ISSN 1306 - 696X

TURKISH JOURNAL of TRAUMA & EMERGENCY SURGERY

Ulusal Travma ve Acil Cerrahi Dergisi

Volume 32 | Number 11| November 2026

www.tjtes.org

TURKISH JOURNAL of TRAUMA & EMERGENCY SURGERY

Ulusal Travma ve Acil Cerrahi Dergisi

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Tel	+90 212 - 588 62 46
Fax *(Faks)*	+90 212 - 586 18 04

p-ISSN 1306-696x • **e-ISSN 1307-7945** • Included in Index Medicus, Medline; EMBASE, Excerpta Medica; Science Citation Index-Expanded (SCI-E), Scopus, DOAJ, EBSCO, ProQuest, CINAHL, Pubmed and Turkish Medical Index. *(Index Medicus, Medline; EMBASE, Excerpta Medica; Science Citation IndexExpanded (SCI-E), Scopus, DOAJ, EBSCO, ProQuest, CINAHL, Pubmed ve TÜBİTAK ULAKBİM Türk Tıp Dizini'nde yer almaktadır.)*

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Our journal is indexed in several prestigious databases, with the indexing history detailed below:

As of 2001, the journal has been indexed in Index Medicus / Medline and Scopus. Starting from 2005, it is included in Excerpta Medica and EMBASE. From 2007 onwards, it has been listed in the Science Citation Index Expanded (SCI-E) and the Journal Citation Reports / Science Edition. Since 2014, the journal is indexed in EBSCOhost and ProQuest. As of 2023, it has been added to PubMed Central.

The journal's impact factor in SCI-E indexed journals is 1.1 according to the 2023 Journal Citation Reports (JCR). In PubMed, the journal is cited as 'Ulus Travma Acil Cerrahi Derg'.

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Unless specifically indicated otherwise at the time of submission, rejected manuscripts will not be returned to the authors, including accompanying materials.

Priority of publications is given to original studies; therefore, selection criteria are more refined for reviews and case reports.

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The cover letter must contain a brief statement that the manuscript has been read and approved by all authors, that it has not been submitted to, or is not under consideration for publication in, another journal. It should contain the names and signatures of all authors. The cover letter is uploaded at the 10th step of the "Submit New Manuscript" section, called "Upload Your Files".

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TURKISH JOURNAL OF TRAUMA & EMERGENCY SURGERY
ULUSAL TRAVMA VE ACİL CERRAHİ DERGİSİ
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TURKISH JOURNAL OF TRAUMA & EMERGENCY SURGERY
ULUSAL TRAVMA VE ACİL CERRAHİ DERGİSİ
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EXPERIMENTAL STUDY

Diagnostic accuracy of oblique radiographic views for ulnar-sided carpometacarpal dislocations: A cadaveric study

Omar Aljasim,[1] Can Yener,[1] Mesut Demirkoparan,[1] Arman Vahabi,[1] Ali Engin Daştan,[1] Nadir Özkayın,[1] Okan Bilge,[2,3] Hüseyin Günay,[1] Levent Küçük[1]

[1]Department of Orthopedic Surgery, Ege University Faculty of Medicine, İzmir-*Türkiye*
[2]Department of Anatomy, Ege University Faculty of Medicine, İzmir-*Türkiye*
[3]Interventional Anatomy and Plastination Research Center, Ege University Faculty of Medicine, İzmir-*Türkiye*

ABSTRACT

BACKGROUND: Dislocations and fracture-dislocations of the ulnar-sided carpometacarpal (CMC) joints are rare injuries that are often overlooked during initial clinical evaluations, primarily due to subtle radiographic findings and overlapping anatomical structures. Missed or delayed diagnosis can result in chronic instability, persistent pain, and suboptimal functional outcomes. This study aimed to assess and compare the diagnostic sensitivity and specificity of different oblique radiographic projections in identifying fifth CMC joint dislocations using a controlled cadaveric model.

METHODS: Six human cadaveric hands, preserved with the modified Larssen solution, were used in this study. Oblique fluoroscopic images were acquired at 30°, 45°, and 60° angles from the lateral view, under three different joint conditions: Native alignment, 25% dislocation, and 50% dislocation of the fifth CMC joint. Standardized imaging was performed using a fixed digital setup. A total of 54 randomized images were included in a questionnaire reviewed by 20 orthopedic surgeons (7 consultants and 13 senior registrars), who classified the fifth CMC joint status as "dislocated," "not dislocated," or "uncertain." Sensitivity, specificity, and overall diagnostic accuracy were calculated for each oblique angle.

RESULTS: The 60° oblique radiographs exhibited the highest sensitivity for identifying dislocations but had a moderate reduction in specificity. In contrast, the 30° view showed the highest specificity but the lowest sensitivity. The 45° oblique radiographs provided a more balanced diagnostic profile. Overall, the 60° oblique radiographs achieved the greatest diagnostic accuracy. Interestingly, senior registrars demonstrated significantly higher diagnostic accuracy than consultants.

CONCLUSION: While the 60° oblique radiographs showed the best performance in detecting fifth CMC dislocations, their sensitivity was not sufficient for use as a standalone diagnostic tool. When clinical suspicion persists despite inconclusive radiographs, computed tomography scan is recommended.

Keywords: Carpometacarpal joint; dislocation; oblique radiograph.

INTRODUCTION

Dislocations and fracture-dislocations involving the carpometacarpal (CMC) joints of the ring and little fingers are relatively rare and may be missed on initial radiographic evaluation.[1] Due to their infrequency, no evidence-based diagnostic or management guidelines have been developed, and most available data are derived from case series and individual author experience.[2,3] This injury is commonly seen in young males and more frequently affects the dominant hand.

Cite this article as: Aljasim O, Yener C, Demirkoparan M, Vahabi A, Daştan AE, Özkayın N, et al. Diagnostic accuracy of oblique radiographic views for ulnar-sided carpometacarpal dislocations: A cadaveric study. Ulus Travma Acil Cerrahi Derg 2026;32:1323-1328.

Address for correspondence: Omar Aljasim
Department of Orthopedic Surgery, Ege University Faculty of Medicine, İzmir, Türkiye
E-mail: omar.aljasim.md@gmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(11):1323-1328 DOI: 10.14744/tjtes.2026.17529
Submitted: 24.01.2026 Revised: 03.04.2026 Accepted: 05.05.2026 Published: 05.11.2026
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[4,5] These injuries typically result from direct impact, such as a punch against a hard surface, which generates axial loading combined with a lever mechanism that causes extension or flexion of the metacarpal relative to the distal carpal row.[6,7]

The fifth CMC joint is a shallow saddle-shaped articulation with limited intrinsic stability, allowing approximately 30° of motion necessary for effective power grip.[3,8] The fifth CMC joint is supported by the dorsal and palmar CMC ligaments, the ulnar collateral ligament, the pisometacarpal ligament, the dorsal and palmar intermetacarpal ligaments, and the interosseous intermetacarpal ligament complex.[9] The fourth–fifth intermetacarpal ligament is the primary stabilizer of the fifth CMC joint.[3]

Diffuse swelling can obscure the typical clinical deformity, while conventional radiographs may be insufficient to diagnose the injury. Henderson and Arafa reviewed 21 cases of dorsal dislocation of CMC joints, of which 15 were missed during the initial evaluation in the emergency department.[10] When CMC dislocations occur alongside adjacent metacarpal fractures, the fracture may distract the examiner's attention, making the associated dislocation more difficult to detect.[11] Delayed diagnosis may result in suboptimal outcomes, as non-operative management often fails to achieve full reduction, leading to limited range of motion, diminished grip strength, persistent pain, functional impairment, and degenerative joint changes.[4]

Diagnosis and management of metacarpal head and shaft fractures are generally achievable using anteroposterior, lateral, and 30°-45° oblique radiographs (in pronation or supination).[12-14] However, fractures and fracture–dislocations involving the base of the fifth metacarpal and the fifth CMC joint remain more challenging to assess due to bony overlap. Several authors have proposed different radiographic methods to aid in the early diagnosis of this injury. These include assessing the parallelism of the M lines, alignment of articular margins, joint space symmetry, cortical contour continuity, and hand positioning.[15] Additional techniques involve drawing metacarpal cascade lines on posteroanterior radiographs, measuring the angle between the second and fifth metacarpals on true lateral views, and evaluating the capitate–metacarpal angle.[16-18] A study by Johnson et al.[19] found that a 60° oblique radiograph was the most sensitive projection for detecting fifth CMC dislocations. This study aimed to re-evaluate and validate the diagnostic sensitivity and specificity of various oblique radiographic angles in detecting fifth CMC dislocations using a cadaveric model.

