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Risk factors and outcome of acute kidney injury in elderly trauma patients

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ABSTRACT

Background: Acute Kidney Injury (AKI) is associated with significant morbidity. The risk factors for AKI in elderly trauma patients have not been defined.

Methods: Injured patients 75 years old or older from 2014 to 2016 were evaluated. AKI was identified by RIFLE criteria. Patients with and without AKI were compared with chi square, ANOVA, and logistic regression.

Results: 836 patients were 75 years old or older. Patients with AKI were more commonly male, hypotensive on admission with a greater Injury Severity Score but age, diabetes, hypertension and baseline creatinine were similar. Patients with AKI had a higher mortality that did not increase with RIFLE stage. Male sex, ISS, hypotension on admission and presence of an extremity injury were independently associated with AKI by logistic regression.

Conclusion: AKI in elderly trauma patients is associated with magnitude of injury and shock but not pre-existing medical comorbidities and it significantly increased the risk of death.

Introduction

Elderly patients are a rapidly growing subset of the population in the United States.[1] Not surprisingly, the number of elderly patients who are injured and present for treatment at trauma centers is increasing.[1] This demographic change is one reason that falls are the most common mechanism of injury in many trauma centers.[1,2] However, elderly patients often remain independent and highly functioning for decades and can be injured by the same high speed mechanisms as younger trauma patients such as motor vehicle crashes and motorcycle crashes. Organ dysfunction is a significant contributor to morbidity and mortality after injury.[3] Renal failure was a component of the earliest definitions of Multiple Organ Dysfunction Syndrome (MODS) and the magnitude of renal failure was incorporated into the common MODS scoring systems that were developed.[3–5] The term Acute Kidney Injury (AKI) has essentially replaced the terms “renal failure” or “renal dysfunction” to describe the loss of baseline renal function following illness or injury.[6] Consensus definitions for AKI[7] and several scoring systems to estimate glomerular filtration rate and the magnitude of AKI have been developed. These tools include the Modification of Diet in Renal Disease (MDRD) equation,[8,9] the Acute Kidney Injury Network (AKIN) classification,[10] and the Risk, Injury, Failure, Loss of kidney function, and End-stage kidney disease (RIFLE) classification.[10,11] While the MDRD equation is complicated, the AKIN and RIFLE criteria are easy to apply. Both AKIN and RIFLE have been used to assess AKI in patients suffering critical illness, burns, and multisystem trauma and both correlate with outcome.[12–16]

Risk factors for AKI in injured patients have been identified and include age, injury severity, and the presence of medical comorbidities.[13–17] However, these risk factors have been defined in studies containing substantial numbers of young patients and demonstrate that older patients are at risk for AKI compared to young healthy patients. However, the incidence of AKI and the risk factors for AKI specific to older patients have not been described. We hypothesized that elderly trauma patients would be at increased risk for AKI after injury from a greater prevalence of baseline medical comorbidities, injury related factors, and the increasing use of contrasted radiologic studies for diagnosis (computed tomography) and therapy (interventional radiology).[18] We examined the frequency, risk factors, magnitude and impact of AKI on outcome in this population. Our data demonstrate that

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any degree of AKI in the injured elderly patient, regardless of how minor, is associated with significant morbidity and increased mortality.

Material and methods

We performed a retrospective analysis of injured patients admitted to our adult Level 1 Trauma Center from 2014 through 2016. This study was reviewed and approved by the University of Louisville School of Medicine Institutional Review Board. Elderly patients were defined as those ≥75 years of age. Demographic, injury, and outcome data were abstracted from our trauma registry. The medical records were reviewed and baseline creatinine, highest creatinine, day of highest creatinine, number of contrasted imaging studies, use of interventional radiology, and number of contrasted imaging studies from transferring facilities were assessed. Ventilator days were used as a surrogate marker for respiratory failure. RIFLE criteria[9,10] were applied retrospectively using creatinine measurements from the medical record. Baseline creatinine values were defined as the initial creatinine level measured in our facility. Given the inconsistent availability of records from transferring facilities, creatinine measurements from transferring hospitals were not included. Patients were defined as having AKI if they had a RIFLE score ≥1.

Data are presented as the mean ± standard deviation. Numerical values between groups were compared using Analysis of Variance. Categorical variables were compared using chi square. Variables that had a value of $p \leq 0.20$ on univariate analysis were assessed by logistic regression for their association with the development of AKI. Values with a $p < 0.05$ were considered statistically significant.

