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SCIENTIFIC ARTICLE

Severity of disease scoring systems and mortality after non-cardiac surgery

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Abstract
Background: Mortality after surgery is frequent and severity of disease scoring systems are used for prediction. Our aim was to evaluate predictors for mortality after non-cardiac surgery.
Methods: Adult patients admitted at our surgical intensive care unit between January 2006 and July 2013 was included. Univariate analysis was carried using Mann–Whitney, Chi-square or Fisher's exact test. Logistic regression was performed to assess independent factors with calculation of odds ratio and 95% confidence interval (95% CI).
Results: 4398 patients were included. Mortality was 1.4% in surgical intensive care unit and 7.4% during hospital stay. Independent predictors of mortality in surgical intensive care unit were APACHE II (OR = 1.24); emergent surgery (OR = 4.10), serum sodium (OR = 1.06) and FiO_2 at admission (OR = 14.31). Serum bicarbonate at admission (OR = 0.89) was considered a protective factor. Independent predictors of hospital mortality were age (OR = 1.02), APACHE II (OR = 1.09), emergency surgery (OR = 1.82), high-risk surgery (OR = 1.61), FiO_2 at admission (OR = 1.02), post-operative acute renal failure (OR = 1.96), heart rate (OR = 1.01) and serum sodium (OR = 1.04). Dying patients had higher scores in severity of disease scoring systems and longer surgical intensive care unit stay.
Conclusion: Some factors influenced both surgical intensive care unit and hospital mortality.

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PALAVRAS-CHAVE
Mortalidade após cirurgia;
Sistemas de classificação da gravidade da doença;
APACHE II;
SAPS II;
Unidade de terapia intensiva cirúrgica;
Cirurgia não cardíaca

Sistemas de classificação da gravidade da doença e mortalidade após cirurgia não cardíaca

Resumo
Justificativa: A mortalidade após cirurgia é frequente e os sistemas de classificação da gravidade da doença são usados para a previsão. Nosso objetivo foi avaliar os preditivos de mortalidade após cirurgia não cardíaca.
Métodos: Os pacientes adultos admitidos em nossa unidade de terapia intensiva cirúrgica entre janeiro de 2006 e julho de 2013 foram incluídos. Análise univariada foi realizada usando o teste de Mann-Whitney, qui-quadrado ou exato de Fisher. Regressão logística foi realizada para avaliar fatores independentes com cálculo de razão de chances (*odds ratio* – OR) e intervalo de confiança de 95% (IC 95%).
Resultados: No total, 4.398 pacientes foram incluídos. A mortalidade foi de 1,4% na unidade de terapia intensiva cirúrgica e de 7,4% durante a internação hospitalar. Os preditivos independentes de mortalidade na unidade de terapia intensiva cirúrgica foram APACHE II (OR = 1,24); cirurgia de emergência (OR = 4,10), sódio sérico (OR = 1,06) e FiO_2 na admissão (OR = 14,31). Bicarbonato sérico na admissão (OR = 0,89) foi considerado um fator protetor. Os preditivos independentes de mortalidade hospitalar foram idade (OR = 1,02), APACHE II (OR = 1,09), cirurgia de emergência (OR = 1,82), cirurgia de alto risco (OR = 1,61), FiO_2 na admissão (OR = 1,02), insuficiência renal aguda no pós-operatório (OR = 1,96), frequência cardíaca (OR = 1,01) e sódio sérico (OR = 1,04). Os pacientes moribundos apresentaram escores mais altos de gravidade da doença nos sistemas de classificação e mais tempo de permanência em unidade de terapia intensiva cirúrgica.
Conclusão: Alguns fatores tiveram influencia sobre a mortalidade tanto hospitalar quanto na unidade de terapia intensiva cirúrgica.

Introduction

It is estimated that 234.2 million people are submitted to surgery every year.[1] According to the 2012 European Surgical Outcomes Study, postoperative mortality was 4% before hospital discharge and 5.5% at 1 year.[2] The majority of deaths occurred in older patients who undergo major emergent surgery and who have severe coexisting diseases as well as in patients that develop complications.[3–6]

There are several risk factors described for morbidity and mortality after surgery, which may be divided into three categories: patient-related, surgery-related and anesthesia-related. Developed countries have major morbidity due to postoperative complications (12% in United States) and evidence increasingly suggests that postoperative complications have a major impact on mortality.[3,4,7,8] The risks of surgery and anesthesia are low for most patients but aging and associated patient's co-morbidities, as well as the increasing number of patients and surgeries performed, make postoperative morbidity and mortality more likely.[4,9]

