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Comparison of Risk Scores for the Prediction of Outcomes after Surgery for Acute Type A Aortic Dissection

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Abstract

We compared the performance of four existing risk models and a newly developed risk score for type A acute aortic dissection surgery. In 327 consecutives with type A aortic dissection surgery patients during 2003/03-2017/03 at our centre, operative mortality occurred in 65 (19.9%). Independent predictors of operative mortality were critical pre-operative state and malperfusion syndrome, and a novel additive "CritMal" Score was constructed from this. C-statistics (95% confidence interval) for operative mortality were EuroSCORE 0.60 (0.52-0.67), EuroSCORE II 0.64 (0.57-0.72), Rampoldi 0.68 (0.59-0.76), Leontyev 0.56 (0.48-0.64), and CritMal 0.72 (0.64-0.80) respectively. This is the first study externally assessing surgical scores for aortic dissection surgery, with modest accuracy for all and moderate for CritMal. There is room for improvement of these risk models, and further refinements and external validation are warranted for clinical application.

Keywords: *Aortic dissection, Aorta, Aortic surgery, Risk score*

Introduction

Type A aortic dissection has a high risk of mortality and morbidities from fatal complications of cardiac tamponade, aortic regurgitation, vessel rupture and malperfusion of critical organ (s) [1-3]. Operative mortality remains amongst the highest of all cardiovascular operations at 17-25% in contemporary studies, although this remains significantly lower than the > 50% mortality rate without surgical intervention [1-3]. Despite the widespread uptake of risk models in cardiac surgery [4-6] and recent development of aortic dissection specific scores [7,8], their accuracy for risk stratification in the aortic dissection surgery setting is rarely studied and not well established. This study compared the performance of four risk models and a newly developed risk score at predicting mortality and morbidity outcomes after type A aortic dissection surgery.

Methods

Consecutive patients undergoing cardiac surgery for acute type A aortic dissection at Auckland City Hospital from March 2003-March 2017 were extracted from the institution's cardiothoracic surgical database. Relevant characteristics included demographics, presentation, past history and investigation results were recorded. Four risk scores were retrospectively calculated for all patients including the original EuroSCORE [4], Euro SCORE II [5] the IRAD score [7] and the Leontyev Scorecard [8]. Note that the first two scores are logistic scores while the two latter scores were only published as additive scores. Critical pre-operative state included presence of inotropic support, cardiogenic shock, mechanical ventilation and/or cardiopulmonary resuscitation between point of first health contact of presentation until surgery. Malperfusion syndrome was the evidence of end-organ dysfunction from ischaemia as a result of aortic dissection, and scored as per the Leontyev Scorecard – coronary (new ischaemic ECG changes, troponin elevation and/or new regional wall motion abnormalities on echocardiography) 1, extremity (new signs of limb ischaemic or pulse deficit) or neurological (now cerebrovascular event) 2 and visceral (new signs of mesenteric ischaemic such as abdominal pain, bowel paralysis and lactic acidosis) 3 [8].The main outcomes of interest followed that of the Society of Thoracic Surgeon's (STS) definitions [6]. Operative mortality referred to death in-hospital and/or within 30-days of operation. Composite morbidity during index surgical admission included post-operative stroke, acute kidney injury, ventilation > 24 hours, deep sternal wound infection and return to theatre. Mortality during follow-up up until 31 January 2019 was checked against the National mortality database.

Median (lower quartile-upper quartile) and frequency (percentage) were used to present quantitative and categorical variables. Univariable analysis was performed using Mann-Whitney U Test or Fisher's Exact Test for operative mortality. Multivariable analysis was used to identify predictors for operative mortality using stepwise logistic regression and variables with $P < 0.10$ in univariable analysis to calculate odds ratios (95% confidence interval), and an additive risk score was constructed based on these odds ratios for parameters that are independent predictors. Discrimination of risk scores for adverse outcomes was evaluated with the c-statistics (area under the receiver-operative characteristics curves, with 95% confidence interval) (95%CI). Calibration with logistic scores was assessed by observed/expected ratio, Hosmer-Lemeshow Test and Brier score. All tests were two-tailed and $P < 0.05$ deemed statistically significant.

