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Epidemiology and outcomes of acute kidney injury in critically ill surgical patients☆,☆☆,★

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ABSTRACT

Purpose: Acute kidney injury (AKI) is common in critically ill patients but is poorly defined in surgical patients. We studied AKI in a representative cohort of critically ill surgical patients.
Methods: This was a retrospective 1-year cohort study of general surgical intensive care unit patients. Patients were identified from a prospective database, and clinical data were reviewed. Acute kidney injury events were defined by risk, injury, failure, loss, and end-stage renal classification criteria. Outcomes were inpatient and 1-year mortality, inpatient lengths of stay, and discharge renal function. Risk factors for AKI and outcomes were compared by univariate and multivariate analyses.
Results: Of 624 patients, 296 (47%) developed AKI. Forty-two percent of events were present upon admission, whereas 36% occurred postoperatively. Risk, injury, failure, loss, and end-stage renal classification distributions by grade were as follows: risk, 152 (51%); injury, 69 (23%); and failure, 75 (25%). Comorbid diabetes, emergency admission, major surgery, sepsis, and illness severity were independently associated with renal dysfunction. Patients with AKI had significantly worse outcomes, including increased inpatient and 1-year mortality. Acute kidney injury starting before admission was associated with worse renal dysfunction and greater renal morbidity than de novo inpatient events.
Conclusions: Acute kidney injury is common in critically ill surgical patients and is associated with increased mortality, persisting renal impairment and greater resource use.

1. Introduction

Acute kidney injury (AKI) affects approximately 20% of hospitalized patients and up to 67% of those admitted to an intensive care unit (ICU), making it among the most common organ dysfunctions among the critically ill [1-7]. Depending on severity, AKI contributes to short-term mortality rates between 40% and 70% [8-14], and survivors are at increased risk for chronic kidney disease (CKD) and late death [9-11,15-18]. Acute kidney injury is associated with significantly increased resource utilization and health care costs [3-5]. Because surgical care and perioperative events and comorbidities interact to contribute to renal dysfunction in different patterns than in nonsurgical patients [19-26], surgical patients have unique risk factors for renal dysfunction.

Although the patterns and burden of AKI among select surgical subgroups have been reported [19-23,27], few investigations have studied it in a general surgical cohort [23,25]. Indeed, one potentially valuable resource to study perioperative AKI, the American College of Surgeons–National Surgical Quality Improvement Program database, has limited sensitivity for renal dysfunction because it only includes renal events with serum creatinine greater than or equal to 2 mg/dL or requiring dialysis [24,28]. Other studies have been limited to postoperative renal dysfunction and have excluded other manifestations such as events starting before surgery or occurring in the late postoperative period [19,24-26,28]. As such, further research is required to better understand broader general surgical populations at risk for AKI, especially critically ill surgical patients. The purpose of this study was to benchmark the epidemiology and outcomes of AKI in a cohort of critically ill surgical patients. We hypothesized that renal dysfunction in this population is common and is associated with a significantly higher burden of morbidity, mortality, and resource utilization.

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2. Methods

This was a retrospective 1-year cohort study of critically ill surgical patients approved by the University of Maryland School of Medicine Institutional Review Board. This data set was designed to capture patients' first and any subsequent AKI episodes and was used for a previously published, separate study of recurrent kidney injury that selectively analyzed patients who recovered from an initial episode of AKI [29]. This report is intended to serve as a separate, distinct analysis of primary AKI among critically ill surgical patients.

The setting was the 19-bed surgical ICU (SICU) at the University of Maryland Medical Center, a quaternary care academic hospital. As previously described, it is the primary ICU for acute care, general, vascular, transplant, thoracic, orthopedic, otolaryngology, and oral-maxillofacial surgery patients requiring critical care [30]. It also serves as an ancillary ICU for neurosurgical patients and admits medical patients on an emergency basis when nonsurgical ICUs have reached maximum capacity. Cardiac surgery and trauma patients are admitted to separate, dedicated units. The unit is run as a semiclosed, collaborative unit with multidisciplinary input on patient management, with all orders and critical care decisions made by the dedicated ICU service. Renal replacement therapy (RRT) is primarily provided as continuous venovenous hemodiafiltration using a Prismaflex system (Gambro, Lund, Sweden).

Consecutive adult SICU admissions between January 1 and December 31, 2012, were identified from a prospective Acute Physiology and Chronic Health Evaluation (APACHE) IV database (Cerner) [31-34]. To determine unique patients, the first SICU admission per hospitalization per patient was included. Clinical and renal data were abstracted both from the APACHE IV database and by individual chart review. One-year postdischarge survival was obtained from the Social Security Death Index, which was queried 15 months after the final discharge. Patients on chronic dialysis, who had documented previous AKI, nephrectomy, organ transplant, or with only 1 inpatient creatinine value, were excluded. Outcomes included inpatient and 1-year mortality (overall and censored for inpatient deaths); renal morbidity, as discharge renal function and recurrent kidney injury; and SICU and hospital lengths of stay as measures of resource utilization.