Results

During the study period from 2014 through 2016, 9923 injured patients were entered into our trauma registry and 851 patients were ≥ 75 years old. We excluded 9 patients because they died in the Emergency Department (ED) or had a length of hospital stay of 0 days and 6 patients because they had no creatinine values during their hospitalization. Of the remaining 836 patients, 66 (7.9%) developed an AKI defined as RIFLE ≥1 during their hospitalization. Demographic data for patients with and without AKI after injury are listed in Table 1. Patients who developed AKI were more often male and had a lower mean ED systolic blood pressure although the mean ED systolic blood pressure for patients with AKI, while lower than patients without AKI, was still essentially normal (Table 1). Patients with AKI more frequently suffered hypotension defined as an ED systolic blood pressure less than 90 mm Hg (Table 1). Some authors have suggested that a systolic blood pressure less than 110 mm Hg should define hypotension in elderly patients[19] and patients with AKI more frequently suffered hypotension if that criteria for hypotension was used (Table 1). There was no difference in age, incidence of diabetes, incidence of hypertension or frequency of preexisting renal insufficiency between patients who did or did not develop AKI (Table 1). Baseline creatinine values were similar between groups but, as expected, maximum creatinine values were higher for patients who developed AKI (Table 1).

Injury data are provided in Table 2. Most of these elderly patients suffered blunt injury. While a greater proportion of injured elderly patients who developed AKI were injured in motor vehicle crashes or motorcycle crashes compared to those who did not develop AKI, differences in mechanism of injury did not reach statistical significance (Table 2). Elderly patients who developed AKI had a higher Injury Severity Score (ISS), were more likely to have a chest injury, and were more likely to have an extremity injury (Table 2). Elderly patients with AKI were also more likely to have a pelvic fracture (including acetabular and sacral fractures) as their extremity injury than patients who did not develop AKI (Table 2). The proportion of elderly patients who suffered a head injury was similar between groups. The magnitude of individual injuries as measured by maximum AIS score was similar for all body regions except chest, where elderly patients who developed AKI had a higher mean maximum chest AIS score than patients who did not develop AKI. Despite having a similar AIS for most body regions, elderly patients who developed AKI were more likely to have combinations of injuries as reflected by greater ISS and were more likely to be triaged from the ED to the Intensive Care Unit (ICU) or the Operating Room (OR) for treatment of their injuries (Table 3). As expected, patients who developed AKI had a longer ICU stay, longer hospital stay, and spent more time on a ventilator (Table 3). However, utilization of interventional radiology for diagnosis or therapy was not statistically different between groups (Table 3). We found

Table 1
Demographics.

	No Acute Kidney Injury	Acute Kidney Injury
N (%)	770 (92.1)	66 (7.9)
Age, years	82.9 ± 5.8	82.9 ± 5.8
Male, %	44.8	68.2[1]
Diabetes, %	19.2	22.7
Hypertension, %	71.4	62.1
Chronic Renal Insufficiency/Failure, %	4.2	6.1
Other Comorbidities, %	51.0	54.5
Initial Creatinine, mg/dl	1.1 ± 0.5	1.2 ± 0.7
Maximum Creatinine, mg/dl	1.2 ± 0.6	2.3 ± 1.1[1]
Day of Maximum Creatinine	2.0 ± 2.6	5.0 ± 4.5[1]
Emergency Department pulse, bpm	84 ± 31	90 ± 19
Emergency Department Systolic Blood Pressure, mmHg	146 ± 29	137 ± 37[2]
Emergency Department Glasgow Coma Scale	14 ± 3	13 ± 3
Emergency Department Systolic Blood Pressure ≤ 90, %	2.7	13.6[1]
Emergency Department Systolic Blood Pressure ≤ 110, %	11.6	24.2[2]

[1]$p < 0.001$. [2]$p < 0.05$.

Table 2
Injury characteristics.

	No Acute Kidney Injury	Acute Kidney Injury
Blunt Injury n (%)	734 (95.3)	59 (89.4)
Mechanism, %		
Fall	60.9	43.9
MVC/MCC/ATV	31.2	43.9
Burn	3.8	7.6
GSW/Stab	0.5	1.5
Injury Severity Score	13.6 ± 8.1	18.3 ± 9.7[1]
Head Injury, n (%)	352 (45.7)	24 (36.4)
Head AIS	3.3 ± 1.1	3.1 ± 1.3
Neck Injury, n (%)	148 (9.2)	13 (19.7)
Neck AIS	2.4 ± 0.7	2.5 ± 0.9
Chest Injury, n (%)	335 (43.4)	46 (69.7)[1]
Chest AIS	2.6 ± 0.7	3.0 ± 0.8[2]
Abdominal Injury, n (%)	135 (17.4)	16 (24.2)
Abdominal AIS	2.3 ± 0.6	2.6 ± 0.7
Extremity Injury, n (%)	257 (33.4)	41 (62.1)[1]
Extremity AIS	2.3 ± 0.5	2.4 ± 0.6
Pelvic Fracture, n (%)	57 (7.4)	14 (21.2)[1]

[1]$p < 0.001$. [2]$p < 0.05$.
AIS: Abbreviated Injury Score; ATV: All Terrain Vehicle; MVC: Motor Vehicle Crash; MCC: Motor Cycle Crash; GSW: Gun Shot Wound.