Half of the postoperative adverse events were identified as avoidable.[10] Reducing rates of postoperative complications and their effective management may be one approach to reduce postoperative mortality.[3,4,8] Immediate postoperative care allows a close monitoring and early intervention to prevent early postoperative complications and deaths. Patients with increased risk of complications may require more extensive monitoring in a Surgical Intensive Care Unit (SICU) which may contribute to a better outcome, decreasing morbidity and mortality. However, there are few SICU's beds and high costs of their use.[11,12]

To improve postoperative care, severity of disease scoring systems is used to predict prognosis and estimate the morbidity and mortality of patients. Acute Physiology and Chronic Health Evaluation II (APACHE II) and Simplified Acute Physiology Score II (SAPS II) are two worldwide-used severity of disease scoring systems.[13–15] They may be used to predict mortality with the calculation of the Standardized Mortality Ratio (SMR), the ratio of observed to predicted mortality, which can be used as indicators of the quality of ICU care,[16–18] although some authors argue that they should not be used for that.[19,20] Several risk indices have been developed over the past years based on the relationship between comorbidities and perioperative morbidity and mortality. The Revised Cardiac Risk Index (RCRI) has become well known and, although it is not a severity of disease score, it has been used to predict the risk of cardiac complications after surgery, being incorporated in the preoperative risk factors guidelines.[21,22]

The aim of the present study was to evaluate the determinants of mortality using parameters included in severity of disease scoring systems in a cohort of critical surgical patients.

Methods

Data collection

The study protocol was approved by the research ethics committee of our hospital. This retrospective cohort study was carried out in the multidisciplinary Post-Anesthesia Care Unit (PACU) at Hospital São João, an 1124 bed community teaching hospital in Porto, Portugal. Included in the PACU was a Surgical Intensive Care Unit (SICU) with five beds to which critically ill surgical patients were admitted, monitored and treated.

All patients admitted at SICU who underwent non-cardiac surgery between 1st January 2006 and 19th July 2013 were eligible for inclusion. Patients less than 18 years old, medical patients, re-admittance for the same medical reason during the studied period and SICU Length Of Stay (LOS) lower than 12 h were excluded.

The following variables were recorded in the SICU: age, type of admission (elective or non-elective surgery), mechanical ventilation, LOS and mortality. APACHE II and SAPS II were calculated and all variables and parameters of those scores were evaluated separately.[13,15] Organ insufficiency (considering presence of at least one organ failure defined by APACHE II) and previous renal insufficiency (considering creatinine >2 $mg.dL^{-1}$ and/or oliguria of <500 $mL.day^{-1}$ were also evaluated.

RCRI was evaluated using criteria developed by Lee et al.: high-risk surgery (intraperitoneal, intrathoracic, or suprainguinal vascular procedures), history of ischemic heart disease, history of congestive heart disease, preoperative insulin therapy, preoperative serum creatinine >2.0 $mg.dL^{-1}$ and history of cerebrovascular disease.[21]

Statistical analysis

Kolmogorov–Smirnov Test for normality of the underlying variable was performed. The Mann–Whitney *U*, the Chi-square and Fisher's exact test were used in the univariate analyses to compare continuous variables and proportions, respectively. To assess independent predictive factors of postoperative mortality we used multiple binary logistic regressions. After applying the Bonferroni's correction for multiple comparisons, all the variables included in severity of disease scoring systems that had $p \leq 0.001$ in the univariate analyses were entered in a logistic multiple regression binary analysis with forward elimination method to examine covariate effects on mortality, calculating an odds ratio (OR) and 95% confidence interval (CI). The statistical software SPSS version 22.0 for Windows (SPSS, Chicago, IL) was used to analyze the data.

Results

During the study period there were 4561 admissions in the SICU and 4398 patients met the inclusion criteria. A total of 163 patients were excluded: 53 with a LOS <12 h, 42 were admitted more than once, 38 were younger than 18 years old and 30 were admitted for medical reasons.

The median age was 65 years, 61% were male and 13% were admitted after non-elective surgery. The median postoperative length of stay was 20 h (IQR 16–42 h). Sixty patients (1.4%) died in the SICU and 327 (7.4%) died during hospital stay.

