Acute Kidney Injury after Major Abdominal Surgery: A Retrospective Cohort Analysis

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Background. We analyzed the incidence, risk factors, and prognosis of acute kidney injury (AKI) in a cohort of patients undergoing major abdominal surgery. Methods. A total of 450 patients were retrospectively studied. AKI was defined by an increase in serum creatinine (SCr) ≥ 0.3 mg/dl or by an increase in SCr ≥ 50% and/or by a decrease in urine output to 0.5 ml/kg/hour for 6 hours, in the first 48 hours after surgery. Logistic regression method was used to determine predictors of AKI and in-hospital mortality. A two-tailed P value < 0.05 was considered significant. Results. One hundred one patients (22.4%) had postoperative AKI. Age (adjusted odds ratio (OR) 1.02, 95% confidence interval (CI) 1.01–1.05), nonrenal Revised Cardiac Risk Index score (adjusted OR 1.9, 95% CI 1.3–3.1, P = 0.003), intraoperative erythrocyte transfusions (adjusted OR 2.2, 95% CI 1.4–3.5, P < .0001), and nonrenal Simplified Acute Physiology Score II (adjusted OR 1.03, 95% CI 1.01–1.06, P = 0.0191) were associated with postoperative AKI. AKI was associated with increased in-hospital mortality (20.8% versus 2.3%, P < .0001; unadjusted OR 11.2, 95% CI 4.8–26.2, P < .0001; adjusted OR 3.7, 95% CI 1.2–11.7, P = 0.024). Conclusion. AKI was common in patients undergoing major abdominal surgery and was associated with in-hospital mortality.

1. Introduction

Acute kidney injury (AKI) occurs commonly in hospitalized patients and it has a detrimental impact on patient outcome. In fact, AKI is associated with increased costs, length of hospital stay and mortality [1–4].

The clinical characteristics and the impact of AKI in cardiac surgery has been extensively studied [5–9], and most of the published data regarding AKI in noncardiac surgery population are limited to high-risk aortic procedures [10–15]. Only few studies addressed AKI after noncardiac and nonvascular surgery [16–20] which has a distinct pathophysiology from cardiac and vascular surgery. As a result, it is inappropriate to assume that the risk factors for AKI after noncardiac and nonvascular surgery are the same as those after cardiac and vascular surgery. The purpose of this study was therefore to evaluate the incidence, risk factors, and outcome of AKI in the first 48 hours after surgery in a cohort of patients undergoing major nonvascular abdominal surgery.

2. Methods

Patients aged 18 years or more who underwent scheduled or urgent major nonvascular abdominal surgery admitted to the Post-Anesthesia Care Unit (PACU) of the Service of Surgery II of the Centro Hospitalar Lisboa Norte, EPE (Lisbon, Portugal), between January 2010 and February 2011 were eligible for the study. Centro Hospitalar Lisboa Norte, EPE, comprises
two tertiary and teaching hospitals (Hospital de Santa Maria and Hospital de Pulido Valente) providing medical assistance to an area with almost 3.000.000 inhabitants. The PACU is an eight bed unit in which surgical patients are admitted and closely monitored in the postoperative period, being managed by a dedicated intensivist.

Major abdominal surgery was considered whenever intraperitoneal approach under general anesthesia was performed and the predictable length of stay for patients in a given diagnosis-related group exceeded two days [21–23]. Exclusion criteria were chronic kidney disease on renal replacement therapy; requirement for renal replacement therapy in the week before surgery, less than 48 hours of hospital stay; and/or less than two determinations of serum creatinine (SCr).

For patients undergoing more than one surgery within the same hospitalization only the first surgery was considered for analysis.

Since this was a retrospective and observational study that did not evaluate a specific therapeutic or prophylactic intervention, study approval was waived by the Ethical Committee of our Hospital according to Institutional guidelines.

