OTJHS
Online Turkish Journal of Health Sciences

e-ISSN: 2459-1467

OTSBD
Online Türk Sağlık Bilimleri Dergisi

Online Turkish Journal of Health Sciences 2025;10(3):296-303 *Online Türk Sağlık Bilimleri Dergisi 2025;10(3):296-303*

Epidemiological and Clinical Predictors of Mortality in Firearm Injuries: A Retrospective Study from a Level-1 Trauma Center

Ateşli Silah Yaralanmalarında Mortaliteyi Öngören Epidemiyolojik ve Klinik Faktörler: Seviye-1 Travma Merkezinden Retrospektif Bir Çalışma

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ABSTRACT

Objective: Firearm-related injuries remain a significant cause of trauma morbidity and mortality worldwide. This study aimed to evaluate the epidemiological and clinical characteristics of firearm injuries and identify predictors of in-hospital mortality.

Materials and Methods: This retrospective cohort study included patients presenting with firearm injuries to Marmara University Pendik Training and Research Hospital during the period spanning from January 1 to December 31, 2024. Data on demographics, injury mechanism, anatomical injury sites, trauma scores, vital signs, laboratory findings, interventions, and outcomes were collected. Univariate logistic regression analyses were performed to identify factors associated with mortality, along with their odds ratios (OR).

Results: A total of 119 patients were included (mean age: 33.3 ± 12.8 years; 89.1% male). The overall in-hospital mortality rate was 9.2%. Non-survivors were more likely to be female and have suicide-related injuries. Univariate analysis revealed that female gender (OR: 6.286), suicide intent (OR: 40.125), lower Glasgow Coma Scale (OR: 0.490), lower Revised Trauma Score (OR: 0.113), and higher Injury Severity Score (OR: 1.323) were independent predictors of mortality. Head/neck and chest injuries were associated with higher mortality and increased need for surgery and blood transfusion.

Conclusions: Early assessment of vital signs, trauma scores, and anatomical injury sites can provide valuable prognostic information in firearm-related trauma. Beyond mortality, the high rates of hospitalization and surgical intervention highlight the broader burden of firearm injuries on healthcare systems.

Keywords: Emergency care, firearm injuries, injury severity, mortality, trauma score

ÖZ

Amaç: Ateşli silah yaralanmaları dünya genelinde önemli bir travma morbidite ve mortalite nedenidir. Bu çalışmanın amacı, ateşli silah yaralanmalarının epidemiyolojik ve klinik özelliklerini değerlendirmek ve hastane içi mortaliteyi öngören faktörleri belirlemektir.

Materyal ve Metot: Bu retrospektif kohort çalışmaya, Marmara Üniversitesi Pendik Eğitim ve Araştırma Hastanesi'ne 1 Ocak–31 Aralık 2024 tarihleri arasında ateşli silah yaralanması nedeniyle başvuran hastalar dahil edildi. Hastaların demografik verileri, yaralanma mekanizması, anatomik yaralanma bölgeleri, travma skorları, vital bulguları, laboratuvar değerleri, uygulanan girişimler ve klinik sonuçları değerlendirildi. Hastane içi mortalite ile ilişkili faktörleri belirlemek amacıyla univaryant lojistik regresyon analizleri yapıldı ve olasılık oranları (OR) hesaplandı.

Bulgular: Toplam 119 hasta çalışmaya dahil edildi (ortalama yaş: 33,3 ± 12,8 yıl; %89,1 erkek). Genel hastane içi mortalite oranı %9,2 idi. Hayatını kaybeden hastalar arasında kadın cinsiyet ve intihar girişimi daha yaygındı. Univaryant analizlerde kadın cinsiyet (OR: 6,286), intihar girişimi (OR: 40,125), düşük Glasgow Koma Skoru (OR: 0,490), düşük Revize Travma Skoru (OR: 0,113) ve yüksek Travma Şiddet Skoru (OR: 1,323) mortalite ile ilişkili bulundu. Baş-boyun ve göğüs yaralanmaları daha yüksek mortalite, cerrahi girişim ihtiyacı ve kan transfüzyonu ihtiyacı ile ilişkiliydi.

