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Risk Stratification Scores in Elective Open Abdominal Aortic Aneurysm Repair: Are They Suitable for Preoperative Decision Making?

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WHAT THIS PAPER ADDS

- Despite numerous attempts at devising an accurate preoperative risk score to help identify high-risk patients undergoing open elective abdominal aortic aneurysm (AAA) repair no ideal method has been found. This paper highlights once again that there is no model widely accepted, or repeatedly validated, in predicting mortality or cardiac events following AAA repair. In addition, the repeated difficulties in risk score prediction, including geographical variation and their development based on small sample sizes, raise the question of whether an entirely different form of stratifier should be sought.

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ABSTRACT

Objectives: Risk indices help quantify the risk of cardiovascular events and death prior to making decisions about prophylactic AAA repair. This paper aims to study the predictive capabilities of 5 validated indices.
Design and methods: A prospective observational multi-centre cohort study from August 2005 to September 2007 in Glasgow recruited 106 consecutive patients undergoing elective open AAA repair. The Glasgow Aneurysm Score (GAS), Vascular physiology only Physiological and Operative Severity Score for enUmeration of Mortality (V(p)-POSSUM), Vascular Biochemical and Haematological Outcome Model (VBHOM), Revised Cardiac Risk Index (RCRI) and Preoperative Risk Score of the Estimation of Physiological Ability and Surgical Stress Score (PRS of E-PASS) were calculated. Indices were compared using receiver operating characteristic (ROC) analysis and area under the curve (AUC) estimates. End points were all-cause mortality, Major Adverse Cardiac Events (MACE) and cardiac death.
Results: GAS, VBHOM and RCRI did not predict outcome. V(p)-POSSUM predicted MACE (AUC = 0.681), cardiac death (AUC = 0.762) and all-cause mortality (AUC = 0.780), as did E-PASS (AUC = 0.682, 0.821, 0.703 for MACE, cardiac death and all-cause mortality respectively).
Conclusion: Whilst V(p)-POSSUM and E-PASS predicted outcome, the less complex RCRI and GAS performed poorly which questions the utility of decision making based on these surgical risk indices.

Introduction

Prophylactic surgical repair of an abdominal aortic aneurysm (AAA) is associated with a mortality of around 5–6% in the UK.[1,2] The UK small aneurysm trial comparing surgical repair with observation of a small AAA recruited 1090 men and women aged 60–76 years with infrarenal AAAs measuring 4.0–5.5 cm whom were considered fit for surgery. Prospective follow-up of these patients randomised to either early surgery or routine surveillance demonstrated a greater risk of death from surgery, primarily cardiac in origin, than in the observation group for the first three years of follow-up.[2] Survival was subsequently worse in the surveillance group so that survival curves crossed at three years, and although this never reached statistical significance the importance of operative mortality and patient selection has been underlined. Greater discrimination of those at risk of perioperative death with poorer short-term survival would improve management.

Several surgical risk indices have been developed to help define the risk of perioperative death for a given patient. The Eagle[3] and Vanzetto[4] scores, which use physiological factors in conjunction with electrocardiogram (ECG) analysis and myocardial thallium scanning, have been shown to be useful in predicting cardiac events

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in major vascular surgery. However, despite further external validation in predicting mortality after elective open AAA repair,[5] their need for cardiac testing make them unfavourable for preoperative stratification. The Leiden score and modifications[6] are unique in that they employ a corrective factor for institution-specific mortality rates. However the Leiden score has not consistently shown satisfactory predictive capabilities. When applied to UK small aneurysm trial data it predicted death with only moderate accuracy (AUC 0.72) and was shown to have poor predictive power and calibration.[7]

The Estimation of Physiological Ability and Surgical Stress (E-PASS) was found to accurately predict postoperative outcome in open elective AAA surgery, even with the preoperative component used alone.[5,8] The Glasgow Aneurysm Score (GAS),[9] Physiological and Operative Severity Score for enumeration of Mortality (POSSUM)[10,11] and Vascular Biochemical and Haematological Outcome Model (VBHOM)[12] have all been validated, showing good predictive capabilities and can be used as preoperative scoring systems.[13] In addition, Lee's revised cardiac risk index (RCRI)[14] predicts mortality in vascular surgery including elective open AAA repair.[15]

The aim of this study is to compare five validated preoperative risk stratification scoring systems for patients undergoing open elective AAA repair, and to assess their ability to predict all-cause mortality and major adverse cardiac events (MACE) in the perioperative period.

Methods

Study population

A prospective, observational, multi-centre cohort study was performed involving the 3 major vascular units within Glasgow (Gartnavel General Hospital, Glasgow Royal Infirmary and the Southern General Hospital). A cohort of consecutive patients admitted for elective open AAA repair was identified between August 2005 and September 2007. All patients were approached the evening prior to surgery and informed consent obtained. Patients were excluded if they were receiving endovascular aortic aneurysm repair, required unplanned surgery undertaken within less than 24 h of admission, if they were unable to give informed consent, or if they had evidence of preoperative cardiac ischaemia measured by preoperative ECG and cardiac troponin I (cTnI).

