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Research Article

Risk Factors and Outcomes of Acute Kidney Injury in Trauma Patients Admitted to Critical Care Units

Mehrdad Karajizadeh[1], Golnar Sabetian[1*], Najmeh Bordbar[1], Haniyeh Kazemi[2], Roham Borazjani[1], Shahram Paydar[1], Mansoor Masjedi[3]

[1] Trauma Research Center, Shahid Rajaee (Emtiaz) Trauma Hospital, Shiraz University of Medical Sciences, Shiraz, Iran.
[2] Department of Physiology, The Medical School, Shiraz University of Medical Sciences, Shiraz, Iran.
[3] Anesthesiology and Critical Care Research Center, Shiraz University of Medical Sciences, Shiraz, Iran.

***Corresponding Author:** Golnar Sabetian, Trauma Research Center, Rajaee Hospital, 6th Floor, Chamran Ave. Shiraz, Iran., Tel: +98-71-36254206, Email: gsabetian@yahoo.com

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Abstract

Introduction: This study aimed to determine the AKI prevalence and the contributing factors among trauma patients admitted to the ICU of the only level-one trauma center in south Iran.

Methods: The present study was a retrospective cohort of patients with post-traumatic AKI admitted to the intensive care units of Shahid Rajaee (Emtiaz) Trauma Hospital in Shiraz, Iran, between March 21, 2021, and February 20, 2022. The variables were obtained from the Iran Intensive Care Unit Registry program (IICUR). Demographic features (age, sex, height, weight), vital signs including heart rate, respiratory rate, temperature, blood pressure, outcome, and laboratory findings were gathered.

Results: In total, 2271 trauma patients admitted to the ICUs were included in 398 cases (17.5%) developed with AKI. Most AKI patients, 249 (62.60%) were in stage 1 disease. Of 77(19.30%) individuals in stage 2, 72(18.10%) were in stage 3 of the disease. Most AKI patients were male, with a mean age of 52.92± 22.06 years. AKI patients were hospitalized in the intensive care unit for significantly more days than patients without AKI and were more severe regarding APACHE II and GCS (p-value <0.001).

Conclusion: Acute renal injury in ICU trauma patients is a common complication with significant mortality and length of hospital stay. Age, high APACHE II score, minimum systolic blood pressure, acute renal injury, and low GCS score are strong risk factors associated with mortality in intensive care unit patients. Patients with acute kidney injury are five times more likely to die.

Keywords: Acute Kidney Injury, Trauma, ICU.

Introduction

Organ failure is the third leading cause of death in trauma patients [1]. Kidney dysfunctions are usually affected, and several factors, including dehydration, crush injuries, and the use of contrast agents, increase the chance of post-traumatic acute kidney injury (AKI). A systematic review and meta-analysis study reported that the pool incidence of post-traumatic AKI was 24% in all 25,182 included patients [2]. AKI increases the mortality rate, hospital length of stay (HLOS), and intensive care unit length of stay (ICU-LOS) [3, 4]. Previous studies have shown that the prevalence of AKI is higher in trauma patients admitted to the ICU [5, 6].

Patients with acute renal impairment were admitted to the intensive care unit six days longer than others [7, 8]. The mortality rate in patients with acute renal impairment is 27%, and the mortality rate in patients with acute renal impairment is significantly higher than in other patients [2]. Renal recovery occurs in 96% of patients with acute renal injury after trauma [9].

Several studies addressed the risk factors associated with post-traumatic AKI development. Stewart et al. sought AKI risk factors after combat trauma among veterans for nine years using KDIGO (Kidney Disease: Improving Global Outcomes) serum creatinine criteria.

The independent predictors of AKI were the African American race, age, injury severity score, burn, and presenting vital signs [10].

Fujinaga et al. used the same serum creatinine criteria in Japanese trauma patients admitted to the ICU of a tertiary center. 19.8 % of included patients developed AKI. Male sex, higher age, and more blood transfusion were associated with AKI development [11].