MATERIALS AND METHODS

This study was approved by the Ege University Review Board (Date: 04.09.2025, Decision no: 25-9T/20). Six human cadaveric hands, preserved using the modified Larssen solution, were utilized. The cadavers had a mean age of 51 years (range: 25–60 years) and included three males and three females. All donors had no known osteomuscular disorders, and each specimen was examined to confirm the absence of CMC joint arthropathies. A dorsal longitudinal incision was made over the fifth CMC joint. Soft tissue dissection was carried out to expose the joint, with the extensor carpi ulnaris tendon retracted ulnarly. Sharp dissection was used to release all the fifth CMC ligaments, allowing complete dislocation of the fifth metacarpal base. The total sagittal width of the fifth metacarpal base was measured using a digital caliper. Reference points were marked at 25% and 50% along the dorsal aspect of the metacarpal base, where 0.8 mm drill holes were subsequently created for the placement of a radiolucent fixator (Fig. 1a and b). A digital camera (Nikon D90 model, Tokyo, Japan) was used to capture fluoroscopic images displayed on the monitor, with the camera held in a fixed position throughout the experiment. Three consecutive fluoroscopic images were obtained at 30°, 45°, and 60° oblique angles by pronating the hand incrementally from the true lateral position while the fifth CMC joint was reduced. The joint was then dislocated sequentially to the 25% and 50% positions (Fig. 2a-c). At each dislocation level, three fluoroscopic images were again captured at the same oblique angles (Fig. 3a-c). All fluoroscopic views were digitally recorded using the fixed camera setup.

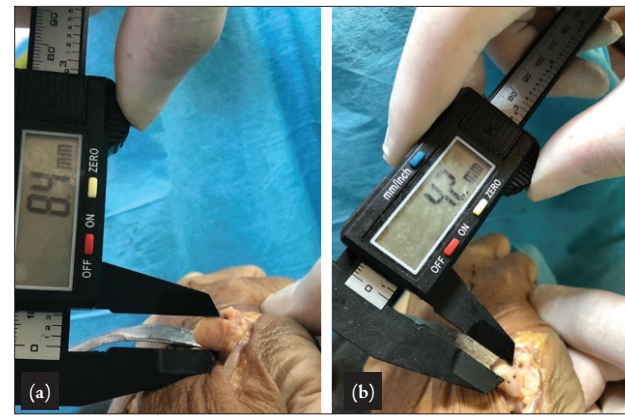


Figure 1. Dislocation of the base of the fifth metacarpal following dissection. **(a)** Measurement of the sagittal width of the fifth metacarpal base to determine the degree of dislocation. **(b)** Reference markings indicating 25% and 50% dislocation positions for guide hole placement.

Dissection, fixation, and fluoroscopic imaging were performed by three senior orthopedic residents. Subsequently, a questionnaire was created using the Google Forms platform, comprising 54 randomized fluoroscopic images. These images were presented to 20 orthopedic surgeons, including 7 orthopedic consultants (attending) and 13 senior orthopedic registrars (residents). Reviewers were instructed to focus on the fifth CMC joint in each image and classify it as either: dislocated, not dislocated, or uncertain. Responses to all images were mandatory. For the purpose of analysis, "uncertain" responses were considered incorrect. The three senior orthopedic residents who performed the experiment did not participate in the questionnaire assessment.

Data obtained in the study were analyzed using the Statisti-

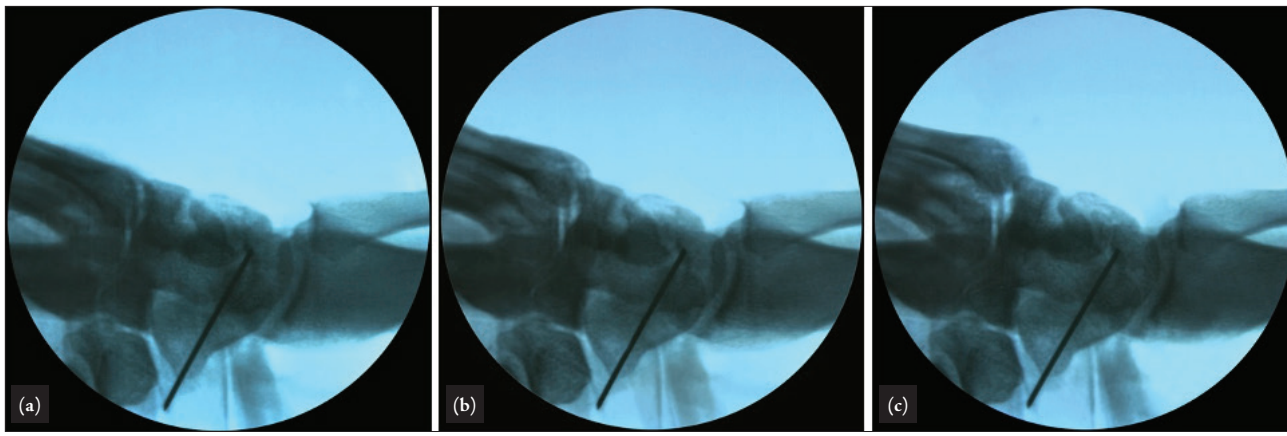


Figure 2. Consecutive fluoroscopic views taken at 45° oblique pronation. **(a)** Fifth metacarpal base in a reduced position. **(b)** Fifth metacarpal base with 25% dislocation. **(c)** Fifth metacarpal base with 50% dislocation (Images were post-processed to remove photographic artifacts (screen reflections and border shadows) without modification of fluoroscopic content, anatomical structures, or joint appearances).

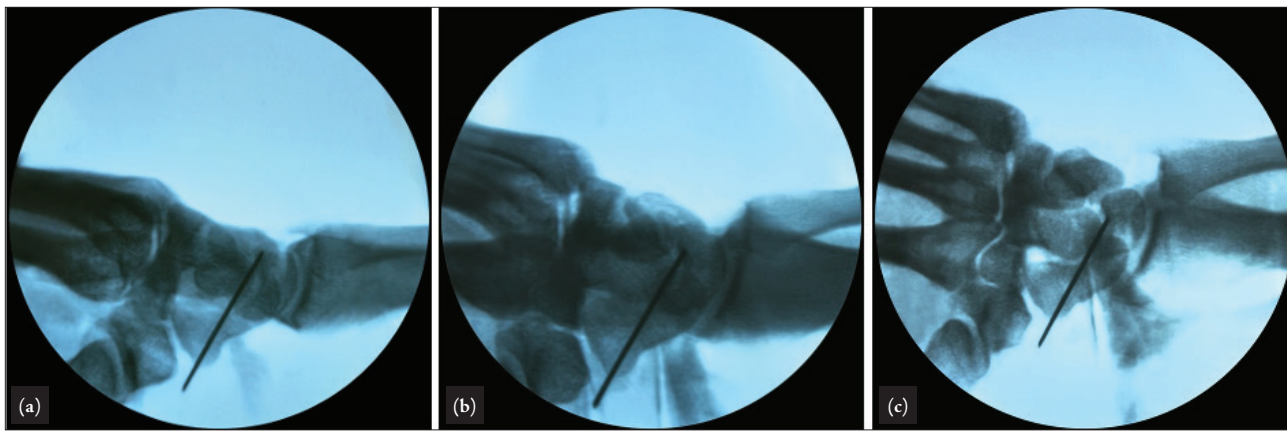


Figure 3. Consecutive fluoroscopic views of the fifth metacarpal base in 50% dislocated position. **(a)** 30° oblique view. **(b)** 45° oblique view. **(c)** 60° oblique view (Images were post-processed to remove photographic artifacts [screen reflections and border shadows] without modification of fluoroscopic content, anatomical structures, or joint appearances).

cal Package for the Social Sciences (SPSS), version 26.0 (IBM Corp., Armonk, NY, USA). In this study, the Chi-Square test was used to compare the diagnostic performance of the evaluator in assessing joint dislocation status at different angle positions (30°, 45°, 60°), and the results were presented as numerical (n) and percentage (%) distributions. The evaluator's diagnostic performance at each angle position was assessed using sensitivity, specificity, positive/negative likelihood ratios (LR+/LR−), positive/negative predictive values (PPV/NPV), and accuracy metrics, with reference to the gold standard. For dependent group comparisons, McNemar's test was applied. The level of statistical significance was set at α=0.05 (two-tailed).

