Rev Bras Anestesiol. 2018;68(5):492–498

REVISTA BRASILEIRA DE ANESTESIOLOGIA

Publicação Oficial da Sociedade Brasileira de Anestesiologia
www.sba.com.br

SCIENTIFIC ARTICLE

Predictors of in-hospital mortality in patients undergoing elective surgery in a university hospital: a prospective cohort

Adriene Stahlschmidt*, Betânia Novelo, Luiza Alexi Freitas, Sávio Cavalcante Passos, Jairo Alberto Dussán-Sarria, Elaine Aparecida Félix, Patrícia Wajnberg Gamermann, Wolnei Caumo, Luciana Paula Cadore Stefani

Hospital de Clínicas de Porto Alegre, Porto Alegre, RS, Brazil

Received 17 May 2017; accepted 6 April 2018
Available online 3 July 2018

KEYWORDS
Perioperative care;
Non-elective surgeries;
Postoperative complications;
Hospital mortality

Abstract
Introduction: Morbidity and mortality associated with urgent or emergency surgeries are high compared to elective procedures. Perioperative risk scores identify the non-elective character as an independent factor of complications and death. The present study aims to characterize the population undergoing non-elective surgeries at the Hospital de Clínicas de Porto Alegre and identify the clinical and surgical factors associated with death within 30 days postoperatively.
Methodology: A prospective cohort study of 187 patients undergoing elective surgeries between April and May 2014 at the Hospital de Clínicas, Porto Alegre. Patient-related data, pre-operative risk situations, and surgical information were evaluated. Death in 30 days was the primary outcome measured.
Results: The mean age of the sample was 48.5 years, and 84.4% of the subjects had comorbidities. The primary endpoint was observed in 14.4% of the cases, with exploratory laparotomy being the procedure with the highest mortality (47.7%). After multivariate logistic regression, age (odds ratio [OR] 1.0360, $p < 0.05$), anemia (OR 3.961, $p < 0.05$), acute or chronic renal insufficiency (OR 6.075, $p < 0.05$), sepsis (OR 7.027, $p < 0.05$), and patient-related risk factors for mortality, in addition to the large surgery category (OR 7.502, $p < 0.05$) were identified.
Conclusion: The high mortality rate found may reflect the high complexity of the institution's patients. Knowing the profile of the patients assisted helps in the definition of management priorities, suggesting the need to create specific care lines for groups identified as high risk in order to reduce perioperative complications and deaths.

* Corresponding author.
E-mail: adristah@gmail.com (A. Stahlschmidt).

https://doi.org/10.1016/j.bjane.2018.04.009

PALAVRAS-CHAVE
Cuidado perioperatório;
Cirurgias não eletivas;
Complicações pós-operatórias;
Mortalidade hospitalar

Preditores de mortalidade intra-hospitalar em pacientes submetidos a cirurgias não eletivas em um hospital universitário: uma coorte prospectiva

Resumo
Introdução: Quando comparada a procedimentos eletivos, a morbimortalidade associada às cirurgias de urgência ou emergência é alta. Escores de risco perioperatório identificam o caráter não eletivo como fator independente de complicações e morte. O presente estudo objetiva caracterizar a população submetida a cirurgias não eletivas no Hospital de Clínicas de Porto Alegre e identificar fatores clínicos e cirúrgicos associados à morte em 30 dias no pós-operatório.
Metodologia: Coorte prospectiva de 187 pacientes submetidos a cirurgias não eletivas entre abril e maio de 2014 no Hospital de Clínicas de Porto Alegre. Avaliaram-se dados relacionados ao paciente, situações de risco pré-operatórias e informações do âmbito cirúrgico. Mensurou-se óbito em 30 dias como desfecho primário.
Resultados: A média de idade da amostra foi 48,5 anos; 84,4% dos indivíduos apresentavam comorbidades. O desfecho primário foi observado em 14,4% dos casos, laparotomia exploradora foi o procedimento com maior mortalidade (47,7%). Após regressão logística multivariada, identificaram-se idade (*odds ratio* [OR] 1.0360, $p < 0,05$), anemia (OR 3.961, $p < 0,05$), insuficiência renal aguda ou crônica agudizada (OR 6.075, $p < 0,05$) e sepse (OR 7.027, $p < 0,05$) como os fatores de risco relacionados ao paciente significativos para mortalidade, além da categoria cirurgia de grande porte (OR 7.502, $p < 0,05$).
Conclusão: A elevada taxa de mortalidade encontrada pode refletir a alta complexidade dos pacientes da instituição. O conhecimento do perfil dos pacientes atendidos auxilia na definição de prioridades de gerenciamento, sugere a necessidade de criação de linhas de cuidado específicas para grupos identificados como de alto risco, a fim de reduzir complicações e óbitos no perioperatório.