Bjornstad et al. found out that severe anemia (hemoglobin< 10g/dl) and time between injury and hospital arrival were the sole independent risk factors for predicting AKI following trauma in an African prospective, single-center cohort study [12].

Considering such significant heterogeneity, as Søvik et al. [2] mentioned, the results of the previous studies may not be pervasive in the other populations. Moreover, determining the prevalence of AKI and its predictors in trauma patients admitted to the intensive care unit is essential for planning and managing trauma patients. Therefore, this study aimed to determine the AKI prevalence and the contributing factors among trauma patients admitted to the ICU of the only level-one trauma center in south Iran.

Methods

The present study was a retrospective cohort of patients with post-traumatic AKI admitted to the intensive care units of Shahid Rajaee (Emtiaz) Trauma Hospital in Shiraz, Iran, between March 21, 2021, and February 20, 2022. Our trauma center is the largest and the only level-one trauma center in southern Iran, comprising six 9-bed ICUs. The current study was reported based on the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement [13].

Using a convenient sampling method, we included all adult trauma patients (Age≥ 16 years old) admitted to ICUs of Shahid Rajaee (Emtiaz) Trauma Hospital in Shiraz. On the other hand, the exclusion criteria were age younger than 16 and a positive history of chronic kidney diseases.

Chronic kidney disease is defined based on previous study that includes at least one of the following: (A) glomerular filtration rate (GFR) < 60 mL/min/1.73 m2; (B) Albuminuria (ACR ≥ 30 mg/g); (C) Urine sediment abnormalities; (D) Electrolyte and other abnormalities due to tubular disorders; (E) Abnormalities detected by histology; (f) Structural abnormalities detected by imaging; or (G) History of kidney transplantation [14].

Patients were classified into the AKI and non-AKI groups based on KDIGO Criteria, and variables were compared.

The ICU registry Database was queried from March 21, 2021, to February 20, 2022, considering the inclusion and exclusion criteria. The Iran Intensive Care Unit Registry program (IICUR) obtained the variables. This program was approved by the Ethics Committee of Shiraz University of Medical Sciences in 2018 (Ethic Number IR.SUMS.REC.1397.559) and recognized by the Iran Ministry of Health as the first and single registry of adult ICUs in Iran. IICUR was developed with The Australian and New Zealand Intensive Care Society. IICUR includes patients admitted or readmitted to ICUs for more than 24 hours. Patients admitted to ICU (or other units) for solitary procedures (e.g., central line insertion) were not recruited.

Demographic features (age, sex, Body mass index (BMI)), vital signs, including heart rate, respiratory rate, temperature, and blood pressure, as well as laboratory findings, were gathered. The age was categorized to fit for APACHE II. The mean arterial pressure was calculated according to the systolic and diastolic blood pressure. Laboratory findings were blood PH, serum level of sodium and potassium, hematocrit, and white blood cell count. Injury-related features were the initial Glasgow coma scale (GCS) and the mechanisms of injury.

Renal functions were monitored using the serum level of blood urea nitrogen (BUN), creatinine level, and urine output. The urine output was measured during the first 24 hours of ICU admission. All variables except creatinine and CPK were extracted from the registry program. The serum level of creatinine was recruited from the hospital database to report the arrival of creatinine and its changes. Any comorbidities such as cirrhosis, Class IV congestive heart failure, severe chronic obstructive pulmonary disease (COPD), dialysis, and immunocompromised conditions were also gathered.

The APACHE II was calculated [15]. For physiological variables, maximum and minimum values of 24 hours of initial ICU admission were considered. Acute kidney injury was defined based on the KDIGO criteria

(Table1). The on-arrival creatinine level was considered as the reference creatinine [5].

Table 1: Kidney Disease: Improving Global Outcomes serum creatinine criteria definition.