Table 1 displays the characteristics of all patients enrolled in the study and the comparison between patients who survive and who died during SICU stay. In univariate analysis, patients that died in SICU were older and more likely submitted to an emergent surgery. They were admitted more frequently with mechanical ventilation, a Glasgow coma scale <9 and organ insufficiency as defined by APACHE II. Patients that died in the SICU had lower hematocrit, lower body temperature, lower systolic and mean arterial pressure, higher heart and respiratory rate, higher urea and creatinine serum concentration, higher total bilirubin, higher FiO_2, lower PaO_2, higher $PaCO_2$, lower serum bicarbonate, lower pH and higher serum sodium during the first 24 h of SICU stay. They also developed postoperative acute renal failure more frequently.

Table 2 presents severity of disease scores and length of stay in the SICU. Patients that died were more likely to have congestive heart failure or preoperative renal insufficiency and were submitted more frequently to a high-risk surgery. Patients not surviving had higher scores of APACHE II (median 22 vs. 8); SAPS II (median 44 vs. 18), RCRI $\geq$ 2 more often and a longer SICU stay (median 46 vs. 20).

In Table 3, the results of the multivariate analyses for mortality during SICU stay show that APACHE II (OR = 1.24), emergent surgery (OR = 4.10), serum sodium (OR = 1.06) and FiO_2 at admission (OR = 14.31) were independent predictors of mortality. Serum bicarbonate at admission (OR = 0.89) was considered a protective factor.

Table 4 displays the characteristics of all patients enrolled in the study and the comparison between patients who survive and who died during hospital stay. In univariate analysis, patients that died before hospital discharge were older and more likely submitted to an emergent surgery. They were admitted more frequently with mechanical ventilation, a Glasgow coma scale <9 and organ insufficiency as defined by APACHE II. Patients that died during hospital stay had lower hematocrit, lower body temperature, lower systolic and mean arterial pressure, higher heart rate, higher urea and creatinine serum concentration, higher total bilirubin, higher FiO_2, higher $PaCO_2$, lower serum bicarbonate, lower pH and higher serum sodium during the first 24 h of SICU stay. They also developed postoperative acute renal failure more frequently.

Table 5 presents severity of disease scores and length of stay at SICU. Patients that died were more likely to have congestive heart failure or preoperative renal insufficiency and were submitted more frequently to a high-risk surgery. Patients not surviving had higher scores of APACHE II (median 12 vs. 8), SAPS II (median 27 vs. 18), RCRI $\geq$ 2 more often and a longer SICU stay (median 36 vs. 20).

In Table 6 the results of the multivariate analyses for mortality during hospital stay show that age (OR = 1.02), APACHE II (OR = 1.09), emergent surgery (OR = 1.82), high-risk surgery (OR = 1.61), FiO_2 at admission (OR = 1.02), postoperative acute renal failure (OR = 1.96), heart rate (OR = 1.01) and serum sodium (OR = 1.04) were independent predictors of mortality.

Table 1 Univariate analysis of mortality predictors in SICU – patients' characteristics.