RESULTS

Oblique radiographs taken at a 60° angle demonstrated the highest sensitivity but the lowest specificity for detecting fifth CMC dislocation. Whereas those taken at a 30° angle

Table 1. Sensitivity and specificity of different oblique radiographic views in diagnosing fifth carpometacarpal joint dislocation

Oblique radiographic angles	Sensitivity % (95% CI)	Specificity % (95% CI)
30°	31.05 (25.0–37.6)	92.47 (85.1–96.9)
45°	64.53 (58.0–70.7)	84.27 (75.0–91.1)
60°	65.56 (59.6–71.2)	79.25 (65.9–89.2)

CI: Confidence interval.

showed the lowest sensitivity but the highest specificity (Table 1). The diagnostic accuracy of orthopedic residents was significantly higher than that of orthopedic consultants, at 58.8% and 49.2%, respectively (p=0.002). When uncertain responses were considered incorrect, the percentages of correct diagnoses were 45.3% for 30° oblique radiographs, 59.5% for 45° radiographs, and 60.8% for 60° radiographs (p<0.001). Regarding the degree of dislocation, candidates correctly identified 25% dislocation in 39% of cases, 50% dislocation in 58% of cases, and reduced joints in 78.1% of cases. After excluding uncertain responses, the accuracy of 30°, 45°, and 60° oblique radiographs was 49.36% (43.7–55.1), 69.97% (64.7–74.9), and 67.80% (62.4–72.9), respectively. The LR+/LR− for 30°, 45°, and 60° oblique radiographs were 4.13/0.75, 4.10/0.42, and 3.16/0.46, respectively. PPV/NPVs for 30°, 45°, and 60° oblique radiographs were 90.67/36.29, 91.52/47.47, and 94.15/31.11.

DISCUSSION

Dislocation of the fifth CMC joint can be easily missed at initial presentation due to swelling on the dorsum of the hand, which may obscure visible deformity or make clinical signs, such as a palpable lump, difficult to detect.[20] Furthermore, overlapping of the metacarpal bones on lateral radiographs and of the carpal bones on anteroposterior views can make accurate diagnosis even more challenging, especially for inexperienced surgeons.[19,21] A delayed diagnosis may prevent successful closed reduction, making open surgical reduction necessary to restore joint alignment.[22] Zhang et al.[4] reported six missed diagnoses out of 26 cases. Conservative treatment in these patients led to poor clinical outcomes and eventually resulted in degenerative arthritis. In a study evaluating the impact of radiological re-assessments on forensic reports, misinterpretation of bone fractures was a common source of error, with the upper limb representing the second most frequently affected region. False-negative and false-positive rates for metacarpal fractures were 7.1% and 16.4%, respectively. These inaccuracies may influence not only diagnosis and treatment but also the outcomes of forensic evaluations.[23]

Fisher et al.[15] described a method for detecting fourth and fifth metacarpal dislocations on posteroanterior views by identifying parallel "M lines" and ensuring joint surfaces are aligned with a consistent 1–2 mm space. In addition, fractures at the base of the metacarpals or carpal bones should raise suspicion of a CMC dislocation. Hodgson and Shewring found that metacarpal cascade lines should converge toward a point just proximal to the distal radius articular surface. Deviation from this convergence may help detect even minor dislocations of the fourth and fifth CMC joints.[16] Parkinson and Paton identified a method to diagnose dislocation of the fifth CMC by measuring the angle between the axis of the fifth and the fourth metacarpal bone and found that mean of the normal angle was 9.5° while in dislocated cases, it was 39.5°.[17] However, this method was unreliable for subluxation where the angle was 14°. Henderson and Arafa recommend obtaining a lateral hand radiograph if a posteroanterior view shows loss of joint symmetry, overlap, or metacarpal shortening, or if there is dorsal hand swelling with no clear abnormality on standard views.[10,18]

Cain et al.[8] demonstrated that 45° pronation oblique radiographs can help diagnose injuries to the fourth and fifth CMC joints, while 15° pronation oblique views are useful for assessing damage to the dorsal aspect of the fifth CMC joint. Niechajev evaluated oblique radiographs at 30° and 60° in both pronation and supination positions and found that the 60° supination view was superior, as it allowed the base of the fifth metacarpal to be free from overlap and provided a clear view of the intermetacarpal joint.[2] Stapczynski suggested using a 45° oblique supination view with the fingers extended (Norgaard view) or cupped (Ball-Catcher's view) to improve visualization of the CMC joints.[24] Bora and Didizian described that a clear view of the fifth CMC articular surface can be obtained by pronating the forearm 30° from the routine anteroposterior position.[22] Previous authors based their suggested radiographic views mostly on their experience and common clinical practice. In addition, supination views are helpful in visualizing fractures at the base of the fifth metacarpal but may miss dorsal dislocations. In contrast, pronation views are more effective in detecting dorsal dislocations but may fail to reveal injuries of the fourth and fifth CMC joints. All previous approaches may be practical for experienced orthopedic surgeons; however, it can be difficult for general practitioners and emergency doctors to remember and apply in a busy clinical setting.

Hassan et al.[25] evaluated the diagnostic accuracy of four radiographic views (posteroanterior, lateral, pronated oblique, and supinated oblique) for ring and little finger CMC joint injuries among orthopedic trainees and emergency nurse practitioners. The 15°–20° pronated oblique view from the true lateral demonstrated the highest sensitivity, whereas the supinated oblique showed the lowest. Furthermore, the combination of posteroanterior, true lateral, and pronated oblique views correctly identified 78% of injuries.

A previous cadaveric study by Johnson et al.[19] reported high sensitivity and specificity of 60° pronated radiographs from the lateral compared to 30° and 45°. In our study, we aimed to validate and build upon the existing findings. This is particularly valuable for early and accurate diagnosis, which remains a challenge in clinical settings. Results of this study also showed 60° as the most sensitive angle as previously reported. However, the sensitivity rates were lower than previously reported, which may be due to the limited radiographic quality, as the images were acquired using fluoroscopy and a digital camera. In addition, sensitivity at 45° was comparable to sensitivity at 60° angle unlike previously reported where 30° angle was comparable to 60° angle.

In a study evaluating the diagnostic power of plain radio-

graphs (anteroposterior, lateral, and oblique) for fourth and fifth CMC fracture–dislocations found low sensitivity and only slight interobserver agreement, suggesting that computed tomography (CT) scan should be incorporated into emergency diagnostic protocols for these injuries.[26] Potini et al.[18] described a screening method based on measuring the capitate-metacarpal angle and recommended CT scanning for patients with angles >15°. The findings of the present study, in which the best-performing 60° oblique view demonstrated a sensitivity of only 65.6%, are consistent with this recommendation and further support the use of CT as an adjunct when clinical suspicion persists.

Radiology perception research has shown that diagnostic accuracy for specific radiographic tasks improves with training.[27] It is interesting to note that the average accuracy of the trainees was higher than that of the consultants. Similar results were reported in a study to evaluate the diagnostic accuracy between radiologists and radiology residents to diagnose appendicular fractures.[28] Differences in diagnostic performance may relate to more recent training exposure among residents, reduced reliance on clinical history, and the presence of supervisory safeguards, whereas consultants may depend more on clinical context and independent reporting. In this study, performance was highly task-specific rather than uniformly experience-dependent which suggests that seniority alone does not guarantee superior diagnostic performance for uncommon or subtle findings. In addition, trainees were based in a tertiary trauma center, particularly within a specialized hand trauma unit.

In clinical practice, CMC joint fracture–dislocations occur more often than pure dislocations without fracture, and dorsal dislocations are much more common than volar ones.[15] The present model, which simulated pure dorsal dislocation at standardized degrees, therefore represents a situation that may be less visible on radiographs than typical clinical cases, which often include associated hamate or metacarpal base fractures that provide additional imaging clues. Accordingly, the sensitivity values reported here should be considered cautious estimates; oblique views may perform better in real clinical settings where fracture fragments make the injury easier to detect on radiographs. However, clinicians must carefully evaluate radiographs to avoid missing associated dislocations in regions not directly related to the fracture site.[11]

This study had several limitations. The fifth CMC dislocation was experimentally induced and may not fully represent actual clinical injuries, which often involve fracture-dislocations or bony fragments. However, by focusing on simple dislocations with minimal dislocation, the study may have demonstrated a method that is even more sensitive when applied to more complex injuries. All reviewers were informed that the study concerned fifth CMC dislocations, which may have introduced expectation bias and potentially influenced the accuracy of their assessments.

CONCLUSION

Based on current and previous evidence, initial assessment should include standard posteroanterior, true lateral, and 60° pronation oblique radiographs. If the mechanism involves axial loading and clinical signs such as dorsal swelling and point tenderness over the CMC joint persist despite inconclusive radiographs, CT imaging should be obtained. This stepwise approach balances radiation exposure and resource use while minimizing the risk of missed diagnoses.

Ethics Committee Approval: This study was approved by the Ege University Review Board (Date: 04.09.2025, Decision No: 25-9T/20). The authors declare that the work described has been carried out in accordance with the Declaration of Helsinki of the World Medical Association, revised in 2013, for experiments involving humans.

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: O.A., C.Y., M.D., A.V., A.E.D., N.Ö., O.B., H.G., L.K.; Design: O.A., C.Y., M.D., A.V., A.E.D., N.Ö., O.B., H.G., L.K.; Supervision: O.A., C.Y., M.D., A.V., A.E.D., N.Ö., O.B., H.G., L.K.; Resource: O.A., O.B.; Materials: O.A., O.B.; Data collection and/or processing: O.A., M.D., C.Y.; Analysis and/or interpretation: N.Ö., A.E.D., A.V.; Literature review: O.A., M.D.; Writing: O.A., A.V.; Critical review: O.A., C.Y., M.D., A.V., A.E.D., N.Ö., O.B., H.G., L.K.