Sonuç: Ateşli silah yaralanmalarında vital bulgular, travma skorları ve anatomik yaralanma bölgelerinin erken değerlendirilmesi prognostik açıdan önemli bilgiler sağlayabilir. Mortalitenin ötesinde, bu hastalardaki yüksek yatış ve cerrahi müdahale oranları, ateşli silah yaralanmalarının sağlık sistemine olan ciddi yükünü de ortaya koymaktadır.

Anahtar Kelimeler: Acil bakım, ateşli silah yaralanmaları, mortalite, travma skoru, yaralanma şiddeti

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Yayın Bilgisi / Article Info:
Gönderi Tarihi/ Received: 16/06/2025
Kabul Tarihi/ Accepted: 13/08/2025
Online Yayın Tarihi/ Published: 15/09/2025

Atıf / Cited: Kudu E and et al. HaEpidemiological and Clinical Predictors of Mortality in Firearm Injuries: A Retrospective Study from a Level-1 Trauma Center. *Online Türk Sağlık Bilimleri Dergisi* 2025;10(3):296-303. doi: 10.26453/otjhs.1720328

INTRODUCTION

Firearm-related injuries have emerged as one of the more persistent contributors to trauma care burden across the globe.[1] In the United States, these incidents lead to over 48,000 deaths each year, yet the toll is not limited to fatalities.[2] While many patients survive firearm injuries, the aftermath often includes lasting impairments, including mobility issues, disrupted cognitive function, and psychological disturbances that may persist for years.[3] The complexity of these outcomes underscores the importance of a prompt and well-coordinated clinical response, beginning most critically at the point of entry: the emergency department (ED). Early evaluation, stabilization, and appropriate triage play a crucial role in determining outcomes.[4]

Both globally and in Türkiye, the increasing availability of firearms and the rising incidence of interpersonal violence have led to a growing clinical and forensic burden.[5,6] Despite the increasing frequency of these injuries, a need remains for region-specific data that captures their evolving epidemiological and clinical characteristics and informs strategies for effective trauma care delivery.[7]

By evaluating vital signs, injury locations, trauma scores, patient demographics, and injury intent, early predictors of poor outcomes can be identified to optimize acute management strategies. In this context, this study aims to address that need by examining firearm injury cases in a level-1 trauma center in Türkiye, with a focus on identifying the key factors associated with in-hospital mortality, thereby providing insights that may support early risk stratification and guide improvements in trauma management practices.

MATERIALS AND METHODS

Ethics Committee Approval: The study protocol received approval from the Marmara University Clinical Research Ethics Committee (Date: 31.01.2025, decision no: 09.2025-25-0053). Given its retrospective design, the requirement for informed consent was waived by the ethics committee. The study was conducted in alignment with the Declaration of Helsinki and complies with the STROBE guidelines for reporting observational studies.[8]

Study Design and Settings: A single-center retrospective cohort study was carried out at Marmara University Pendik Training and Research Hospital, which is a level-1 trauma center with advanced diagnostic and surgical capabilities.

Study Participants: We retrospectively analyzed all patients who presented with firearm-related injuries to Marmara University Pendik Training and Research Hospital between January 1 and December 31, 2024. Patients with missing critical data (e.g., outcome status) were excluded from the study.

Variables and Data Sources: Data were obtained from the hospital's electronic health records and patient files. For each patient, demographic information (age and sex) and the mechanism of injury (homicide or suicide) were recorded. Clinical variables included the anatomical location of the injury (head/neck, chest, abdomen, upper extremity, lower extremity), initial Glasgow Coma Scale (GCS), Revised Trauma Score (RTS),[9] and Injury Severity Score (ISS),[10] as well as initial laboratory values (complete blood count, biochemistry and blood gas results). During treatment, the need for blood transfusions and surgical interventions was recorded. Additionally, hospital length of stay and clinical outcomes (discharge, admission, or in-hospital mortality) were also recorded.