Variables	Total ($n=4398$)	Survival group ($n=4338$)	Mortality group ($n=60$)	p-Value
Gender, n (%)				0.518[a]
Male	2681 (61.0)	2642 (60.9)	39 (65.0)	
Female	1717 (39.0)	1696 (39.1)	21 (35.0)	
Age, median (IQR)	65.0 (54.0–74.0)	65.0 (53.0–74.0)	72.5 (59.5–79.8)	<0.001[b]
Type of admission, n (%)				<0.001[a]
Elective surgery	3827 (87.0)	3803 (87.7)	24 (40.0)	
Non-elective surgery	571 (13.0)	535 (12.3)	36 (60.0)	
Mechanical ventilation at admission, n (%)	1341 (30.5)	1291 (29.8)	50 (83.3)	<0.001[a]
Organ insufficiency,[d] n (%)	682 (15.5)	658 (15.2)	24 (40.0)	<0.001[a]
Hematocrit, median (IQR)	33.0 (29.8–36.3)	33.0 (29.9–36.4)	28.8 (22.9–33.0)	<0.001[b]
Body temperature, median (IQR)	35.4 (34.6–36.0)	35.8 (34.6–36.0)	34.0 (33.0–35.3)	<0.001[b]
Systolic pressure, median (IQR)	122.0 (102.0–144.0)	122.0 (102.0–144.0)	76.5 (66.0–88.8)	<0.001[b]
Mean arterial pressure, median (IQR)	85.0 (71.0–96.0)	85.0 (71.0–96.0)	53.0 (47.3–63.0)	<0.001[b]
Heart rate, median (IQR)	83 (69–98)	83 (68–98)	112 (88–133)	<0.001[b]
Respiratory rate, median (IQR)	14 (12–16)	14 (12–16)	16 (14–16)	<0.001[b]
Serum urea, median (IQR)	30.0 (20.0–40.0)	30.0 (20.0–40.0)	45.0 (23.5–70.0)	0.001[b]
Serum creatinine, median (IQR)	8.3 (6.5–11.0)	8.2 (6.5–11.0)	15.6 (9.0–25.3)	<0.001[b]
Total bilirrubin, median (IQR)	4.0 (1.0–7.0)	4.0 (1.0–7.0)	6.0 (4.0–10.8)	<0.001[b]
FiO_2, median (IQR)	0.40 (0.35–0.40)	0.40 (0.34–0.40)	0.52 (0.40–1.00)	<0.001[b]
PaO_2, median (IQR)	100.0 (100.0–110.0)	100.0 (100.0–110.0)	98.0 (75.5–138.6)	0.039[b]
$PaCO_2$, median (IQR)	39.5 (35.0–45.0)	39.4 (35.0–45.0)	42.7 (36.0–54.0)	0.001[b]
Serum bicarbonate, median (IQR)	22.0 (21.0–24.0)	22.0 (21.0–24.0)	19.4 (17.0–22.0)	<0.001[b]
pH, median (IQR)	7.40 (7.35–7.40)	7.40 (7.35–7.40)	7.28 (7.17–7.35)	<0.001[b]
Serum potassium, median (IQR)	3.80 (3.40–4.10)	3.80 (3.40–4.10)	3.90 (3.13–4.45)	0.806[b]
Serum sodium, median (IQR)	140 (137–142)	140 (137–142)	145 (140–152)	<0.001[b]
Leucocytes count, median (IQR)	11.0 (8.0–14.0)	11.0 (8.0–11.0)	9.5 (4.0–19.0)	0.230[b]
Glasgow coma scale (<9), n (%)	54 (1.2)	46 (1.1)	8 (13.3)	<0.001[e]
Acute renal failure,[c] n (%)	285 (6.5)	264 (6.1)	21 (35.0)	<0.001[e]

APACHE II, Acute Physiology and Chronic Health Evaluation; IQR, interquartile range (P25–P75); SAPS II, Simplified Acute Physiology Score; SICU, Surgical Intensive Care Unit.

[a] Chi-square test.

[b] Mann–Whitney test.

[c] Previous renal insufficiency: creatinine >2 $mg.dL^{-1}$ and/or oliguria <500 $mL.day^{-1}$.

[d] Organ insufficiency: presence of at least one organ failure defined by APACHE II.

[e] p-Value with Fisher's exact test.

Discussion

The study of outcome in critical care patients has been primarily focused on hospital survival and heath care resources utilization, adjusted according to the severity of illness. ICU mortality strongly depend on the severity of illness of the population being analyzed.[23] Several risk models have been developed for assessing mortality after ICU admission and may also be useful in surgical patients.

Although previous studies have focused on identifying predictors of postoperative morbidity and mortality evaluating and quantifying comorbidities, perioperative factors and the presence of postoperative complications,[2–5,24–32] none have attempted to identify predictors from routine physiological and analytical postoperative parameters included in severity of disease scoring systems.

In a large study with 46,539 patients submitted to surgery, only 4% died before hospital discharge, however, only 27% were submitted to major surgery and admitted at SICU in the postoperative period.[2] A multicenter study including 84,730 patients submitted to general or vascular surgery reported different mortality rates between hospitals, varying from 3.5% to 6.9%.[5] A few years ago, we measured the mortality rate after major surgery in our hospital which was 7.6% in SICU and 15.7% before hospital discharge.[7] Fortunately, we were able to reduce that mortality, improving the post-operative care in our SICU.

Type of admission is a variable that has been studied and found to be related to mortality.[5,6,9,29,33] It seems that patients undergoing non-elective surgery are likely to have a worse prognosis since they are more severely ill, have a less functional reserve or may not be medically optimized for surgery. Emergency surgeries can be complex and they usually require a careful intraoperative care.[9,34] In our study, non-elective surgery was considered an independent predictor of mortality, increasing the risk of death both during SICU and hospital stay.

Table 2 Univariate analysis of mortality predictors in SICU − criteria developed by Lee et al. and risk scores.