Table 3
Treatment and outcome.

	No Acute Kidney Injury	Acute Kidney Injury
Emergency Department Disposition, n (%)		
Floor	374 (48.6)	9 (13.6)[1]
Intensive Care Unit	348 (45.2)	50 (75.8)
Operating Room	34 (4.4)	6 (9.1)
NA	14 (1.8)	1 (1.5)
Intensive Care Unit stay, days	2.4 ± 5.3	8.1 ± 10.9[1]
Ventilator days, days	0.6 ± 2.5	4.2 ± 6.9[1]
Hospital stay, days	5.5 ± 5.7	10.7 ± 11.5[1]
Contrasted CT at Referring Hospital, n (%)	57 (7.4)	7 (10.6)
Number of CTs at Referring Hospital	0.1 ± 0.3	0.1 ± 0.3
Number of CTs after Admission (48 h)	0.6 ± 0.6	0.7 ± 0.6
Interventional Radiology, n (%)	15 (1.9)	3 (4.5)
Mortality, n (%)	88 (11.4)	30 (45.5)[1]

[1] $p < 0.001$. NA: Not available.

no difference in the percentage of patients who underwent a Computed Tomography (CT) scan with contrast at a referring hospital prior to transfer, total number of contrasted CT scans performed prior to transfer, or total number of contrasted CT scans performed within the first 48 h of arrival at our trauma center between elderly patients who did not and did develop AKI (Table 3) (all $p > 0.1$). Mortality was high for both groups but was significantly higher for elderly patients who developed an AKI (Table 3).

We stratified magnitude of AKI by RIFLE stage (Table 4). Most patients had Stage 1 and few elderly patients developed Stage 3 AKI. Mean age, percentage of male patients (Table 4), and frequency of shock (SBP ≤ 90 mm Hg) (data not shown) were not different based on RIFLE stage 1. Elderly patients who developed stage 2 and 3 AKI had a higher ISS, longer ICU length of stay, and longer total hospital stay compared to stage 1 AKI patients but mortality was not statistically different based on RIFLE stage (Table 4). We performed logistic regression analysis using all variables that had a $p < 0.20$ on univariate analysis and the results are demonstrated in Table 5. Age, Injury Severity Score, presence of an extremity injury, and hypotension (SBP ≤ 90 mm Hg) were all independently associated with development of an AKI while presence of a head injury and chest injury approached but did not reach statistical significance (Table 5). If systolic blood pressure ≤ 110 mm Hg was used as the definition of hypotension, blood pressure was no longer significantly associated with AKI while male sex, ISS, chest injury and extremity injury remained statistically significant (data not shown).

Table 4
RIFLE stage.

	RIFLE Stage		
	1	2	3
N	43	18	5
Age, years	82.7 ± 5.8	82.9 ± 6.1	84.0 ± 6.6
Male, %	62.8	72.2	100
Injury Severity Score	17.3 ± 9.7	20.5 ± 10.7	19.2 ± 5.0[1]
Intensive Care Unit stay, days	6.1 ± 8.4	10.6 ± 13.0	16.8 ± 17.7[1]
Hospital stay, days	8.7 ± 8.9	12.5 ± 13.1	21.0 ± 19.5[1]
Mortality, %	44.2	55.6	20.0

[1] $p < 0.001$.

Discussion

The development of organ dysfunction/failure in the recovery period after injury significantly decreases the likelihood of survival, prolongs ICU length of stay, and is associated with significant morbidity.[3] This is particularly true for elderly patients who may already have significant medical comorbidities that interfere with recovery independent of the development of post-traumatic organ dysfunction. We hypothesized that elderly trauma patients would be particularly susceptible to the development of AKI and that their risk factors would be different than younger patients. The incidence of AKI varies depending on the definition of AKI used and the patient population studied. We previously demonstrated an incidence of renal dysfunction of 2.3–4.0% in patients with an ISS ≥ 14 when defined as a creatinine ≥ 2.0 mg/dl.[3,17] The incidence of AKI is 6–25% for patients admitted to the ICU using AKIN/RIFLE criteria.[14–16] In our study of elderly patients 75 years old or older, we demonstrate an incidence of AKI of 7.9% (Table 1). This incidence is similar to prior studies of ICU patients[14–16] even though 45.8% of our patients were admitted to a non-ICU floor (Table 3). Our data demonstrate that in injured elderly patients, AKI is primarily associated with factors that are already established when patients present for care such as male sex, hypotension, presence of chest and extremity injuries, and increased overall injury severity as measured by ISS. The development of AKI was associated with a significant increase in mortality in this population. Interestingly, mortality did not differ by the magnitude or stage of AKI. Stage 3 AKI, which frequently requires renal replacement therapy, was not associated with a higher mortality than stage 1 AKI in this population but was associated with greater ICU and hospital length of stay. These data confirm that development of AKI of any magnitude is a significant complication for elderly trauma patients and substantially complicates recovery from injury.