Outcomes: The primary outcome of the study was in -hospital mortality. Secondary outcomes included surgical intervention, hospitalization, and duration of hospitalization.

Statistical Analysis: All statistical analyses were carried out using IBM SPSS Statistics for Windows, version 23.0 (IBM Corp., Armonk, NY, USA). The distribution characteristics of the continuous variables were assessed visually through histograms. Categorical variables were summarized as frequencies with percentages. For numeric data, normally distributed variables were expressed as means with standard deviations, whereas non-normally distributed variables were described using medians and interquartile ranges. Group comparisons were made using the Chi-square test for categorical variables. Depending on the distribution pattern, continuous variables were compared using either the Student's t-test or the Mann–Whitney U test. To explore potential predictors of in-hospital mortality, univariate logistic regression analysis was performed. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 124 patients with firearm injuries presented to the emergency department during the study period. Five patients who left the hospital against medical advice and without completing treatment were excluded from the final analysis. Thus, a total of 119 patients were included in the study. The majority were male (89.1%), with a mean age of 33.3 ± 12.8 years. Among these, 63 patients (52.9%) were discharged from the ED, while 48 (40.3%) required hospitalization. Specifically, 39 were admitted to inpatient wards, and 9 to intensive care units (ICUs). In-hospital mortality occurred in 11 patients (9.2%), including deaths in the ED (n = 5), operating room (n = 3), and ICU (n = 3) (Figure 1).

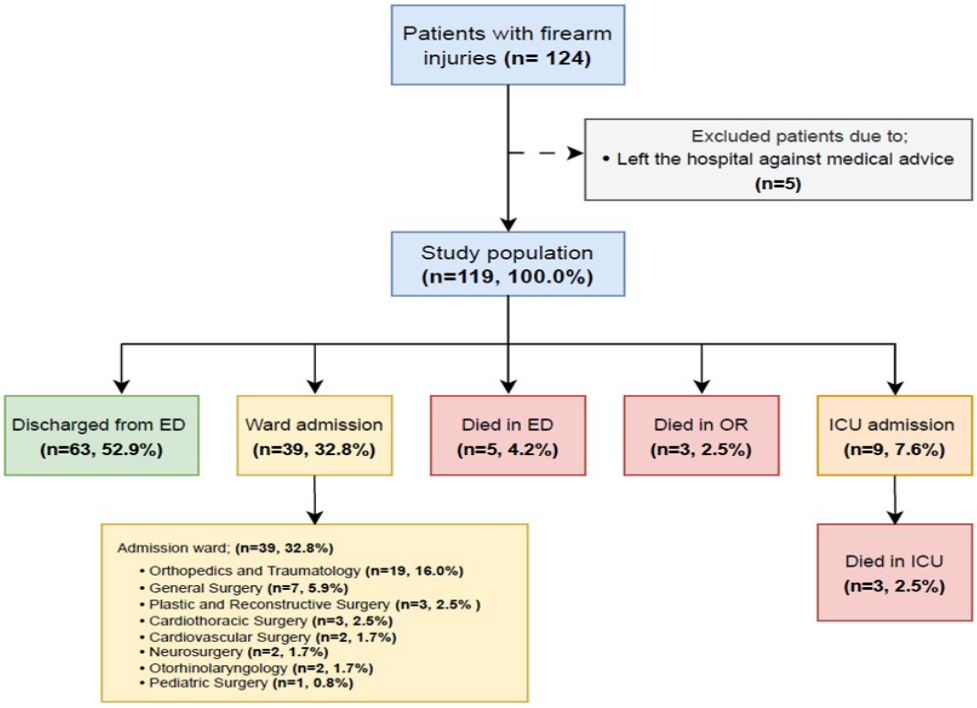

Figure 1: Flow chart of the study. ED: Emergency department; ICU: Intensive care unit; OR: Operating room.