Patients and preoperative assessment

Demographic data and factors relating to the cardiac risk of surgery were gathered for each patient by history and case-note review. Collection of patient data, including preoperative blood tests, ensured information was gathered to allow calculation of the 5 scoring systems named below. Detailed definitions are available at the referenced publications.

Glasgow aneurysm score[9]

Data were collected based on:

$$\begin{aligned}\text{GAS} = {} & \text{Age} + (17 \text{ for shock}) + (7 \text{ for myocardial disease}) \\ & + (10 \text{ for cerebrovascular disease}) \\ & + (14 \text{ for renal disease})\end{aligned}$$

Vascular (physiology only) – physiological and operative severity score for enumeration of mortality[11]

Physiological parameters including age, presence and severity of both cardiac and respiratory disease, ECG changes, systolic blood pressure, pulse rate, haemoglobin, white cell count, urea, sodium, potassium and Glasgow coma scale were collected for online calculation of the V(p)-POSSUM score at http://www.riskprediction.org.uk/vasc-index.php. The score was calculated using the following equation:

$$\ln(R/1-R) = -8.0616 + (0.1552 \times \text{physiological score})$$

Vascular biochemical and haematological outcome model[12]

The results of preoperative plasma urea, sodium, potassium, haemoglobin, white cell count with the addition of age or male gender were applied to the following equation:

$$\begin{aligned}\text{VBHOM} = {} & \ln_e(R/1-R) \\ = {} & -2.257 + (0.1511 \times \text{sex}) \\ & + (0.9940 \times \text{mode of admission}) + 0.05923 \\ & \times \text{age on admission}\{\text{years}\} + (0.001401 \\ & \times \text{urea}\{\text{mmol/l}\}) + (-0.01303 \\ & \times \text{sodium}\{\text{mmol/l}\}) + (-0.03585 \\ & \times \text{potassium}\{\text{mmol/l}\}) + (-0.2278 \\ & \times \text{haemoglobin}\{\text{g/dl}\}) + (0.02059 \\ & \times \text{white cell count}\{\times 109/\text{l}\})\end{aligned}$$

R is the risk of death. Sex takes the value 1 for male and 0 for female, and mode of admission takes the value 0 for elective and 1 for non-elective admissions.

Lee's revised cardiac risk index (RCRI)[14]

The RCRI was calculated by scoring one for each of; high-risk surgery, ischaemic heart disease, congestive heart failure, cerebrovascular disease, the use of insulin therapy for diabetes mellitus or a preoperative creatinine level $>$ 2 mg/dl ($>$176 μmol/l).

Preoperative risk score of the estimation of physiological ability and surgical stress score[8]

The PRS component of the E-PASS score was calculated based on the following equation:

$$\begin{aligned}\text{PRS} = {} & -0.0686 + 0.00345(\text{age}) + 0.323(\text{cardiac score}) \\ & + 0.205(\text{pulmonary score}) + 0.153(\text{diabetes score}) \\ & + 0.148(\text{performance status index}) + 0.0666(\text{ASA})\end{aligned}$$

Postoperative follow-up

Postoperative screening for cardiac events was performed by serial ECGs and cTnI measurement on the morning of the 2nd and 5th postoperative days. If a patient was due to be discharged prior to the fifth postoperative day, tests were conducted on the morning of discharge instead of day 5. Additional postoperative investigations were conducted at the discretion of the treating surgeon. Patients were reviewed at an outpatient clinic 6–8 weeks post-procedure.

End points

End points for the study were MACE (non-fatal myocardial infarction and cardiac death), cardiac death and death from any cause. The definition of a non-fatal myocardial infarction used was that of the Joint European Society of Cardiology/American College of Cardiology Committee.[16] Cardiac death was defined as death secondary to myocardial infarction, cardiogenic shock or intractable dysrhythmia, and was determined by a review of post-operative data by two cardiologists. If a patient had died of a non-cardiac cause the date and cause of death were noted. If no cause of death was noted then a death certificate review was performed.

Statistical analysis

Statistical analysis was performed using the SPSS® statistical software package (SPSS, Chicago, Illinois, USA). Normal distributed data were reported as mean ± standard deviation. Non-parametric data was reported as median and interquartile range. Mann–Whitney *U* test was used to test the differences between non-parametric continuous variables in different subgroups. A 2-sample *t*-test was used to compare continuous variables in normally distributed data. Receiver operating characteristics were plotted and the area under the curve (AUC) estimated. A *p*-value <0.05 was considered statistically significant.

Ethical approval

Local research and development, and central ethics committee approval was obtained for the study. All patients were provided with an information sheet and had signed a study consent form.

Results

Patient characteristics and preoperative blood testing

During the study period 111 patients met the inclusion criteria and were invited to participate. Two patients declined and a further 3 were found to have elevated preoperative cTnI and were not included, resulting in 95% inclusion. None of these five patients developed a cardiac complication or died following their procedure. The median age of the remaining 106 patients was 73 (66–77) years. The male to female ratio showed a male predominance of 5:1. The majority of patients had smoked at some point in their life (85%) of whom 35 (33%) currently smoked. One fifth of patients had suffered a previous MI with similar numbers having suffered from

Table 1
Preoperative patient characteristics and laboratory results, and their distribution according to outcome.

