Surgery Today (2019) 49:836–842
https://doi.org/10.1007/s00595-019-01805-w

ORIGINAL ARTICLE

Predicting mortality in patients admitted to the intensive care unit after open vascular surgery

Pedro Reis[1,2] · Ana Isabel Lopes[1] · Diana Leite[1] · João Moreira[1] · Leonor Mendes[1] · Sofia Ferraz[1] · Tânia Amaral[1] · Fernando Abelha[1,2]

Received: 17 July 2018 / Accepted: 23 March 2019 / Published online: 9 April 2019

Abstract

Purposes Vascular surgery (VS) has a higher perioperative mortality than other types of surgery. We compared different scores for predicting mortality in patients admitted to the intensive care unit (ICU) after open VS.

Methods Patients admitted to the ICU after open VS from 2006 to 2013 were included. We calculated the Acute Physiology and Chronic Health Evaluation (APACHE), Simplified Acute Physiology Score (SAPS), Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity (POSSUM) and Preoperative Score to Predict Postoperative Mortality (POSPOM). We performed multivariate logistic regression to assess independent factors with the calculation of odds ratios (ORs) and 95% confidence intervals (CIs). We tested the predictive ability of the scores using the area under the receiver operating characteristics curve (AUROC).

Results A total of 833 consecutive patients were included. Hospital mortality was 5.1% (1.3% after intermediate-risk and 8.4% after high-risk surgery). In the multivariate analysis, the age (OR 1.04, 95% CI 1.01–1.08, $p=0.013$), smoking status (OR 2.46, 95% CI 1.16–5.21, $p=0.019$), surgery risk (OR 2.92, 95% CI 1.05–8.08, $p=0.040$), serum sodium level (OR 1.17, 95% CI 1.10–1.26, $p<0.001$), urea (OR 1.01, 95% CI 1.01–1.02, $p=0.001$) and leukocyte count (OR 1.05, 95% CI 1.01–1.10, $p=0.009$) at admission were considered independent predictors. Hematocrit (0.86, 95% CI 0.80–0.93, $p<0.001$) was considered an independent protective factor. The AUROC of our model was 0.860, compared to SAPS (0.752), APACHE (0.774), POSPOM (0.798) and POSSUM (0.829).

Conclusion The observed mortality was within the predicted range (1–5% after intermediate-risk and > 5% after high-risk surgery). POSSUM and POSPOM had slightly better predictive capacity than SAPS or APACHE.

Keywords Hospital mortality · SAPS · APACHE · Intensive care unit · Vascular surgery

✉ Pedro Reis
pedrojreis@hotmail.com

Ana Isabel Lopes
analopes13@gmail.com

Diana Leite
dianaleite.a@gmail.com

João Moreira
joaopbmoreira@gmail.com

Leonor Mendes
leonor.cftmendes@gmail.com

Sofia Ferraz
soferraz@gmail.com

Tânia Amaral
taniaamaral22@gmail.com

Fernando Abelha
fernando.abelha@gmail.com

[1] São João Hospital Centre, Alameda Prof Hernani Monteiro, 4200-319 Porto, Portugal

[2] Faculdade de Medicina da Universidade do Porto, Alameda Prof Hernani Monteiro, 4200-319 Porto, Portugal

Introduction

Vascular surgery (VS) accounts for 0.5–2% of the 234 million surgeries performed every year [1, 2]. Anesthetic and surgical techniques along with better planning and monitoring have decreased the intraoperative mortality [3]. However, postoperative mortality is still frequent, and 4% of patients die before hospital discharge while 5.5% die within a year [4, 5]. Deaths predominantly occur in older patients and those who undergo major or emergent surgery, who have severe coexisting diseases or who develop complications [6–9]. Perioperative complications may affect 12% of patients, a rate that tends to increase with age and comorbidities [7, 10, 11]. Immediate postoperative care allows for closer monitoring and early intervention to reduce complications and deaths [6, 7, 11]. High-risk patients or those who receive certain surgeries may benefit from admission to a surgical intensive care unit (SICU), but these beds have a limited capacity and are expensive to occupy [12, 13].