Informed Consent: The authors declare that this report does not contain any personal information that could lead to the identification of the patient(s) and/or volunteers.

Conflict of Interest: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Financial Disclosure: This study received financial support from the Ege University Scientific Research Project Coordination Office under grant numbers TGA2020-21992 and TGA-2020-21125.

Use of AI for Writing Assistance: The authors acknowledge the use of AI-based tools for language enhancement and formatting assistance in manuscript preparation. No AI-generated content was used for data interpretation, analysis, or scientific conclusions.

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DENEYSEL ÇALIŞMA - *ÖZ*

Ulnar taraflı karpometakarpal çıkıkların saptanmasında oblik x-ray projeksiyonlarının değerlendirilmesi: Bir kadavra çalışması

AMAÇ: Ulnar taraflı karpometakarpal (KMK) eklemlerin çıkıkları ve kırık-çıkıkları nadir görülen yaralanmalardır ve genellikle ilk klinik değerlendirmelerde gözden kaçırılır. Bunun başlıca nedeni, radyografik bulguların belirsiz olması ve anatomik yapıların üst üste binmesidir. Kaçırılan veya gecikmiş tanı, kronik instabiliteye, sürekli ağrıya ve suboptimal fonksiyonel sonuçlara yol açabilir. Bu çalışma, kontrollü bir kadavra modelinde beşinci KMK eklem çıkıklarının tanısında farklı oblik radyografik projeksiyonların tanısal duyarlılık ve özgüllüğünü değerlendirmeyi ve karşılaştırmayı amaçlamıştır.
GEREÇ VE YÖNTEM: Bu çalışmada, modifiye Larssen solüsyonu ile korunan Altı insan kadavra eli kullanıldı. Beşinci KMK eklemin doğal hizası, %25 çıkık ve %50 çıkık olmak üzere üç farklı eklem durumunda, lateral görünümden 30°, 45° ve 60° açılarda oblik floroskopik görüntüler alındı. Standartize görüntüleme sabit bir dijital sistemle gerçekleştirildi. Toplam 54 randomize görüntü, 20 ortopedi cerrahı (7 uzman ve 13 kıdemli asistan) tarafından incelenen bir anket haline getirildi. Cerrahlar beşinci KMK ekleminin durumunu "çıkık", "çıkık değil" veya "belirsiz" olarak sınıflandırdı. Her oblik açı için duyarlılık, özgüllük ve genel tanısal doğruluk hesaplandı.
BULGULAR: 60° oblik radyografiler, çıkıkların tespitinde en yüksek duyarlılığı gösterdi ancak özgüllükte orta düzeyde bir azalma oldu. Buna karşılık 30° görünüm en yüksek özgüllüğe sahipken en düşük duyarlılığa sahipti. 45° oblik radyografiler daha dengeli bir tanısal profil sundu. Genel olarak 60° oblik radyografiler en yüksek tanısal doğruluğu sağladı. İlginç bir şekilde, kıdemli asistanlar uzmanlara göre anlamlı derecede daha yüksek tanısal doğruluk gösterdi.
SONUÇ: 60° oblik radyograf, beşinci KMK çıkıklarının tespitinde en iyi performansı göstermesine rağmen, duyarlılığı tek başına tanısal araç olarak kullanılacak düzeyde yeterli değildir. Klinik şüphe radyografilerde belirsizliğe rağmen devam ediyorsa, bilgisayarlı tomografi (BT) taraması önerilir.

Anahtar sözcükler: Çıkık; karpometakarpal eklem; oblik radyografiler.

Ulus Travma Acil Cerrahi Derg 2026;32(11):1323-1328 DOI: 10.14744/tjtes.2026.17529

EXPERIMENTAL STUDY

Protective effects of pramipexole on testicular torsion and detorsion injury in rats

Engin Kölükçü,[1] Kenan Yalçın,[1] Hüseyin Biçer,[2] Uğur Kulu,[3] Velid Unsal,[4] Muzaffer Katar,[5] Fikret Gevrek[6]

[1]Department of Urology, Tokat Gaziosmanpaşa University Faculty of Medicine, Tokat-*Türkiye*
[2]Department of Urology, Kayseri City Hospital, Kayseri-*Türkiye*
[3]Department of Neurology, Tokat Gaziosmanpaşa University Faculty of Medicine, Tokat-*Türkiye*
[4]Mardin Artuklu University, Faculty of Health Sciences and Central Research Laboratory, Mardin-*Türkiye*
[5]Department of Biochemistry, Tokat Gaziosmanpaşa University Faculty of Medicine, Tokat-*Türkiye*
[6]Department of Histology and Embryology, Tokat Gaziosmanpaşa University Faculty of Medicine, Tokat-*Türkiye*

ABSTRACT

BACKGROUND: Testicular torsion induces ischemia–reperfusion injury, which is predominantly mediated by oxidative stress and inflammatory cascades. Pramipexole, a pharmacological agent widely used in neurological practice, possesses potent antioxidant, anti-inflammatory, and anti-apoptotic properties. The aim of this experimental study was to evaluate the potential protective effects of pramipexole on testicular ischemia–reperfusion injury using a rat model of testicular torsion-detorsion, through both biochemical and histopathological analyses.

METHODS: A total of 18 male rats were randomly divided into three groups. Group 1 was designated as the control group. In Group 2, only a testicular torsion-detorsion model was established to evaluate testicular ischemia–reperfusion injury. In Group 3, a similar torsion-detorsion model was created. In addition, rats in this group received intraperitoneal pramipexole (0.5 mg/kg) immediately after testicular detorsion. The aim was to assess the effects of pramipexole on testicular ischemia–reperfusion injury. At the end of the experiment, blood samples were collected for biochemical analyses, and orchiectomy was performed for histopathological evaluation of testicular tissues.

RESULTS: Biochemical analyses showed that malondialdehyde (MDA) levels were significantly increased in Group 2 compared with the other groups ($p<0.001$). Similarly, tumor necrosis factor-alpha and interleukin-1beta levels were significantly higher in Group 2 than in the other groups ($p<0.001$). In Group 3, both pro-inflammatory cytokine levels and MDA levels were significantly reduced compared with Group 2 ($p<0.001$). Furthermore, glutathione peroxidase and superoxide dismutase activities were significantly increased in Group 3 compared with Group 2 ($p=0.002$ and $p<0.001$, respectively). Histopathological evaluation revealed a significant improvement in all testicular damage scores, including vasocongestion, inflammation, and edema, in Group 3 compared with Group 2 ($p<0.001$). Likewise, the mean Johnsen score in Group 3 was calculated as 8.37±0.62, which was significantly higher than that observed in Group 2 ($p<0.001$).

CONCLUSION: Pramipexole appears to be an effective pharmacological agent in alleviating the effects of testicular ischemia–reperfusion injury.

Keywords: Ischemia–reperfusion; pramipexole; testis.

Cite this article as: Kölükçü E, Yalçın K, Biçer H, Kulu U, Unsal V, Katar M, et al. Protective effects of pramipexole on testicular torsion and detorsion injury in rats. Ulus Travma Acil Cerrahi Derg 2026;32:1329-1336.

Address for correspondence: Engin Kölükçü
Department of Urology, Faculty of Medicine, Tokat Gaziosmanpaşa University, Tokat, Türkiye
E-mail: drenginkolukcu@gmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(11):1329-1336 DOI: 10.14744/tjtes.2026.62297
Submitted: 13.03.2026 Revised: 03.10.2026 Accepted: 09.10.2026 Published: 05.11.2026
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INTRODUCTION

Testicular torsion is a urological emergency characterized by the rotation of the testis around the axis of the spermatic cord, which compromises blood flow to the testis.[1] The incidence of this condition is estimated to be approximately 1 in 4,000 males under the age of 25.[2] More than three-quarters of cases present to emergency departments with scrotal pain and/or swelling.[3] Early diagnosis and prompt implementation of appropriate treatment algorithms are crucial to prevent testicular loss in this emergency condition.[1] In this context, early detorsion procedures within the traditionally accepted "6-hour golden window" in testicular torsion is believed to be important for maintaining testicular viability. However, even after successful treatment, a high incidence of testicular atrophy has been reported in the post-operative period.[3] One of the main causes of this condition is ischemia–reperfusion injury that occurs following detorsion of the testis. During ischemia–reperfusion injury, restoration of the anatomical position of the spermatic cord after surgical intervention leads to the reestablishment of tissue perfusion. The rapid reoxygenation of the testis subsequently results in the excessive generation of reactive oxygen species (ROS), causing destructive tissue damage. Minimizing ischemia–reperfusion injury plays a critical role in improving the reproductive health outcomes of patients treated for testicular torsion.[2]

Pramipexole is a non-ergot dopamine receptor agonist chemically known as (S)-2-amino-4,5,6,7-tetrahydro-6-(propylamino).[4] It is currently used safely in the treatment of Parkinson's disease. Recent clinical trials have also reported beneficial effects of pramipexole in the treatment of major depressive episodes and restless leg syndrome.[5-8] Pramipexole exerts its therapeutic effect on neurodegenerative disorders by restoring dopamine signal balance.[9] In addition, recent experimental studies have demonstrated the anti-inflammatory, anti-apoptotic and antioxidant properties of pramipexole. In this context, the potential role of pramipexole in oxidative damage has been investigated in a limited number of tissues, including the central nervous system, retina, and heart, in various experimental animal models.[10-12] After the treatment of testicular torsion, oxidative damage occurring due to excessively elevated ROS levels has highly destructive effects on the tissue. Although pramipexole has been shown to reduce inflammation and oxidative stress in different tissues, we thought that it may have similar effects in testicular torsion and protective effects against tissue damage.