	All subjects ($n = 106$)	MACE ($n = 16$)	Cardiac death ($n = 5$)	All-cause mortality ($n = 9$)
Sex				
Male	88 (83%)	13/88 (15%)	5/88 (6%)	7/88 (8%)
Female	18 (17%)	3/18 (17%) $p = 0.733$	0/18 (0%) $p = 0.586$	2/18 (11%) $p = 1.0$
Angina				
Present	25 (25%)	4/25 (16%)	2/25 (8%)	4/25 (17%)
Absent	81 (76%)	12/81 (15%) $p = 1.0$	3/81 (4%) $p = 0.590$	5/83 (6%) $p = 0.210$
Previous MI				
Present	23 (22%)	5/23 (22%)	2/23 (9%)	3/23 (13%)
Absent	83 (78%)	11/83 (13%) $p = 0.332$	3/83 (4%) $p = 0.583$	6/83 (7%) $p = 0.404$
Diabetes				
Present	9 (8%)	3/9 (33%)	2/9 (22%)	2/9 (22%)
Absent	97 (92%)	13/97 (13%) $p = 0.134$	3/97 (3%) $p = 0.056$	7/97 (7%) $p = 0.169$
CVD				
Present	22 (21%)	2/22 (9%)	2/22 (9%)	4/22 (18%)
Absent	84 (79%)	14/84 (17%) $p = 0.515$	3/84 (4%) $p = 0.581$	5/84 (6%) $p = 0.087$
CCF				
Present	13 (12%)	5/13 (38%)	4/13 (31%)	5/13 (38%)
Absent	93 (88%)	11/86 (12%) $p = 0.026$	1/86 (1%) $p = 0.004$	4/86 (5%) $p = 0.011$
CRF				
Present	8 (8%)	0/8 (0%)	0/8 (0%)	1/8 (13%)
Absent	98 (92%)	16/98 (16%) $p = 0.604$	5/98 (5%) $p = 1.0$	8/98 (8%) $p = 1.0$
COPD				
Present	25 (22%)	3/25 (12%)	2/25 (8%)	3/25 (12%)
Absent	81 (78%)	13/81 (16%) $p = 0.757$	3/81 (4%) $p = 0.590$	6/81 (7%) $p = 0.682$
Urea (mmol/l)	7.5 (3.7)			
Present		8.43 (4.48)	10.68 (7.19)	9.98 (5.66)
Absent		7.35 (3.56) $p = 0.285$	7.36 (3.44) $p = 0.050$	7.28 (3.43) $p = 0.037$
Creatinine (μmol/l)	109.2 (39.4)			
Yes		116.1 (43.1)	141.2 (65.2)	131.3 (51.2)
No		107.9 (38.9) $p = 0.450$	107.6 (37.5) $p = 0.062$	107.1 (37.8) $p = 0.078$
Serum Na^+ (mmol/l)	4.2 (0.48)			
Yes		139.7 (1.82)	139.6 (2.07)	138.8 (2.68)
No		138.9 (2.84) $p = 0.324$	139.0 (2.75) $p = 0.655$	139.1 (2.74) $p = 0.741$
Serum K^+ (mmol/l)	139.1 (2.7)			
Yes		4.14 (0.75)	4.24 (0.53)	4.32 (0.53)
No		4.22 (0.41) $p = 0.558$	4.21 (0.48) $p = 0.880$	4.20 (0.47) $p = 0.456$
Haemoglobin (g/dl)	13.3 (1.9)			
Yes		12.90 (2.37)	11.96 (3.48)	12.14 (2.50)
No		13.34 (1.77) $p = 0.391$	13.33 (1.76) $p = 0.108$	13.38 (1.78) $p = 0.058$
WCC ($\times 10^3/\mu l$)	7.9 (1.8)			
Yes		8.43 (1.26)	8.08 (1.70)	8.23 (1.56)
No		7.79 (1.93) $p = 0.208$	7.88 (1.86) $p = 0.818$	7.86 (1.88) $p = 0.574$
Platelets ($\times 10^3/\mu l$)	231.4 (83.2)			
Yes		214.5 (111.2)	146.6 (30.1)	212.2 (115.7)
No		234.4 (77.6) $p = 0.381$	235.6 (82.8) $p = 0.019$	233.2 (80.1) $p = 0.473$
PT (s)	11.98 (1.94)			
Yes		12.37 (2.52)	14.2 (3.96)	12.89 (3.26)
No		11.91 (1.83) $p = 0.382$	11.87 (1.76) $p = 0.008$	11.9 (1.78) $p = 0.144$

MACE – major adverse cardiac event, MI – myocardial infarction, CVD – cerebrovascular disease, CCF – congestive cardiac failure, CRF – chronic renal failure, COPD – chronic obstructive pulmonary disease, WCC – white cell count, PT – prothrombin time.
All laboratory variables are given as mean (±SD).
All analyses performed using fishers exact or a 2-sample *t*-test.