2.1. Variables. Manual patient medical charts and electronic hospital database were reviewed by eight investigators (CT, RR, NR, IM, LP, SD, MJM, and MP) to study demographic data (age, gender, and ethnicity), preoperative patient characteristics [scheduled versus urgent surgery, comorbidity, namely, diabetes mellitus, hypertension, ischemic heart disease, congestive heart failure, cerebrovascular disease, chronic obstructive pulmonary disease (COPD), cirrhosis, solid malignancy, hematological malignancy, the American Society of Anesthesiologists (ASA) score, hemoglobin, and SCr], surgical procedure, intraoperative patient characteristics (duration of anesthesia, blood pressure, fluids, and vasoactive drugs), Simplified Acute Physiology Score version II (SAPS II), postoperative complications (hemorrhage, anastomotic leak, surgical site infection, need for mechanical ventilation, and AKI), fluid balance, need for renal replacement therapy, intensive care unit (ICU) admission, and in-hospital mortality.

2.2. Definitions. Acute kidney injury was defined and staged by to the recently proposed Kidney Disease Improving Global Outcomes (KDIGO) classification [24]. Accordingly, AKI was defined by an increase in absolute SCr of at least 0.3 mg/dL or by a percentual increase in SCr equal to or higher than 50% (1.5X baseline value) and/or by a decrease in urine output (UO) (documented oliguria lower than 0.5 mL/kg/hour for more than 6 hours) [24] and staged as follows: stage 1, if there was an increase in absolute SCr of at least 0.3 mg/dL or a percentual increase in SCr 1.5 to 2X baseline value and/or a decrease in UO (documented oliguria lower than 0.5 mL/kg/hour for more than 6 hours); stage 2, if there was a percentual increase in SCr 2 to 3X baseline value and/or a decrease in UO (documented oliguria lower than 0.5 mL/kg/hour for more than 12 hours); and stage 3, if there was a percentual increase in SCr equal to or higher than 3X baseline value and/or a decrease in UO (documented oliguria lower than 0.3 mL/kg/hour for more than 24 hours or anuria for more than 12 hours) or in patients with baseline SCr > 4.0 mg/dL if the patient first achieved the SCr based change specified in the definition (either ≥ 0.3 mg/dL or an increase of ≥ 1.5X baseline value) or if patients required renal replacement therapy independently of the stage (defined by SCr and/or UO) they were in at the moment they initiated renal replacement therapy. In order to relate AKI with surgical procedure itself, thus eliminating the potential influence of other factors arising in the postoperative period, AKI was only considered in the first 48 hours after surgery. Preoperative SCr was considered baseline SCr.

Diabetes mellitus was diagnosed according to the World Health Organization criteria [25] and hypertension was diagnosed based on the seventh report of the Joint National Committee (JNC 7) [26].

Cerebrovascular disease was defined as history of transient ischemic attack or history of cerebrovascular accident and COPD included emphysema and chronic bronchitis.

The ASA score was used to evaluate preoperative patients’ physical status [27].

The Revised Cardiac Risk Index (RCRI) score [22], assigning one point for each of the following risk factors: high-risk surgery, ischemic heart disease, congestive heart failure, cerebrovascular disease, diabetes mellitus requiring insulin therapy, and preoperative SCr higher than 2.0 mg/dL, was calculated to characterize the patients at risk to develop postoperative complications. As intraperitoneal procedure was performed, surgery was considered as high-risk in all cases [22].

Intraoperative systolic and diastolic blood pressure (SBP and DBP, resp.) were recorded every 5 minutes and intraoperative mean arterial pressure (MAP) was calculated as [(2 × DBP) + SBP]/3. When blood pressure was measured both invasively and noninvasively, invasive measurements were used for the current analysis. Intraoperative hypotension (IOH) was defined as intraoperative mean arterial pressure (MAP) <65 mmHg. The number of IOH episodes was registered.

The hemoglobin level justifying erythrocytes transfusion was variable and at physician discretion in patients with active hemorrhage and/or in hemodynamically unstable patients. Conversely, erythrocytes transfusion was performed if hemoglobin level was 7-8 g/dL (alternatively 9-10 g/dL in aged patients and/or in patients with acute coronary syndrome) in hemodynamically stable euvoletic patients [28, 29].

The SAPS II was used to evaluate illness severity and was calculated based on the worst variables recorded during the first 24 hours of PACU admission [30].