Introduction

According to data from the World Health Organization (WHO), more than 234 million surgical procedures are performed annually.[1] In developed countries, surgical mortality is estimated to oscillate between 0.4% and 0.8% and complications occur in 3–17% of cases[2]; these figures are even higher in developing countries.[3] When evaluating only non-elective procedures, these rates increase and, although there is a shortage of work in this context, mortality is reported about 10 times higher.[4,5] This can be explained both by the lack of time to perform a satisfactory preoperative evaluation and consequent improvement of the risk situations and by the profile of the patients admitted in this context.

A number of challenges are present when performing non-elective surgical procedures, the difficulty of balancing the demand between elective and emergency surgeries, improving the flow of bed occupancy, and providing quality patient care are the main ones. In order to solve them, the creation of institutional protocols appears as an adequate way of ordering the management without affecting the quality of care.[2]

In the creation of such protocols, a systematic review of the literature points to baseline clinical conditions as the most relevant factor for increasing mortality.[3] In the light of this, how best to stratify the risk of patients undergoing non-elective procedures was assessed.[4,6] However, current tools to assess perioperative risk are not validated for different populations, they may not reflect the Brazilian reality, since each institution has unique characteristics with its own demand and resources, which need to be considered when implanting a model of care.

In that sense, the Service of Anesthesia and Perioperative Medicine of the Hospital de Clínicas de Porto Alegre (SAMPE/HCPA) developed and validated with national data the SAMPE model of Perioperative Mortality Prediction. This score is composed of four variables that are easily collected in the preoperative period: age, classification according to the American Society of Anesthesiologists (ASA), size of the procedure, and type of surgery (urgent or elective).[7]

In order to improve the flow and quality of patient care in our institution and considering that urgent and emergency surgeries were identified as independent predictors of mortality, the present study aims to characterize the population undergoing non-elective surgeries at HCPA and to identify clinical factors and surgical complications associated with death within 30 days postoperatively.

Method

A prospective cohort study that evaluated patients undergoing surgeries in the emergency room of the Hospital de Clínicas de Porto Alegre (HCPA) surgical block. HCPA is a university quaternary institution of reference in the south of the country, linked to the Federal University of Rio Grande

do Sul; it has 741 beds and performs about 20,000 surgeries per year, attending all age groups. The study was approved by the Ethics and Research Committee of the same institution, registered under number 14-0252.

Consecutive adult patients were included between April 21, 2014 and May 20, 2014. Patients younger than 16 years or undergoing diagnostic or outpatient procedures were excluded.

Preoperative, perioperative, and postoperative data were obtained by reviewing the electronic medical records and printed anesthesia records. The researchers were resident physicians trained in the search for information related to preoperative comorbidities, surgery, and anesthesia, as well as details of perioperative and postoperative complications.

Among the data related to surgery, the following were evaluated: temporal classification, according to international guidelines—in emergency, urgency, non-urgent/non-elective, and elective[2] (Table 1); size of surgery, according to the classification by Glance et al.[8]; time between the surgical indication and its performance; duration of the procedure; and reintervention requirement (Table 1).[9]

The follow-up of the cases occurred by daily review of the medical records until hospital discharge, or until the 30th day of hospitalization if the patient remained in prolonged hospitalization after surgery. The primary outcome was mortality, defined as in-hospital death within 30 days. In the evaluation of postoperative complications, the Postoperative Morbidity Survey (POMS) scale was used, composed of nine domains, which register morbidity according to the presence or absence of pre-established criteria.[10]