Variables	Total ($n = 4398$)	Survival group ($n = 4338$)	Mortality group ($n = 60$)	p-Value
High-risk surgery, n (%)	2382 (54.2)	2334 (53.8)	48 (80.0)	<0.001[a]
History of ischemic heart disease, n (%)	617 (14.0)	607 (14.0)	10 (16.7)	0.554[a]
History of congestive heart disease, n (%)	691 (15.7)	673 (15.5)	18 (30.0)	0.002[a]
Preoperative insulin therapy, n (%)	215 (4.9)	213 (4.9)	2 (3.3)	1[c]
Preoperative serum creatinine >2.0 $mg.dL^{-1}$, n (%)	281 (6.4)	272 (6.3)	9 (15.0)	0.013[c]
History of cerebrovascular disease, n (%)	559 (12.7)	548 (12.6)	11 (18.3)	0.188[a]
RCRI $\geq$2, n (%)	328 (7.5)	317 (7.3)	11 (18.3)	0.004[c]
APACHE II, median (IQR)	8.0 (6.0–12.0)	8.0 (6.0–12.0)	22.0 (19.0–26.0)	<0.001[b]
SAPS II, median (IQR)	18.0 (13.3–26.7)	18.0 (13.3–25.0)	43.7 (37.8–57.8)	<0.001[b]
SICU LOS (hours), median (IQR)	20.0 (16.0–42.0)	20.0 (16.0–41.0)	46.0 (19.5–82.8)	<0.001[b]

RCRI, Revised Cardiac Risk Index; SICU, Surgical Intensive Care Unit; APACHE II, Acute Physiology and Chronic Health Evaluation; IQR, Interquartile range (P25–P75); SAPS II, Simplified Acute Physiology Score; SICU, Surgical Intensive Care Unit.
[a] Chi-square test.
[b] Mann–Whitney test.
[c] p-Value with Fisher's exact test.

Table 3 Multivariate analysis of mortality predictors in SICU.

Variables	Simple OR	p-Value	Adjusted OR (95% CI)[b]	p-Value[a]
Age	1.04 (1.02–1.06)	<0.001	–	
Non-elective surgery	10.66 (6.31–18.01)	<0.001	3.88 (2.02–7.46)	<0.001
Mechanical ventilation	11.80 (5.96–23.34)	<0.001	–	
Organ insufficiency	3.78 (2.21–6.34)	<0.001	–	
Hematocrit	0.86 (0.83–0.90)	<0.001	–	
Body temperature	0.53 (0.45–0.62)	<0.001	–	
Systolic pressure	0.95 (0.94–0.96)	<0.001	–	
Mean arterial pressure	0.92 (0.91–0.94)	<0.001	–	
Heart rate	1.05 (1.04–1.06)	<0.001	–	
Respiratory rate	1.04 (1.01–1.07)	0.023	–	
Serum urea	1.02 (1.01–1.02)	<0.001	–	
Serum creatinine	1.04 (1.03–1.05)	<0.001	–	
Total bilirrubin	1.00 (1.00–1.01)	0.252	–	
FiO_2	1.08 (1.07–1.09)	<0.001	1.03 (1.02–1.05)	<0.001
$PaCO_2$	1.07 (1.05–1.09)	<0.001	–	
Serum bicarbonate	0.74 (0.67–0.81)	<0.001	0.88 (0.82–0.95)	0.001
pH, median	0.86 (0.84–0.88)	<0.001	–	
Serum sodium	1.23 (1.18–1.28)	<0.001	1.06 (1.01–1.11)	0.010
Glasgow coma scale	0.72 (0.67–0.78)	<0.001	–	
Acute renal failure	8.3 (4.8–14.3)	<0.001	–	
APACHE II	1.38 (1.31–1.41)	<0.001	1.25 (1.18–1.31)	<0.001
SAPS II	1.14 (1.12–1.16)	<0.001	–	
SICU LOS (hours)	1.01 (10.1–1.01)	<0.001	–	
High-risk surgery	3.4 (1.8–6.5)	<0.001	–	

APACHE II, Acute Physiology and Chronic Health Evaluation; IQR, interquartile range (P25–P75); SAPS II, Simplified Acute Physiology Score; SICU, Surgical Intensive Care Unit.
[a] Adjusted for age, mechanical ventilation on admission, previous renal insufficiency, organ insufficiency, hematocrit, body temperature, systolic pressure, mean arterial pressure, heart rate, respiratory rate, urea, creatinine, total bilirubin, FiO_2, $PaCO_2$, serum bicarbonate, pH, Serum sodium, Glasgow coma scale and SAPS II.
[b] A logistic regression analysis with inclusion severity of disease scoring systems' variables with $p \leq 0.001$ was used.

Table 4 Univariate analysis of hospital mortality predictors – patients' characteristics.