In this population of elderly trauma patients we did not find an association between AKI and several risk factors shown to be associated with AKI in prior studies such as diabetes and hypertension.[17,18] The percentage of patients in this data set with diabetes and hypertension was high (20% and 70%, respectively) and so the relative contribution of these risk factors to the development of AKI may not be as evident in the elderly as it may be in younger patients. It is also possible that diabetes and hypertension in previous studies are primarily surrogate markers for age. Since our analysis was limited to patients ≥ 75 years old, the relative contribution of these comorbidities may be less substantial or less detectable. We could not demonstrate any association between development of AKI and contrasted imaging studies (CT scans or IR procedures) in this patient population. This finding is surprising and the reason for this is unclear. Lower osmolarity contrast agents can certainly mitigate some of the risk for AKI with contrasted studies and we did not evaluate the type of contrast used for the CT/IR studies in this study period. It is also possible that health care providers were already sensitized to concerns about contrast-induced nephropathy in elderly trauma patients and had already limited the number of contrasted studies in older patients. The low number of contrasted CT scans in this study (<1 study in the initial 48 h) would be consistent with that behavior. Similarly, the high frequency of falls and the relatively low ISS of patients in this dataset could indicate that fewer CT scans were ordered by providers due to less frequent high velocity mechanisms of injury.

Development of AKI in this patient population was associated with several factors that cannot be modified by health care providers such as age, sex, and magnitude of injury. However, a fatalistic approach to AKI is not optimal since development of even stage 1 AKI was associated with significant morbidity and mortality. We found increased ICU and hospital length of stay with more

Table 5
Logistic regression for acute kidney injury.

Variable	Odds Ratio	95% Confidence Interval		Significance
		Lower	Higher	
Male	2.609	1.448	4.701	0.001
Diabetes	1.311	0.673	2.556	0.426
Hypertension	0.719	0.401	1.287	0.266
Initial creatinine	1.124	0.702	1.799	0.626
Injury Severity Score	1.060	1.024	1.098	0.001
Head Injury	0.571	0.299	1.089	0.089
Chest Injury	1.794	0.953	3.378	0.070
Abdominal Injury	0.572	0.280	1.168	0.125
Extremity Injury	2.780	1.574	4.911	0.001
Emergency Department SBP	1.004	0.993	1.014	0.499
Emergency Department SBP $\leq$ 90 mm Hg	3.942	1.287	12.072	0.016

SBP: Systolic Blood Pressure.

severe AKI in this patient population. However, we did not find a correspondingly increased mortality rate with severe (Stage 3) AKI. This was somewhat surprising since more severe AKI/renal failure is typically assumed to confer a greater risk of death. Since the mean age of patients in this data set was ≥82 years, the impact of care limitations in this population needs to be considered. It is possible that any degree of renal dysfunction, no matter how mild or severe, prompted discussions about quality of life and likelihood of recovery that could have influenced the extent of subsequent care, aggressiveness of care and duration of hospital stay.[20] We know that increasing numbers of elderly trauma patients are presenting to trauma centers with advanced directives already established or have had discussions with family members about quality of life in the event of a serious illness.[21] It is possible that some patients who would have ultimately progressed to Stage 3 AKI had their care limited or withdrawn early in their hospital course when their AKI fulfilled only stage 1 or 2 criteria.[20,22] How the changing culture emphasizing quality of recovery, quality of life, and early identification of futile care may have influenced the results of this analysis is hard to define. Our data suggest, however, that in this population of elderly patients, development of any degree of AKI has as detrimental an impact on prognosis and outcome as advanced AKI.

Conclusion

AKI developed in 7.9% of elderly trauma patients ≥75 years of age. While magnitude of AKI correlated with resource utilization and length of stay, any degree of AKI was significantly associated with increased mortality. Meticulous medical care and continued vigilance are required to minimize the consequences of AKI in elderly trauma patients.

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