Risk models, such as the Simplified Acute Physiology Score (SAPS) and Acute Physiology and Chronic Health Evaluation (APACHE), were designed to predict mortality after ICU admission [14–16]. They focus on the severity of illness at admission, which may not be adequate for post-surgical patients [17]. The Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity (POSSUM), with or without the Portsmouth (P-POSSUM) modification and its Vascular variant (V-POSSUM), has been used to predict the 30-day mortality and morbidity after VS, but they include pre- and intraoperative variables, which may preclude their use in preoperative planning and risk estimation [18, 19]. The Preoperative Score to Predict Postoperative Mortality (POSPOM) overcomes this problem but was derived using many types of surgery [20]. The National Surgical Quality Improvement Program (NSQIP) of the American College of Surgeons (ACS) has also developed a score for predicting the postoperative mortality that can be calculated online, including a subset for use in VS, but they did not publish the equation, making it unavailable for broad clinical research [21, 22]. Assessing the mortality risk is important in an era rife with concerns about variations in the quality of care and use of healthcare resources.

The aim of this study was to evaluate the determinants of hospital mortality (HM) in a cohort of patients admitted to the SICU after open VS. In addition, we compared our model with the ICU risk scores SAPS or APACHE and the surgical risk scores V-POSSUM or POSPOM for mortality prediction after VS.

Materials and methods

Study design, setting and participants

We conducted a retrospective cohort study including all patients admitted to the Surgical ICU after open VS from January 2006 to July 2013 in a large academic hospital. We defined exposures and outcomes and planned the analysis before looking at the data. The institutional ethics committee approved the protocol. This report complies with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational cohort studies [23].

Data collection

We prospectively collected the following variables at ICU admission: age, gender, medical history, type of admission (elective or emergent), type of surgery and ventilation. Surgeries were divided into intermediate risk (carotid endarterectomy and peripheral angioplasty) and high risk (open aortic surgery, lower limb revascularization, thromboembolectomy and amputation) according to the joint guidelines of European Society of Cardiology (ESC) and European Society of Anesthesiology (ESA) [24]. During the ICU stay, prospective records were collected, including data on the vital signs, laboratory results, major cardiovascular events (MACE) (stroke, acute myocardial infarction defined as a rise in troponin > 0.034 ng/ml in the first 72 h after surgery, de novo atrial fibrillation or heart failure including pulmonary edema, ventricular fibrillation or cardiac arrest, complete heart block), renal complications (acute kidney injury as defined by the Acute Kidney Injury Network criteria [25]), length of stay (LOS) and mortality. The ICU records at admission included the SAPS and APACHE scores, whereas the POSSUM and POSPOM were calculated in retrospective.

Statistical analyses

We used descriptive statistics to summarize the data. We performed the Kolmogorov–Smirnov test and a histogram analysis to assess the normality of data and selected parametric (independent sample *t* test) or non-parametric tests (Mann–Whitney *U* test) accordingly. To compare proportions between groups in the univariate analysis, we used the Chi square test. We determined independent predictors of MACE using multivariate logistic regression with the forward conditional method, calculating the odds ratios (OR) and 95% confidence intervals (CIs). We created a model using the adjusted OR of the independent variables

as scoring points and analyzed the area under the receiver operating characteristics curve (AUROC) of the different risk indexes to measure their predictive discrimination. We used the Hosmer–Lemeshow test to determine the goodness of fit of our model (calibration), with $p > 0.05$ taken to indicate no significant difference between the predictive model and observed data. To reduce the risk of overfitting, we selected the leave-one-out cross-validation approach and bootstrapping method ($n = 1000$ samples). We performed Bonferroni correction for multiple comparisons. We used Stata software, version 14 (StataCorp) and SPSS software, version 23 (IBM) to analyze the data.

Results

We admitted 833 patients to the SICU after open VS, most of them male (80%). The HM was 5.1% overall, 1.3% after intermediate-risk surgery ($n = 5/382$) and 8.4% ($n = 38/451$) after high-risk surgery. Table 1 presents the variable distribution by HM. Aortic surgery was more common than

Table 2 Mortality by surgical site according to the expected risk

Surgical risk	Surgical site	Mortality (%)
Intermediate	Carotid	0.8
	Lower limb	1.5
High-risk	Lower limb	7.1
	Aortic	8.3