2.3. Statistical Analysis. Continuous variables are expressed as mean (standard deviation) and categorical variables as percentage of number of cases. Comparisons between patients with and without AKI were performed using the Student’s t-test and the χ²-test, respectively, for continuous and categorical variables. Logistic regression method was used to
3. Results

During the study period, 492 patients underwent nonvascular major abdominal surgery in the Service of Surgery II of our Hospital; 10 of them were chronic kidney disease patients on dialysis and were not included. None of the patients had received a renal transplant or required renal replacement therapy in the week before surgery. From the 482 remaining patients, 32 patients were hospitalized less than 48 hours and/or had less than two SCr determinations within the hospitalization and were excluded from the analysis. Therefore, in this study, we focused on 450 patients and analyzed them as a cohort. Patient characteristics are described in Table 1.

3.1. Incidence and Risk Factors of AKI. One-hundred one patients (22.4%) developed AKI in the first 48 hours after surgery, as follows: 64 patients (63.4%) were at stage 1, 20 patients (19.8%) were at stage 2, and 17 patients were at stage 3 (16.8%). Patients with postoperative AKI were older (P < 0.0001) and were more likely to have preexisting ischemic heart disease (P = 0.001), preexisting congestive heart failure (P = 0.008), preexisting cerebrovascular disease (P < 0.0001), preexisting COPD (P < 0.0001), and solid malignancies (P = 0.005), to be ASA IV/V (P = 0.009), to have higher RCRI score (P < 0.0001) and nonrenal RCRI score (P < 0.0001). Additionally, patients with AKI were more likely to have lower preoperative hemoglobin levels (P < 0.0001) and higher preoperative SCr (P < 0.0001). Colorectal surgery (P = 0.006), longer duration of anesthesia (P = 0.021), intraoperative hypotension episodes (P < 0.0001), intraoperative colloids, and crystalloids as compared with crystalloids without colloids (P < 0.0001), as well as the amount of colloids used (P < 0.0001), intraoperative erythrocytes transfusions (P < 0.0001), and intraoperative

| Variable | Value | p-value |
|----------|-------|---------|
| Age (years) | 62 (16) | 0.0001 |
| Male N (%) | 227 (50.4) | 0.0001 |
| Caucasian N (%) | 431 (95.8) | 0.0001 |
| Diabetes mellitus N (%) | 84 (18.7) | 0.0001 |
| Hypertension N (%) | 225 (50) | 0.0001 |
| Ischemic heart disease N (%) | 54 (12) | 0.0001 |
| Congestive heart failure N (%) | 25 (5.6) | 0.0001 |
| Cerebrovascular disease N (%) | 29 (6.4) | 0.0001 |
| COPD N (%) | 25 (5.6) | 0.0001 |
| Cirrhosis N (%) | 9 (2) | 0.0001 |
| Solid malignancy N (%) | 190 (42.2) | 0.0001 |
| Hematological malignancy N (%) | 8 (1.8) | 0.0001 |
| ASA IV/V N (%) | 48 (10.7) | 0.0001 |
| RCRI score | 1.3 (0.6) | 0.0001 |
| Nonrenal RCRI | 1.2 (0.5) | 0.0001 |
| Preoperative hemoglobin (g/dL) | 11.1 (4.4) | 0.0001 |
| Preoperative SCr (mg/dL) | 1 (0.5) | 0.0001 |
| Urgency surgery N (%) | 101 (22.4) | 0.0001 |

Type of surgery

- Laparoscopy N (%) | 55 (12.2) | 0.0001 |
- Laparotomy N (%) | 390 (86.7) | 0.0001 |
- Laparoscopy converted to laparotomy N (%) | 5 (1.1) | 0.0001 |
- Colorectal N (%) | 222 (49.3) | 0.0001 |
- Gastric N (%) | 85 (18.9) | 0.0001 |
- Hepatobiliary and pancreatic1 N (%) | 65 (14.4) | 0.0001 |
- Small bowel N (%) | 19 (4.2) | 0.0001 |
- Esophageal N (%) | 11 (2.4) | 0.0001 |
- Other surgery N (%) | 48 (10.7) | 0.0001 |

Intraoperative characteristics

- Duration of anesthesia (min.) | 223 (100) | 0.0001 |
- IOH (number of records) | 1 (1.8) | 0.0001 |
- Crystalloids without colloids N (%) | 175 (38.9) | 0.0001 |
- Crystalloids and colloids N (%) | 275 (61.1) | 0.0001 |
- Erythrocytes (units) | 0.5 (0.7) | 0.0001 |
- Vasoactive drugs use N (%) | 80 (17.7) | 0.0001 |

