients (%)
Age, years, mean (SD)	59.1 (10.3)
Sex (female)	37 (25.2)
Resuscitation before surgery	5 (3.4)
Previous cardiac surgery	2 (1.4)
Intubation/ventilation at referral	10 (6.8)
Catecholamines at referral	8 (5.4)
Aortic valve regurgitation	
• None	46 (31.3)
• Grades I–II	70 (47.6)
• Grades III–IV	31 (21.1)
Malperfusion	
• None	134 (91.2)
• Coronary (cor)	3 (2.0)
• Visceral (visc)	2 (1.4)
• Peripheral (perif)	7 (4.8)
• Cor + visc + perif	1 (0.7)
Preoperative hemiparesis	4 (2.8)
Extension of dissection	
• Aortic arch	120 (81.6)
• Supra-aortic vessels	53 (36.1)
• Descending or further downstream	86 (58.5)
Location of primary entry tear within aortic arch	9 (6.1)

SD: standard deviation.

Table 3: Surgical procedures for patients with acute type A aortic dissection

Surgical procedure	Number of patients	Concomitant procedure
Graft interposition	48	CABG—5 pts; debranching—4 pts (including Carrel patch in 2 pts)
Graft interposition + AV resuspension	48	CABG—4 pts; MVr—1 pt; MVR—1 pt
Graft interposition + AVR	3	
Aortic root replacement—Bentall/Cabrol	42/3	CABG—9 pts; debranching—3 pts (including Carrel patch in 2 pts)
Aortic root remodelling—TironeDavid	3	CABG—1 pt; debranching—1 pt

AV: aortic valve; AVR: aortic valve replacement; CABG: coronary artery bypass grafting; MVr: mitral valve repair; MVR: mitral valve replacement; pts: patients.

Table 4: Surgical procedures regarding weight of the intervention (European System for Cardiac Operative Risk Evaluation II classification)

Weight of intervention	Surgical procedure	Number of patients	Total number of patients
Single non-CABG	Graft interposition (hemiarch included—21/43 patients)	43	43
Two procedures	Graft interposition + CABG	5	50
	Graft interposition + AV resuspension	42	
	Graft interposition + AVR	3	
	(hemiarch included—27/50 patients)		
Three procedures	Graft interposition + AV resuspension + CABG	4	54
	Graft interposition + AV resuspension + MVr	1	
	Graft interposition + AV resuspension + MVR	1	
	Aortic root replacement—Bentall/Cabrol	42/3	
	Aortic root remodelling—Tirone David	3	
	(hemiarch included—18 out of 54 patients)		

Aortic root replacement and remodelling by definition (EuroSCORE II) are coded as 3 procedures; therefore, concomitant CABG procedures are not listed.
AV: aortic valve; AVR: aortic valve replacement; CABG: coronary artery bypass grafting; EuroSCORE II: European System for Cardiac Operative Risk Evaluation II; MVr: mitral valve repair; MVR: mitral valve replacement.

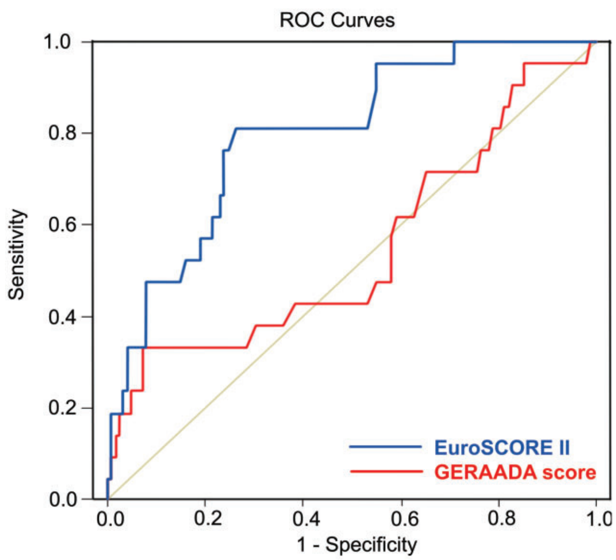


Figure 1: Comparison of the areas under the receiver operative characteristic curves of the German Registry of Acute Aortic Dissection Type A (area under the curve = 0.550; 95% confidence interval: 0.402–0.698) scores and the European System for Cardiac Operative Risk Evaluation II (area under the curve = 0.799; 95% confidence interval: 0.701–0.896). The comparison of the areas under the curve (Hanley–McNeil test) showed a significant difference between the European System for Cardiac Operative Risk Evaluation II and the German Registry of Acute Aortic Dissection Type A score (*z*-statistic—3.113; *P* = 0.002).