Statistical analysis

Frequencies and percentages were calculated for categorical variables; continuous variables are presented as mean ± standard deviation (SD). Fisher's and χ^2 tests were used to compare categorical variables and Student's *t*-test for continuous variables. To build the logistic regression model, LASSO (Least Absolute Shrinkage and Selection Operator) technique was used to select the predictor variables with more accuracy and less possibility of overfitting due to the reduced number of events in relation to the number of predictors. This technique is considered a regularization method that selects the significant variables and reduces the coefficients of unimportant predictors.[11,12] Odds ratios and 95% confidence intervals (CI) were calculated to determine the association magnitude. A *p*-value <0.05 was considered statistically significant. Sigma Stat (SPSS) version 22.0 and the Statistical Analysis System (SAS Studio) were used.

Table 1 Temporal classification of surgeries.

Emergency: Immediate risk to life, organ or limb
Urgency: If not performed within hours can cause injury, including life-threatening or organ dysfunction
Non-urgent and non-elective (NU/NE) or time-sensitive procedure: If not performed within days can cause injury (organic dysfunction or reduced quality of life)
Elective

Source: Guidelines ACC/AHA (American College of Cardiology/American Heart Association) 2014 (9).

Results

Demographic data, clinical characteristics, and surgical procedures

During the study period, 187 patients were followed up, mean age was 48 (±20.6 years), 48% male, 38% ASA II, 29% ASA III, and 16% ASA ≥IV (Table 2).

Among the surgeries, 24.1% were stratified as minor, 43.3% as intermediate, and 32.6% as major; the mean time to perform the procedure was 2.1 ± 1.2 h. Regarding temporal classification: 12.3% of the surgeries were configured as emergencies (2.1% of those with organ or limb risk), 46% as urgencies, 28.3% as non-urgent and non-elective, and 13.4% as elective. The most frequent procedures were cholecystectomy, exploratory laparotomy (EL), minor genitourinary tract procedures (26.7, 23.5, and 12.3%, respectively). EL was highlighted by the high mortality rate (47.7%) and was responsible for 85.1% of all deaths, in addition to the highest reintervention rate (20.4% × 10.6% of total cases).

There was a great variability in the mean time between the surgical indication and its effective execution, totaling 28.3 ± 66 h, distributed as follows: 54% performed in ≤12 h; 26.2% between 12 and 24 h; 11.2% between 24 and 48 h; 8.5% after 48 h of indication. Significant intraoperative bleeding (>500 mL) occurred in 8% of cases, particularly among death cases (22.2%).

Morbidity and mortality and in-hospital complications

The postoperative mortality was 14.4%; 96.3% had one or more preoperative risk situations present. Among the preoperative clinical risk situations, anemia, acute renal failure (ARF) or acute chronic kidney disease (CKD), sepsis, shock, hemodynamic instability, and metastatic neoplasia were noted in order of prevalence. Anemia, the most frequent, was present in 74.07% of the patients with primary outcome. Among the deaths, the presence of ARF or acute CKD (59.25%) and sepsis (44.4%) were also noted. Regarding postoperative follow-up, complications were recorded on POMS scale in 52.4% of the patients, with infectious, pulmonary, and cardiovascular events being the most frequent (36.4, 26.3, 14.4, and 12.3%, respectively).

Risk predictors

The significant variables identified by the univariate analysis or those with greater plausibility to be associated with the outcome were included in the Lasso technique for pre-selection for the logistic regression model. We adopted this strategy to reduce the possibility of overfitting due to the small number of events in relation to the possible predictors. We chose to exclude from the model the ASA classification because, although universally accepted and with a defined prognostic value, it is composed of the

Table 2 Cohort description[a] and association with 30-day mortality.