Table 1 Results of the univariate analysis of hospital mortality

Variables	Survival group $n = 790$	Mortality group $n = 43$	p value
Male gender, *n* (%)	624 (79.0)	38 (88.4)	0.138*
Age (years), median [IQR]	69 [60–76]	73 [67–78]	**0.010**†
Prior medical history, *n* (%)			
Arterial hypertension	398 (50.4)	24 (55.8)	0.488*
Diabetes mellitus	183 (23.2)	13 (30.2)	0.287*
Current smoker	164 (20.8)	16 (37.2)	**0.011***
Peripheral arterial disease	236 (29.9)	19 (44.2)	**0.046***
Coronary disease	257 (32.5)	19 (44.2)	0.114*
Congestive heart failure	179 (22.7)	22 (51.2)	**< 0.001***
Cerebrovascular disease	367 (46.5)	12 (27.9)	**0.017***
Chronic kidney disease	67 (8.5)	11 (25.6)	**0.001***
Emergent surgery, *n* (%)	63 (8.0)	11 (25.6)	**< 0.001***
High-risk surgery, *n* (%)	413 (52.3)	38 (88.4)	**< 0.001***
At admission			
Mechanical ventilation, *n* (%)	170 (21.5)	19 (44.2)	**< 0.001***
Body temperature, median [IQR]	35.9 [34.9–36.1]	35.0 [34.3–36.0]	0.116†
Systolic pressure, median [IQR]	133 [110–158]	105 [78–144]	**< 0.001**†
Mean arterial pressure, median [IQR]	89 [74–100]	78 [57–97]	**0.011**†
Heart rate, median [IQR]	78 [65–89]	91 [78–116]	**< 0.001**†
Respiratory rate, median [IQR]	14 [12–16]	16 [14–16]	**0.010**†
Hematocrit, median [IQR]	33.0 [29.7–36.0]	29.0 [22.5–33.0]	**< 0.001**†
Serum urea, median [IQR]	32 [25–43]	50 [30–70]	**< 0.001**†
Serum creatinine, median [IQR]	0.9 [0.7–1.2]	1.3 [0.8–2.1]	**< 0.001**†
Serum potassium, median [IQR]	3.8 [3.5–4.1]	3.9 [3.5–4.6]	0.171†
Serum sodium, median [IQR]	139 [137–141]	144 [140–147]	**< 0.001**†
Leukocytes count, median [IQR]	10.4 [7.9–12.9]	13.4 [7.6–20.0]	**0.002**†
During stay			
Cardiovascular events, *n* (%)	38 (4.8)	16 (37.2)	**< 0.001***
Renal complications, *n* (%)	33 (4.3)	10 (23.3)	**< 0.001***
Length of stay (hours), median [IQR]	21 [17–43]	44 [18–68]	**0.001**†

IQR interquartile range [P25–P75]

* Chi square test, † Mann–Whitney test

lower limb surgery or carotid endarterectomy and had a significantly higher mortality (8.4% vs. 6.2% vs. 0.8%, respectively; $p < 0.001$). Table 2 shows the HM by surgical site according to the expected risk. Regarding the type of admission, elective surgery had an HM rate of 4.2%, whereas emergent surgery had a rate of 14.9%. The incidence of cardiovascular events was 6.5%, and that of renal complications was 6.8% during the SICU stay; both were associated with a higher HM ($p < 0.001$). Almost half (49%) of the HM incidents occurred during the SICU stay.

Table 3 shows the difference in mortality scores. All listed scores were significantly higher ($p < 0.001$) in the mortality group than in the survival group. POSSUM predicted an HM of 5.3% ($n = 44$) and observed/expected ratio of 0.98 (43/44). Table 4 shows the results of multiple logistic regression for assessing the effect of pre-admission and at-admission variables on HM. The age, smoking status, surgery risk, serum sodium level, urea and leukocyte count at admission were considered independent predictors. Hematocrit after surgery was considered an independent protective factor with a 14% adjusted risk reduction for each 1% increase in hematocrit.

Figure 1 graphically displays the AUROC of the different scores. Our model had an AUROC of 0.860 with a Hosmer–Lemeshow test for the goodness of fit of 0.90. The ICU scores SAPS (0.752) and APACHE (0.774) were slightly worse than the surgical risk scores POSPOM (0.798) and POSSUM (0.829). Using the leave-one-out cross-validation approach and the bootstrap analysis resulted in the same AUROC: 0.858.