When comparing survivors and non-survivors, the mean age was 32.9 ± 12.9 years and 37.1 ± 11.9 years, respectively, with no statistically significant difference between the groups (p=0.303). Several other parameters demonstrated significant differences. Female sex and suicide-related injuries were more prevalent among non-survivors (p=0.019 and p<0.001, respectively). Non-survivors also presented with markedly compromised physiological parameters, including lower systolic and diastolic blood pressures, decreased respiratory rate, and significantly reduced Glasgow Coma Scale scores (all p<0.001). Laboratory findings showed lower hemoglobin, hematocrit, and pH levels, as well as a significantly elevated base deficit (all p<0.001), suggesting greater physiological derangement. Trauma severity was also notably worse in this group, with lower Revised Trauma Scores and higher Injury Severity Scores (both p<0.001). In terms of interventions, all non-survivors received blood transfusions (p<0.001), and none underwent basic medical treatment alone (p=0.003). Additionally, non-survivors had a significantly shorter median length of hospital stay compared to survivors (1 hour vs. 9 hours, p=0.014). These findings are detailed in Table 1.

In terms of anatomical injury distribution, the most frequently affected region was the lower extremities (61.3%), followed by the upper extremities (23.5%), abdomen (22.7%), head/neck (17.6%), and chest (14.3%). As some patients sustained injuries involving more than one anatomical region, the total number of injury sites exceeds the total number of patients. While this limits direct comparisons, several meaningful differences were observed. Patients with chest and head/neck injuries had notably higher in-hospital mortality rates (41.2% and 19.0%, respectively), compared to other anatomical groups. These regions also demonstrated lower Revised Trauma Scores (RTS) and higher Injury Severity Scores (ISS), reflecting more severe trauma. Specifically, the median ISS reached 16 (IQR: 10–75) for chest injuries and 9 (IQR: 4–23) for head/neck injuries. Blood transfusion was required in 64.7% of chest injury cases and 33.3% of head/neck injuries, further highlighting their clinical severity. Surgical interventions were most frequent among patients with abdominal injuries (55.6%) and chest injuries (58.8%), while also elevated in upper extremity trauma (46.4%). Lower extremity injuries, although common, were associated with the lowest mortality (2.7%), highest discharge rate from the ED (64.4%), and shortest median hospital stay (6 hours, IQR: 3–78). These findings suggest that the anatomical site of injury plays a critical role in predicting clinical outcomes and resource utilization in firearm-related trauma (Table 2).

Table 1. Comparison of baseline demographic, clinical, laboratory, and outcome characteristics between survivors and non-survivors among patients with firearm injuries.

Variables	Subcategory	All patients (n=119)	Survivors (n=108)	Non-survivors (n=11)	p
Age (year), mean ± SD		33.3 ± 12.8	32.9 ± 12.9	37.1 ± 11.9	0.303
Gender, n (%)	Male	106 (89.1)	99 (91.7)	7 (63.6)	**0.019**
	Female	13 (10.9)	9 (8.3)	4 (36.4)	
Intent of injury, n (%)	Homicide	101 (84.8)	93 (86.1)	8 (72.7)	
	Unintentional	14 (11.8)	14 (12.9)	0 (0.0)	**0.001**
	Suicide	4 (3.4)	1 (0.9)	3 (27.2)	
Vitals, median (IQR)	Systolic BP (mmHg)	125 (110-135)	127 (113-136)	60 (0-84)	**0.001**
	Diastolic BP (mmHg)	78 (65-88)	80 (70-89)	40 (0-56)	**0.001**
	Pulse rate (beats per min)	82 (75-89)	82 (76-89)	45 (0-95)	**0.007**
	Respiratory rate (/min)	24 (18-34)	25 (18-34)	8 (0-12)	**0.001**
Glasgow Coma Scale, median (IQR)		15 (15-15)	15 (15-15)	3 (3-8)	**0.001**
Laboratory parameters, median (IQR)	Hemoglobin (g/dL)	14.7 (13.3-15.7)	14.8 (13.7-15.8)	11.6 (7.0-12.8)	**0.001**
	Hematocrit (%)	42.5 (39.4-45.8)	42.9 (40.3-46.2)	33.7 (22.2-36.7)	**0.001**
	ALT (U/L)	24.0 (17.0-33.8)	23.5 (17.0-33.0)	40.0 (14.5-403.8)	0.296
	AST (U/L)	33.0 (27.0-42.8)	33.0 (27.0-41.8)	40.5 (29.8-327.5)	**0.040**
	Creatinine (mg/dL)	0.9 (0.8-1.1)	0.91 (0.8-1.07)	0.81 (0.71-1.16)	0.413
	pH	7.33 (7.28-7.37)	7.34 (7.31-7.38)	7.18 (7.02-7.3)	**0.001**
	Base deficit (mmol/L)	3.5 (1.6-5.6)	2.6 (1.5-4.6)	9.8 (4.8-14.5)	**0.001**
	Lactate (mmol/L)	3.4 (2.3-5.3)	3.3 (2.3-5.0)	5.4 (2.6-17.0)	0.081
Trauma score, median (IQR)	Revised Trauma Score	7.55 (7.55-7.84)	7.55 (7.55-7.84)	2.33 (0.00-3.51)	**0.001**
	Injury Severity Score	5 (4-13)	5 (4-9)	75 (25-75)	**0.001**
Intervention, n (%)	Basic medical intervention	48 (40.3)	48 (43.6)	0 (0.0)	**0.003**
	Blood transfusion	31 (26.1)	20 (18.5)	11 (100.0)	**0.001**
	Surgery	46 (38.7)	39 (36.1)	7 (63.6)	0.074
Length of stay (hours), median (IQR)		7 (3-112)	9 (4-116)	1 (1-14)	**0.014**