Stages	Definition [15]
Stage 1	Increase in serum creatinine of ≥0.3 mg/dL or 1.5 to 1.9 times baseline within 7 days
Stage 2	Increase in serum creatinine to 2.0 to 2.9 times baseline
Stage 3	Increase in serum creatinine to ≥3.0 times baseline OR Initiation of kidney replacement therapy

Our primary outcome was the mortality rate in the overall population, specifically among patients developing AKI. The secondary outcomes were the HLOS and ICU length of stay. Data were analyzed using the SPSS software version 24. Data were described as mean (standard deviation) for quantitative variables and number (%) for the categorical ones. The independent sample t-test and $\chi 2$ were used to compare variables between the two groups. The binary logistic regression model was used to predict factors affecting mortality in AKI patients. P-values less than 0.05 were considered statistically significant.

Results

In total, 2271 trauma patients admitted to the ICUs were included in 398 cases (17.5%) developed with AKI. Most AKI patients, 249 (62.60%) were in stage 1 disease. The flow of data is represented in Figure 1. Of 77(19.30%) individuals in stage 2, 72(18.10%) were in stage 3 of the disease. The demographic features and trauma-related characteristics are listed in Table 2. Most AKI patients were male, with a mean age of 52.92± 22.06 years. The baseline and maximum value of creatinine in this study are shown in Figure 2.

Table 2: Baseline characteristics and injury-related parameters among patients with and without acute kidney injury (N=2271).

Characteristics	Without AKI (N = 1873)	With AKI (N = 398)	P-value
Male sex, n (%)	1496 (82.70%)	314 (17.30)	0.66
Age, years (Mean ± SD)	44.73 ± 20.78	52.92 ± 22.06	<0.0001
BMI(kg/m2) (Mean ± SD)	25.06(4.80)	25.18(3.35)	0.38
Mechanisms of injury			0.005
Blunt	1703(81.80%)	379(18.20%)	
Penetrating	170(89.9%)	19(10.10%)	
ISS (median: Interquartile range)	17(16)	25(15)	<0.0001
APACHE II (median: Interquartile range)	16(9)	23 (12)	<0.0001
GCS, n (%)			0.001
GCS 3-8	51 (3.60%)	19 (8.60%)	
GCS 9-12	331 (23.60%)	60 (27.10%)	
GCS 13-15	1023 (72.80%)	142 (64.30%)	
Min Temperature, °C	36.86 ± 0.80	36.68 ±0.92	<0.0001
Max Heart Rate	103.61 ± 20.10	112.26 ± 23.54	<0.0001
Min Heart Rate	75.35 ± 16.74	80.32 ± 19.09	<0.0001
Max Systolic Blood Pressure	140.31 ± 17.87	144.02 ±20.38	<0.0001
Min Systolic Blood Pressure	106.73 ± 14.47	100.53 ± 19.05	<0.0001
Max Diastolic Blood Pressure	82.44 ± 13.99	84.01 ± 15.48	0.05
Min Diastolic Blood Pressure	65.52 ± 12.40	62.13 ± 14.01	<0.0001
Max Mean Arterial Blood Pressure	101.39 ± 13.20	103.74 ± 15.03	0.002
Min Mean Arterial Blood Pressure	78.94 ± 11.73	74.61 ± 14.49	<0.0001
Max Respiratory Rate	21.79 ± 4.36	23.08 ± 6.09	<0.0001
Min Respiratory Rate	13.91 ± 2.54	14.60 ± 4.01	<0.0001
Min= Minimum, Max= Maximum, GCS= Glasgow Coma Scale, APACHE = Acute Physiology and Chronic Health Evaluation			

Sodium, potassium, creatinine, glucose, BS, BUN, CPK, and lactate were significantly higher in the AKI group (all p-values <0.05). On the other hand, Bicarbonate, Hematocrit, and PH were significantly lower in the AKI group (all p-values <0.05). There were no white blood cell count differences between AKI and non-AKI groups (Table 3).

AKI patients were hospitalized in the intensive care unit for significantly more days than patients without AKI and were more severe regarding APACHE II and GCS. The mortality rate of AKI trauma patients was about 30% higher than those in patients without AKI (Table 4).