Using a previously described method [7,29], baseline serum creatinine was defined as the lowest of within 1 year before admission, at hospital or SICU admission, or, for patients without CKD, the Modification of Diet in Renal Disease equation solved for creatinine assuming a glomerular filtration rate of 75 mL/min per 1.73 m^2 [35]. A calculated value to estimate baseline creatinine in selected cases ensured patients admitted with AKI in progress were not assigned an artificially poor baseline renal function. The primary end point was inpatient AKI as diagnosed and staged by risk, injury, failure, loss and end-stage renal classification (RIFLE) creatinine criteria (by increase from baseline creatinine: risk $\geq$1.5$\times$, injury $\geq$2$\times$, and failure $\geq$3$\times$) [36]; because postdischarge renal function was not routinely available, the RIFLE Loss and End-stage renal disease outcome criteria were not assessed. Adapting the definition proposed by Bellomo et al [36], recovery from AKI was 2 or more serial creatinine values below a patient's RIFLE-Risk threshold, as a sustained improving trend without RRT for more than 24 hours [29]. Acute kidney injury exposure was calculated as the total time with renal dysfunction meeting AKI definition, regardless of recovery, whereas AKI duration was the time from onset to recovery.

The primary analysis was between patients with or without AKI. Subgroup analysis of AKI patients was performed between those admitted to the hospital with AKI in progress vs patients who developed de novo inpatient renal dysfunction. Groups were compared by 2-sided Pearson χ^2 or Fisher exact test as appropriate for categorical data. Normally distributed continuous data were compared by independent Student t test and reported as mean ± SD, whereas nonnormally distributed data were analyzed using Mann-Whitney U test and reported as median and interquartile range (IQR). Variables associated with AKI or mortality with a univariate P < .10 were included in multivariate logistic regression. Significance was set at P < .05.

Table 1
Cohort and subgroup characteristics

	All patients (n = 624)	No AKI (n = 328)	AKI (n = 296)	P
Age, years ± SD	59 ± 15	57 ± 17	62 ± 14	.0001
Male, n (%)	369 (59)	199 (61)	170 (57)	.41
Black, n (%)	199 (32)	105 (32)	94 (32)	.95
Hypertension, n (%)	288 (46)	139 (42)	149 (50)	<.05
Diabetes, n (%)	165 (26)	66 (20)	99 (33)	.0001
CKD, n (%)	42 (7)	18 (5)	24 (8)	.19
Baseline creatinine, mg/dL ± SD	0.84 ± 0.52	0.83 ± 0.58	0.86 ± 0.45	.63
APACHE III ± SD	54 ± 28	44 ± 19	66 ± 32	.0001
APACHE sepsis diagnosis, n (%)	42 (7)	7 (2)	35 (12)	.0001
Emergency status,[a] n (%)	236 (38)	98 (30)	138 (47)	.0001
Mechanical ventilation, n (%)	474 (76)	225 (69)	249 (84)	.0001
Median duration, days (IQR)	2 (1-5)	1 (0-3)	3 (1-9)	.0001
Operative management, n (%)	519 (83)	271 (83)	248 (84)	.70
Laparotomy, n (%)	181 (29)	63 (19)	118 (40)	.0001

[a] Emergency status defined as admission from the emergency department or to the emergency general surgery service or need for emergency surgical intervention for the primary admitting diagnosis.

3. Results

From January to December 2012, there were 886 unique SICU admissions. A total of 262 patients (30%) were excluded: 167 transplant recipients, 40 on chronic dialysis, 39 with prior AKI, 25 after nephrectomy, and 3 with single creatinine values. For the cohort of 624 patients, 369 (59%) were male, mean age was 59 ± 15 years, APACHE III score was 54 ± 28, and 76% of patients required mechanical ventilation (Table 1). General surgery specialty patients accounted for most admissions (52%) (acute care, 22%; vascular, 22%; and general surgery, 8%), and 83% of patients received surgical management for their primary diagnosis. The breakdown of creatinine values used to define patients' baseline renal function was as follows: 114 (18%) preadmission, 252 (40%) hospital admission, 130 (21%) SICU admission, and 128 (21%) calculated.

Nearly half (296, 47%) of the cohort developed AKI (Table 2). A total of 124 patients (42%) had AKI that started before hospitalization and was present upon admission, whereas 172 (58%) occurred as de novo inpatient events. Of these, 107 (62%) occurred postoperatively at a median of 3 (IQR, 1-10) days after surgery. The RIFLE distributions

Table 2
Summary of AKI events

	AKI events (n = 296)
Present upon admission, n (%)	124 (42)
De novo inpatient AKI, n (%)	172 (58)
Postoperative, n (%)	107 (36)
Interval, days (IQR)	3 (1-10)
Baseline creatinine, mg/dL ± SD	0.86 ± 0.45
Peak creatinine, mg/dL ± SD	2.17 ± 1.54
Peak:baseline creatinine ± SD	2.58 ± 1.67
Maximum RIFLE grade	
Risk, n (%)	152 (51)
Injury, n (%)	69 (23)
Failure, n (%)	75 (25)
RRT, n (%)	35 (12)
Duration, days (IQR)	8 (4-14)
AKI exposure, days (IQR)	4 (2-10)
Recovery,[a] n (%)	216 (73)
Duration before recovery, days (IQR)	3 (2-6)
Recovery to baseline,[b] n (%)	79 (27)
Death with AKI in progress, n (%)	33 (11)

[a] Recovery defined as return of creatinine to less than 1.5× baseline.
[b] Recovery to baseline defined as creatinine returning to less than or equal to baseline.