ALT: Alanine aminotransferase; AST: Aspartate aminotransferase; BP: Blood pressure; IQR: Interquartile range; SD: Standard deviation.

Table 2. Comparison of clinical characteristics, interventions, and outcomes by injury site among patients with firearm injuries (n = 119).

Injury Site	All patients	Head/ neck	Chest	Abdomen	Upper extremity	Lower extremity
n (%)	119 (100.0)	21 (17.6)	17 (14.3)	27 (22.7)	28 (23.5)	73 (61.3)
RTS, median (IQR)	7.55 (7.55-7.84)	7.55 (5.14-7.84)	5.14 (0.65-7.55)	7.55 (7.10-7.84)	7.69 (7.55 - 7.84)	7.55 (7.55-7.84)
ISS, median (IQR)	5 (4-13)	9 (4-23)	16 (10-75)	9 (4-16)	7 (4-14)	4 (4-9)
X-ray, n (%)	90 (75.6)	12 (57.1)	6 (35.3)	14 (51.9)	26 (92.9)	71 (97.3)
Computed Tomography, n (%)	104 (87.4)	19 (90.5)	11 (64.7)	24 (88.9)	23 (82.1)	67 (91.8)
Blood Transfusion, n (%)	31 (26.1)	7 (33.3)	11 (64.7)	9 (33.3)	6 (21.4)	13 (17.8)
Surgery, n (%)	46 (38.7)	7 (33.3)	10 (58.8)	15 (55.6)	13 (46.4)	24 (32.9)
LOS (hour), median (IQR)	7 (3-112)	9 (4-118)	5 (1-97)	29 (4-140)	17 (4-115)	6 (3-78)
Discharge from ED, n (%)	63 (52.9)	10 (47.6)	2 (11.8)	11 (40.7)	13 (46.4)	47 (64.4)
In-hospital mortality, n (%)	11 (9.2)	4 (19.0)	7 (41.2)	4 (14.8)	3 (10.7)	2 (2.7)

ED: Emergency department; ISS: Injury Severity Score; IQR: Interquartile range; LOS: Length of stay; RTS: Revised Trauma Score.