	Total	Survivors	30-Day mortality	Adjusted waste	*p*
Sample	187	160 (85.6%)	27 (14.4%)		
Sex (male)	90 (48.13%)	76 (84.4%)	14 (15.6%)		0.67
Age (years)	48.5 ± 20.6	46.37 ± 20.6	61.41 ± 16.04	$F = 4.39$	0.037
ASA status					
I	31 (16.6%)	31 (19.4%)	0	2.5	0.01
II	71 (38%)	64 (40%)	7 (26%)	4.0	<0.001
III	55 (29.4%)	47 (29.4%)	8 (29.6%)	0	1
≥IV	30 (16.1%)	18 (7.5%)	12 (44.4%)	7.7	<0.001
Risk situations					
Anemia	54 (28.8%)	34 (21.2%)	20 (74.1%)	5.6	<0.001
Shock	14 (7.48%)	5 (3.1%)	9 (33.3%)	5.5	<0.001
Hemodynamic instability	18 (9.6%)	9 (5.6%)	9 (33.3%)	4.5	<0.001
Cardiopathy	21 (11.2%)	20 (12.5%)	1 (3.7%)	0.3	0.73
ARF or acute CKD	33 (17.6%)	17 (10.6%)	16 (59.2%)	6.1	<0.001
Sepsis	24 (12.8%)	12 (7.5%)	12 (44.4%)	5.3	<0.001
Metastatic neoplasia	6 (3.2%)	2 (1.2%)	4 (14.8%)	3.7	<0.001
Surgery size					
Minor	45 (24.1%)	42 (26.2%)	3 (11.1%)	1.7	0.09
Intermediate	81 (43.3)	79 (49.4%)	2 (7.4%)	4.1	0.00
Major	61 (32.6%)	39 (24.4%)	22 (81.5%)	5.9	0.00
Temporal classification					
Emergency	23 (12.3%)	12 (7.5%)	11 (40.7%)	4.9	<0.001
Urgency	86 (46%)	72 (45%)	14 (51.9%)	0.7	0.48
NU/NE	78 (41.7%)	76 (40.6%)	2 (7.4%)	2.6	0.001
Procedure					
VLP cholecystectomy	50 (26.7%)	49 (30.6%)	1 (3.7%)	2.9	<0.001
Exploratory laparotomy	44 (23.5%)	23 (14.4%)	21 (77.8%)	7.2	<0.001
Minor GUT procedure	23 (12.3%)	21 (13.1%)	2 (7.4%)	0.8	0.42
Appendectomy	16 (8.5%)	16 (10%)	0	1.7	0.09
Surgical debridement	9 (4.8%)	8 (5%)	1 (3.7%)	0.3	0.76
Minor neurosurgery	7 (3.7%)	6 (3.7%)	1 (3.7%)	0	<0.001
Duration of surgery (h)	2.1 ± 1.2	1.99 (0.99)	2.32 (1.86)	$F = 6.28$	0.013
Intraoperative bleeding	15 (8%)	9 (5.6%)	6 (22.2%)	2.9	0.013
Reintervention	33 (17.64%)	23 (14.4%)	10 (37%)	2.9	0.04
Time from indication to execution					
≤12 h	101 (54%)	81 (50.6%)	20 (74.1%)	2.3	0.02
12–24 h	49 (26.2%)	47 (29.4%)	2 (7.4%)	2.4	0.02
24–48 h	21 (11.2%)	16 (10%)	5 (18.5%)	1.3	0.10
≥48 h	16 (8.5%)	16 (10%)	0	1.7	0.09
Complications (POMS)					
Pulmonary	49 (26.2%)	31 (19.4%)	18 (66.7%)	5.2	<0.001
Infectious	68 (36.4%)	52 (32.5%)	16 (59.2%)	2.7	0.01
Renal	23 (12.3%)	11 (6.9%)	12 (44.4%)	5.5	<0.001
Gastrointestinal	15 (8%)	7 (4.4%)	8 (29.6%)	4.5	<0.001
Cardiovascular	27 (14.4%)	14 (8.7%)	13 (48.1%)	5.4	<0.01
Neurologic	10 (5.3%)	4 (2.5%)	6 (22.2%)	4.2	<0.001
Surgical wound	17 (9.1%)	12 (7.5%)	5 (18.5%)	1.8	0.07

ARF, acute renal failure; CKD, chronic kidney disease; VLP, videolaparoscopic; GUT, genitourinary tract; NU, non-urgent; NE, non-elective.
[a] Data presented as mean ± SD or *n* (%).