Discussion

In this study, we assessed the incidence and possible predictors associated with HM following SICU admission after VS. The estimated mortality according to ESA guidelines is

Table 3 Intensive care and surgical risk scores by mortality

Risk scores	Survival group $n = 790$	Mortality group $n = 43$	p value
SAPS, median [IQR]	19 [13–25]	31 [16–46]	**< 0.001***
APACHE, median [IQR]	9 [7–12]	15 [11–21]	**< 0.001***
POSPOM, median [IQR]	14 [12–16]	18 [16–23]	**< 0.001***
V-POSSUM, median [IQR]	25 [21–29]	34 [29–40]	**< 0.001***

IQR interquartile range [P25–P75], *SAPS* Simplified Acute Physiology Score, *APACHE II* Acute Physiology and Chronic Health Evaluation, *V-POSSUM* Vascular Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity, *POSPOM* Preoperative Score to Predict Postoperative Mortality

* Mann–Whitney test

Table 4 Results of the multivariate analysis of mortality predictors

Variables	OR (95% CI)	p value	Adjusted OR (95% CI)	p value
Age	**1.04 (1.01–1.07)**	**0.018**	**1.04 (1.01–1.08)**	**0.013**
Current smoker	**2.26 (1.19–4.30)**	**0.013**	**2.46 (1.16–5.21)**	**0.019**
Peripheral arterial disease	1.86 (1.00–3.46)	0.049	1.08 (0.48–2.44)	0.857
Congestive heart failure	3.58 (1.92–6.65)	< 0.001	1.87 (0.85–4.12)	0.122
Chronic kidney disease[a]	3.71 (1.79–7.69)	0.001	1.89 (0.70–5.11)	0.209
Emergent surgery	3.97 (1.91–8.25)	< 0.001	1.63 (0.62–4.30)	0.326
High-risk surgery	**6.94 (2.70–17.81)**	**< 0.001**	**2.92 (1.05–8.08)**	**0.040**
Mechanical ventilation	2.89 (1.55–5.40)	0.001	1.02 (0.44–2.37)	0.962
Systolic blood pressure	0.98 (0.97–0.99)	< 0.001	0.99 (0.98–1.00)	0.127
Heart rate	1.03 (1.02 -1.05)	< 0.001	1.04 (0.99–1.03)	0.149
Respiratory rate	1.16 (1.04–1.31)	0.010	1.04 (0.89–1.21)	0.614
Hematocrit	**0.84 (0.79–0.90)**	**< 0.001**	**0.86 (0.80–0.93)**	**< 0.001**
Serum urea	**1.02 (1.01–1.03)**	**< 0.001**	**1.01 (1.01–1.02)**	**0.001**
Serum creatinine	1.60 (1.28–2.00)	< 0.001	0.89 (0.60–1.33)	0.570
Serum sodium	**1.22 (1.15 -1.30)**	**< 0.001**	**1.17 (1.10–1.26)**	**< 0.001**
Leukocytes	**1.06 (1.02–1.10)**	**0.006**	**1.05 (1.01–1.10)**	**0.009**