Postoperative complications

- Hemorrhage N (%) | 45 (10) | 0.0001 |
- Anastomotic leak N (%) | 21 (4.7) | 0.0001 |
- Surgical site infection N (%) | 71 (15.8) | 0.0001 |
- Need for MV N (%) | 11 (2.4) | 0.0001 |
- Admission to ICU N (%) | 13 (2.9) | 0.0001 |
- SAPS II | 23 (17.4) | 0.0001 |
| Nonrenal SAPS II | 20.8 (15.4) | 0.0001 |
| Length of PACU stay (days) | 4.4 (8.6) | 0.0001 |
| Length of hospital stay (days) | 12 (12.6) | 0.0001 |
| PACU mortality N (%) | 20 (4.4) | 0.0001 |
| In-hospital mortality N (%) | 29 (6.4) | 0.0001 |

COPD: chronic obstructive pulmonary disease. ASA: American Society of Anesthesiologists. RCRI: Revised Cardiac Risk Index. SCr: serum creatinine. IOH: intraoperative hypotension. MV: mechanical ventilation. ICU: intensive care unit. SAPS II: Simplified Acute Physiology Score, version II. PACU: Post-Anaesthesia Care Unit. Hepatobiliary and pancreatic surgery includes gallbladder surgery (N = 40), hepatic surgery (N = 15), pancreatic surgery (N = 6), and bile ducts surgery (N = 4).
Table 2: Characteristics of patients with postoperative AKI (N = 101) and with no postoperative AKI (N = 349).

| Variable                  | No AKI (N = 349) | AKI (N = 101) | P       |
|---------------------------|------------------|---------------|---------|
| **Preoperative characteristics** |                  |               |         |
| Age (years)               | 60.6 (15.7)      | 71.1 (13.2)   | <0.0001 |
| Male N (%)                | 168 (48.1)       | 59 (58.4)     | 0.069   |
| Caucasian N (%)           | 335 (96)         | 96 (95)       | 0.679   |
| Diabetes mellitus N (%)   | 62 (17.8)        | 22 (21.8)     | 0.362   |
| Hypertension N (%)        | 168 (48.1)       | 57 (56.4)     | 0.142   |
| Ischemic heart disease N (%) | 32 (9.2)    | 22 (21.8)     | 0.001   |
| Congestive heart failure N (%) | 14 (4)       | 11 (10.9)     | 0.008   |
| Cerebrovascular disease N (%) | 13 (3.7)     | 16 (15.8)     | <0.0001 |
| COPD N (%)                | 13 (3.7)         | 12 (11.9)     | <0.0001 |
| Cirrhosis N (%)           | 7 (2)            | 2 (1.9)       | 0.987   |
| Solid malignancy N (%)    | 135 (38.7)       | 55 (54.5)     | 0.005   |
| Hematological malignancy N (%) | 6 (1.7)   | 2 (1.9)       | 0.861   |
| ASA IV/V N (%)            | 23 (6.6)         | 15 (14.9)     | 0.009   |
| RCRI score               | 1.2 (0.5)        | 1.6 (0.8)     | <0.0001 |
| Nonrenal RCRI score      | 1.2 (0.4)        | 1.5 (0.8)     | <0.0001 |
| Preoperative hemoglobin (g/dL) | 11.3 (1.7) | 10.5 (1.6)   | <0.0001 |
| Preoperative SCr (mg/dL)  | 0.9 (0.4)        | 1.2 (0.7)     | <0.0001 |
| Urgency surgery N (%)     | 75 (21.5)        | 26 (25.7)     | 0.367   |
| **Type of surgery**       |                  |               |         |
| Laparoscopy N (%)         | 47 (13.5)        | 8 (79)        | 0.134   |
| Laparotomy N (%)          | 297 (85.1)       | 93 (92)       | 0.07    |
| Colorectal N (%)          | 160 (45.8)       | 62 (61.4)     | 0.006   |
| Gastric N (%)             | 71 (20.3)        | 14 (13.9)     | 0.143   |
| Hepatobiliary and pancreatic N (%) | 55 (15.8) | 10 (9.9)     | 0.140   |
| Small bowel N (%)         | 14 (4)           | 5 (4.9)       | 0.679   |
| Esophageal N (%)          | 8 (2.3)          | 3 (2.9)       | 0.698   |
| Other surgery N (%)       | 41 (11.7)        | 7 (6.9)       | 0.167   |
| **Intraoperative characteristics** |                  |               |         |
| Duration of anestesia (min.) | 218 (92)    | 244 (121)     | 0.021   |
| IOH (number of records)   | 0.9 (1.7)        | 1.6 (2.1)     | <0.0001 |
| Crystalloids without colloid N (%) | 80 (29)   | 21 (12)       | <0.0001 |
| Amount of Crystalloids (L) | 2.3 (1.3)      | 2.3 (1.3)     | 0.905   |
| Crystalloids and colloid N (%) | 21 (12)    | 80 (29)       | <0.0001 |
| Amount of Crystalloids (L) | 2.2 (1.1)      | 2.5 (1.5)     | 0.054   |
| Amount of colloid (L)      | 0.4 (0.3)       | 0.7 (0.4)     | <0.0001 |
| Erythrocytes (units)      | 0.4 (0.5)       | 1 (1)         | <0.0001 |
| Vasoactive drugs use N (%) | 55 (15.8)      | 25 (24.8)     | 0.037   |