Table 2
Preoperative risk scores compared to patient outcome.

	All subjects	MACE	Cardiac death	All-cause mortality
GAS	77 (72–84)			
Yes		79 (71–84)	77 (70–85)	84 (74–87)
No		71 (72–84) $p = 0.846$	71 (72–84) $p = 0.911$	77 (71–83) $p = 0.227$
V(p)-POSSUM	29 (27–34)			
Yes		33 (28–37)	34 (32–37)	34 (29–37)
No		29 (26–32) $p = 0.028$	29 (26–33) $p = 0.030$	29 (26–33) $p = 0.038$
VBHOM	−2.66 (−3.07 to −2.23)			
Yes		−2.53 (−2.96 to −2.08)	−2.57 (−2.78 to −1.85)	−2.33 (−2.62 to −2.21)
No		−2.67 (−3.12 to −2.26) $p = 0.232$	−2.66 (−3.08 to −2.23) $p = 0.340$	−2.72 (−3.10 to −2.30) $p = 0.069$
RCRI	2 (1–3)			
Yes		2 (1–3)	3 (1–4)	2 (1–4)
No		2 (1–3) $p = 0.735$	2 (1–3) $p = 0.448$	2 (1–3) $p = 0.415$
PRS	0.46 (0.26–0.64)			
Yes		0.63 (0.46–0.67)	0.65 (0.59–1.02)	0.65 (0.40–0.93)
No		0.42 (0.25–0.60) $p = 0.019$	0.44 (0.26–0.62) $p = 0.017$	0.44 (0.26–0.62) $p = 0.050$

MACE – major adverse cardiac event, GAS – Glasgow aneurysm score, V(p)-POSSUM – physiological component of vascular physiological and operative severity score for enumeration of mortality, VBHOM – vascular biochemical and haematological outcome model, RCRI – revised cardiac risk index, PRS – preoperative risk score of estimation of physiological ability and surgical stress.
All scores recorded as median (interquartile range).
All analyses performed using Mann–Whitney *U* test.

cerebrovascular disease. Other patient characteristics are detailed in Table 1. The majority of laboratory variables were within normal reference ranges for the local population [Table 1].

Risk indices and outcome

Complete datasets required for the calculation of all 5 preoperative risk indices were collected in all 106 patients. Of these 16 (15%) suffered MACE within 30 days, of whom 5 patients suffered a cardiac death and 11 had a non-fatal MI. The 30-day all-cause postoperative mortality was 8.5% (9 deaths), of which 7 deaths occurred prior to hospital discharge (6.6% in-hospital mortality).

Platelet levels and prothrombin times were significantly higher in those that suffered a cardiac death ($p = 0.019$ and $p = 0.008$ respectively) on univariate analysis. Serum urea was significantly higher in patients who died from all-cause mortality ($p = 0.037$). Urea levels were also higher in those who suffered cardiac death, although this was not significant ($p = 0.050$). Haemoglobin levels were lower in those that died of all-cause mortality, although again this was not significant ($p = 0.058$).

Glasgow aneurysm score, vascular biochemical and haematological outcome model and Lee's revised cardiac risk index

The median GAS, VBHOM and RCRI scores were not significantly different in those patients who suffered MACE, cardiac death, or in those who died of all-cause mortality [Table 2]. ROC analysis revealed low accuracy in predicting MACE, cardiac death and all-cause mortality for all 3 scores. Sensitivities and specificities were poor and all 3 scores appeared to perform poorly in all outcome measures [Table 3].

Vascular (physiology only) – physiological and operative severity score for enumeration of mortality

There was a difference in median V(p)-POSSUM with higher scores in those who suffered MACE ($p = 0.028$), cardiac death ($p = 0.030$), and in those who died of all-cause mortality ($p = 0.038$) [Table 2]. ROC analysis revealed an AUC of 0.681 in predicting MACE

Table 3
Results of receiver operating characteristic curve analysis for each score according to outcome.

	AUC	95% CI	SE	*p*-Value	Cut-off	Sens.	Spec.	PPV	NPV
MACE									
GAS	0.515	0.374–0.657	0.072	0.846	77.5	50%	53%	14%	86%
V(p)-POSSUM	0.681	0.549–0.814	0.067	0.021	20.5	63%	67%	35%	93%
VBHOM	0.592	0.455–0.730	0.070	0.241	−2.59	56%	56%	16%	88%
RCRI	0.525	0.364–0.687	0.082	0.747	>1	63%	38%	15%	85%
PRS	0.682	0.559–0.805	0.063	0.021	0.55	69%	64%	27%	93%
Cardiac death									
GAS	0.515	0.285–0.745	0.117	0.911	76.5	60%	46%	5.2%	96%
V(p)-POSSUM	0.762	0.596–0.928	0.085	0.048	20.5	80%	65%	15%	99%
VBHOM	0.626	0.430–0.822	0.100	0.344	−2.59	60%	56%	5%	96%
RCRI	0.596	0.285–0.907	0.159	0.470	>2	60%	68%	9%	97%
PRS	0.821	0.697–0.945	0.063	0.016	0.63	80%	76%	15%	99%
All-cause mortality									
GAS	0.622	0.436–0.808	0.095	0.227	77.5	56%	54%	10%	93%
V(p)-POSSUM	0.780	0.667–0.893	0.057	0.006	20.5	89%	68%	21%	99%
VBHOM	0.684	0.555–0.813	0.066	0.069	−2.48	67%	73%	15%	95%
RCRI	0.578	0.361–0.796	0.111	0.438	>2	45%	68%	11%	93%
PRS	0.703	0.516–0.890	0.095	0.045	0.55	78%	63%	15%	97%