Factors related to mortality following trauma in intensive care units were determined by logistic regression. Age, APACHE II score, lowest systolic blood pressure, GCS score, and acute renal injury were the leading causes of death in patients (Table 5).

Table 3: Laboratory finding of trauma patients with or without acute kidney injury.

Characteristics	Without AKI (N = 1873)	With AKI (N = 398)	P-value
Max Sodium	139.70 ± 4.74	141.87 ± 6.86	<0.001
Min Sodium	137.35 ± 4.26	138.57 ± 5.75	<0.001
Max Potassium	4.2 ± 0.6	4.4 ± 0.8	<0.001
Min Potassium	4 ± 0.5	4.2 ± 0.7	<0.001
Max Bicarbonate	23.23 ± 3.55	22.50 ± 4.71	0.001
Min Bicarbonate	19.28 ± 3.48	17.78 ± 4.29	<0.001
Max creatinine	1.20±1.23	1.57±1.37	<0.001
Min creatinine	1.11±0.96	1.33±0.64	<0.001
Max Urea	17.29 ± 10.69	21.27 ± 10.88	<0.001
Max Albumin	3.62 ± 0.61	3.37 ± 0.72	<0.001
Min Albumin	3.40 ± 0.53	2.73 ± 0.94	0.01
Max Glucose	146.90 ± 56.64	183.75 ± 93.30	<0.001
Min Glucose	123 ± 53.43	143.40 ± 57.48	<0.001
Min Hematocrit	0.32 ± 0.06	0.31 ± 0.06	0.01
Baseline BS	158.33±69.06	183.97±78.32	<0.0001
Max BS	117.75±71.00	141.43±111.49	<0.0001
Max BUN	17.89±11.80	35.68±26.79	<0.0001
Max CPK	1252.33±2106.60	1610.40±2560.58	0.03
Baseline Lactate	23.70±13.07	32.75±29.66	<0.0001
Max lactate	24.61±12.99	36.38±29.71	<0.0001
PH	7.37 ± 0.07	7.33 ± 0.10	<0.0001

