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Epidemiology, Clinical Outcomes, and Emergency Department Utilization Among Trauma Patients in Northern Iran: A Retrospective Cross-Sectional Study

Farzad Bozorgi[1,2], Farzane Doodiyan[3], Shiv Kumar Mudgal[4], Vipin Patidar[4], Iraj Goli Khatir[1], Mohammad Sazgar[1], Zohreh Hosseini Marznaki[5], Fatemeh Hosseini Aghamalaki[6], Seyed Mohammad Hosseininejad[7]*

[1]*Department of Emergency Medicine, Faculty of Medicine, Mazandaran University of Medical Sciences, Sari, Iran*
[2]*Orthopedic Research Center, Mazandaran University of Medical Sciences, Sari, Iran*
[3]*Student Research Committee, School of Medicine, Mazandaran University of Medical Sciences, Sari, Iran*
[4]*College of Nursing, All India Institute of Medical Sciences, Deoghar, Jharkhand, India*
[5]*Imam Ali Hospital at Amol City, Mazandaran University of Medical Sciences, Sari, Iran*
[6]*Yahya Nejad Hospital at Babol City, Babol University of Medical Sciences, Babol, Iran*
[7]*Gut and Liver Research Center, Non-Communicable Disease Institute, Mazandaran University of Medical Sciences, Sari, Iran*

***Corresponding author:** *Seyed Mohammad Hosseininejad*
Address: Gut and Liver Research Center, Non-Communicable Disease Institute, Mazandaran University of Medical Sciences, Sari, Iran.
Tel: +98-9036071037;
e-mail: drhoseininejad@yahoo.com

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ABSTRACT

Objective: This study aimed to investigate the epidemiological characteristics, clinical outcomes, and emergency department (ED) utilization patterns among trauma patients in northern Iran.
Methods: This retrospective cross-sectional study was conducted in northern Iran from January 2021 to December 2023. Systematic random selection was used to choose 2,350 trauma patients from the hospital's electronic health record (EHR) system. Data regarding demographic, trauma-related characteristics, clinical outcomes, and ED utilization were extracted from the EHR. Descriptive statistics and inferential analyses, including Chi-square and independent t-tests, were used to examine factors associated with patient outcomes.
Results: Trauma-related mortality was significantly associated with the 19–39-year age group, marital status, severe head injury (indicated by a low Glasgow Coma Scale score), driver status, and early-morning accidents (all $p<0.001$). Prolonged ED length of stay (LOS; >6 hours) was significantly associated with therapeutic procedures, including fracture immobilization, fixation, wound dressing, arterial blood gas analysis, and oxygen therapy. Conversely, diagnostic imaging (CT scans and sonography) showed no significant independent effect on ED LOS. The most common ED interventions were fracture immobilization (96.8%), sonography (85.1%), and CT scans (77.5%). Prolonged LOS in the ED was strongly associated with therapeutic procedures such as fixation, wound dressing, arterial blood gas analysis, and oxygen therapy, whereas diagnostic imaging showed no significant effect.
Conclusion: The findings underscore the necessity for targeted preventive measures aimed at young adult drivers and the expeditious delivery of therapeutic interventions, such as wound care and fracture immobilization, to reduce ED LOS. These region-specific insights regarding emergency service utilization are essential for trauma system planning in resource-limited settings.

Keywords: Epidemiology; Clinical outcomes; Emergency service utilization; Trauma patients.

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Introduction

Trauma is a significant and rising public health concern worldwide, contributing to millions of deaths and cases of disabilities annually while placing a heavy burden on healthcare systems, especially emergency departments (EDs) [1]. The epidemiology of trauma, including its etiology, demographic distribution, and clinical consequences, varies significantly across different socioeconomic and geographic contexts [2]. Given the time-sensitive nature of trauma care, effective management in the ED is critical to minimizing the risk of secondary injury, reducing disability rates, and mitigating associated financial costs [3].

Trauma is a leading cause of mortality in Iran, as in many other countries, and it is especially prevalent among the young, economically active male demographic [4, 5]. Recent studies conducted across several Iranian trauma centers highlight the high incidence of road traffic injuries (RTIs), particularly those involving two-wheeled vehicles. Furthermore, these studies revealed concerning non-compliance with road safety measures, such as helmet use (18-33% of riders) and seatbelt use (34-41% of drivers), which exacerbate injury severity [6, 7]. Consequently, these patients require substantial healthcare resources for clinical management. According to a registry-based investigation, around 4.2% of trauma patients required mechanical ventilation, a need that was substantially associated with both injury severity and lower Glasgow Coma Scale (GCS) scores [5]. In addition, a significant proportion of these patients require extended ED stays, intensive care unit (ICU) admission, and a range of diagnostic and therapeutic interventions, including advanced imaging and surgery [4, 8].