Table 3 Factors associated with outcome-logistic regression.[a]

	B	SEM	Odds ratio (95% CI)	*p*
Anemia	1.37	0.602	3.70 (1.14–12.05)	0.029
ARF or acute CKD	2.05	0.611	7.82 (2.36–25.89)	0.001
Sepsis	1.75	0.618	5.78 (1.72–19.42)	0.005
Major	2.180	0.79	8.85 (1.85–42.3)	0.006

ARF, acute renal failure; CKD, chronic kidney disease.
[a] Variables tested using LASSO technique, which were not significant and did not enter the final model: age, hemodynamic instability, cardiac disease, metastatic neoplasia, surgical time, intraoperative bleeding, reintervention, temporal classification.

clinical factors defined in the study as preoperative clinical risk situations. Age was grouped in age groups due to its non-linear behavior and, nevertheless, it was not included in the final model. Anemia (OR = 3.70, 95% CI 1.14–12.05), ARF or acute CKD (OR = 7.82, 95% CI 2.36–25.89), and sepsis (OR = 5.78, 95% CI −1.72 to 19.42) were maintained as significant patient-related risk factors for 30-day mortality. Among the surgical factors, only the large category (OR 8.85, 95% CI 1.85–42.3) was related to the outcome after logistic regression (Table 3).

Discussion

Our study confirmed high in-hospital mortality in patients undergoing elective surgeries (14.4%). The data found are compatible with those of the national literature on severe patients hospitalized in Intensive Care Units (ICUs) in the postoperative period of non-cardiac surgeries.[13] This result reflects the high complexity of the population served (45.4% ASA ≥III) and it shows the difficulty of access and early diagnosis of surgical diseases in the population served by the Brazilian Unified Health System.

Aiming to define strategies to improve the outcomes of surgical patients, the present study sought to examine the clinical and surgical factors involved in the higher incidence of complications and death in non-elective surgeries. Preoperative risk situations, such as anemia, ARF or acute CKF, and sepsis, have made patients more susceptible to death, so patients with these comorbidities may set up a target group for preoperative intervention prior to referral to the surgical block. Anemia is a prevalent finding both in critical patients (about 60% of those admitted to the ICU) and in those undergoing high-risk surgical procedures.[14,15] A recent systematic review has shown that it contributes to anastomosis dehiscence[16] and postoperative infection, in addition to being associated with hemodynamic instability and tissue hypoperfusion in critically ill patient, it is an independent risk factor for death in these individuals.

The high prevalence of sepsis among patients who died (44.4%) corroborates the profile of patients seen in the emergency room of this hospital, which does not include trauma. The results found are compatible with other Brazilian studies, with sepsis rates up to 73% among deaths and high prevalence of multiple organ and system dysfunction secondary to this condition.[13] In order to minimize this outcome, early administration of antibiotics and performing resuscitation in the first hours seem to prevent tissue hypoperfusion, which is associated with worsening of symptoms. Proper management of septic shock, according to Surviving Sepsis Campaign guidelines,[17] although questioned in recent studies,[18] seems to have played a role in resuscitation in this condition.

Another factor identified in our study is that the perioperative incidence of ARF or acute CKD varies according to its etiology, definition, and type of surgery; however, for all cases, renal failure is associated with mortality rates ranging from 60% to 90%. Postoperative renal dysfunction is also accompanied by a higher incidence of gastrointestinal bleeding, respiratory infection, and sepsis. Although several preventive strategies have been described, they lack substantial clinical trials for confirmation; there is better evidence of benefits only for maintenance of normovolemia.[19]

The variable 'major surgery' was an independent predictor of mortality. The high mortality rate among exploratory laparotomies (47.7%) stands out, accounting for 85.1% of all deaths. These rates are higher than those in the literature, whose mortality rate after elective major abdominal surgeries may be as high as 17%, but usually stays between 3% and 7%.[20] It is known that urgent abdominal surgery is accompanied by several factors that increase the risk of postoperative complications, such as fasting, multiple drug use, immobility, use of nasogastric tubes, and delayed bladder catheterization. Of these, many are modifiable; care should be taken to prevent complications especially in more vulnerable populations.[21]

Recent audit showed a high mortality rate (14.9%) for laparotomies in 35 hospitals in the United Kingdom. This fact motivated the NELA project — National Emergency Laparotomy Audit, consisting of a series of preoperative, intraoperative, and postoperative measures to improve outcomes in this population with multiple comorbidities undergoing surgeries under non-elective conditions. Among the preoperative measures, we highlight the management planned by the surgeon and diagnostic definition as soon as possible, formal access to risk of death and complications, early administration of antibiotics, and early surgery. The results of this project are still expected.[22]

The time interval between the indication of surgery and its performance, a factor regarded as important considering the context of non-elective surgeries, did not change the mortality. This fact strengthens the hypothesis that the use of structured preoperative care that minimizes the impact of the identified risk situations seems to be more relevant than reducing the time to perform the surgery.