The independent predictors are highlighted in bold

OR odds ratio, *CI* confidence interval

[a]Glomerular filtration rate < 60 ml/min

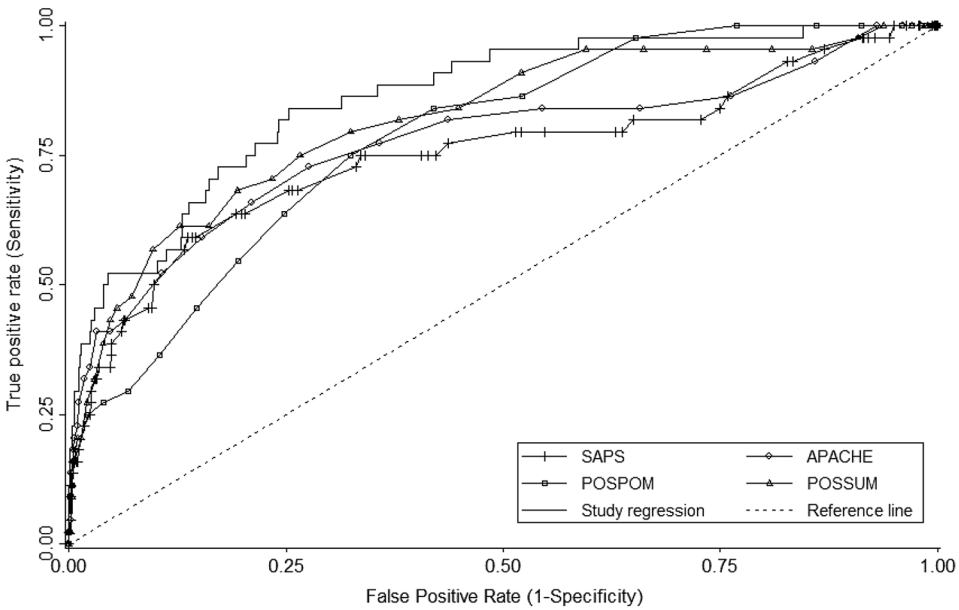

Fig. 1 Area under the receiver operating characteristic curve of the risk scores. *SAPS* Simplified Acute Physiology Score, *APACHE* Acute Physiology and Chronic Health Evaluation, *POSPOM* Preoperative Score to Predict Postoperative Mortality, *POSSUM* Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity

SAPS - Simplified Acute Physiology Score. APACHE - Acute Physiology and Chronic Health Evaluation. POSPOM - Preoperative Score to Predict Postoperative Mortality. POSSUM - Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity.

1–5% for intermediate-risk surgery and > 5% for high-risk surgery [24]. In our sample, we found similar mortality rates: 1.3% after intermediate-risk surgery and 8.4% after high-risk surgery. In our model, high-risk surgery was considered an independent risk factor increasing the risk of HM by almost threefold. Our results are consistent with previous studies showing that the mortality during ICU admission depends on the type of admission [8–10, 26, 27]. Patients undergoing emergent surgery may be more severely ill, with more uncontrolled comorbidities and a less functional reserve than in healthy patients. Furthermore, the surgeries can be more complex and intraoperative care may be suboptimal in these patients [10, 28].

In critical care, serum sodium levels have been associated with mortality [29–33]. Hypernatremia is a common complication, especially if patients are unconscious, intubated or sedated, and may indicate a hyperosmolar state and transiently intracellular dehydration [34]. In addition, age has also been associated with postoperative mortality, and the predictive ability of some scores varies according to age intervals [5, 8, 35, 36]. Both age and the serum sodium level remained independent predictors in our multivariate logistic regression analysis, which may explain why so many ICU or surgical risk scores include these parameters.

Patients who developed cardiovascular or renal complications had a higher mortality than those without such events. This has been studied in the past, and cardiovascular complications were implicated in 42% of deaths [10, 26, 37, 38]. An elevated serum urea level may reflect acute kidney injury, a known cause of increased mortality [39–42]. The LOS is also influenced by these complications along with severe illness, which may explain the differences observed [9, 37, 38, 43]. An active smoking status increases the risk of complications and mortality after surgery [44]. This may explain why the serum urea level and smoking status were considered independent predictors for mortality.

The hematocrit after surgery was an independent protective factor. Numerous studies have shown a relationship between the hematocrit or hemoglobin levels and the outcome, especially in VS patients with coronary heart disease [45–49]. Velescu et al. proved that patients with a preoperative hemoglobin level < 10 g/dl had an increased mortality rate with an adjusted OR of 3.9 [45]. Both anemia and perioperative red blood cell transfusion independently increase the risk of MACE and mortality, but unfortunately, we only had the hematocrit available for our analysis. This parameter may be considered a proxy for hemoglobin levels.

The preoperative patient evaluation using risk scores is much more objective than traditional observation-only assessment. The POSSUM score consists of 12 physiologic and 6 intraoperative variables. Even though authors advocate having scores for different surgeries (vascular, colorectal, esophagogastric), the models do not substantially differ between these procedures. Despite only using 12 physiologic variables, POSSUM was the best score for predicting HM in patients admitted to the SICU after VS in the present study. The mortality prediction with POSSUM ($n = 44$) was very close to what we observed ($n = 43$), resulting in an observed/expected ratio of 0.98. The POSPOM score was created to predict mortality after many types of surgery, so it is

unsurprising that it performed slightly worse than POSSUM. However, it has the advantage of using only preoperative variables, and the surgical specialty can be differentiated to some degree by adding more points according to the surgical risk. We, therefore, believe that it is also a good option for use in this situation. The SAPS and APACHE were specifically designed to predict mortality after ICU admission, and several modified versions of these scores have been developed over time. However, in the present cohort of patients submitted to VS, SAPS and APACHE performed worse than POSSUM or POSPOM and should be replaced by these surgical risk scores in ICU admission after surgery.