Although the overall burden of trauma in Iran has been well documented, there remains a limited understanding of the specific factors influencing emergency service utilization [9]. The clinical course of a trauma patient in the ED is affected by a complex interplay of demographic factors (e.g., age, sex), trauma characteristics (e.g., mechanism, severity), and the utilization of services ranging from simple radiography to life-sustaining ventilatory support [10]. Understanding these regional epidemiological and clinical features is not merely an academic exercise but a necessity to optimize staffing, improve operational processes, improve financial planning, and ultimately enhance patient care [11].

While the epidemiological burden and inpatient outcomes of trauma have been well documented in previous Iranian studies [4, 5, 8], a substantial knowledge gap remains regarding the factors influencing ED length of stay (LOS) and resource utilization patterns in northern Iran. These metrics are critical markers of patient flow and ED efficiency. Therefore, this study aimed to examine the association between the epidemiological and clinical characteristics of trauma patients and their subsequent mortality and emergency department utilization at a major tertiary hospital in northern Iran. By elucidating these trends, this study sought to provide practical insights to improve the effectiveness and efficiency of emergency care for trauma patients in the region.

Materials and Methods

This retrospective, cross-sectional study examined the use of emergency services and the epidemiological and clinical characteristics of trauma patients. The study was conducted at the ED of Imam Khomeini Hospital, a major tertiary trauma center in Sari, Iran. This setting was selected because it serves a mixed urban and rural population, acts as the primary trauma referral center in northern Iran, and thus provides a representative and generalizable sample for evaluating regional emergency care trends.

The study population included all patients presenting to the ED with trauma between January 2021 and December 2023. Exclusion criteria comprised patients with incomplete medical records, those transferred to another facility, patients who left against medical advice (LAMA), and individuals whose primary diagnosis was non-traumatic (e.g., medical diseases, poisonings).

A representative sample was obtained using a systematic random sampling procedure. A list of 7,052 eligible patients who visited the ED during the study period was generated from the hospital's electronic health record (EHR) system. The first case was selected randomly from the first three eligible patients; subsequently, every third patient was included from the chronologically ordered list until the target sample size of 2,350 was achieved. This approach helped minimize selection bias and improved the generalizability of the findings to the broader trauma population.

Data were retrieved using a standardized, pre-tested data collection tool adapted from previous trauma registry studies and the World Health Organization injury surveillance guidelines [12, 13]. Data were collected across four main domains:

1) Demographic characteristics included age, sex, marital status, and place of residence. Substance use and other demographic details were recorded based on patient self-reports or clinician evaluations during triage. 2) Trauma-related characteristics included the mechanism of injury and time of arrival at the ED. 3) Clinical and triage information: The Emergency Severity Index (ESI) version 4, a validated five-level triage tool that categorizes patients based on acuity and anticipated resource needs, was used by trained ED personnel to assign triage levels at admission. Levels range from ESI 1 (requiring immediate life-saving intervention) to ESI 5 (stable and expected to require no resources) [14].

The ESI level assigned by the triage nurse served

as the primary measure of injury acuity. In the rare instances where a physician's documented reassignment differed significantly, the physician's final level was used to ensure clinical accuracy. For analysis, injury severity was categorized based on the final ESI assignment as follows: resuscitation (Level 1), emergent (Level 2), urgent (Level 3), less urgent (Level 4), and non-urgent (Level 5). Vital signs at initial presentation were measured using calibrated equipment, including systolic blood pressure (hypotension defined as ≤90 mmHg), heart rate (tachycardia defined as ≥100 beats per minute), oxygen saturation (hypoxemia defined as <90% on room air), and respiratory rate (tachypnea defined as ≥20 breaths per minute). The level of consciousness was also assessed using the GCS and classified as mild (13-15), moderate (9-12), or severe (3-8).

Emergency service utilization outcomes were measured, including ED LOS, defined as the time from registration to ED discharge and automatically logged by the EHR system, and the utilization of specific diagnostic services and therapeutic procedures. ED LOS was dichotomized at 6 hours (≤6 hours vs. >6 hours) based on the institutional throughput criteria serving as an internal quality benchmark.