MACE – major adverse cardiac event, GAS – Glasgow aneurysm score, V(p)-POSSUM – physiological component of vascular physiological and operative severity score for enumeration of mortality, VBHOM – vascular biochemical and haematological outcome model, RCRI – revised cardiac risk index, PRS – preoperative risk score of estimation of physiological ability and surgical stress, AUC – area under the curve, CI – confidence interval, SE – standard error, Sens. – sensitivity, Spec. – specificity, PPV – positive predictive value, NPV – negative predictive value.

with the best cut-off for V(p)-POSSUM of 20.5, an AUC of 0.762 in predicting cardiac death and an AUC of 0.780 for predicting all-cause mortality, with once again a cut-off of 20.5 for both outcome measures [Table 3].

Preoperative risk score of the estimation of physiological ability and surgical stress score

The median PRS was higher in those who suffered MACE ($p = 0.019$) and cardiac death ($p = 0.017$). The median PRS was higher in the all-cause mortality group than in the survivors, although this was just not significant ($p = 0.050$) [Table 2]. ROC analysis revealed an AUC of 0.682 in predicting MACE and 0.703 in predicting all-cause mortality, with a cut-off of 0.55 for both outcome measures. ROC analysis revealed an AUC of 0.821 for predicting cardiac death [Fig. 1] with a cut-off of 0.63 [Table 3].

Tertile analyses of risk indices

Tertile analysis was performed by dividing each index grouping into 3 equal classes based on even distribution with the aim of examining stepwise increase in MACE, cardiac death and mortality between groups. For GAS ($p = 0.584$, $p = 0.891$ and $p = 0.264$ respectively), VBHOM ($p = 0.395$, $p = 0.174$ and $p = 0.070$) and RCRI ($p = 1.0$, $p = 0.368$ and $p = 0.867$) there were no significant differences in the tertile rates of MACE, cardiac death and all-cause mortality.

For V(p)-POSSUM sequential increases were seen in rates for MACE and all-cause mortality with rates in MACE of 4%, 13% and 29%, and in all-cause mortality of 0%, 8% and 16% ($p = 0.013$ and $p = 0.030$ respectively). In cardiac death there was no significant rate change between tertiles with rates of 0%, 4% and 10% ($p = 0.130$) [Fig. 2a].

For the PRS component of E-PASS there were significant increases in rates for all outcome measures with rates of 6%, 13% and 27% in MACE, 0%, 3% and 12% in cardiac death, and rates of 6%, 3% and 18% in all-cause mortality ($p = 0.038$, $p = 0.015$ and $p = 0.032$ respectively) [Fig. 2b].

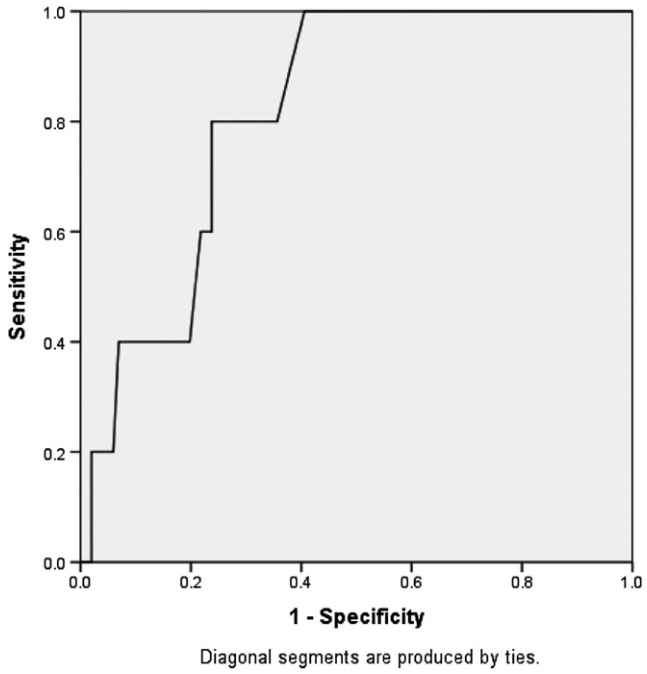

Figure 1. Receiver operating characteristics curve for PRS and cardiac death with an area under the curve of 0.821.