Characteristics	All	No operative mortality	Operative mortality	P-value
N	327	262	65	
Demographics				
Age (years)	60.6 (51.4-70.2)	59.7 (51.0-70.0)	61.6 (54.1-72.8)	0.159
Female	124 (37.9%)	97 (37.0%)	27 (41.5%)	0.568
Ethnicity				0.382
Caucasian	151 (46.2%)	116 (44.3%)	35 (53.8%)	
Maori	45 (13.8%)	40 (15.3%)	5 (7.7%)	
Pacific	91 (27.8%)	73 (27.9%)	18 (27.7%)	
Other	40 (12.2%)	33 (10.1%)	7 (2.1%)	
Body mass index (kg/m2)	28.9 (24.7-34.8)	28.5 (24.3-34.7)	28.1 (24.4-33.4)	0.893
Presentation				
Migrating chest pain	120 (36.7%)	96 (36.6%)	24 (36.9%)	1
Heart failure	17 (5.2%)	9 (3.4%)	8 (12.3%)	0.009
Pulse deficit	50 (15.3%)	37 (14.1%)	13 (20.0%)	0.25
Critical pre-operative state	62 (19.0%)	39 (14.9%)	23 (35.4%)	< 0.001
Malperfusion syndrome (all)	154 (47.1%)	111 (42.4%)	43 (66.2%)	< 0.001
Coronary	102 (31.2%)	79 (30.2%)	23 (35.4%)	0.455
Limb	31 (9.5%)	21 (8.0%)	10 (15.4%)	0.095
Neurological	29 (8.9%)	18 (6.9%)	11 (16.9%)	0.025
Other viscera	27 (8.3%)	15 (5.7%)	12 (18.5%)	0.002
Emergency surgery	319 (97.6%)	254 (96.9%)	65 (100.0%)	0.365
Past history				
Cardiac surgery	11 (3.4%)	8 (3.1%)	3 (4.6%)	0.462
Myocardial infarction	24 (7.3%)	21 (8.0%)	3 (4.6%)	0.435
Congestive heart failure	9 (2.8%)	7 (2.7%)	2 (3.1%)	1
Atrial fibrillation	26 (8.0%)	18 (6.9%)	8 (12.3%)	0.196
Hypertension	197 (60.2%)	163 (62.2%)	34 (52.3%)	0.158
Diabetes	18 (5.5%)	14 (5.3%)	4 (6.2%)	0.764
Smoking active	71 (21.7%)	60 (22.9%)	11 (16.9%)	0.4
Infective endocarditis	2 (0.6%)	2 (0.8%)	0 (0.0%)	1
Stroke	14 (4.3%)	9 (3.4%)	5 (7.7%)	0.164
Peripheral vascular disease	33 (10.1%)	25 (9.5%)	8 (12.3%)	0.495
Chronic respiratory disease	49 (15.0%)	42 (16.0%)	7 (10.8%)	0.337
Pulmonary hypertension	3 (0.9%)	2 (0.8%)	1 (1.5%)	0.488
Dialysis	3 (0.9%)	3 (1.1%)	0 (0.0%)	1
Poor mobility	6 (1.8%)	5 (1.9%)	1 (1.5%)	1
Investigation				
Ejection fraction impaired < 50%	47 (14.3%)	36 (13.7%)	11 (16.9%)	0.554
Aortic regurgitation (moderate or severe)	114 (34.9%)	88 (33.6%)	26 (40.0%)	0.383
Creatinine clearance (ml/min)	81 (58-109)	84 (89-111)	67 (55-91)	0.015
Operative variables				
Cardiopulmonary bypass time (minutes)	174 (134-221)	173 (130-212)	201 (150-280)	0.002
Outcome				
Composite morbidity	212 (65.0%)	163 (62.5%)	49 (75.4%)	0.059
Stroke	63 (19.3%)	41 (15.7%)	22 (33.8%)	0.02