Data were anonymized before entry into IBM SPSS Statistics for Windows (version 20.0, IBM Corp., Armonk, NY, USA). Descriptive statistics were presented as frequency and percentages for categorical variables, median with interquartile range for non-normally distributed continuous data, and mean±SD for normally distributed continuous data. Inferential analyses were performed to identify factors associated with patient outcomes. Two binary logistic regression analyses were performed to identify independent predictors of patient outcomes. The first model examined factors associated with

Table 1. Distribution of epidemiological and clinical variables among 2,350 trauma patients, classified by clinical outcome

Variable	Categories	Total (n=2,350)	Survived (n=1,927)	Deceased (n=423)	*p*-value
Age (mean±SD)		37.52±16.98	37.64±17.45	36.99±14.6	0.42
Age (year)	≤18	242 (10.3)	213 (88)	29 (12)	0.001
	19-39	1177 (50.1)	940 (79.9)	237 (20.1)	
	40-60	679 (28.9)	551 (81.1)	128 (18.9)	
	≥61	252 (10.7)	223 (88.5)	29 (11.5)	
Sex	Male	1904 (81)	1560 (81.9)	344 (18.1)	0.86
	Female	446 (19)	367 (82.3)	79 (17.7)	
Marital status	Single	1030 (43.8)	898(87.2)	132(12.8)	<0.001
	Married	965(41.1)	741(76.8)	224 (23.2)	
	Divorced	253(10.8)	206 (81.4)	47 (18.6)	
	Widowed	102 (4.3)	82 (80.4)	20 (19.6)	
Smoking	Yes	650 (27.7)	542 (83.4)	108 (16.6)	0.28
	No	1700 (72.3)	1385 (81.5)	315 (18.5)	
Substance use	Yes	526 (22.4)	415 (78.9)	111 (21.1)	0.06
	No	1824 (77.6)	1512 (82.9)	312 (17.1)	
Alcohol consumption	Yes	135 (5.7)	116 (85.9)	19 (14.1)	0.22
	No	2215 (94.3)	1811 (81.8)	404 (18.2)	
Occurrence of trauma (Time)	4:00 AM -12:00 AM	698 (29.7)	525 (75.2)	173 (24.8)	<0.001
	12:00 AM-8:00 PM	941 (40)	786 (83.5)	155 (16.5)	
	8:00 PM- 4:00 AM	711 (30.3)	616 (86.6)	95 (13.4)	
Place of event	Rural	403 (17.1)	337 (83.6)	66 (16.4)	0.63
	Semi-urban	1098 (46.7)	895 (81.5)	203(18.5)	
	City	849 (36.1)	695(81.9)	154(18.1)	
Mechanism of injury	RTA	1158 (49.3)	910 (78.58)	248 (21.42)	<0.001
	Falls	629 (26.8)	540 (85.85)	89 (14.15)	
	Burns	358 (15.2)	285 (79.60)	73 (20.40)	
	Others	205 (8.7)	192 (93.65)	13 (6.35)	
Clinical Characteristics					
O_2 saturation		95(89-98)	95(90-98)	92(89-98)	0.63
Blood pressure		120 (110-125)	120 (110-125)	120 (110-125)	0.11
Pulse rate		80 (80-85)	80 (78.5-85)	82 (80-86)	0.25
Temperature		37 (36.8-37)	37 (36-37)	37 (36-37)	0.3
Respiratory rate		16 (14-18)	16 (14-18)	16 (14-18)	0.08
Glasgow Coma Scale	(3-8)	318 (13.5)	147 (46.2)	171 (53.8)	<0.001
	(9-12)	368 (15.7)	277 (75.3)	91 (24.7)	
	(13-15)	1664 (70.8)	1503 (90.3)	161 (9.7)	

SD: Standard deviation

mortality, and the second model examined factors associated with prolonged ED LOS. Independent variables for both models were selected based on clinical relevance and significant findings from bivariate analyses (p<0.10). These variables included demographic characteristics (age group, sex, marital status), trauma-related factors (time of occurrence, role in incident), clinical parameters (GCS category, vital signs), and clinical interventions (e.g., wound dressing, oxygen therapy). Categorical variables were entered using indicator coding, with the reference categories specified in the respective tables. Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were calculated, and statistical significance was set at p<0.05. Missing data were handled via exclusion from analyses involving the specific missing variable.