Table 3 presents the results of univariate logistic regression analyses evaluating predictors of in-hospital mortality among patients with firearm injuries. Several variables were found to be significantly associated with mortality. Female patients exhibited a significantly higher risk of death compared to males (OR 6.29, 95% CI: 1.54–25.62, p=0.01). Suicide-related injuries were strongly associated with mortality, demonstrating a markedly increased risk compared to other injury intents (OR 40.13, 95% CI: 3.73–431.15, p=0.002). Among physiological parameters, lower systolic and diastolic blood pressures were both significantly associated with increased mortality risk (SBP: OR 0.959, 95% CI: 0.940–0.979, p<0.001; DBP: OR 0.943, 95% CI: 0.916–0.970, p<0.001), as were lower respiratory rate (OR 0.791, 95% CI: 0.700–0.893, p<0.001) and lower GCS score (OR 0.490, 95% CI: 0.345–0.696, p<0.001). Trauma severity measures also showed strong associations with mortality. A lower RTS was associated with a significantly increased risk of death (OR 0.113, 95% CI: 0.026–0.487, p=0.003), while a higher ISS was similarly predictive of mortality (OR 1.323, 95% CI: 1.091–1.603, p=0.004).

Table 3. Logistic regression analysis shows the factors affecting survival.

Variable	**Odds Ratio** (95%CI)	p
Female gender	6.286 (1.542-25.624)	**0.01**
Age, years	1.003 (0.991-1.016)	0.63
Suicide intent	40.125 (3.734-431.149)	**0.002**
Systolic blood pressure	0.959 (0.940-0.979)	**0.001**
Diastolic blood pressure	0.943 (0.916-0.970)	**0.001**
Respiratory rate	0.791 (0.700-0.893)	**0.001**
Glasgow Coma Scale	0.490 (0.345-0.696)	**0.001**
Revised Trauma Score	0.113 (0.026-0.487)	**0.003**
Injury Severity Score	1.323 (1.091-1.603)	**0.004**

CI: Confidence interval.

DISCUSSION AND CONCLUSION

This study investigated firearm-related injuries at a level 1 trauma center, aiming to examine epidemiological trends while also identifying the key clinical determinants of mortality. The analysis revealed that certain physiological parameters and trauma scores were consistently associated with poor outcomes, emphasizing their importance in early risk assessment. Of particular note is the prognostic impact of injury intent and anatomical location. Furthermore, our study has shown that findings such as unstable vital signs and impaired consciousness are associated with mortality. Rapid intervention and aggressive treatment approaches are required for these patients.

There are many different results in the literature regarding the effect of gender on mortality.[4,7,11,12] While many studies show no differences,[4,7,11] some studies, like ours, indicate that mortality is higher in women.[12] These differences suggest that major factors such as sociodemographic variables may influence trauma outcomes. In particular, suicide attempts involving firearms are associated with particularly high mortality.[11] The lethality of such injuries stems from the mechanism of harm, which often results in extensive and irreversible damage, leaving limited opportunity for medical intervention.[11] These findings underscore the importance of identifying individuals at risk of self-harm involving firearms and implementing preventive strategies, including mental health interventions and restrictions on access to firearms, to reduce the likelihood of fatal outcomes in this vulnerable population.[13]

Abnormal vital signs are associated with mortality in firearm injuries, as in many other diseases.[14,15] Low systolic and diastolic blood pressure, high heart and respiratory rates, and low GCS scores were more common in those who did not survive, suggesting possible involvement of early physiological deterioration and central nervous system damage. Many scoring systems have been developed to assist physicians in making decisions and predicting prognosis.[16,17] These models attempt to guide clinicians by combining important predictors.[9,10,13] In this regard, the RTS, which integrates GCS, blood pressure, and respiratory rate in a structured manner, is widely used in trauma patients.[9] In our study, it was observed that RTS was significantly lower in patients who died. While trauma scores alone may not be decisive, their ability to integrate multiple clinical dimensions into a single risk estimate makes them valuable tools in high-pressure emergency care settings.[16]

In addition, several laboratory findings demonstrated strong associations with in-hospital mortality, warranting closer clinical attention. Lower hemoglobin and hematocrit levels observed in non-survivors likely reflect significant blood loss or hemodilution due to aggressive fluid resuscitation, both of which are indicative of physiological compromise.[1,4] More notably, markedly elevated base deficit and decreased pH levels were found in fatal cases, underscoring the prognostic importance of metabolic aci-

dosis in trauma.[1] Base deficit has been widely validated as a sensitive marker of tissue hypoperfusion and shock severity, with established correlations to transfusion needs and adverse outcomes in trauma patients.[7,19] Similarly, systemic acidemia, as reflected by low pH values, may indicate impaired perfusion and ongoing anaerobic metabolism.[1] Incorporating these laboratory markers into early triage and decision-making protocols may enhance the timely identification of critically ill patients and guide the intensity of resuscitative efforts in firearm-related trauma.