Among the surgical factors, we highlight the importance of supervision to resident physicians by preceptors. Although

it has not reached statistical significance in our study, this factor has already been highlighted in the literature by the New South Wales Health Emergency Surgery Guidelines as one of the main goals of service restructuring.[2] Similarly, the duration of the surgery, although it had no association in the present work (mean duration of 2.1 ± 1.2 h), recent studies with a sample composed mostly of elective surgeries have identified duration longer than 130 min as an independent risk factor for complications, as well as being associated with a longer hospital stay.[23]

Because the cohort had a limited number of patients and although the death outcome was significant in this high-risk population, the regression model variables were selected with a penalty technique called Lasso to reduce the possibility of overfitting. In this scenario, one should consider the limitation of the odds ratio values obtained due to large confidence intervals. In addition, the present study is limited by the observational design, sample size, and patient recruitment in a single hospital. However, it can contribute significantly to standardizing care in the context in which it was developed. Knowledge of the profile of this served patients helps in the definition of management priorities, suggests the need to create specific care lines for groups identified as high risk in order to reduce perioperative complications and deaths.

It is important to emphasize that our study was conducted in a tertiary institution of a developing country, which, together with the severity of the study population, may have influenced the results. The association between perioperative mortality and the Human Development Index (HDI) among different countries was recently evaluated in patients undergoing general anesthesia. The authors concluded that perioperative mortality has declined significantly over the last 50 years, particularly in developed countries.[24] However, in developing countries, this rate is still higher than that of developed countries (19–51/10,000 in Brazil *versus* 20/10,000).[3]

A recent cohort[25] supported these results, showing great variability of post-surgical mortality among European countries, much higher in countries with a lower development index. These studies corroborate the importance of health system organization in post-surgical outcomes. The recognition of high surgical risk patients, who are responsible for the highest number of perioperative deaths, is fundamental for the creation of protective strategies and differentiated care lines. Comparative data from American hospitals have shown that post-surgical survival is greater in those who early recognize the most severe patients, although the number of complications is similar between institutions.[26]

Therefore, it can be concluded that improved outcomes depends fundamentally on two factors: first, the recognition of patients at greater risk, which allows the adoption of individual and stratified care, assists in managing the flow of surgical patients in the short, medium, and long term; and second, early treatment of complications, by minimizing situations of failure to rescue, which allows the reduction of adverse outcomes. Factors associated with difficulty in recognizing and treating complications include the high volume of patients and the reduced nursing staff, as well as communication failure and no risk escalation.[27]

The recognition of failures in the surgical patient care process is important so that improvements can be proposed in different moments of the perioperative period, in an attempt to reduce the fragmentation of care.