Results

This study included 2,350 trauma patients; the majority of them were young adult males (mean age 37.52±16.98 years; 81% male, 43.8% single), with a history of smoking (27.7%) and substance use (22.4%). Clinically, most patients (70.8%) presented with mild head injuries (GCS: 13-15), and their initial vital signs were predominantly within normal limits. Although the overall mean age did not differ significantly between survivors and non-survivors (p=0.42), categorical analysis revealed that mortality was significantly higher in the 19-39 years age group than in other age groups (p<0.001). Furthermore, mortality was significantly associated with severe head injuries (GCS: 3-8), driver status, and accident occurrences between 4:00 AM and 12:00 PM (p<0.001). Geographically, the majority of accidents (46.7%) occurred in semi-urban locations, primarily between 12:00 PM and 8:00 PM. Passengers accounted for nearly half (46%) of all victims. However, the specific location of the event had no significant effect on survival outcomes. There were no statistically significant differences in the median (IQR) values of blood pressure, temperature, pulse rate, respiration rate, and oxygen saturation between survivors and non-survivors (p>0.05; Table 1). The overall in-hospital mortality rate during the study period was 18% (423/2350).

Table 2 details the utilization of emergency services. The most commonly performed interventions were fracture immobilization (96.8%), pain management (95.2%), fluid resuscitation (90.31%), sonography (85.1%), and CT scans (77.5%). Multivariable logistic regression analysis identified several independent predictors of prolonged ED LOS (Table 3). Therapeutic procedures, particularly wound dressing, were strongly associated with extended LOS (OR=4.69, p<0.001). In contrast, diagnostic imaging, including CT scans, did not significantly predict prolonged stays. Interestingly, higher injury severity (lower GCS) was associated with shorter ED stays (GCS: 3-8; OR= 0.047, p<0.001), likely reflecting the rapid transfer of critically ill patients to the operating room or ICU. Additional factors associated with prolonged ED stays included age 19-39 years (OR=1.898, p=0.009) and trauma occurrence between 4:00 AM and 12:00 PM (OR=2.335, p<0.001).

Multivariable logistic regression also identified several significant predictors of mortality (Table 4). Patients aged 19–39 years had 3.032 times higher odds of death compared to those aged over 61 (p<0.001). Mortality was also significantly higher among patients with a history of substance use (OR=1.429, p=0.039) and for accidents occurring between 4:00 AM and 12:00 PM (OR=3.064, p<0.001) compared to their respective reference groups. Furthermore, each one-unit increase in systolic blood pressure was associated with a slight reduction in the odds of mortality (OR=0.985, p=0.015), whereas each one-unit increase in temperature was associated with increased odds of mortality (OR=1.086, p=0.024). Notably, while no individual vital sign demonstrated a statistically significant difference between survivors and non-survivors in univariate analysis (Table 1), the

Table 2. Emergency service utilization and length of stay in the ED among 2,350 trauma patients

Emergency service utilization		Total n (%)	Under 6 hours n (%)	Above 6 hours n (%)
Overall length of stay (mean±SD)		5.69±1.92 hours		
ABG	Yes	407 (17.3)	0 (0)	407 (17.3)
Fracture immobilization	Yes	2274 (96.8)	1851 (81.4)	423 (18.6)
Dressing	Yes	715 (30.4)	464 (64.9)	251 (35.1)
Oxygen therapy	Yes	526 (22.4)	415 (78.9)	111 (21.1)
Fast sonography	Yes	351 (14.9)	276 (78.6)	75 (21.4)
Blood analysis	Yes	2075 (88.3)	1702 (82)	373 (18)
CT scan	Yes	1821 (77.5)	1479 (81.2)	342 (18.8)
MRI	Yes	420 (17.9)	356 (84.8)	64 (15.2)
Chest X-ray	Yes	1888 (80.3)	1538 (81.5)	350 (18.5)
Fluid resuscitation	Yes	2123 (90.31)	788 (37.12)	1335 (62.88)
Pain management	Yes	2237 (95.2)	968 (43.28)	1269 (56.72)
Chest tube insertion	Yes	153 (6.51)	44 (28.76)	109 (71.24)

ABG: Arterial blood gas; CT: Computed tomography; MRI: Magnetic resonance imaging

multivariate regression revealed that, after controlling for injury severity and other confounders, blood pressure and temperature emerged as significant independent predictors of mortality (Table 4).

Figure 1 shows the distribution of injury severity based on a modified version of ESI. The majority of patients were categorized in the resuscitation tier (39.53%), followed by emergent (20.68%) and urgent cases (20.30%). A smaller proportion of patients fell into the less urgent (13.23%) and non-urgent (6.26%) categories. Figure 2 shows the frequency of different mechanisms of injury. Burns were the most common mechanism, accounting for 15.2% of cases, followed by spinal cord injuries (11.4%), other injuries (11.1%), and head injuries (10.3%). Bruises or abrasions constituted 9.8% of cases, while abdominal injuries (9.0%), sprain/dislocation (8.8%), and lacerations or cuts (8.7%) showed relatively similar proportions. Thoracic injuries accounted for 8.0%, and fractures represented the lowest proportion at 7.6%.