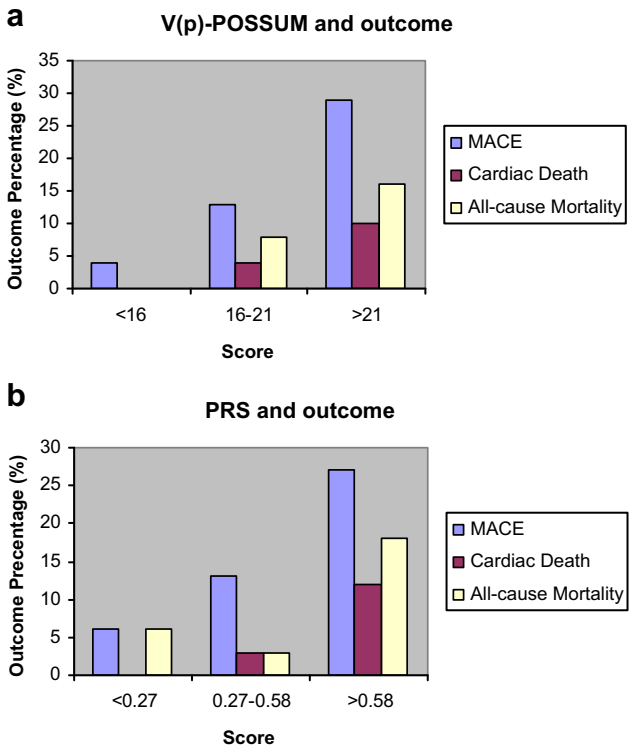

Figure 2. Tertile analysis for individual risk scores. MACE – major adverse cardiac event, V(p)-POSSUM – physiological component of vascular physiological and operative severity score for enumeration of mortality, PRS – preoperative risk score of estimation of physiological ability and surgical stress. All analyses were performed using Mann–Whitney *U* test.

Discussion

Preoperative risk stratification is of importance in elective open AAA repair and, since opinion and experience alone are often the only tools of the vascular surgeon in selecting operative candidates, an optimal risk stratifier has been sought. A number of risk scoring systems derived from patients undergoing non-cardiac surgery have been devised, but most seem to lack accuracy.[13–15] Based on a review of the literature, the 5 most suitable preoperative risk scoring indices have been identified and prospectively evaluated with an emphasis on predicting MACE, cardiac death and all-cause mortality in the immediate postoperative period.

The two scoring systems that performed well were V(p)-POSSUM and the Preoperative Risk Score component of E-PASS. In this cohort, the physiology component of V(p)-POSSUM was a significant predictor of all outcome measures. POSSUM scoring has long been advocated as the most fitting scoring system in non-cardiac surgery.[17] This may be due to the inclusion of a relatively high number of important serum and physiological markers, providing a more detailed account of physiological reserve. However, POSSUM has been shown to over-predict death in low risk patients,[18] despite modification including the vascular adaption.[19] It is therefore expected that V(p)-POSSUM would perform well in predicting all-cause mortality in the elective open AAA patient, given the higher risk associated with this surgery type compared to other types of non-cardiac and vascular procedures. It was an unexpected finding that it would perform well in predicting MACE, although this may reflect its ability to predict morbidity in general. Whilst this index appears to perform well, there is overriding concern with the effect of area-wide variation, and whilst V(p)-POSSUM allows for variations in the hospital case mix it is not

robust in different geographical locations.[19,20] Further, its original development as that of an audit tool including operative data continues to raise questions about its use in the preoperative setting when guiding clinical decision making.

The PRS component of the E-PASS score predicted MACE and cardiac death, and whilst it did not appear to predict all-cause mortality on univariate testing it did perform well on tertile analysis and in ROC curve analysis. The main concern with E-PASS is that the original scoring system requires operative data to calculate its overall score thus precluding its use for preoperative risk assessment. However a strong correlation between the PRS component and outcome has been shown which therefore permits its use in the preoperative setting.[8] It may be the very premise of this scoring system, where each patient's physiological reserve is scored, that gives a more accurate outcome measure.

Of the other scoring systems only VBHOM showed utility in predicting all-cause mortality. However, this did not reach statistical significance and VBHOM performed poorly in predicting MACE or cardiac death. This confirms previous validations where VBHOM was shown to under-predict perioperative complications and over-predict mortality.[17] This may be explained by the fact that VBHOM was devised including patients who underwent emergency AAA repair.

The GAS and RCRI performed poorly in this prospective cohort. The GAS was constructed using a population of 500 patients undergoing both emergency and elective AAA repair in Glasgow over a 10 year period between 1980 and 1990.[9] This was a retrospective data analysis and produced a simple index of risk. Despite numerous validations in different populations[21–25] the GAS has been criticised for not reliably identifying individual high-risk patients and being consistently inaccurate in predicting morbidity,[5,24] whilst also performing poorly when compared to other scoring systems.[5] The GAS also fails to allow for treatment or optimisation of a patient's comorbid condition and scores for the presence of disease rather than the functional effects of the disease process. More surprising is that the score is a poor predictor in the very population from which it was derived, which may be in part explained by the increasing age and improving health states of the population.