The present study aimed to investigate the potential protective effects of pramipexole against testicular ischemia–reperfusion injury in a rat model of testicular torsion and detorsion. To the best of our knowledge, this study represents the first experimental investigation in the English literature evaluating the effects of pramipexole in a rat model of experimentally induced testicular ischemia–reperfusion injury.

MATERIALS AND METHODS

Experimental Animals and Environment All experimental interventions were performed after obtaining ethical approvals (Animal Experiments Tokat Gaziosmanpasa University Local Ethics Committee, decision number 2025 HADYEK-18 date: 14.05.2025). Eighteen male Albino Wistar rats (200–400 g, 11–17 weeks old) were included in our study. Surgical interventions were performed at a constant temperature of 22±2°C under a 12-h light/dark cycle.

Surgery Procedure

All experimental interventions were performed under sterile conditions and with an adequate depth of anesthesia. A total of 18 rats were randomly assigned to three groups.

Group 1 was assigned as the control group. In this group, only unilateral orchiectomy was performed. Testicular tissues were subjected to histopathological examination, and blood samples were collected from the inferior vena cava for biochemical analysis.

Group 2 was designated as the ischemia–reperfusion group. Based on the protocol described in the literature, a left ilioinguinal incision was made, and unilateral testicular exposure was achieved. The testicles were rotated counterclockwise by 720° for 180 min and then fixed to the scrotum with 5-0 polyglactin sutures (Pegelak, Doğan Company, Turkey). After 180 min, the testicular torsion was terminated, and the testicle was returned to its original anatomical position. The testicles were then left in their normal anatomical position for 180 min to allow restoration of blood flow. A unilateral orchiectomy was performed after a total of 360 min of invasive procedures.[13] Testicular tissues were subjected to histopathological examination, and blood samples were collected from the inferior vena cava for biochemical analysis.

Group 3 was designated as the treatment group. A similar testicular torsion-detorsion model was created as in Group 2. In addition, pramipexole (0.5 mg/kg) was administered intraperitoneally to the rats in this group immediately after testicular detorsion.[14] Testicular tissues were subjected to histopathological examination, and blood samples were collected from the inferior vena cava for biochemical analysis, similar to the other groups.

At the end of all procedures, rats will be sacrificed by cervical dislocation.

Histopathologic Examination

At the end of the experiment, testicular tissues obtained following orchiectomy were fixed in formalin solution. The testes were sectioned transversely through the middle and embedded in paraffin blocks in the same orientation. The slides were mounted with entellan and covered with coverslips to prepare hematoxylin–eosin stained testicular tissue sections for histopathological analysis. The stained sections were examined under a light microscope (Nikon Eclipse 200, Japan) at ×40 magnification. Microscopic evaluation was performed on an average of 6–7 serial sections per sample, and in each section, five randomly selected fields were analyzed, with ap-

proximately 25–30 seminiferous tubules evaluated in total. All analyses were performed in a blinded manner using a coding system. Testicular tissue damage was histopathologically assessed in terms of hemorrhage, congestion, inflammation, and edema. These parameters were graded as 0: Normal, 1: Mild, 2: Moderate, and 3: Severe.[15] Subsequently, germ cell maturation, spermatogenesis processes and seminiferous tubule architecture, germ cell maturation, and spermatogenesis processes were evaluated according to the Johnsen scoring criteria.[16] All histopathological evaluations were performed by the same experienced histologist.

Biochemical Analyses

Measurement of malondialdehyde (MDA) levels

MDA is an end product of lipid peroxidation and serves as an important biomarker for the assessment of cellular damage. MDA determination is based on its reaction with thiobarbituric acid under acidic conditions at 90°C. As a result of this reaction, a pink-colored MDA–TBA complex (chromogen) is formed, and MDA levels are determined spectrophotometrically by measuring the absorbance at 532 nm.[17]

Determination of glutathione peroxidase (GSH-Px) activity

GSH-Px catalyzes the oxidation of reduced GSH to oxidized glutathione (GSSG) in the presence of hydrogen peroxide. The GSSG generated by GSH-Px is subsequently reduced back to GSH by glutathione reductase, accompanied by the oxidation of NADPH to $NADP^+$. GSH-Px activity was calculated by monitoring the decrease in absorbance at 340 nm, corresponding to the oxidation of NADPH.[18]

Determination of Superoxide Dismutase (SOD) Activity

SOD activity was determined according to the method described by Sun et al.[19] The principle of this method is based on the reduction of nitroblue tetrazolium by superoxide radicals generated through the xanthine/xanthine oxidase system. Measurements were performed by assessing the degree of inhibition of this reduction by the SOD enzyme, and activity levels were calculated accordingly.

Enzyme-Linked Immunosorbent Assay (ELISA)

Serum tumor necrosis factor-alpha (TNF- alpha) and interleukin-1beta (IL-1 beta) levels were measured using ELISA kits (Bioassay Technology Laboratory brand, Code: E0764Ra and Code: E0119Ra, respectively) according to the manufacturer's instructions. The kits were obtained from Atlas Bioassay Technology Laboratory. Measurements were performed using a Thermo Scientific Multiskan FC microplate reader.

Statistical Analysis

Descriptive statistics were used to summarize the general characteristics of the study groups. Normality assumptions were assessed before parametric analyses. Continuous variables were expressed as mean±standard deviation or median (minimum–maximum) according to distribution characteristics. Differences between groups were analyzed using one-way analysis of variance. Post hoc comparisons were conducted using Tukey's HSD or Tamhane's T2 test, as appropriate. $p<0.05$ was considered statistically significant. All statistical analyses were conducted using IBM Statistical Package for the Social Sciences Statistics for Windows, Version 27.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Histopathological Findings

The histopathological results are presented in detail in Table 1 and Figure 1. In the tissue samples from Group 1, no marked

Table 1. Comparison of inflammation, edema, vasocongestion and Johnsen scores in histopathological samples between rat groups

	Groups	n	Mean±SD	Median (min-max)	p	Post hoc p
Edema	1	6	0.22±0.04	0.24 (0.16–0.26)	<0.001*	1–2: <0.001*
	2	6	2.31±0.18	2.32 (2.08–2.63)		1–3: <0.001*
	3	6	1.25±0.15	1.28 (1.05–1.44)		2–3: <0.001*
Inflammation	1	6	0.18±0.07	0.18 (0.07–0.27)	<0.001*	1–2: <0.001*
	2	6	1.86±0.11	1.8 (1.74–2.03)		1–3:<0.001*
	3	6	0.99±0.2	0.92 (0.81–1.4)		2–3: <0.001*
Vasocongestion	1	6	0.17±0.05	0.15 (0.1–0.23)	<0.001*	1–2: <0.001*
	2	6	2.39±0.15	2.3 (2.26–2.6)		1–3:<0.001*
	3	6	1.12±0.04	1.12 (1.07–1.18)		2–3: <0.001*
Johnsen score	1	6	9.71±0.09	9.7 (9.59–9.89)	<0.001*	1–2: <0.001*
	2	6	5.99±0.3	6.04 (5.63–6.31)		1–3: <0.001*
	3	6	8.37±0.62	8.5 (7.25–9.13)		2–3: <0.001*

SD: Standard deviation. Test: One-Way analysis of variance (ANOVA). (Differences between groups were examined with post hoc Tukey HSD or Tamhane's T2). *The p-value is significant at the 0.05 level.