Acute kidney injury	134 (41.0%)	101 (38.4%)	33 (50.8%)	0.091
Ventilation > 24 hours	129 (39.6%)	93 (35.6%)	36 (55.4%)	0.004
Deep sternal wound infection	8 (2.5%)	7 (2.7%)	1 (1.5%)	1
Return to theatre	94 (28.8%)	65 (24.8%)	29 (44.6%)	0.005

Table 1. *Key characteristics and outcomes - median (quartiles) or frequency (%) and their univariable analysis for operative mortality*

Outcome/score	**Rate**	**EuroSCORE**	**EuroSCORE II**	**IRAD**	**Leontyev**	**CritMal**
Median (quartiles)		20.1 (12.2-33.1) %	4.4 (2.6-8.9) %	0.7 (0.0-1.9)	4 (3-6)	1 (0-2)
Operative mortality	65(19.9%)	0.60(0.52-0.67)	0.64 (0.57-0.72)	0.68 (0.59-0.76)	0.56 (0.48-0.64)	0.72 (0.64-0.80)
Observed/expected ratio		0.8	2.8	N/A	N/A	N/A
Mortality during follow-up		0.64 (0.57-0.70)	0.65 (0.59-0.71)	0.62 (0.55-0.68)	0.63 (0.57-0.70)	0.61 (0.54-0.68)
Composite morbidity	212 (65.0%)	0.61 (0.55-0.68)	0.59 (0.53-0.66)	0.60 (0.53-0.66)	0.58 (0.51-0.64)	0.71 (0.64-0.78)
Stroke	63 (19.3%)	0.52 (0.45-0.60)	0.53 (0.45-0.61)	0.51 (0.43-0.59)	0.52 (0.44-0.60)	0.65 (0.56-0.74)
Acute kidney injury	134 (41.0%)	0.54 (0.47-0.60)	0.54 (0.48-0.60)	0.58 (0.52-0.65)	0.55 (0.49-0.62)	0.66 (0.59-0.73)
Ventilation > 24 hours	129 (39.6%)	0.60 (0.54-0.67)	0.60 (0.54-0.66)	0.56 (0.49-0.62)	0.59 (0.53-0.66)	0.62 (0.55-0.69)
Deep sternal wound infection	8 (2.5%)	0.60 (0.40-0.80)	0.60 (0.40-0.80)	0.52 (0.39-0.66)	0.53 (0.31-0.74)	0.58 (0.38-0.78)
Return to theatre	94 (28.8%)	0.56 (0.49-0.63)	0.56 (0.49-0.63)	0.55 (0.48-0.62)	0.52 (0.45-0.60)	0.62 (0.55-0.69)

Table 2. *Performance of risk scores for predicting outcomes - c-statistic (95% confidence interval) unless specified. C-statistics with P-value > 0.06 are in bold.*

Results

A total of 327 patients underwent surgery for type A aortic dissection over the 14-year study period. Key characteristics and outcomes with univariable analyses for operative mortality are shown in Table 1. Median age was 60.6 years and 124 (37.9%) were female. Critical pre-operative state and malperfusion syndrome were present in 62 (19.0%) and 154 (47.1%) respectively. Operative mortality occurred in 65 (19.9%). Composite morbidity occurred in the majority 212 (65.05%), with a significant minority having stroke, acute kidney injury, ventilation > 24 hours and return theatre (19-41%).Over mean follow-up of 4.3+/-3.3 years, 1, 5, and 10-year survivals were 79.0%, 71.7% and 57.8% respectively.

Amongst pre-operative variables, operative mortality was associated in univariable analysis with heart failure presentation, critical pre-operative state, malperfusion syndrome, and lower creatinine clearance. In the multivariable analysis, critical pre-operative state and malperfusion syndrome per category were independent predictors of operative mortality with odds ratios (95% confidence intervals) of 3.17 (1.60-6.27) and 1.63 (1.25-2.12) respectively. A novel risk score "CritMal" was constructed from this model, out of a maximum of 5, with patients having critical pre-operative state scoring 2, and malperfusion syndrome depending on organ affectedscoring as coronary 1, limb or neurological 2and visceral 3.