Several limitations associated with the present study warrant mention. We did not have access to data on all the intraoperative variables necessary to calculate the total POSSUM. Some scores consider the 30-day mortality, but we were only able to study the HM. In addition, we included patients encountered over a long period of time, and surgical techniques may have improved over time.

Conclusion

In conclusion, the HM in patients admitted to the SICU after open VS was 5.1%. The observed mortality was within the predicted range (1–5% after intermediate-risk and > 5% after high-risk surgery). The mortality group had significantly higher scores in SAPS, APACHE, POSSUM and POSPOM than the survival group. A longer LOS and cardiovascular and renal complications were associated with a higher HM. We identified the following independent risk factors for mortality: age, smoking status, surgery risk, serum sodium level, urea and leukocyte count at admission to the SICU. The surgical risk scores POSSUM and POSPOM predicted HM better than the ICU scores SAPS and APACHE in patients admitted to the SICU after VS.

Author contribution All authors were involved in data collection. PR was responsible for the data analysis and manuscript writing. FA coordinated the project and revised the manuscript. All authors approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest All authors have nothing to declare.

References

1. Weiser TG, Regenbogen SE, Thompson KD, Haynes AB, Lipsitz SR, Berry WR, et al. An estimation of the global volume of surgery: a modelling strategy based on available data. Lancet. 2008;372(9633):139–44.
2. Gupta PK, Gupta H, Sundaram A, Kaushik M, Fang X, Miller WJ, et al. Development and validation of a risk calculator for prediction of cardiac risk after surgery. Circulation. 2011;124(4):381–7.
3. Ohlsson H, Winso O. Assessment of the surgical Apgar Score in a Swedish setting. Acta Anaesthesiol Scand. 2011;55(5):524–9.
4. Pearse RM, Moreno RP, Bauer P, Pelosi P, Metnitz P, Spies C, et al. Mortality after surgery in Europe: a 7 day cohort study. Lancet. 2012;380(9847):1059–65.
5. Monk TG, Saini V, Weldon BC, Sigl JC. Anesthetic management and one-year mortality after noncardiac surgery. Anesth Analg. 2005;100(1):4–10.
6. Khuri SF, Henderson WG, DePalma RG, Mosca C, Healey NA, Kumbhani DJ, et al. Determinants of long-term survival after major surgery and the adverse effect of postoperative complications. Ann Surg. 2005;242(3):326–41.
7. Ghaferi AA, Birkmeyer JD, Dimick JB. Variation in hospital mortality associated with inpatient surgery. N Engl J Med. 2009;361(14):1368–75.
8. Pearse RM, Harrison DA, James P, Watson D, Hinds C, Rhodes A, et al. Identification and characterisation of the high-risk surgical population in the United Kingdom. Crit Care. 2006;10(3):R81.
9. Abelha FJ, Castro MA, Landeiro NM, Neves AM, Santos CC. Mortality and length of stay in a surgical intensive care unit. Rev Br Anestesiol. 2006;56(1):34–45.
10. Leung JM, Dzankic S. Relative importance of preoperative health status versus intraoperative factors in predicting postoperative adverse outcomes in geriatric surgical patients. J Am Geriatr Soc. 2001;49(8):1080–5.
11. Hall BL, Hamilton BH, Richards K, Bilimoria KY, Cohen ME, Ko CY. Does surgical quality improve in the American College of Surgeons National Surgical Quality Improvement Program: an evaluation of all participating hospitals. Ann Surg. 2009;250(3):363–76.
12. Weissman C. The enhanced postoperative care system. J Clin Anesth. 2005;17(4):314–22.
13. Simpson JC, Moonesinghe SR. Introduction to the postanaesthetic care unit. Perioperat Med. 2013;2(1):5.
14. Knaus WA, Draper EA, Wagner DP, Zimmerman JE. APACHE II: a severity of disease classification system. Crit Care Med. 1985;13(10):818–29.
15. Vincent JL, Moreno R. Clinical review: scoring systems in the critically ill. Crit Care. 2010;14(2):207.
16. Le Gall JR, Lemeshow S, Saulnier F. A new Simplified Acute Physiology Score (SAPS II) based on a European/North American multicenter study. J Am Med Assoc. 1993;270(24):2957–63.
17. Halpern NA, Pastores SM, Greenstein RJ. Critical care medicine in the United States 1985-2000: an analysis of bed numbers, use, and costs. Crit Care Med. 2004;32(6):1254–9.
18. Mosquera D, Chiang N, Gibberd R. Evaluation of surgical performance using V-POSSUM risk-adjusted mortality rates. ANZ J Surg. 2008;78(7):535–9.
19. Midwinter MJ, Tytherleigh M, Ashley S. Mortality and morbidity risk in Vascular Surgery using POSSUM and Portsmouth predictor equation. Br J Surg. 1999;86:471–4.
20. Le Manach Y, Collins G, Rodseth R, Le Bihan-Benjamin C, Biccard B, Riou B, et al. Preoperative Score to Predict Postoperative Mortality (POSPOM): derivation and Validation. Anesthesiology. 2016;124(3):570–9.
21. Liu Y, Cohen ME, Ko CY, Bilimoria KY, Hall BL. Considerations in releasing equations for the american college of surgeons NSQIP surgical risk calculator in: reply to Wanderer and Ehrenfeld. J Am Coll Surg. 2016;223(4):674–5.
22. Bilimoria KY, Liu Y, Paruch JL, Zhou L, Kmiecik TE, Ko CY, et al. Development and evaluation of the universal ACS NSQIP surgical risk calculator: a decision aid and informed consent tool for patients and surgeons. J Am Coll Surg. 2013;217(5):833–42.

23. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet. 2007;370:1453–7.
24. Kristensen SD, Knuuti J, Saraste A, Anker S, Botker HE, De Hert S, et al. 2014 ESC/ESA Guidelines on non-cardiac surgery: cardiovascular assessment and management: the Joint Task Force on non-cardiac surgery: cardiovascular assessment and management of the European Society of Cardiology (ESC) and the European Society of Anaesthesiology (ESA). Eur J Anaesthesiol. 2014;31(10):517–73.
25. Mehta RL, Kellum JA, Shah SV, Molitoris BA, Ronco C, Warnock DG, et al. Acute Kidney Injury Network: report of an initiative to improve outcomes in acute kidney injury. Crit Care. 2007;11(2):R31.
26. Devereaux PJ, Chan MT, Alonso-Coello P, Walsh M, Berwanger O, et al. Association between postoperative troponin levels and 30-day mortality among patients undergoing noncardiac surgery. J Am Med Assoc. 2012;307(21):2295–304.
27. Rhodes A, Moreno RP, Metnitz B, Hochrieser H, Bauer P, Metnitz P. Epidemiology and outcome following post-surgical admission to critical care. Intensive Care Med. 2011;37(9):1466–72.
28. Weissman C, Klein N. The importance of differentiating between elective and emergency postoperative critical care patients. J Crit Care. 2008;23(3):308–16.
29. Darmon M, Diconne E, Souweine B, Ruckly S, Adrie C, Azoulay E, et al. Prognostic consequences of borderline dysnatremia: pay attention to minimal serum sodium change. Crit Care. 2013;17(1):R12.
30. Funk GC, Lindner G, Druml W, Metnitz B, Schwarz C, Bauer P, et al. Incidence and prognosis of dysnatremias present on ICU admission. Intensive Care Med. 2010;36(2):304–11.
31. Darmon M, Timsit JF, Francais A, Nguile-Makao M, Adrie C, Cohen Y, et al. Association between hypernatraemia acquired in the ICU and mortality: a cohort study. Nephrol Dial Transplant. 2010;25(8):2510–5.
32. Waite MD, Fuhrman SA, Badawi O, Zuckerman IH, Franey CS. Intensive care unit-acquired hypernatremia is an independent predictor of increased mortality and length of stay. J Crit Care. 2013;28(4):405–12.
33. Stelfox HT, Ahmed SB, Khandwala F, Zygun D, Shahpori R, Laupland K. The epidemiology of intensive care unit-acquired hyponatraemia and hypernatraemia in medical–surgical intensive care units. Crit Care. 2008;12(6):R162.
34. Lindner G, Funk GC. Hypernatremia in critically ill patients. J Crit Care. 2013;28(2):216.
35. Naughton C, Feneck RO. The impact of age on 6-month survival in patients with cardiovascular risk factors undergoing elective non-cardiac surgery. Int J Clin Pract. 2007;61(5):768–76.
36. Skonetzki S, Lüders F, Engelbertz C, Malyar NM, Freisinger E, Meyborg M, et al. Aging and outcome in patients with peripheral artery disease and critical limb ischemia. J Post-Acute Long-Term Care Med. 2016;17(10):927–32.
37. Maia PC, Abelha FJ. Predictors of major postoperative cardiac complications in a surgical ICU. Portug J Cardiol. 2008;27(3):321–8.