Variables	Total (n = 4398)	Survival group (n = 4071)	Mortality group (n = 327)	p-Value
Gender, n (%)				0.938[a]
Male	2681 (61.0)	2481 (60.9)	200 (61.2)	
Female	1717 (39.0)	1590 (39.1)	127 (38.8)	
Age, median (IQR)	65 (54–74)	65 (53–74)	71 (59–78)	<0.001[b]
Type of admission, n (%)				<0.001[a]
Elective surgery	3827 (87.0)	3598 (88.4)	229 (70.0)	
Non-elective surgery	571 (13.0)	535 (12.3)	98 (30.0)	
Mechanical ventilation at admission, n (%)	1341 (30.5)	1181 (29.0)	160 (48.9)	<0.001[a]
Organ insufficiency,[d] n (%)	682 (15.5)	585 (14.4)	97 (29.7)	<0.001[a]
Hematocrit, median (IQR)	33.0 (29.8–36.3)	33.0 (30.0–36.5)	31.0 (27.0–34.9)	<0.001[b]
Body temperature, median (IQR)	35.4 (34.6–36.0)	35.8 (34.7–36.0)	35.2 (34.0–36.0)	<0.001[b]
Systolic pressure, median (IQR)	122.0 (102.0–144.0)	122.0 (103.0–144.0)	112.0 (87.0–138.0)	<0.001[b]
Mean arterial pressure, median (IQR)	85.0 (71.0–96.0)	85.0 (71.0–96.0)	78.0 (60.0–91.0)	<0.001[b]
Heart rate, median (IQR)	83 (69–98)	82 (68–96)	89 (78–108)	<0.001[b]
Respiratory rate, median (IQR)	14 (12–16)	14 (12–16)	14 (12–16)	0.113[b]
Serum urea, median (IQR)	30.0 (20.0–40.0)	30.0 (20.0–40.0)	36.0 (20.0–50.0)	<0.001[b]
Serum creatinine, median (IQR)	8.3 (6.5–11.0)	8.1 (6.4–10.7)	9.7 (7.0–16.0)	<0.001[b]
Total bilirrubin, median (IQR)	4.0 (1.0–7.0)	4.0 (1.0–7.0)	6.0 (3.0–9.0)	<0.001[b]
FiO_2, median (IQR)	0.40 (0.35–0.40)	0.40 (0.35–0.40)	0.40 (0.40–0.50)	<0.001[b]
PaO_2, median (IQR)	100.0 (100.0–110.0)	100.0 (100.0–110.0)	100.0 (90.0–120.0)	0.151[b]
$PaCO_2$, median (IQR)	39.5 (35.0–45.0)	39.1 (35.0–45.0)	41.0 (35.0–45.0)	0.007[b]
Serum bicarbonate, median (IQR)	22.0 (21.0–24.0)	22.0 (21.0–24.0)	22.0 (20.0–24.0)	0.003[b]
pH, median (IQR)	7.40 (7.35–7.40)	7.40 (7.35–7.40)	7.36 (7.30–7.40)	<0.001[b]
Serum potassium, median (IQR)	3.80 (3.40–4.10)	3.8 (3.5–4.0)	3.7 (3.3–4.1)	0.078[b]
Serum sodium, median (IQR)	140 (137–142)	140 (137–142)	141 (138–142)	<0.001[b]
Leucocytes count, median (IQR)	11.0 (8.0–14.0)	11.0 (8.0–14.0)	11.7 (7.5–16.0)	0.134[b]
Glasgow coma scale (<9), n (%)	54 (1.2)	37 (0.9)	17 (5.2)	<0.001[e]
Acute Renal failure,[c] n (%)	285 (6.5)	222 (5.5)	63 (19.3)	<0.001

APACHE II, Acute Physiology and Chronic Health Evaluation; IQR, interquartile range (P25–P75); SAPS II, Simplified Acute Physiology Score; SICU, Surgical Intensive Care Unit.

[a] Chi-square test.

[b] Mann–Whitney test.

[c] Previous renal insufficiency: creatinine >2 $mg.dL^{-1}$ and/or oliguria <500 $mL.day^{-1}$.

[d] Organ insufficiency: presence of at least one organ failure defined by APACHE II.

[e] *p*-Value with Fisher's exact test.