Table 3. Multivariable logistic regression analysis of predictors for prolonged ED length of stay among 2,350 trauma patients

Variable		Estimate	Std. Error	Wald	df	*p*-value	OR	95% CI	
								Lower	Upper
Length of Stay	Dressing (Yes)	1.954	0.142	190.355	1	<0.001	4.689	3.314	5.346
	Oxygen therapy (Yes)	0.207	0.150	1.893	1	0.169	1.230	0.916	1.652
	Fast sonography (Yes)	-0.1361	0.175	4.239	1	0.039	0.697	0.494	0.983
	CT scan (Yes)	0.27	0.158	2.941	1	0.086	1.310	0.962	1.785
	Injury_severity (Urgent)	-0.353	0.203	3.041	1	0.038	0.702	0.472	1.045
	Injury_severity (Emergent)	-0.483	0.200	5.809	1	0.016	0.617	0.416	0.914
	Injury_severity (Resuscitation)	-0.595	0.178	11.215	1	0.001	0.552	0.390	0.781
	Occurrence of trauma Time (4:00 AM -12: AM)	0.848	0.168	25.574	1	<0.001	2.335	1.681	3.244
	Occurrence of trauma Time (12: AM-8:00 PM)	0.189	0.165	1.317	1	0.251	1.208	0.875	1.669
	Age (≤18)	0.031	0.327	0.009	1	0.925	1.031	0.544	1.956
	Age (19-39)	0.641	0.244	6.888	1	0.009	1.898	1.176	3.063
	Age (40-60)	0.205	0.26	0.623	1	0.430	1.228	0.738	2.042
	Level of consciousness (GCS: 3-8)	-3.051	0.172	314.958	1	<0.001	0.047	0.034	0.066
	Level of consciousness (GCS: 9-12)	-1.633	0.191	73.276	1	<0.001	0.195	0.134	0.284

OR: Odds ratio; CI: Confidence interval; CT: Computed tomography; GCS: Glasgow Coma Score

Table 4. Multivariable logistic regression analysis of predictors for mortality among 2,350 trauma patients.

Variable		Estimate	SE	Wald	df	*p*-value	OR	95% CI	
								Lower	Upper
Mortality	Age (≤18)	0.344	0.387	0.789	1	0.374	1.41	0.661	3.009
	Age (19-39)	1.109	0.308	12.962	1	<0.001	3.032	1.658	5.547
	Age (40-60)	0.624	0.322	3.752	1	0.06	1.866	0.993	3.508
	Sex (Male)	0.341	0.200	2.911	1	0.088	1.406	0.951	2.081
	Marital status (Single)	-0.388	0.338	1.318	1	0.251	0.678	0.350	1.316
	Marital status (Married (	0.276	0.344	0.643	1	0.423	1.317	0.672	2.584
	Marital status (Divorced)	0.158	0.378	0.175	1	0.676	1.171	0.558	2.459
	Smoking (Yes)	-0.106	0.167	0.403	1	0.525	0.900	0.649	1.247
	Drug consumption (Yes)	0.357	0.173	4.278	1	0.039	1.429	1.019	2.005
	Alcohol consumption (Yes)	-0.256	0.349	0.540	1	0.463	0.774	0.391	1.533
	Occurrence of trauma Time (4:00 AM-12:00 PM)	1.12	0.192	33.91	1	<0.001	3.064	2.102	4.467
	Occurrence of trauma Time (12:00 AM-8:00 PM)	0.089	0.196	0.208	1	0.648	1.094	0.745	1.605
	Place of event (Rural)	-0.46	0.166	0.079	1	0.779	0.955	0.69	1.321
	Place of event (Semi-urban)	-0.175	0.213	0.669	1	0.413	0.84	0.553	1.276
	O_2 Saturation	0.027	0.014	3.710	1	0.059	1.027	1	1.055
	Blood Pressure	-0.015	0.006	5.909	1	0.015	0.985	0.972	0.987
	Pulse rate	-0.014	0.009	3.106	1	0.078	0.985	0.968	1.002
	Temperature	0.082	0.036	5.097	1	0.024	1.086	1.011	1.166
	Respiratory rate	0.048	0.043	1.27	1	0.260	1.05	0.965	1.142
	Level of consciousness (GCS: 3-8)	-2.562	0.184	93.555	1	<0.001	0.077	0.054	0.111
	Level of consciousness (GCS: 9-12)	-1.339	0.211	40.236	1	<0.001	0.262	0.173	0.396