The most unexpected finding is that the RCRI performed worst. As the only score of the 5 included that was specifically designed to evaluate cardiac risk it is unexpected that it not only failed to predict mortality but also failed to predict cardiac events. This lack of predictive value may be due to the high-risk population within which it was used, immediately scoring every patient 1 prior to further scoring. It is likely that this diminishes the sensitivity of the index, as has been suggested in the published literature, where concern has been expressed at the grouping of intraperitoneal and major vascular surgery together, and where open AAA repair has shown to have worse outcome than all other operation subgroups that are considered together in the RCRI.[26,27] This lack of subgrouping is taken into account in the ESC/ESA Guidelines for preoperative cardiac risk assessment and perioperative cardiac management in non-cardiac surgery.[28] This may improve the accuracy of the RCRI, which plays a key role in the algorithm proposed by Poldermans et al. The results of this study do however raise concern about the use of these guidelines in open elective AAA repair.

The principal limitation of this prospective cohort is the small sample size. Although MACE occurred with sufficient frequency to draw reasonable conclusions, all-cause mortality and in particular cardiac death were low in absolute numbers. A larger cohort would have been more conducive to risk estimation. In contrast, however, the end points were well-defined and most vascular surgical practices will deal with numbers similar to this cohort. This therefore questions the utility of scoring systems that require large numbers to be clinically relevant.

In conclusion, it appears both the PRS component of E-PASS and V(p)-POSSUM have advantages in predicting outcome following elective open AAA repair over other scoring systems. Whilst V(p)-POSSUM appears to be the best stratification score (and easily accessible on the internet) with regard to all-cause mortality, its inability to predict mortality rates in individual patients may make E-PASS a more favourable alternative, having been developed specifically as an aid to clinical decision making, although further validation is required.[13,29] Both the RCRI and GAS lacked predictive power. As the simplest forms of risk score these are possibly the most often used in the clinical environment, and the results are therefore disappointing for real life clinical practice. The increasingly aged population with greater use of medical therapy and synchronous rise in EVAR may mean that more up to date indices such as the customised probability model[30] or other risk prediction models[31,32] will show greater predictive abilities, however these await widespread validation and acceptance in risk assessing for open elective AAA repair. Based on the results of this study it would be advisable not to base clinical decision making in aneurysm surgery on RCRI or GAS scoring. Further, the complexity of those scores that do show predictive abilities make their use in the clinical setting on an individual patient basis debatable, and it may be these scores should remain audit tools rather than tools on which to guide decision making.

Conflict of Interest/Funding

None declared.

References

1 Ernst CB. Abdominal aortic aneurysm. *N Engl J Med* 1993;**328**(16):1167–72.
2 Mortality results for randomised controlled trial of early elective surgery or ultrasonographic surveillance for small abdominal aortic aneurysms. The UK Small Aneurysm Trial Participants. *Lancet* 1998;**352**(9141):1649–55.
3 Eagle KA, Coley CM, Newell JB, Brewster DC, Darling RC, Strauss HW, et al. Combining clinical and thallium data optimizes preoperative assessment of cardiac risk before major vascular surgery. *Ann Intern Med* 1989;**110**:859–66.
4 Vanzetto G, Machecourt J, Blendea D, Fagret D, Borrel E, Magne JL, et al. Additive value of thallium single-photon emission computed tomography myocardial imaging for prediction of perioperative events in clinically selected high cardiac risk patient having abdominal aortic surgery. *Am J Cardiol* 1996;**77**:143–8.
5 Nesi F, Leo E, Biancari F, Bartolucci R, Rainio P, Satta J, et al. Preoperative risk stratification in patients undergoing elective infrarenal aortic aneurysm surgery: evaluation of five risk scoring methods. *Eur J Vasc Endovasc Surg* 2004;**28**:52–8.
6 Steyerberg EW, Kievit J, de Mol Van Otterloo JC, van Bockel JH, Eijkemans MJ, Habbema JD. Perioperative mortality of elective abdominal aortic aneurysm surgery. A clinical prediction rule based on literature and individual patient data. *Arch Intern Med* 1995;**155**:1998–2004.
7 Kertai MD, Steyerberg EW, Boersma E, Bax JJ, Vergouwe Y, van UH, et al. Validation of two risk models for perioperative mortality in patients undergoing elective abdominal aortic aneurysm surgery. *Vasc Endovascular Surg* 2003;**37**:13–21.
8 Tang T, Walsh SR, Fanshawe TR, Gillard JH, Sadat U, Varty K, et al. Estimation of physiologic ability and surgical stress (E-PASS) as a predictor of immediate outcome after elective abdominal aortic aneurysm surgery. *Am J Surg* 2007;**194**:176–82.
9 Samy AK, Murray G, MacBain G. Glasgow aneurysm score. *Cardiovasc Surg* 1994;**2**:41–4.
10 Copeland G, Jones D, Walters M. POSSUM: a scoring system for surgical audit. *Br J Surg* 1991;**78**:355–60.
11 Prytherch DR, Sutton GL, Boyle JR. Portsmouth POSSUM models for abdominal aortic aneurysm surgery. *Br J Surg* 2001;**88**:958–63.
12 Tang T, Walsh SR, Prytherch DR, Lees T, Varty K, Boyle JR. VBHOM, a data economic model for predicting the outcome after open abdominal aortic aneurysm surgery. *Br J Surg* 2007;**94**:717–21.
13 Patterson BO, Holt PJE, Hinchliffe R, Loftus IM, Thompson MM. Predicting risk in elective abdominal aortic aneurysm repair: a systematic review of current evidence. *Eur J Vasc Endovasc Surg* 2008;**36**:637–45.
14 Lee TH, Marcantonio ER, Mangione CM, Thomas EJ, Polanczyk CA, Cook EF, et al. Derivation and prospective validation of a simple index of prediction of cardiac risk of major noncardiac surgery. *Circulation* 1999;**100**:1043–9.