Table 2 lists the performance of risk scores at predicting adverse outcomes. All existing scores were able to modestly discriminated operative mortality, composite morbidity and mortality during follow-up (c-statistic < 0.70), except for the Leontyev Scorecard which was not able to discriminate operative mortality. EuroSCORE slightly over-estimated operative mortality (observed/expected ratio 0.8) while EuroSCORE II severely under-estimated this (observed/expected ratio 2.8). The CritMal score had the highest c-statistic for operative mortality and composite morbidity, and was the only score able to detect stroke, acute kidney injury and return to theatre.

Discussion

IThis is the first study externally assessing the performance of surgical risk scores for predicting outcomes after type A aortic dissection surgery. This is a high-risk procedure with operative mortality of 17-25% in the literature and our cohort, so it is important to try and improve outcomes [1-3]. Risk stratification can play a role in this acute condition to determine the risk of major complications and mortality, consent patients for surgery, and most importantly can guide which patients need extra attention for optimal peri-operative management. The external evaluation of risk scores is important to identify strengths and weaknesses before wider clinical applicability, and also because scores tend to perform best from the cohort they were developed from and internally validated.

The EuroSCORE and EuroSCORE II had modest discrimination for operative mortality (c-statistic 0.60-0.64), which is understandable as they were derived from general cardiac surgery cohorts which only have a small proportion of aortic dissection operations [4,5]. The older EuroSCORE surprisingly had better calibration than the EuroSCORE II despite the latter being the updated version and used more widely in current practice. One of the EuroSCOREs parameters is surgery on the aorta which attempts to recalibrate the score for this setting, however this appears insufficient as it is applied to all types of elective and acute aortic surgery which have very different risk [4,5]. The score would need further re-calibration or additional parameters such as malperfusion syndrome to increase accuracy when applying to aortic dissection surgery.

On the other hand, the ICAD and Leontyev scores were derived specifically from aortic dissection operations [7,8]. Despite having common parameters mortality predictors found in our study and others [3,9], discriminative ability was modest for the ICAD score (0.68) and poor for the Leonytev Scorecard (0.56). Their performances for post-operative complications were also modest at best. This highlighted the complexity of factors and their interactions to contribute to adverse events for this operation, and other potentially important factors such as right ventricle function and frailty may not be collected in these registries [10]. Another downside of these additive scores was that their full logistic models including constants were not published like the EuroSCOREs to allow calibration to be assessed and this can impede clinical applicability.

Our novel CritMal score had the highest c-statistic for operative mortality and most post-operative complications. Apart from this it also has another advantage of simplicity with only 2 parameters, and this encourages clinical utility. Both parameters of the CritMal score have been replicated in other aortic dissection surgery cohorts as predictors of adverse outcomes [1,3,8,9]. There remains room for improvement for this score on both the discrimination and calibration fronts, and further external evaluation and refinements are necessary before being applied widely in clinical decision-making for type A aortic dissection

This study had some limitations. It is a single centre observational study. Sample size was moderate but compensated by high event rates, although not all statistically significant predictors would have been identified. Retrospective calculation of risk scores may introduce bias, and calibration of additive risk scores could not be evaluated. The only longitudinal outcome obtainable and assessed was mortality but other important measures such as repeat operations, stroke, cardiovascular readmissions and echocardiographic measures are also important. We also did not externally validate the CritMal score in a separate cohort.

In conclusion, current surgical risk models only modestly discriminated outcomes in our cohort of type A dissection surgery, and the EuroSCOREs had suboptimal calibration for operative mortality. The novel CritMal risk score had the highest c-statistic for operative mortality and almost all the post-operative complications evaluated and its simplicity is attractive. There remains room for improvement and further refinements and external validation in larger dissection surgery cohorts are warranted for risk models to be routinely in clinical practice.

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