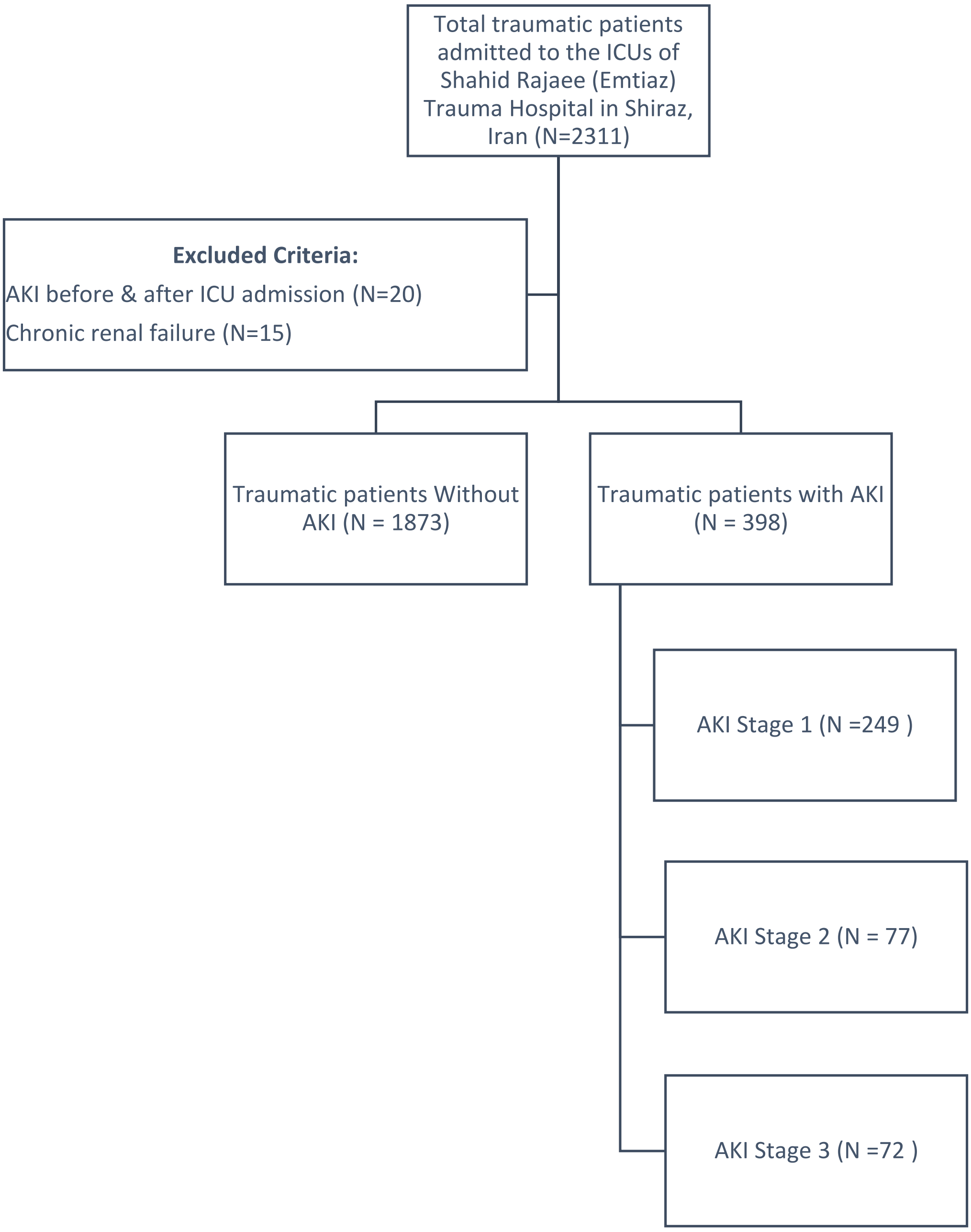

Figure 1: Data flow chart traumatic patients admitted to the ICUs of Shahid Rajaee (Emtiaz) Trauma Hospital with or without AKI.

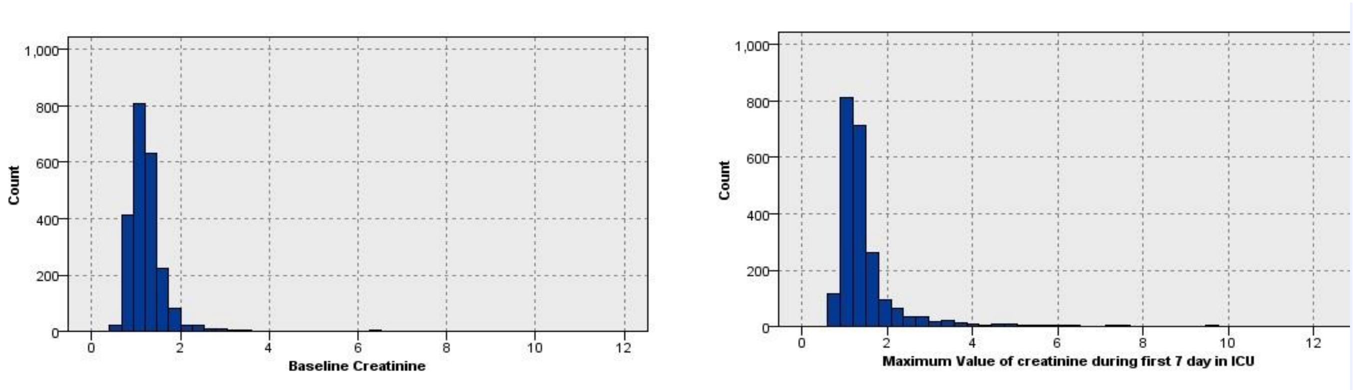

Figure 2: Baseline and maximum value of creatinine in patient admitted to traumatic ICU.

Table 4: Measured outcomes compared between patients with or without acute kidney injury.