In multivariate analysis FiO_2 was another independent predictor of mortality. Higher FiO_2 is frequently required in patients with impaired tissue oxygenation trying to avoid the harmful effects of hypoxia. In fact it is well documented that the PaO_2/FiO_2 ratio is associated with mortality, however, both SAPS II and APACHE II use FiO_2 as a variable.[35,36] In our study, we did not studied the PaO_2/FiO_2 ratio but the isolated FiO_2 parameter, which may be considered as a relevant surrogate indicator of that fraction. In a previous study, higher FiO_2 remained an independent predictor of mortality even after adjustment for PaO_2/FiO_2 ratio,[37] suggesting poor prognosis not only because these patients are more severely ill with impaired tissue oxygenation, but also because of hyperoxia and ventilation side-effects.[37–39]

Some authors have found serum sodium to be a reliable risk factor for mortality[40–44] and we also arrive to the same

Table 5 Univariate analysis of hospital mortality predictors − criteria developed by Lee et al. and risk scores.

Variables	Total ($n=4398$)	Survival group ($n=4071$)	Mortality group ($n=327$)	p-Value
High-risk surgery, n (%)	2382 (54.2)	2153 (52.9)	229 (70.0)	<0.001[a]
History of ischemic heart disease, n (%)	617 (14.0)	568 (14.0)	49 (15.0)	0.605[a]
History of congestive heart disease, n (%)	691 (15.7)	616 (15.1)	75 (22.9)	<0.001[a]
Preoperative insulin therapy, n (%)	215 (4.9)	198 (4.9)	17 (5.2)	0.787[c]
Preoperative serum creatinine >2.0 mg.dL^{-1}, n (%)	281 (6.4)	237 (5.8)	44 (13.5)	<0.001[c]
History of cerebrovascular disease, n (%)	559 (12.7)	515 (12.7)	44 (13.5)	0.674[a]
RCRI ≥ 2, n (%)	328 (7.5)	287 (7.0)	41 (12.5)	<0.001[c]
APACHE II, median (IQR)	8.0 (6.0–12.0)	8.0 (6.0–11.0)	12.0 (9.0–18.0)	<0.001[b]
SAPS II, median (IQR)	18.0 (13.3–26.7)	17.8 (13.3–24.4)	26.7 (18.0–38.0)	<0.001[b]
SICU LOS (hours), median (IQR)	20.0 (16.0–42.0)	20.0 (16.0–41.0)	36.0 (19.0–68.0)	<0.001[b]

RCRI, Revised Cardiac Risk Index; SICU, Surgical Intensive Care Unit; APACHE II, Acute Physiology and Chronic Health Evaluation; IQR, interquartile range (P25–P75); LOS, length of stay; SAPS II, Simplified Acute Physiology Score; SICU, Surgical Intensive Care Unit.
[a] Chi-square test.
[b] Mann–Whitney test.
[c] p-Value with Fisher's exact test.

Table 6 Multivariate analysis of hospital mortality predictors.

Variables	Simple OR	p-Value	Adjusted OR (95% CI)[b]	p-Value[a]
Age	1.03 (1.03–1.04)	<0.001	1.02 (1.01–1.03)	<0.001
Non-elective surgery	3.26 (2.52–4.20)	<0.001	1.82 (1.34–2.48)	<0.001
Mechanical ventilation	2.35 (1.87–2.94)	<0.001	–	
Organ insufficiency	2.51 (1.95–3.24)	<0.001	–	
Hematocrit	0.92 (0.90–0.94)	<0.001	–	
Body temperature	0.78 (0.72–0.85)	<0.001	–	
Systolic pressure	0.99 (0.98–0.99)	<0.001	–	
Mean arterial pressure	0.98 (0.97–0.99)	<0.001	–	
Heart rate	1.03 (1.02–1.03)	<0.001	1.01 (1.01–1.02)	<0.001
Serum urea	1.01 (1.01–1.01)	<0.001	–	
Serum creatinine	1.03 (1.02–1.03)	<0.001	–	
Total bilirrubin	1.00 (1.00–1.01)	0.116	–	
FiO_2	1.05 (1.04–1.06)	<0.001	1.02 (1.01–1.03)	<0.001
pH	0.93 (0.91–0.94)	<0.001	–	
Serum sodium	1.11 (1.09–1.14)	<0.001	1.04 (1.01–1.06)	0.003
Glasgow coma scale	0.80 (0.75–0.84)	<0.001	–	
Acute renal failure	4.14 (3.05–5.62)	<0.001	1.86 (1.28–2.70)	0.001
APACHE II	1.18 (1.16–1.20)	<0.001	1.09 (1.06–1.12)	<0.001
SAPS II	1.07 (1.06–1.08)	<0.001	–	
SICU LOS (hours)	1.01 (1.01–1.01)	<0.001	–	
High-risk surgery	2.08 (1.63–2.66)	<0.001	1.61 (1.24–2.09)	<0.001
History of congestive heart disease	1.67 (1.27–2.19)	<0.001		
Preoperative serum creatinine >2.0	4.14 (3.05–5.62)	<0.001		