Table 2: Continued.

| Variable                  | No AKI (N = 349) | AKI (N = 101) | P       |
|---------------------------|------------------|---------------|---------|
| SAPS II                   | 19.1 (10.9)      | 34.3 (21.3)   | <0.0001 |
| Nonrenal SAPS II          | 173 (9.6)        | 28.4 (17.6)   | <0.0001 |
| Fluid balance (liters)    | 2.4 (2.2)        | 2.6 (2.4)     | 0.475   |

COPD: chronic obstructive pulmonary disease; ASA: American Society of Anesthesiologists. RCRI: Revised Cardiac Risk Index. SCr: serum creatinine. IOH: intraoperative hypotension. SAPS II: Simplified Acute Physiology Score, version II. 

3.2. **Outcome.** Ten out of the 101 patients with AKI (9.9%) received renal replacement therapy (eight patients were treated with continuous venovenous hemodiafiltration and two patients with intermittent hemodialysis). Patients with postoperative AKI were more likely to develop postoperative complications such as hemorrhage (P < 0.0001) and anastomotic leak (P = 0.005), were more likely to be transferred to ICU (P = 0.021), and had lengthened PACU (P < 0.0001) and hospital stay (P = 0.004) (Table 4). Patients with postoperative AKI had higher in-hospital mortality than those patients who did not develop AKI (20.8 versus 2.3%, P < 0.0001; unadjusted OR II, 95% CI 4.8–26.2, P < 0.001). After adjusting for other covariates, AKI was independently associated with increased in-hospital mortality (adjusted OR 3.7, 95% CI 1.2–11.7, P = 0.024) (Table 5). Moderate-to-severe AKI (stages 2 and 3) (in-hospital mortality 62%; unadjusted OR 36.6, 95% CI 15.1–89, P < 0.0001; adjusted OR 27.8, 95% CI 6.2–125, P < 0.0001) was associated with increased mortality, while mild AKI (stage 1) (in-hospital mortality 4.6%, unadjusted OR 0.7, 95% CI 0.2–2.3, P = 0.519) was not. Causes of death in patients with postoperative AKI were sepsis in 10 patients (47.6%), cardiovascular disease in 4 patients (19%), and respiratory failure in 4 patients (19%) and it was unknown in 3 patients (14.3%); sepsis (4 patients, 50%), cardiovascular disease (2 patients, 25%), respiratory failure (one patient, 12.5%), and unknown cause (one patient, 12.5%) were the causes of death in patients who did not have postoperative AKI. vasoactive drugs (P = 0.037) were associated with increased incidence of postoperative AKI. Illness severity as evaluated by SAPS II (P < 0.0001) and nonrenal SAPS II (P < 0.0001) were also higher in patients with postoperative AKI than in those patients who did not have AKI (Table 2). Age (adjusted OR 1.02 per year, 95% CI 1.01–1.05 per year), nonrenal RCRI (adjusted OR 1.9 per point, 95% CI 1.3–3.1, P = 0.003), intraoperative erythrocyte transfusions (adjusted OR 2.2 per unit, 95% CI 1.4–3.5, P < 0.0001), and nonrenal SAPS II (adjusted OR 1.03 per point, 95% CI 1.01–1.06, P = 0.0191) were independently associated with postoperative AKI (Table 3).
Table 3: Univariate and multivariate analysis to determine risk factors of postoperative acute kidney injury.