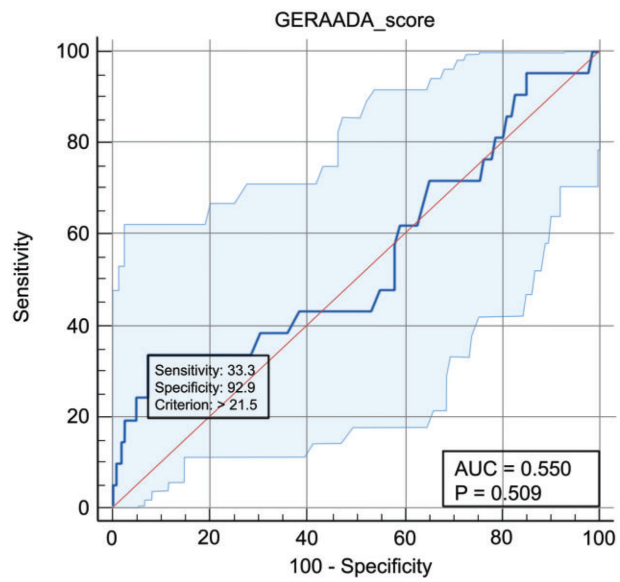


Figure 2: German Registry of Acute Aortic Dissection Type A score discriminative power: area under the curve: 0.550 (95% confidence interval: 0.402–0.698); *P* = 0.509; sensitivity—33.3; specificity—92.9; criterion >21.5.

2006 and 2010, thus representing 84.2% of patients enrolled in developmental GERAADA score database (2537 patients operated on between 2006 and 2015)] reported that mortality following ATAAD surgery significantly increased with longer operating times (total, cardiopulmonary bypass, cardiac ischaemia and circulatory arrest; all $P < 0.02$). The authors [27] emphasized that duration of surgery and prolonged operative times could reflect the complexity of the required repair dictated by the severity of the aortic pathology. Although regression analysis revealed equivalent early outcomes for all surgical techniques [27], maybe cut-off levels for operative times (sometimes a single procedure can take more time than a complex one, especially in aortic dissection surgery) would be a more appropriate risk variable. Interestingly, operative times data have not been tested, even through the univariable analysis during the GERAADA score developmental process [3]. Another, also important risk factor [left ventricular ejection fraction (LVEF)] has also been left out of the univariate analysis during development of the GERAADA score [3]. Thurau *et al.* [25] have also shown (cohort of 512 patients with ATAAD who were operated on between 2006 and 2014) that preoperative LVEF ≤ 35% was an independent predictor of 30-day mortality ($P = 0.003$). Lin *et al.* [28] confirmed that, of 510 patients undergoing ATAAD surgery between July 2007 and February 2018, patients with low LVEF (<50%) had higher in-hospital mortality (23.3% vs 13.9%; $P = 0.03$) compared with the control group (LVEF ≥ 50%). Therefore, we are inclined to believe that inclusion of these factors (operative times, maybe using cut-off levels and LVEF), at least in univariable testing as a

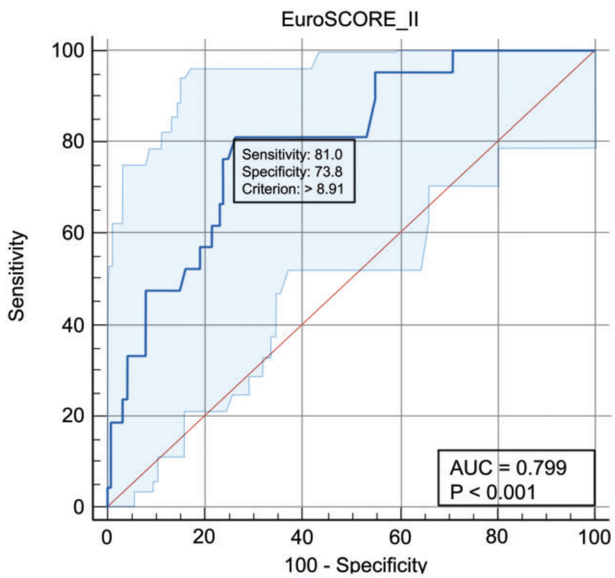


Figure 3: European System for Cardiac Operative Risk Evaluation II discriminative power: area under the curve = 0.799 (95% confidence interval: 0.701–0.896); $P < 0.001$; sensitivity—81.0; specificity—73.8, criterion >8.91.

prescreening method for variable inclusion (for univariable $P < 0.25$ [29]) in a multivariable model, might contribute to a more accurate GERAADA score.

Limitations

The limitation of our study is its single-centre design. Therefore, the results may not represent national and international practices and outcomes. The GERAADA is a multicentre prospective registry including patients undergoing surgery for ATAAD in 56 referral centres in Germany, Austria, Switzerland and Luxembourg. Thus, surgical outcomes might vary from country to country because they are affected by the respective hospital systems and ambulance transportation systems. Shortening of the 'onset of pain to operating room' time might enable surgery in ATAAD patients before the development of more serious complications (e.g. resuscitation, organ malperfusion). Other limitations are the retrospective design of the study and its small sample size, including the limited number of tested events for more precise analysis in different subcategories.

CONCLUSION

Our results clearly demonstrate the better discriminatory power of the EuroSCORE II versus the GERAADA score in the prediction of operative mortality in patients undergoing ATAAD surgery. Both scores confirmed good calibration ability. Prospective clinical trials are required to further evaluate the efficacy of both scores in the initial prediction of operative outcomes.

Conflict of interest: none declared.

Author contributions

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