Characteristics	Without AKI (N = 1873)	With AKI (N = 398)	P-value
ICU length of stay, days (median [IQR])	3.7 (5.25)	7.92 (15.77)	<0.0001
hospital length of stay, days (median [IQR])	9(10)	17(27)	<0.0001
In-hospital Mortality, n (%)			<0.0001
Survival	1781 (95.10%)	226 (56.80%)	
Died	92 (4.90%)	172 (43.20%)	
ICU Mortality, n (%)			<0.0001
Survival	1807(96.50%)	275(69.10%)	
Died	66(3.50%)	123(30.90%)	
Inotropes/ vasopressor	(6.40%)	114(28.90%)	<0.0001

Table 5: Risk factors associated with the occurrence of in-hospital mortality among patients which were selected by the binary logistic regression model.

Parameter	B	OR	95%CI	P-value
Age	0.04	1.048	1.032 - 1.053	<0.0001
APACHE II Score	0.012	1.13	1.08 - 1.18	<0.0001
Min Systolic Blood Pressure during 24 admission at ICU	- 0.02	0.98	0.97 - 0.99	0.001
GCS 13-15(reference)		-		<0.0001
GCS 3-8	1.33	3.79	1.96 - 7.32	<0.0001
GCS 9-12	0.24	1.27	0.70 - 2.31	0.42
AKI	1.774	5.89	3.74 – 9.28	<0.0001
Constant	- 5.28	0.005		

Discussion

Most trauma patients admitted to intensive care units develop acute kidney injury [6]. In this study, the prevalence of acute renal injury in trauma patients was 17.5%. The prevalence of AKI in trauma patients varies in different studies. The prevalence of AKI in the study of Nasu et al. (2022), 14.6% [6], in the study of Harrois et al. (2018), 13% [16] in the study of Haines et al. [5], 19.6%, in the Skinner et al. Study (2014), 15% [7], and in the Bagshaw et al. (2008) study, 18.1 Percentage [3]. The prevalence of AKI in this study is broadly consistent with other studies. However, in previous studies, the prevalence of AKI in trauma patients has varied widely between 6% and 40% [17-19]. The differences in the majority of AKI in these studies are related to the age of patients, the type of hospitalization ward, different criteria for diagnosing AKI, the mechanism and severity of trauma injury, and the duration of follow-up of patients. Because there is no specific drug treatment for patients with AKI and due to the high mortality rate in these patients, the initial prediction of AKI and prevention of AKI is critical.

In this study, most patients were male. The mean age of AKI patients was higher than patients without AKI. In the study of Bagshaw et al. (2008) and the study of Li et al. (2011), AKI patients were older [20, 21]. It seems that because men are more exposed to external accidents than women, the rate of trauma injury is higher in this group. On the other hand, considering that age is one of the risk factors for AKI, the results of the present study seem logical. In addition, AKI patients were hospitalized in the intensive care unit for more days than patients without AKI. In the study of Søvik et al. (2019), AKI patients were hospitalized in the intensive care unit for six days more than patients without AKI[2].

Also, in the present study, AKI patients were more severe regarding APACHE II and GCS. The mortality rate of AKI patients was about 5.7 times higher than the mortality rate in patients without AKI. In other studies, the severity of trauma was higher in AKI patients than in patients without AKI [3, 22]. AKI is one of the strongest predictors of mortality in trauma patients admitted to the ICU [23]. AKI is associated with a 2-3-fold increase in mortality in ICU trauma patients [16, 18]. In the study of Skinner et al. (2014), the mortality rate in patients with AKI was higher than in patients without AKI [7]. In the study by Li et al. (2011), patients with acute renal impairment had lower GCS, and mortality was higher in AKI patients than without AKI [21], which is consistent with the results of this study. In a review and meta-analysis, risk factors for AKI were old age, chronic hypertension, diabetes, high injury severity score, abdominal injury, shock, low Glasgow Coma Scale (GCS), high APACHE II score, and sepsis [2]. Some of these factors are consistent with the results of the present study. Moreover, the AKI group had higher Sodium, potassium, creatinine, glucose, BS, BUN, CPK, and lactate. The findings align with previous results [5, 24, 25]. All these laboratory parameters may be helpful for predicting AKI after severe trauma [26, 27]. Despite being largely unknown, various mechanisms could potentially elucidate the correlation between elevated levels of potassium and ensuing acute kidney injury (AKI) [28-30]. The management of potassium in the renal tubules operates differently than that of Sodium and urea. The distal renal tubules facilitate the exchange of potassium ions with Na-ions. Consequently, potassium secretion is amplified by the reabsorption of Sodium, which is triggered by aldosterone. This process forms a component of the mechanism responsible for the onset of AKI [28-30].