*P<0.05, Age ≥61 as baseline. Sex: Female as baseline. Marital status: Widowed as baseline. Occurrence of trauma: 8:00 PM-4:00 AM as baseline. Place of event: City as baseline. Role in incidence: Unknown as baseline. Glasgow Coma Score: 13-15 as baseline. Statistical test: binary logistic regression. SE: Standard error; OR: Odds ratio; CI: Confidence interval; GCS: Glasgow Coma Score

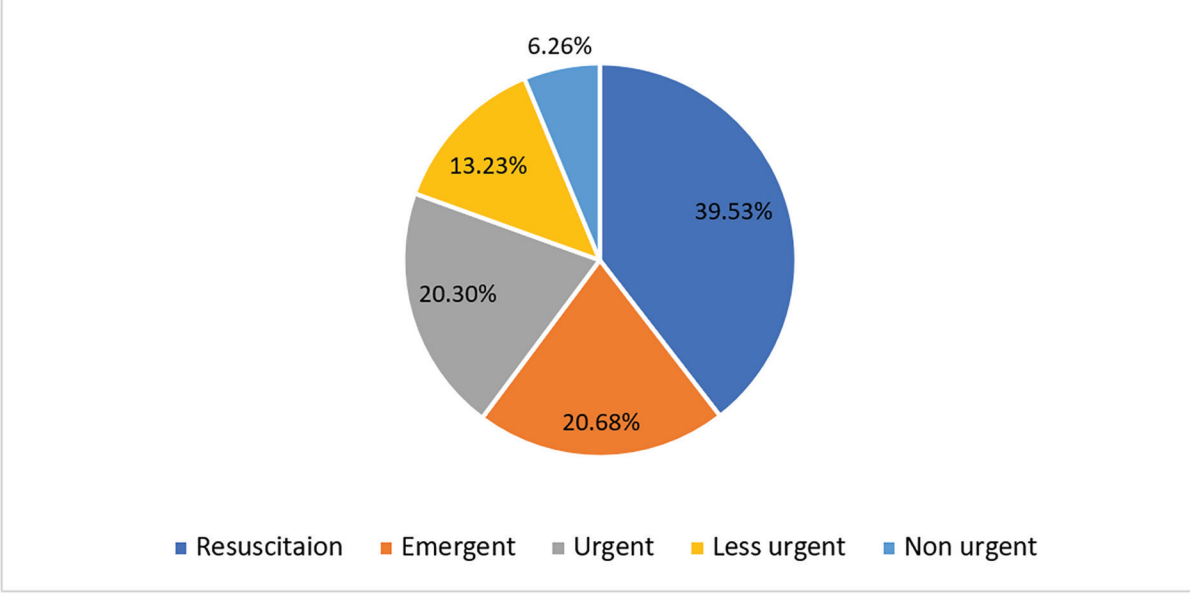

Fig. 1. The figure shows the distribution of trauma patients referred to the ED based on the modified ESI score in 2,350 traumatic patients.