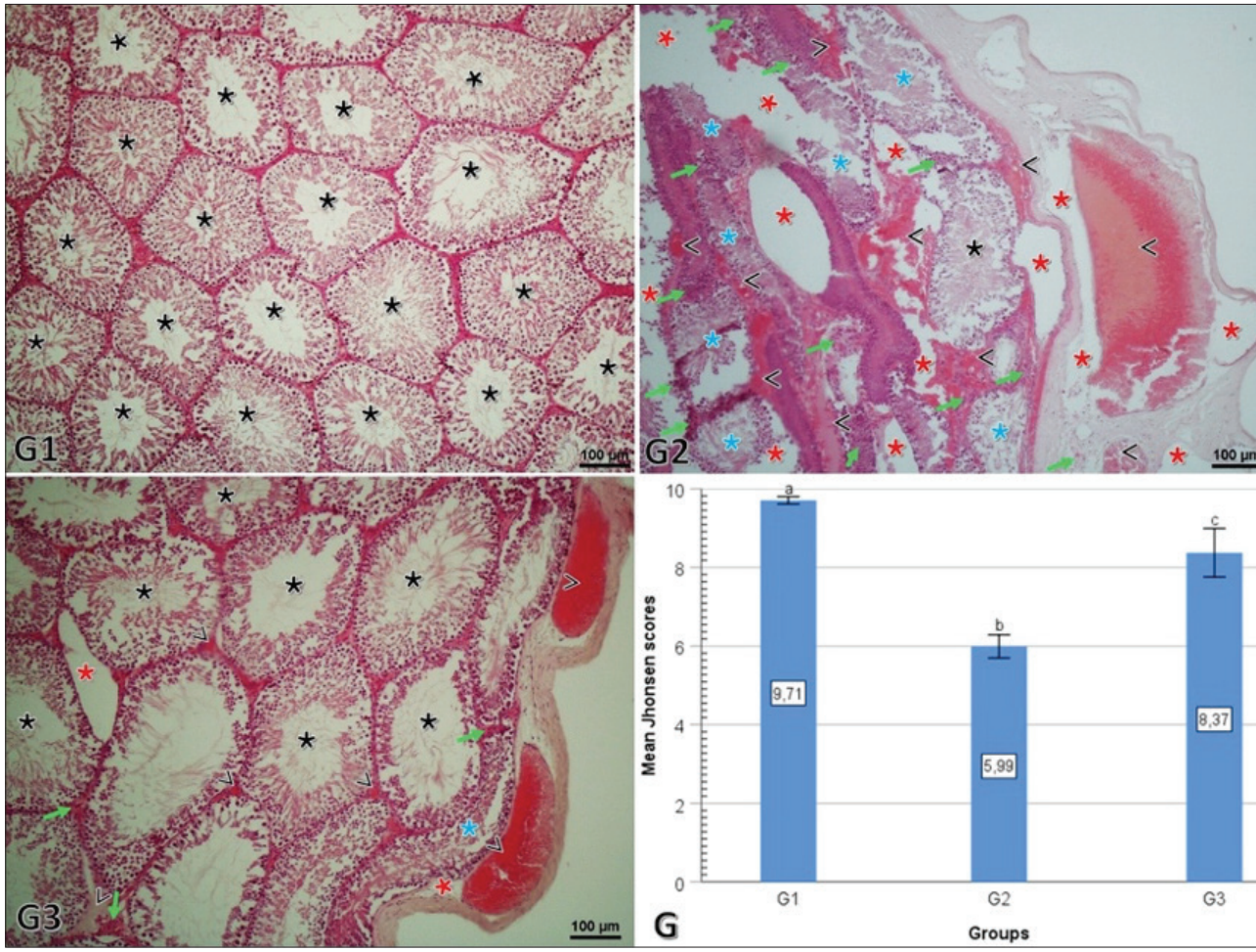


Figure 1. Representative microscopic images of testicular tissue from the rat groups.
In Group 1, seminiferous tubules exhibit a normal histological appearance with an intact seminiferous epithelium, normal interstitial tissue, and numerous spermatozoa within the tubular lumen (black star). This morphology is detailed in panel G1. In Group 2, marked interstitial and tubular tissue damage is observed. These findings include deformed seminiferous tubules with erosion of tubular and interstitial structures, empty tubules with basement membrane detachment and extensive loss of the seminiferous epithelium, germinal epithelium disorganization with accumulation of germinal cells within the lumen, and tubules lacking spermatozoa (blue star). In addition, pronounced interstitial edema (red star), interstitial tissue debris and inflammatory cell infiltration (green arrow), as well as vascular congestion and hemorrhagic areas (arrowhead) are evident. This morphology is detailed in panel G2. In Group 3, the severity of these interstitial and tubular tissue injuries is markedly reduced compared with Group 2. This morphology is illustrated in panel G3. The graphical comparison of mean Johnsen scores among the groups is presented in panel G. Different letters above the bars indicate statistically significant differences between groups. Hematoxylin–eosin staining; scale bar=100 µm.

inflammatory cell infiltration was observed, whereas Group 2 demonstrated severe inflammatory cell infiltration. The inflammatory response was predominantly localized around the seminiferous tubules and within the interstitial areas. In Group 3, the level of inflammation was significantly reduced compared with Group 2 ($p<0.001$). In Group 1, the integrity of the testicular parenchyma was preserved, and no significant vascular hemorrhage was observed. In contrast, Group 2 exhibited marked vascular congestion and hemorrhagic areas between the seminiferous tubules and within the interstitial tissue. Accordingly, the mean vasocongestion score in Group 2 was calculated as 2.39±0.15. In the samples from Group 3, the level of vasocongestion was significantly decreased compared with Group 2 ($p<0.001$). In Group 1, the interstitial areas exhibited normal morphology and no significant edema was detected. In Group 2, extensive edema in the interstitial tissue and an increased distance between stromal cells were observed. In contrast, tissue samples from Group 3 demonstrated a marked reduction in edema findings compared with Group 2 ($p<0.001$).

According to the Johnsen scoring analysis, nearly complete spermatogenesis was observed in the seminiferous tubule

Table 2. Comparison of blood MDA, SOD, GSH-Px, TNF-Alpha, and IL-1 Beta levels among the rat groups

	Groups	n	Mean±SD	Median (Min-Max)	p	Post hoc p
SOD (U/g protein)	1	6	18.41±1.2	18.7 (16.7–19.6)	<0.001*	1–2: <0.001*
	2	6	10.36±1.23	10.41 (8.3–12.09)		1–3: 0.002*
	3	6	15.38±1.31	15.65 (13.41–16.93)		2–3: <0.001*
GSH-PX (U/g protein)	1	6	543.55±87.48	560.15 (432.1–631.5)	<0.001*	1–2: <0.001*
	2	6	307.03±7.38	303.75 (301.5–321.3)		1–3: 0.036*
	3	6	451.62±47.05	446.15 (405.3–512.3)		2–3: 0.002*
MDA (µmol/mL)	1	6	2.86±0.52	2.93 (2.31–3.71)	<0.001*	1–2: <0.001*
	2	6	5.79±0.82	5.98 (4.44–6.81)		1–3: 0.206
	3	6	3.53±0.56	3.53 (3.01–4.06)		2–3: <0.001*
TNF-alpha (ng/L)	1	6	88.21±19.46	85.47 (69.9–113.2)	<0.001*	1–2: <0.001*
	2	6	205.82±47.76	224.3 (115.4–242.31)		1–3: 0.874
	3	6	97.07±14.59	97.7 (76.4–118.7)		2–3: <0.001*
IL-1beta (ng/mL)	1	6	9.82±0.54	10.07 (9.13–10.3)	<0.001*	1–2: <0.001*
	2	6	16.55±1.29	17.16 (14.44–17.74)		1–3: 0.619
	3	6	10.59±2	10.06 (8.76–14.45)		2–3: <0.001*

SOD: Superoxide dismutase; GSH-Px: Glutathione peroxidase; MDA: Malondialdehyde; IL-1Beta: Interleukin 1 beta; TNF-alpha: Tumor necrosis factor alpha; SD: Standard deviation. Test: One-Way analysis of variance (ANOVA). (Differences between groups were examined with post hoc Tukey HSD or Tamhane's T2). *The p-value is significant at the 0.05 level.

epithelium of Group 1, with a mean score of 9.71±0.09. In Group 2, the integrity of the germinal epithelium was markedly disrupted, with loss of spermatozoa in the lumen and a decrease in the number of spermatids. The mean Johnsen score in Group 2 was calculated as 5.99±0.3. In Group 3, partial preservation of the seminiferous epithelial organization and the presence of a limited number of spermatozoa in the lumen were observed. Accordingly, the mean Johnsen score in Group 3 was 8.37±0.62, which was significantly higher than that in Group 2 (p<0.001).

Biomechanical Findings

The mean MDA level, an important marker of lipid peroxidation, was measured as 5.79±0.82 in Group 2, which was significantly higher than that observed in Group 1 (p<0.001). In Group 3, the MDA level showed a marked decrease and was determined to be 3.53±0.56 (p<0.001). When antioxidant enzyme activities were evaluated, both SOD and GSH-Px activities were significantly increased in Group 3 compared with Group 2 (p<0.001 and p=0.02, respectively). Furthermore, the mean TNF-alpha and IL-1beta levels in Group 2 were reported as 205.82±47.76 and 16.55±1.29, respectively. The level of inflammation in Group 2 was significantly higher than that in Group 1 (p<0.001). In Group 3, however, the inflammatory response was significantly suppressed compared with Group 2 (p<0.001) (Table 2).