| Variable | Unadjusted OR (95% CI) | P | Adjusted OR (95% CI) | P |
|----------|------------------------|---|----------------------|---|
| **Preoperative characteristics** | | | | |
| Age (per year) | 1.05 (1.04–1.07) | <0.0001 | 1.02 (1.01–1.05) | 0.049 |
| Male | 1.5 (0.9–2.4) | 0.07 | | |
| Caucasian | 0.8 (0.3–2.3) | 0.680 | | |
| Solid malignancy | 1.9 (1.2–2.9) | 0.005 | 1.4 (0.8–2.4) | 0.274 |
| ASA physical status IV/V | 2.5 (1.2–4.9) | 0.01 | 1.1 (0.4–2.5) | 0.931 |
| Nonrenal RCRI (per point) | 2.9 (1.9–4.3) | <0.0001 | 1.9 (1.3–3.1) | 0.003 |
| Preoperative hemoglobin (per g/dL) | 0.8 (0.7–0.9) | <0.0001 | | |
| Preoperative SCr (per mg/dL increase) | 2.3 (1.5–3.4) | <0.0001 | 1.2 (0.7–2) | 0.411 |
| Urgency surgery | 1.3 (0.8–2.1) | 0.368 | | |
| **Type of surgery** | | | | |
| Laparoscopy versus laparotomy | 0.6 (0.3–1.2) | 0.139 | | |
| Colorectal | 1.9 (1.2–2.9) | 0.006 | 1.6 (0.9–2.7) | 0.122 |
| Gastric | 0.6 (0.3–1.1) | 0.630 | | |
| Hepatobiliary and pancreatic | 0.6 (0.3–1.2) | 0.144 | | |
| Small bowel | 1.2 (0.4–3.5) | 0.680 | | |
| Esophageal | 1.3 (0.3–5) | 0.698 | | |
| Other surgery | 0.6 (0.2–1.3) | 0.559 | | |
| **Intraoperative characteristics** | | | | |
| Duration of anesthesia (per 10 min.) | 1.02 (1–1.05) | 0.024 | 1.01 (0.9–1.1) | 0.208 |
| IOH (per record) | 1.2 (1.1–1.4) | 0.001 | 1.1 (0.9–1.2) | 0.437 |
| Crystallloids with colloids versus crystallloids without colloids | 3 (1.8–5) | <0.0001 | 1.6 (0.9–3) | 0.143 |
| Erythrocytes (per unit) | 3.7 (2.4–5.8) | <0.0001 | 2.2 (1.4–3.5) | <0.0001 |
| Vasoactive drugs use | 1.8 (1.1–3) | 0.039 | 1.1 (0.5–2) | 0.939 |
| Nonrenal SAPS II (per point) | 1.07 (1.05–1.09) | <0.0001 | 1.03 (1.01–1.06) | 0.019 |

OR: odds ratio. CI: confidence interval. COPD: ASA: American Society of Anesthesiologists. RCRI: Revised Cardiac Risk Index. SCr: serum creatinine. IOH: intraoperative hypotension. SAPS II: Simplified Acute Physiology Score, version II. 1Hepatobiliary and pancreatic surgery includes gallbladder surgery (N = 40), hepatic surgery (N = 15), pancreatic surgery (N = 6), and bile ducts surgery (N = 4).