38. Abelha FJ, Botelho M, Fernandes V, Barros H. Quality of life and mortality assessment in patients with major cardiac events in the postoperative period. Rev Br Anestesiol. 2010;60(3):268–84.
39. Flores E, Lewinger JP, Rowe VL, Woo K, Weaver FA, Shavelle D, et al. Increased risk of mortality after lower extremity bypass in individuals with acute kidney injury in the vascular quality initiative. J Vasc Surg. 2017;65(4):1055–61.
40. Huber M, Ozrazgat-Baslanti T, Thottakkara P, Efron PA, Feezor R, Hobson C, et al. Mortality and cost of acute and chronic kidney disease after vascular surgery. Ann Vasc Surg. 2016;30:72–81.
41. Arora P, Davari-Farid S, Pourafkari L, Gupta A, Dosluoglu HH, Nader ND, et al. The effect of acute kidney injury after revascularization on the development of chronic kidney disease and mortality in patients with chronic limb ischemia. J Vasc Surg. 2015;61(3):720–7.
42. O'Hare AM, Sidawy AN, Feinglass J, Merine KM, Daley J, Khuri S, et al. Influence of renal insufficiency on limb loss and mortality after initial lower extremity surgical revascularization. J Vasc Surg. 2004;39(4):709–16.
43. Lobo SM, Rezende E, Knibel MF, Silva NB, Paramo JA, Nacul FE, et al. Early determinants of death due to multiple organ failure after noncardiac surgery in high-risk patients. Anesth Analg. 2011;112(4):877–83.
44. Chen SL, Whealon MD, Kabutey NK, Kuo IJ, Sgroi MD, Fujitani RM. Outcomes of open and endovascular lower extremity revascularization in active smokers with advanced peripheral arterial disease. J Vasc Surg. 2017;65(6):1680–9.
45. Velescu A, Clará A, Cladellas M, Peñafiel J, Mateos E, Ibañez S, et al. Anemia increases mortality after open or endovascular treatment in patients with critical limb ischemia: a retrospective analysis. Eur J Vasc Endovasc Surg. 2016;51(4):543–9.
46. Ad N, Holmes SD, Massimiano PS, Spiegelstein D, Shuman DJ, Pritchard G, et al. Operative risk and preoperative hematocrit in bypass graft surgery: role of gender and blood transfusion. Cardiovasc Revasc Med. 2015;16(7):397–400.
47. Gupta PK, Sundaram A, MacTaggart JN, Johanning JM, Gupta H, Fang X, et al. Preoperative anemia is an independent predictor of postoperative mortality and adverse cardiac events in elderly patients undergoing elective vascular operations. Ann Surg. 2013;258(6):1096–102.
48. Valentijn TM, Hoeks SE, Bakker EJ, van de Luijtgaarden KM, Verhagen HJ, Stolker RJ, et al. The impact of perioperative red blood cell transfusions on postoperative outcomes in vascular surgery patients. Ann Vasc Surg. 2015;29(3):511–9.
49. O'Keeffe SD, Davenport DL, Minion DJ, Sorial EE, Endean ED, Xenos ES. Blood transfusion is associated with increased morbidity and mortality after lower extremity revascularization. J Vasc Surg. 2010;51(3):616–21.