DISCUSSION

The primary treatment strategy for testicular torsion is the restoration of testicular blood flow through testicular detorsion procedures. Although this approach plays a crucial role in re-establishing testicular perfusion and preventing tissue necrosis, it can also lead to ischemia–reperfusion injury, which may have detrimental effects. This condition exacerbates testicular damage by inducing inflammation, oxidative stress, and apoptosis, thereby posing a significant threat to male reproductive health.[20] In the present experimental study, ischemia–reperfusion injury secondary to testicular torsion–detorsion was demonstrated through both biochemical and histopathological findings. Furthermore, our results indicated that pramipexole, a pharmacological agent widely used in neurological practice for the treatment of neurodegenerative disorders, exhibited a significant protective effect against testicular ischemia–reperfusion injury.

Early diagnosis and prompt treatment are critical in the management of testicular torsion. Even when the torsed testis is immediately detorsed and restored to its normal anatomical position, testicular atrophy has still been reported in approximately 25–66.3% of patients.[21] This condition is closely associated with testicular ischemia–reperfusion injury.[22] During the ischemic phase, a marked reduction in cellular energy levels occurs. This process leads to several pathological changes, including decreased activity of antioxidant enzymes, electrolyte imbalances, and inflammatory responses. Consequently, ischemic tissue becomes highly vulnerable to oxidative stress. Following reperfusion of ischemic tissues, the rapid influx of molecular oxygen into the tissue results in the excessive production of reactive ROS. ROS damage

cellular components such as membrane lipids and structural proteins and therefore play a critical role in the pathogenesis of ischemia–reperfusion injury.[23] Testicular tissue is particularly susceptible to oxidative stress due to the high content of polyunsaturated fatty acids in cell membranes and active cellular proliferation occurring in the testes.[22] For this reason, considerable research efforts have focused on identifying novel pharmacological agents capable of minimizing testicular ischemia–reperfusion injury.[2,23]

Pramipexole is a synthetic aminobenzothiazole derivative pharmacological agent with selective activity on dopamine D2 and D3 receptors.[24] Early experimental studies demonstrated that pramipexole exhibits protective effects against oxidative damage by reducing lipid peroxidation and mitochondrial ROS production, while also increasing the activity of antioxidant enzymes such as GSH-Px and catalase, independently of dopaminergic receptor interactions during neuronal oxidative stress.[25] A detailed review of the literature indicates that the neuroprotective effects of pramipexole have been investigated in a relatively limited number of studies, with more recent research mainly focusing on its protective role against cytotoxic damage in different tissues.[11,12] In a study conducted by Shibagaki et al.,[9] the antioxidant efficacy of pramipexole was evaluated in mice subjected to light-induced retinal damage. The authors reported that pramipexole directly scavenged hydroxyl radicals generated from hydrogen peroxide and inhibited caspase-3/7 activation. Furthermore, the study demonstrated that the protective effects of pramipexole on photoreceptors occurred independently of dopamine receptor activation. In our study, treatment with pramipexole resulted in increased SOD and GSH-Px activities, while inflammatory responses were markedly suppressed. Similarly, Andrabi et al.[5] reported that pramipexole administration after ischemic stroke accelerated neurological recovery through mitochondrial mechanisms involved in ischemia–reperfusion injury. In the same study, pramipexole was shown to reduce mitochondrial ROS and calcium levels following ischemia. Our findings also demonstrated improvements in all histopathological parameters associated with testicular tissue damage, including inflammation, edema, and vasocongestion, following pramipexole treatment. In an experimental study by Mo et al.[11] using a model of myocardial ischemia–reperfusion injury, preischemic administration of pramipexole significantly reduced ROS production and consequently decreased the size of myocardial infarction, while also reducing lactate dehydrogenase activity and increasing survival rates. Similarly, in our study, a significant decrease in MDA levels, an end product of lipid peroxidation and an indicator of oxidative damage, was observed following pramipexole treatment. Another important characteristic of pramipexole is its ability to prevent cellular damage in oxidative stress by regulating various stages of the apoptotic cascade. In a study by Fujita et al.,[10] pramipexole was shown to inhibit hydrogen peroxide-induced activation of c-Jun N-terminal kinase and p38 mitogen-activated protein kinase, thereby preventing cellular apoptosis. Similarly, Kitamura et al.[6] reported that pramipexole inhibited 1-methyl-4-phenylpyridinium-induced apoptosis by increasing the expression level of Bcl-2. Due to technical limitations, the apoptotic index could not be evaluated in our study. Another important characteristic of pramipexole is its close interaction with the immune system. In a study by Lieberknecht et al.,[12] the efficacy of pramipexole in mice was evaluated using experimental autoimmune encephalomyelitis, one of the most commonly used models of multiple sclerosis. The study reported that this pharmacological agent inhibited the production of inflammatory cytokines such as TNF-alpha, IL-17, and IL-1beta in peripheral lymphoid tissue by suppressing spinal demyelination and astroglial activation through immunomodulation, thereby improving the manifestations of autoimmune encephalomyelitis. In another study, Lieberknecht et al.[7] evaluated the effects of pramipexole in a mouse model of inflammatory depression. In their study, they reported that pramipexole induced neuroinflammatory modulation by preventing the increase in 3-nitrotyrosine protein and IL-1beta, and that antidepressant effects were observed secondary to this mechanism. Similarly, in our study, rats treated with pramipexole showed a significant decrease in IL-1beta and TNF-alpha levels.

The testis is a metabolically active organ characterized by continuous spermatogenesis, rapid cellular proliferation, substantial mitochondrial activity, and elevated oxygen consumption, rendering testicular cells particularly susceptible to disturbances in oxygen supply and redox homeostasis.[21,26] Several experimental studies have documented that in testicular torsion–detorsion models, within the first few hours of reperfusion, lipid peroxidation markers increase, deficiencies in antioxidant defense systems are observed, and oxidative damage occurs in cell membranes, major proteins, and genomic structures.[2,27] For these reasons, the present experimental study focused on the early outcomes of pramipexole in testicular ischemia–reperfusion injury. Although conventional neuroprotective studies of pramipexole have predominantly employed prolonged or chronic treatment regimens, the acute testicular protective effect observed in our short-term model following a 3-h reperfusion period is plausible, considering the pharmacokinetic properties as well as the biochemical and physiological effects of this pharmacological agent. This phenomenon has been corroborated by biochemical and histopathological evidence reported in previous experimental studies.[9] One of the most important reasons for obtaining an effective and rapid tissue-protective response in experimental studies is that pramipexole possesses a pharmacokinetic profile characterized by high bioavailability, rapid absorption, and extensive distribution. Following oral administration, it is rapidly and completely absorbed, reaching peak plasma concentrations within approximately 2 h, and demonstrates a high absolute bioavailability exceeding 90%.[28,29] On the other hand, pramipexole exhibits a highly pronounced early cytoprotective effect, due to its characteristic biochemical and physiological properties. One of them is that pramipexole exhibits a direct scavenging activity against intracellular hydroxyl radicals.[9] In addition, pramipexole can exert antioxidant activity independently of dopamine receptor ac-

tivation.[30] Ferrari-Toninelli et al.[31] documented that pramipexole suppresses mitochondrial ROS production independently of dopamine receptors and exerts a direct antioxidant effect, protecting cells against hydrogen peroxide-induced death. Another experimental study demonstrated direct evidence of pramipexole's cytoprotective efficacy following ischemia in rats, showing reduced mitochondrial ROS levels and calcium accumulation, preservation of mitochondrial membrane potential and oxidative phosphorylation, and attenuated cytochrome-c translocation from mitochondria to the cytosol.[5] In this study, we determined that the administration of pramipexole minimizes oxidative stress and increases antioxidant enzyme levels during the early phase of testicular ischemia-reperfusion injury.

CONCLUSION

In our study, it was observed that pramipexole exhibited protective efficacy against testicular ischemia–reperfusion injury, characterized by a suppressed inflammatory response, increased antioxidant enzyme activity, and reduced levels of lipid peroxidation. These findings may provide a basis for future experimental and clinical studies aimed at elucidating the therapeutic role of pramipexole in testicular ischemia–reperfusion injury. Further comprehensive experimental and randomized clinical studies are needed to evaluate the potential therapeutic benefits of pramipexole in testicular ischemia–reperfusion injury, particularly in clinical situations such as testicular detorsion surgery.