Table 4: Postoperative complications, length of stay, and mortality.

| Postoperative complications | No AKI (N = 349) | AKI (N = 101) | P |
|----------------------------|-----------------|--------------|---|
| Hemorrhage N (%) | 23 (6.6) | 22 (21.8) | <0.0001 |
| Anastomotic leak N (%) | 11 (3.2) | 10 (10) | 0.005 |
| Surgical site infection N (%) | 53 (15.2) | 18 (17.8) | 0.521 |
| Need for MV N (%) | 6 (1.7) | 5 (4.9) | 0.064 |
| Admission to ICU N (%) | 6 (1.7) | 6 (5.9) | 0.021 |
| Length of PACU stay (days) | 3.6 (7.1) | 6.9 (11.7) | <0.0001 |
| Length of hospital stay (days) | 11.1 (11.3) | 15.2 (16.1) | 0.004 |
| PACU mortality N (%) | 4 (1.1) | 16 (15.8) | <0.0001 |
| In-hospital mortality N (%) | 8 (2.3) | 21 (20.8) | <0.0001 |

AKI: acute kidney injury. PACU: Post-Anaesthesia Care Unit. MV: mechanical ventilation. ICU: intensive care unit.

4. Discussion

We analyzed retrospectively the incidence, predictors, and impact on outcome of AKI in a cohort of 450 patients undergoing major nonvascular abdominal surgery.

The incidence of AKI (22.4%) was similar to that reported for cardiac surgery patients (26 to 30%) [31, 32] and higher than that described for major noncardiac surgery population (7.5%) [17]. Causey and colleagues reported an incidence of postoperative AKI of 11.8% in patients submitted to colorectal surgery. In this study, AKI was defined as an increase in SCr ≥ 50% and not considered an increase in SCr ≥ 0.3 mg/dL within a 48-hour timeframe and UO variations [18]. A large multicentric study performed in mixed cardiac and noncardiac surgery population described a lower incidence of postoperative AKI (1.1%). Exclusion of patients with preoperative SCr > 1.2 mg/dL or preoperative glomerular filtration rate (GFR) < 60 mL/min and a less broad definition of AKI (a rise in SCr level to 2X the baseline value or a 50% reduction in the GFR, not considering UO changes) could be at least in part responsible for this observation [33].

There have been a variety of predictive models developed to stratify risk in patients undergoing cardiac surgery [34–36] and major noncardiac surgery [16]. Similarly to Abella and colleagues [17] we found an association between the RCRI score [22] with postoperative AKI in patients undergoing major noncardiac surgery. It should be remembered that RCRI score was developed for the prediction of cardiac risk based on six independent prognostic factors: high-risk
Table 5: Univariate and multivariate analysis to determine predictors of in-hospital mortality.

| Variable                        | Unadjusted OR (95% CI) | P     | Adjusted OR (95% CI) | P     |
|---------------------------------|------------------------|-------|----------------------|-------|
| **Preoperative characteristics**|                        |       |                      |       |
| Age (per year)                  | 1.1 (1.06–1.2)         | <0.0001 | 1.07 (1.02–1.1)       | 0.014 |
| Male                            | 1.1 (0.5–2.2)          | 0.887 |                      |       |
| Caucasian                       | 1.3 (1.2–9.7)          | 0.831 |                      |       |
| Solid malignancy                | 1.5 (0.7–3.2)          | 0.287 |                      |       |
| ASA physical status IV/V        | 15.4 (6.7–35.6)        | <0.0001 | 9.1 (2.9–27.5)       | <0.0001 |
| Nonrenal RCRI (per point)      | 2.6 (1.5–4.3)          | <0.0001 | 1.6 (0.8–3.2)        | 0.213 |
| Preoperative hemoglobin (per g/dL) | 0.63 (0.5–0.8) | <0.0001 | 0.9 (0.6–1.2)        | 0.501 |
| Preoperative SCr (per mg/dL)    | 2.3 (1.3–3.9)          | 0.003 | 0.6 (0.3–1.4)        | 0.268 |
| Urgency surgery                 | 4.2 (1.9–8.9)          | <0.0001 | 1.9 (0.6–6.3)        | 0.320 |
| **Type of surgery**             |                        |       |                      |       |
| Colorectal                      | 1.3 (0.6–2.7)          | 0.516 |                      |       |
| Gastric                         | 0.7 (0.2–1.9)          | 0.471 |                      |       |
| Hepatobiliary and pancreatic1   | 0.2 (0.03–1.5)         | 0.116 |                      |       |
| Small bowel                     | 0.8 (0.1–6.2)          | 0.800 |                      |       |
| Esophageal                      | 3.4 (0.7–16.5)         | 0.130 |                      |       |
| Other surgery                   | 1.8 (0.7–5)            | 0.242 |                      |       |
| Nonrenal SAPS II (per point)    | 1.13 (1.09–1.2)        | <0.0001 | 1.08 (1.04–1.1)      | <0.0001 |
| Fluid balance (per liter)²      | 0.9 (0.8–1.1)          | 0.918 |                      |       |
| Postoperative AKI               | II.2 (4.8–26.2)        | <0.0001 | 3.7 (1.2–11.7)       | 0.024 |