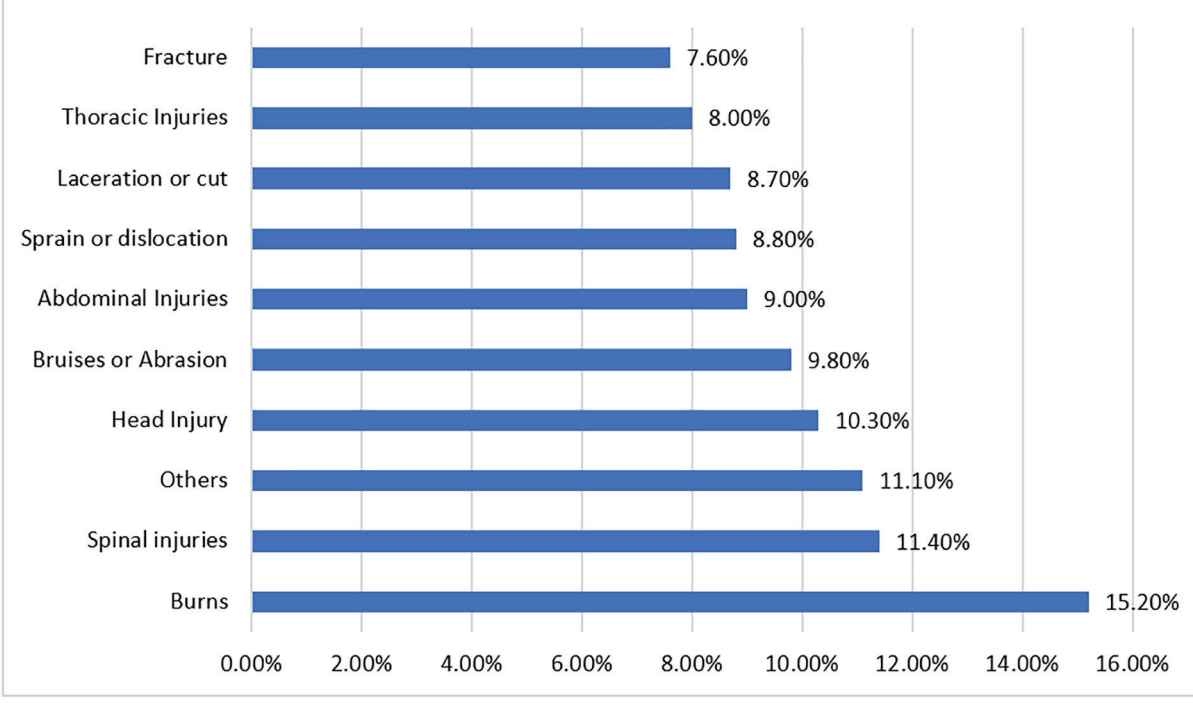

Fig. 2. The figure shows the mechanism of injuries among trauma patients referred to the ED in 2,350 trauma patients.

Discussion

The findings of the present study provided region-specific insights into the use of emergency department (ED) utilization in a resource-limited setting, while remaining consistent with global trends in trauma epidemiology. Notably, our findings demonstrated that ED delays were primarily driven by therapeutic procedures rather than imaging, contrasting with research from high-income nations. This finding has significant implications for trauma system planning in comparable situations.

The analysis of 2,350 trauma patients at a major northern Iranian trauma center confirmed that trauma disproportionately affected young adult males. The mean age in this retrospective analysis was approximately 37.5 years, and the 81% male predominance mirrored findings from other regional studies [4, 15, 16]. Sehat *et al.,* reported that 77.7% of trauma cases were male, with half of the patients aged 20–39 years [17]. Similarly, Roshanaei *et al.,* found a mean patient age of 35.4 years with 71.7% male victims [16]. These statistics reflect a national epidemiological pattern in Iran, where road traffic crashes and other injuries mainly affect the most economically active demographic [18].

The high burden among young men indicated high socioeconomic costs, consistent with global evidence that traumatic injuries in the working-age population cause long-term disability and productivity losses [18, 19].

This study was also characterized by a high prevalence of behavioral risk factors, with more than a quarter of patients reporting a history of substance use or smoking. Previous studies have linked these behaviors to an increased risk of injury [18]. Head injuries were particularly common (70.8% were mild), and patients with severe head trauma (low GCS) exhibited significantly higher mortality. This finding aligned with the literature demonstrating that head injury is one of the leading causes of trauma death in Iran [18]. Given that head and neck injuries are among the most common trauma presentations in Iran alongside low helmet compliance, these findings underscore the critical need for strict enforcement of helmet and seatbelt laws [18]. Consequently, preventive measures against traffic accidents—including helmet use, enforcing speed limits, and intoxication avoidance—are essential to reduce the frequency of serious head injuries and related fatalities [19]. In the unadjusted analysis, married patients appeared to have a higher proportion of mortality than single individuals. However, this association was not statistically significant in multivariate regression. This suggested that the observed difference might be confounded by age and exposure risk rather than a true effect of marital status.

Temporal and situational analyses revealed that incidents occurring in the early morning hours were associated with higher mortality. This finding might be attributed to fatigue, poor visibility, or delayed emergency medical services (EMS) response during off-peak hours. These findings suggested that targeted interventions, such as shift-specific staffing and public education on the risks of nighttime driving, could be beneficial [20, 21]. Furthermore, Paravar *et al.,* confirmed the association between prehospital delay and mortality, demonstrating that prolonged EMS transport times were associated with worse trauma outcomes in Iran [17]. Thus, improving prehospital care and reducing transport delays remain crucial strategies for enhancing survival rates.