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Weiser TG, Regenbogen SE, Thompson KD, et al. An estimation of the global volume of surgery: a modelling strategy based on available data. Lancet. 2008;372:139–44.
2. State of Victoria – Department of Health & Human Services. Good practice in management of emergency surgery: a literature review; 2017. p. 1–79. Available from: https://www2.health.vic.gov.au/about/publications/policiesandguidelines/Good-practice-in-management-of-emergency-surgery-a-literature-review [Internet] [cited 10.05.17].
3. Braz LG, Braz DG, Cruz DS, et al. Mortality in anesthesia: a systematic review. Clinics. 2009;64:999–1006.
4. Neary WD, Foy C, Heather BP, et al. Identifying high-risk patients undergoing urgent and emergency surgery. Ann R Coll Surg Engl. 2006;88:151–6.
5. Pearse RM, Harrison DA, James P, et al. Identification and characterisation of the high-risk surgical population in the United Kingdom. Crit Care. 2006;10:R81.
6. Pearse R. Study Protocol v2.0 – Enhanced Peri-Operative Care for High-risk patients (EPOCH) Trial; 2017. p. 1–28. Available from: http://www.epochtrial.org/epoch.php?page=docs [Internet] [cited 10.05.17].
7. Stefani LC, Gutierrez CS, Castro SMJ, et al. Derivation and validation of a preoperative risk model for postoperative mortality (SAMPE model): an approach to care stratification. PLoS ONE. 2017;12:e122–0187.
8. Glance LG, Lustik SJ, Hannan EL, et al. The surgical mortality probability model. Ann Surg. 2012;255:696–702.
9. Fleisher LA, Fleischmann KE, Auerbach AD, et al. 2014 ACC/AHA guideline on perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. Circulation. 2014;130:2215–45.
10. Grocott MP, Browne JP, Van der Meulen J, et al. The postoperative morbidity survey was validated and used to describe morbidity after major surgery. J Clin Epidemiol. 2007;60:919–28.
11. Pavlou M, Ambler G, Seaman SR, et al. How to develop a more accurate risk prediction model when there are few events. BMJ. 2015;351:h3868.
12. Babyak AM. What you see may not be what you get: a brief, nontechnical introduction to overfitting in regression-type models. Psychosom Med. 2004;66:411–21.
13. Lobo SM, Rezende E, Knibel MF, et al. Epidemiologia e desfecho de pacientes cirúrgicos não cardíacos em unidades de terapia intensiva no Brasil. Rev Bras Ter Intensiva. 2008;20:376–84.
14. Hajjar LA, Fukushima JT, Almeida JP, et al. Strategies to reduce blood transfusion: a Latin-American perspective. Curr Opin Anaesthesiol. 2015;28:81–8.
15. Retter A, Wyncoll D, Pearse R, et al. Guidelines on the management of anaemia and red cell transfusion in adult critically ill patients. Br J Haematol. 2013;160:445–64.
16. van Rooijen SJ, Huisman D, Stuijvenberg M, et al. Intraoperative modifiable risk factors of colorectal anastomotic leakage: why

surgeons and anesthesiologists should act together. Int J Surg. 2016;36 Pt A:183–200.
17. Rhodes A, Evans LE, Alhazzani W, et al. Surviving sepsis campaign: international guidelines for management of sepsis and septic shock: 2016. Intensive Care Med. 2017;43:304–77.
18. ProCESS Investigators, Yealy DM, Kellum JA, et al. A randomized trial of protocol-based care for early septic shock. N Engl J Med. 2014;370:1683–93.
19. Sear JW. Kidney dysfunction in the postoperative period. Br J Anaesth. 2005;95:20–32.
20. Jakobson T, Karjagin J, Vipp L, et al. Postoperative complications and mortality after major gastrointestinal surgery. Medicina. 2014;50:111–7.
21. Merani S, Payne J, Padwal RS, et al. Predictors of in-hospital mortality and complications in very elderly patients undergoing emergency surgery. World J Emerg Surg. 2014;9:43.
22. Saunders DI, Murray D, Pichel AC, et al. Variations in mortality after emergency laparotomy: the first report of the UK Emergency Laparotomy Network. Br J Anaesth. 2012;109:368–75.
23. Grocott MP, Pearse RM. Prognostic studies of perioperative risk: robust methodology is needed. Br J Anaesth. 2010;105:243–5.
24. Bainbridge D, Martin J, Arango M, et al., Evidence-based Peri-operative Clinical Outcomes Research (EPiCOR) Group. Perioperative and anaesthetic-related mortality in developed and developing countries: a systematic review and meta-analysis. Lancet. 2012;380:1075–81.
25. Pearse RM, Moreno RP, Bauer P, et al. Mortality after surgery in Europe: a 7 day cohort study. Lancet. 2012;380:1059–65.
26. Ghaferi AA, Birkmeyer JD, Dimick JB. Variation in hospital mortality associated with inpatient surgery. N Engl J Med. 2009;361:1368–75.
27. Johnston MJ, Arora S, King D, et al. A systematic review to identify the factors that affect failure to rescue and escalation of care in surgery. Surgery. 2015;157:752–63.