Finally, he presented a predictive model of mortality-related factors in patients in trauma intensive care units, age factors, APACHE II score, lowest systolic blood pressure, GCS score, and acute renal injury. In other studies, AKI mortality was higher at older ages [5, 7]. In the study by Bihorac et al. (2010), high APACHE II scores were independently associated with in-hospital mortality of AKI patients [31]. In the study by Nasu et al. (2021) in Japan, minimum prehospital systolic blood pressure was one of the primary risk factors for AKI [22]. Harrois et al. (2018) studied prehospital variables, including maximum prehospital heart rate, minimum mean prehospital arterial pressure, injury severity score, blood lactate, kidney damage, and independent risk factors in AKI predictive models [16]. Prehospital systolic blood pressure is a vital sign that paramedics always measure on the way to the hospital and is a parameter that can always be determined upon arrival at the hospital. These values can predict the high probability of an initial AKI in the future within minutes of the trauma patient arriving in the emergency department. In a review study, the presence of diabetes, high APACHE II score, low GCS score, shock, high ISS, and high age indicate an increased odds ratio of 2 for AKI [2]. The results of this study largely confirm the results of the present study.

Analyzing a large amount of data from trauma patients admitted to intensive care units based on the data of the intensive care unit for the first time in Iran is one of the most important strengths of this study.

One of the most critical limitations of the study was that the study design was retrospective. The injury severity of trauma patients admitted to intensive care units was unavailable. However, given that we had APACHE in this study, there is a direct relationship between APACHE and the severity of the injury. The APACHE score was used in this study. Also, there was no difference between patients with different trauma injury mechanisms, and the incidence of AKI in patients with various trauma injuries was not calculated. Another study limitation was that only the KIDGO diagnostic benchmark was used to identify acute kidney injury. Therefore, it is suggested that in future studies, diagnostic criteria for acute renal injury AKIN [32] and RIFLE [33] be used to identify patients with acute renal injury. Therefore, it is recommended that a prospective study be performed to investigate the prevalence, risk factors for acute renal injury, and the extent of the impact of acute renal injury in trauma patients admitted to intensive care units. Also, artificial intelligence models should be created to predict acute kidney damage in trauma patients admitted to intensive care units, previous studies show that artificial intelligence and modeling is can predicting complication and outcome of trauma patients [34, 35].

Conclusion

Acute renal injury in ICU trauma patients is a common complication with significant mortality and length of hospital stay. Age, high APACHE II score, minimum systolic blood pressure, acute renal injury, and low GCS score are strong risk factors associated with mortality in intensive care unit patients. Patients with acute kidney injury are five times more likely to die. Given this complication's irreversible damage and high cost, it is necessary to predict and prompt treatment of AKI in trauma patients.

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Conflict of Interest Disclosures

The authors declare no conflict of interest.

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Authors' Contributions

MK: conceptual and design study, data acquisition, data analysis, drafted and revision paper. GS: contributed to conceiving and design of the study, interpretation of data, commented on drafts, and made significant revisions to the paper. NB and HK: contributed to the design of the study, interpretation of data, commented on the draft, and made significant revisions to the paper. RB, SP, and MM: contributed to the design of the study, statistical analysis, commented on drafts, and made significant revisions to the paper.

Ethical Statement

This study was approved by the institutional review board of Shiraz University of medical science (Approval ID: IR.SUMS.REC.1401.334).

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