Regarding ED resource utilization, our study found that while advanced diagnostic imaging (X-ray, CT, MRI) was frequently utilized, it was surprisingly not independently associated with prolonged ED LOS. In fact, median ED stay was similar regardless of imaging use, which contrasted with prior U.S. data indicating imaging substantially increases ED LOS [22, 23]. A likely explanation for this discrepancy was confounding by patient acuity. As noted above, the most severely injured patients, who required the most extensive imaging, were also those most rapidly transferred out of the ED to the operating room or ICU. This rapid disposition effectively truncated their ED LOS, neutralizing any association between imaging and prolonged stays in the regression analysis [24]. This finding was further supported by our finding that lower GCS scores were associated with shorter ED stays. Although this rapid turnaround is favorable for ED flow metrics, it highlights the tremendous burden these critically ill patients place on downstream hospital resources. Consequently, ED LOS alone is an insufficient measure of trauma care efficiency and must be interpreted in the context of patient acuity and disposition. In contrast, specific therapeutic procedures (fracture immobilization, wound dressing, oxygen therapy, arterial blood gas analysis) were strongly associated with prolonged ED stays. These interventions are inherently time-consuming and are often limited by resource availability (e.g., procedure rooms, equipment) [25]. In practice, this implies that streamlining these therapeutic processes—for instance, by utilizing dedicated trauma bays, implementing standardized protocols for splinting and wound care, and ensuring the immediate availability of oxygen and ventilation equipment—could substantially reduce ED boarding times for trauma patients.

Overall, our results underscored that in this context, the efficiency of ED throughput and trauma care was more dependent on procedural interventions than on diagnostic imaging. Clinicians and administrators should focus on optimizing patient flow around time-intensive treatments while ensuring the continued availability of imaging for acute diagnosis. The difference between imaging and therapeutic delays also carries significant policy implications. Investment in radiology capacity alone may not reduce ED crowding, whereas improvements in orthopedic services, ICU access, and monitoring may have a greater impact on patient flow and clinical outcomes.

The large sample size and representative design were key strengths of this study. Generalizability was enhanced through the systematic random sampling of all trauma ED visits the 3-year study period at the region's tertiary referral center. Key measures, including patient vital signs, GCS, triage levels, and LOS, were standardized and extracted directly from EHRs, thereby minimizing recall bias. Furthermore, our outcome assessments were anchored to the validated ESI triage system and objective criteria for clinical interventions. By addressing both epidemiology and resource utilization, this study provided a comprehensive picture of trauma care in a real-world ED environment.

Several limitations should be acknowledged. First, as a single-center study, our results might not be fully generalizable to other geographic regions or hospital settings in Iran. Second, retrospective design necessitated reliance on the medical records, which might contain documentation errors or omissions. Third, the exclusion of patients transferred to other facilities or those who left against medical

advice could introduce selection bias, potentially affecting mortality estimates and resource utilization findings. Fourth, the lack of post-discharge follow-up precluded the assessment of long-term functional outcomes. Finally, although we utilized multivariable regression to control for known confounders, residual confounding by unmeasured variables, such as precise anatomical injury severity scores (e.g., ISS) and comprehensive clinical complexity metrics, could not be entirely eliminated due to EHR data limitations. Despite these constraints, our findings remained robust at the level of emergency care, though they should be interpreted within the context of the local health system and patient population.

These findings have clear implications for clinical practice and health policy. First, prevention is paramount. The observed demographic patterns and the profound impact of head injuries on mortality highlight the need for intensified road safety campaigns and stricter law enforcement. Public health initiatives should be prioritized to increase helmet and seatbelt compliance, particularly among young men. Second, improvements to EMS and the broader trauma system are warranted. Investment in prehospital care—such as reducing transport times, enhancing paramedic training, and improving public ambulance availability—may significantly reduce early mortality. Third, the needs of patient care should inform hospital resource planning–since therapeutic procedures account for longer ED stays, hospitals should have adequate staffing (such as on-call orthopedic and surgical teams) and equipment to treat fractures and wounds without delay. Policymakers might use these results to justify expanding trauma care capacity (e.g., dedicated trauma resuscitation beds and surgical suites) and developing standardized clinical protocols to expedite common therapeutic procedures.

In conclusion, the findings of this study provide region-specific insights into emergency services utilization in a resource-limited setting, while remaining consistent with global trends in trauma epidemiology. This study demonstrated that young adult males are the main sufferers of trauma in northern Iran, and that a combination of clinical, demographic, and service utilization determinants significantly influences both mortality and ED LOS. The findings also demonstrated that ED delays were caused by therapeutic procedures rather than diagnostic imaging, which had obvious implications for the trauma system, emphasizing the essential need for targeted preventive measures, streamlined emergency procedures, and overall trauma system strengthening. Although these results are especially pertinent to trauma system planning in northern Iran, similar evaluations in other low- and middle-income regions might benefit from the methodological approach and insights gained into care utilization patterns.

Declaration

Ethics Approval and Consent to Participate: This study was approved by the Ethics Committee of Mazandaran University of Medical Sciences (Ethics code: IR.MAZUMS.IMAMHOSPITAL.REC.1401.024). The study utilized retrospective, anonymized data from medical records. Patient confidentiality was strictly maintained throughout the research process, and the need for informed consent was waived by the ethics committee due to the retrospective nature of the study. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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