15 Gilbert K, Larocque BJ, Patrick LT. Prospective evaluation of cardiac risk indices for patients undergoing noncardiac surgery. *Ann Intern Med* 2000;**133**:356–9.
16 Alpert JS, Thygesen K, Antman E, Bassand JP. Myocardial infarction redefined – a consensus document of 'The Joint European Society of Cardiology/American College of Cardiology Committee' for the redefinition of myocardial infarction. *J Am Coll Cardiol* 2000;**36**:959–69.
17 Jones HJ, de Cossart L. Risk scoring in surgical patients. *Br J Surg* 1999;**86**:149–57.
18 Shuhaiber JH, Hankins M, Robless P, Whitehead SM. Comparison of POSSUM with P-POSSUM for prediction of mortality in infrarenal abdominal aortic aneurysm repair. *Ann Vasc Surg* 2002;**16**:736–41.
19 Prytherch DR, Ridler BM, Beard JD, Earnshaw JJ. Audit and Research Committee TVSSoGBaI. A model for national outcome audit in vascular surgery. *Eur J Vasc Endovasc Surg* 2001;**21**:477–83.
20 Earnshaw JJ, Ridler BMF, Kinsman R. *The Vascular Surgical Society of Great Britain and Ireland national outcome audit report*. London: Vascular Surgical Society of Great Britain and Ireland; 1999.
21 Biancari F, Leo E, Ylonen K, Vaarala MH, Rainio P, Juvonen T. Value of the Glasgow aneurysm score in predicting the immediate and long-term outcome after elective open repair of infrarenal abdominal aortic aneurysm. *Br J Surg* 2003;**90**:838–44.
22 Biancari F, Heikkinen M, Lepantalo M, Salenius JP. Glasgow aneurysm score in patients undergoing elective open repair of abdominal aortic aneurysm: a Finnvasc study. *Eur J Vasc Endovasc Surg* 2003;**26**:612–7.
23 Hirzalla O, Emous M, Ubbink DT, Legemate D. External validation of the Glasgow aneurysm score to predict outcome in elective open abdominal aortic aneurysm repair. *J Vasc Surg* 2006;**44**:712–6.
24 Baas AF, Janssen KJ, Prinssen M, Buskens E, Blankensteijn JD. The Glasgow aneurysm score as a tool to predict 30-day and 2-year mortality in the patients from the Dutch randomised endovascular aneurysm management trial. *J Vasc Surg* 2008;**47**:277–81.
25 Antonello M, Lepidi S, Kechagias A, Frigatti P, Tripepi A, Biancari F, et al. Glasgow aneurysm score predicts the outcome after emergency open repair of symptomatic unruptured abdominal aortic aneurysms. *Eur J Vasc Endovasc Surg* 2007;**33**:272–6.
26 Kumar R, McKinney WP, Raj G, Heudebert GR, Heller HJ, Koetting M, et al. Predicting cardiac complications in patients undergoing non-cardiac surgery. *J Ger Intern Med* 2001;**16**:507–18.
27 Jeffrey CC, Kunsman J, Cullen DJ, Brewster DC. A prospective evaluation of cardiac risk index. *Anesthesiology* 1983;**58**:462–4.
28 Poldermans D, Bax JJ, Boersma E, De Hert S, Eeckhout E, Fowkes G, et al. Guidelines for pre-operative cardiac risk assessment and perioperative cardiac management in non-cardiac surgery. *Eur Heart J* 2009;**30**:2769–812.
29 Tang TY, Walsh SR, Fanshawe TR, Seppi V, Sadat U, Hayes PD, et al. Comparison of risk-scoring methods in predicting the immediate outcome after elective open abdominal aortic aneurysm surgery. *Eur J Vasc Endovasc Surg* 2007;**34**:505–13.
30 Kertai MD, Boersma E, Klein J, van Urk H, Poldermans D. Optimizing the prediction of perioperative mortality in vascular surgery by using a customized probability model. *Arch Intern Med* 2005;**165**:898–904.
31 Giles KA, Schermerhorn ML, O'Malley AJ, Cotterill P, Jhaveri A, Pomposelli FB, et al. Risk prediction for perioperative mortality of endovascular vs open repair of abdominal aortic aneurysms using the Medicare population. *J Vasc Surg* 2009;**50**:256–62.
32 Grant SW, Grayson AD, Purkayastha D, Wilson SD, McCollum C. Logistic risk model for mortality following elective abdominal aortic aneurysm repair. *Br J Surg* 2011;**98**:652–8.