Another critical determinant of prognosis in firearm injury patients is the anatomical location of the injury.[3] Multiple injuries are common in firearm trauma, which limits direct comparisons of these injuries, but certain areas (head/neck and chest) have been consistently associated with higher mortality rates. High -velocity ballistic injuries to these areas cause rapid deterioration of vital organ function (e.g., heart, lungs, brain) due to the cavitation and blast effects of the bullet, which can lead to irreversible damage within minutes if not treated immediately.[18] In a retrospective study by Karaca et al.,[4] the highest mortality rate was observed in patients with head and neck injuries (41%), followed by abdominal (25%) and chest (5.5%) injuries. The ISS is widely used to help clinicians assess the severity of such injuries.[10,19] This anatomy-based scoring system quantitatively determines the trauma load by assigning weighted values to the most severely injured body regions.[10] In our study, a high ISS score was also found to be associated with mortality. Thus, the ISS serves as a practical and validated prognostic tool in the management of firearm-related injuries.[4,20]

Lastly, the rates of diagnostic imaging use in our study were higher than those typically reported in general trauma populations.[21] This trend may reflect a combination of increased clinical caution and the growing influence of defensive medicine, particularly in high-risk scenarios such as firearm injuries.[22] The fear of missing life-threatening injuries has led to a lowering of the threshold for using advanced imaging methods even in hemodynamically stable patients.[23] While this approach may improve diagnostic accuracy, it also raises important questions regarding resource utilization, radiation exposure, and the necessity of evidence-based imaging protocols in the treatment of penetrating trauma.[24,25]

This study has several limitations that should be acknowledged. First, the single-center design may affect the generalizability of the findings, as local social determinants of health could differ substantially from those in other regions. Second, the retrospective nature of the study introduces inherent risks of incomplete or inaccurately recorded data. Nevertheless, because all cases involved medicolegal firearm injuries, institutional documentation was likely more thorough than in standard clinical practice. This enhanced data fidelity likely improved the completeness and reliability of the dataset despite the retrospective design. Furthermore, several subgroup analyses—including those related to female gender and suicide intent—should be interpreted with caution due to small sample sizes, which may have contributed to wide confidence intervals and increased statistical variability in the regression estimates. Finally, although logistic regression was used to identify potential predictors of mortality, the limited number of mortality cases (n = 11) precluded the application of multivariate analysis. This constraint limited our ability to control for potential confounding factors between variables.

In conclusion, firearm injuries present complex clinical and public health challenges. Our study emphasizes the prognostic value of early vital sign assessment, anatomical injury location, and trauma scoring systems in predicting outcomes. High mortality rates in head, neck, and chest injuries highlight the need for rapid identification and aggressive interventions. Beyond mortality, the high rates of hospitalization and surgical intervention underscore the broader morbidity burden and resource demands these injuries impose on healthcare systems.

Ethics Committee Approval: The study protocol received approval from the Marmara University Clinical Research Ethics Committee (Date: 31.01.2025, decision no: 09.2025-25-0053). Given its retrospective design, the requirement for informed consent was waived by the ethics committee.

Conflict of Interest: No conflict of interest was declared by the authors.

Author Contributions: Concept – EK, MBK, MA; Supervision – EK, EA; Materials – EK, MBK, MA, AT, OÖ; Data Collection and/or Processing – EK, AT, OÖ; Analysis and/or Interpretation – EK, EA; Writing –EK, MBK, MA, AT, OÖ, EA.

Peer-review: Externally peer-reviewed.

Other Information: This study was presented as a poster presentation at the 3rd Ulusal Acil Tıp Kongresi, held on June 12-14, 2025, in the Republic of Cyprus.

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