OR: odds ratio. CI: confidence interval. ASA: American Society of Anesthesiologists. RCRI: Revised Cardiac Risk Index. SCr: serum creatinine. SAPS II: Simplified Acute Physiology Score, version II. AKI: acute kidney injury. 1Hepatobiliary and pancreatic surgery includes gallbladder surgery (N = 40), hepatic surgery (N = 15), pancreatic surgery (N = 6), and bile ducts surgery (N = 4). 2Fluid balance within the first two postoperative days.

surgery, ischemic heart disease, congestive heart disease, history of cerebrovascular disease, insulin therapy for diabetes, and preoperative SCr higher than 2.0 mg/dL. An ischemic insult to a more sensitive kidney could therefore explain why RCRI can predict postoperative AKI.

Although patients undergoing urgent surgery were more likely to have preexisting congestive heart failure and solid malignancies, to be ASA IV/V and to have higher preoperative SCr higher than 2.0 mg/dL. An ischemic insult to a more sensitive kidney could therefore explain why RCRI can predict postoperative AKI.

Intraoperative erythrocytes transfusions were a risk factor for postoperative AKI independently of the preoperative hemoglobin level. Although the intended therapeutic effect of erythrocytes transfusion is to improve organ function by increasing tissue oxygen delivery, there is increasing evidence that transfused erythrocytes may actually contribute to organ injury in susceptible patients, particularly in patients undergoing cardiac surgery in whom perioperative transfusion is a risk factor for renal dysfunction and is associated with worse outcomes [38–40]. Transfused stored erythrocytes may impair tissue oxygen delivery, promote a proinflammatory state, exacerbate tissue oxidative stress, and activate leukocytes and the coagulation cascade [41–43].

Patients with AKI had an in-hospital mortality of 20.8% which was slightly lower than that reported in a mixed noncardiac surgery population (27%) [17] and higher than that described in patients undergoing cardiac surgery (5 to 9%) [31, 32, 44, 45]. In a large mixed cardiac and noncardiac surgery population, 30-day and 3-month mortality of patients with AKI were 36% and 48%, respectively [33].

Postoperative AKI was independently associated with increased in-hospital mortality (patients with AKI were 3.7 times more likely to die) and there was a relationship between more severe AKI and increased in-hospital mortality. Despite the fact that AKI has emerged as an independent risk factor of in-hospital mortality, it is not clinically unequivocal if AKI may be per se an aspect of worse clinical condition/surgery (our findings are in line with previous studies [1–3] which have shown that AKI...
predictors and AKI outcomes are closely related) or if AKI itself independently contributes to increased mortality. The mechanism by which AKI itself could contribute to increased mortality remains not completely understood but volume overload, coagulation abnormalities, an increased incidence of sepsis with multiorgan failure, and cytokine or immune-mediated major organ dysfunction are possible explanations [46, 47]. In the present study, causes of death were similar between patients with postoperative AKI and patients who did not have AKI in the postoperative period. Therefore, further studies are needed to ascertain the exact mechanisms by which AKI could confer an increased mortality in patients undergoing major nonvascular abdominal surgery.

This study has some important limitations. First, the single-centre nature of the study largely limits its generalizability, and its retrospective design with a relatively small cohort of patients did not allow the evaluation of other confounders with prognostic importance. Second, we were not able to conclude about the exact mechanisms contributing to increased mortality in postoperative AKI patients submitted to major nonvascular abdominal surgery.

Our study has, however, some important virtues. First, it characterizes, for the first time, the incidence, risk factors, and impact on outcome of AKI (defined according to standardized definition using simultaneously SCr and UO criteria) in major nonvascular abdominal surgery. Second, despite its retrospective design, studied variables were routinely registered in daily practice. Third, many covariates with impact on AKI development and outcome were analyzed. Finally, causes of death were attained.

**Conflict of Interests**

The authors declare that there is no conflict of interests regarding the publication of this paper.

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