APACHE II, Acute Physiology and Chronic Health Evaluation; IQR, interquartile range (P25–P75); SAPS II, Simplified Acute Physiology Score; SICU, Surgical Intensive Care Unit.
[a] Adjusted for age, mechanical ventilation on admission, previous renal insufficiency, hematocrit, body temperature, systolic pressure, mean arterial pressure, heart rate, respiratory rate, serum urea, serum creatinine, total bilirubin, FiO_2, $PaCO_2$, serum bicarbonate, pH, serum sodium, Glasgow coma scale and SAPS II.
[b] A logistic regression analysis with inclusion severity of disease scoring systems' variables with $p \leq 0.001$ was used.

result. Hypernatremia is a common complication in critically ill patients such they may be unconscious, intubated or sedated and may invariably denotes hyperosmolar state and transiently intracellular dehydration.[45]

The multivariate analysis of independent variables showed that higher serum bicarbonate was associated with a reduction of mortality. Low bicarbonate levels could be associated with metabolic acidosis and consequently with case fatalities that have been shown by others.[46–49] Although the deleterious impact of low serum bicarbonate is known, both lower and higher serum bicarbonates may be associated with increased all-cause mortality as a result of the well documented consequences of acid–base abnormalities that have been associated with adverse outcomes and mortality.[50] However, a recent retrospective analysis shows that acidosis itself had no relation with poor outcome which was more dependent on severe conditions that cause acidosis.[51]

A previous study has documented an increased risk of mortality if the patients develop acute kidney failure in the post-operative period with an OR of 3.12 (28). We observed a similar tendency with an OR of 1.86.

Another study reported higher mortality with hypotension or tachycardia in the postoperative period.[52] However, that study included acute patients from many medical areas and not only those submitted to surgery.

The post-operative mortality also depends on the age of the population included in the study.[2,5,53] It could be as low as 3.7% when the age is around 76 years,[10] versus 38% when the median of age is 84 years.[55] In our study, the age was also a risk factor for mortality.

In order to stratify the preoperative risk of patients, we relied on the RCRI. Some comorbidities included in RCRI, history of congestive heart disease or renal disease, were also associated with mortality. Patients that died had more frequently a RCRI score $\geq$2 but only high-risk surgery was considered an independent risk factor for mortality. Perhaps in this particular group of patients, the burden of surgery was more relevant than their comorbidities.

Not surprisingly, patients with prolonged SICU LOS had higher mortality, suggesting that they may have developed postoperative complications or were more severely ill.[6,24–26] Based on previous literature, we can say that the occurrence of postoperative complications decreases survival by 69% with the postoperative period being more important than preoperative comorbidities and intraoperative risk factors.[3,4] Therefore, focus in postoperative intensive care and evaluating physiological variables to early predict outcomes is of paramount importance.

Study limitations

Besides the limitations inherent to a retrospective cohort study, others are present on the design of this study. Preoperative risk assessment is roughly based on three broad but connected categories including several risk factors: surgery-related, patient-related or dependent on patient's functional status. Not knowing the pre-existing conditions of patients beyond the comorbidities present in the Revised Cardiac Risk Index probably may limit the value of conclusions, because comorbidities others than those may influence physiological parameters included in the severity of disease scoring systems. The lack of an American Society of Anesthesiologists Physical Status (ASA-PS) for our sample population is also questionable. Risk prediction models for intraoperative and postoperative mortality have included the ASA-PS classification as a strong predictor of outcome.[22,52,54,55] Furthermore, neither intraoperative hemodynamic parameters nor other postoperative complications beyond organ insufficiency were evaluated in our study which may influence outcome and mortality.

Conclusions

In conclusion, postoperative mortality was 1.4% in SICU and 7.4% during hospital stay. Fatality cases had significantly higher scores in severity of disease scoring systems and a longer SICU stay. Almost all variables included in the severity of disease scoring systems were different between groups. We have identified independent risk factors for mortality at SICU: APACHE II, type of admission, serum sodium and FiO_2 at admission while higher serum bicarbonate was associated with a reduction of mortality We have identified independent risk factors for mortality during hospital stay: age, APACHE II, type of admission, high-risk surgery, FiO_2 at admission, postoperative acute renal failure, heart rate and serum sodium during SICU stay.

Conflicts of interest

The authors declare no conflicts of interest.

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