Limitations of the Study

Several limitations of this study warrant acknowledgment. Although the beneficial effects of pramipexole were demonstrated, the primary constraint is the lack of detailed insights into the underlying molecular mechanisms. Second, our evaluation was restricted to the acute post-treatment phase. Third, the impact of pramipexole on healthy rat testicular tissue was not assessed; additionally, while a control group undergoing unilateral orchiectomy established baseline parameters, a separate sham-operated group was omitted to isolate the specific impact of surgical trauma. Furthermore, we acknowledge that utilizing Bouin's fixation might have provided superior visualization of certain spermatogenic details compared to our processing method. In addition, the consequences of torsion and pramipexole treatment on the contralateral testis were not investigated, as our focus remained strictly on acute alterations induced by ischemia–reperfusion injury in the ipsilateral tissue. Finally, given that testicular torsion is predominantly a pediatric and adolescent emergency, the clinical translatability of pramipexole is currently constrained by the scarcity of safety and dosing data in pediatric populations, where it is not yet indicated. Future studies incorporating extended follow-up periods, comprehensive molecular analyses, pediatric safety profiles, and bilateral tissue sampling are essential to fully elucidate the translational potential of pramipexole.

Ethics Committee Approval: This study was approved by the Animal Experiments Tokat Gaziosmanpasa University Local Ethics Committee (Date: 14.05.2025, Decision No: 2025 HADYEK-18).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: E.K., K.Y., H.B., U.K.; Design: E.K., K.Y., H.B., U.K.; Supervision: E.K., K.Y., H.B., U.K.; Resource: E.K., M.K., V.U., F.G.; Materials: E.K., M.K., V.U., F.G.; Data collection and/or processing: E.K., V.U., M.K., F.G.; Analysis and/or interpretation: E.K., V.U., M.K., F.G.; Literature review: E.K., K.Y., H.B.; Writing: E.K., K.Y., H.B., U.K.; Critical review: E.K., K.Y., H.B., U.K.

Informed Consent: All institutional and national guidelines for the care and use of laboratory animals were followed and approved by the appropriate institutional committees.

Conflict of Interest: None declared.

Financial Disclosure: The author declared that this study has received no financial support.

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DENEYSEL ÇALIŞMA - *ÖZ*

Pramipeksolün sıçanlarda testis torsiyonu ve detorsiyonu yaralanmasına karşı koruyucu etkileri

AMAÇ: Testis torsiyonu, ağırlıklı olarak oksidatif stres ve enflamatuar kaskadların aracılık ettiği iskemi-reperfüzyon hasarına yol açar. Pramipeksol; anti-enflamatuvar, anti-apoptotik ve antioksidan özelliklere sahip nöroloji pratiğinde yaygın olarak kullanılan bir farmakolojik ajandır. Sıçanlarda testis torsiyonu-detorsiyonu modeli oluşturulan bu deneysel çalışmada testiküler iskemi-reperfüzyon hasarında pramipeksolün olası koruyucu etkilerinin hem biyokimsayal hem de histopatolojik olarak değerlendirilmesi amaçlanmıştır.
GEREÇ VE YÖNTEM: Toplam 18 erkek sıçan 3 gruba randomize edildi. Grup-1 kontrol grubu olarak belirlendi. Grup-2'de sadece testis torsiyon-detorsiyon modeli oluşturuldu. Bu grupta testiküler iskemi-reperfüzyon hasarının analiz edilmesi amaçlandı. Grup 3'de ise benzer şekilde testis torsiyon-detorsiyon modeli oluşturuldu. Ek olarak, bu gruptaki sıçanlara testis detorsiyondan hemen sonra intraperitoneal olarak 0,5 mg/kg pramipeksol uygulandı. Bu grupta ise testiküler iskemi- reperfüzyon hasarı üzerine pramipeksolün etkilerinin ölçülmesi hedeflendi. Tüm sıçanlardan deney sonunda kan biyokimsayal analizleri alındı ve orşiektomi uygulanarak testis histopatolojik değerlendirilmesi yapıldı.
BULGULAR: Kan biyokimyasal analizlerinde malondialdehit (MDA) düzeyi Grup 2'de diğer gruplara göre ciddi düzeyde artmış olarak belirlendi ($p<0.001$). Benzer şekilde Grup 2'de diğer gruplara göre tümör nekroz faktörü alfa (TNF-alfa) ve interlökin 1 beta (IL-1beta) seviyeleri oldukça yüksekti ($p<0.001$). Grup 3'de ise Grup 2'e göre hem proinflamatuvar sitokin düzeyleri hemde MDA seviyeleri baskılanmış olarak gözlemlendi ($p<0.001$). Öte yandan Grup 3'de hem glutatyon peroksidaz (GSH-Px) hemde süperoksit dismutaz (SOD) aktivitilerinde Grup 2'e göre belirgin düzeyde artış izlendi (sırasıyla; $p=0.002$, $p<0.001$) Histopatolojik değerlendirmelerimizde ise Grup 3'de vazokonjesyon, inflamasyon ve ödem olmak üzere tüm testiküler hasar skorlarında Grup 2'e göre dramatik olarak iyileşme gözlemlendi ($p<0.001$). Benzer şekilde Grup 3'te ortalama Johnsen skoru 8.37±0.62 olarak hesaplandı ve bu değer Grup 2'e göre oldukça yüksekti ($p<0.001$).
SONUÇ: Pramipeksol; testis iskemi-reperfüzyon hasarının etkilerini hafifletmede etkin bir farmakolojik ajandır.

Anahtar sözcükler: İskemi-reperfüzyon; pramipeksol; testis.

Ulus Travma Acil Cerrahi Derg 2026;32(11):1329-1336 DOI: 10.14744/tjtes.2026.62297

ORIGINAL ARTICLE

Traumatic diaphragmatic injuries from the perspective of thoracic and general surgery: analysis of patient management using the Injury Severity Score (ISS) and Modified Shock Index (MSI)

Ersin Sapmaz,[1] Şahin Kaymak,[2] Hakan Işık,[1] Özgün Aran,[3] Ela Erten,[4] Rahman Şenocak[2]

[1]Department of Thoracic Surgery, Gülhane Training and Research Hospital, Ankara-*Türkiye*
[2]Department of General Surgery, Gülhane Training and Research Hospital, Ankara-*Türkiye*
[3]Department of Thoracic Surgery, Kırıkkale Yüksek İhtisas Hospital, Kırıkkale-*Türkiye*
[4]Department of Anesthesiology and Reanimation, Gülhane Training and Research Hospital, Ankara-*Türkiye*

ABSTRACT

BACKGROUND: Traumatic diaphragmatic injury (TDI) is a rare but severe clinical condition associated with high mortality following blunt or penetrating thoracoabdominal trauma. Due to concomitant injuries, the diagnosis of traumatic diaphragmatic injury remains challenging and may be easily overlooked. This study aimed to evaluate the diagnosis and surgical management of traumatic diaphragmatic injuries through a retrospective analysis conducted at a single center between 2016 and 2024.

METHODS: Data from 41 patients who underwent surgical treatment for TDI between 2016 and 2024 were analyzed. Patients were classified into three groups according to the diagnostic process: those diagnosed intraoperatively without prior imaging (Group 1), those who underwent imaging but were diagnosed intraoperatively (Group 2), and those diagnosed preoperatively by computed tomography (CT) (Group 3). Demographic characteristics, mechanisms of injury, surgical approaches, postoperative complications, and prognostic scores, including the Injury Severity Score (ISS) and Modified Shock Index (MSI), were evaluated.

RESULTS: Most patients were male (97.6%), and the left hemidiaphragm was the most frequently injured side (63.4%). Penetrating trauma (68.2%) was more common than blunt trauma, with gunshot wounds (34.1%) and stab wounds (34.1%) representing the most common mechanisms of injury. Laparotomy was the most frequently performed surgical approach (41.5%), and primary repair was achieved in 92.5% of patients. The overall postoperative complication rate was 37.5%, with atelectasis being the most common complication (26.7%). ISS scores were significantly higher in patients diagnosed intraoperatively than in those diagnosed preoperatively by imaging ($p<0.001$). Patients who underwent surgery within the first two hours after admission had higher ISS scores than those who underwent delayed surgery ($p<0.001$). ISS scores were significantly higher among patients operated on by the General Surgery department than among those treated by the Thoracic Surgery department. In contrast, MSI scores were lower in Thoracic Surgery patients who underwent emergency surgery for hemothorax than in General Surgery patients.

CONCLUSION: TDI remains a diagnostically challenging condition, and early surgical intervention is crucial for reducing mortality. Despite advances in imaging techniques, some cases continue to be overlooked because of concomitant injuries. Therefore, a high index of clinical suspicion and close patient monitoring are essential for timely diagnosis. Furthermore, differences in ISS and MSI scores between patients managed by different surgical specialties may reflect variations in trauma severity, surgical decision-making, and timing of intervention.

Keywords: Diagnosis; Injury Severity Score; Modified Shock Index; surgical treatment; thoracoabdominal trauma; traumatic diaphragmatic injury.

Cite this article as: Sapmaz E, Kaymak Ş, Işık H, Aran Ö, Erten E, Şenocak R. Traumatic diaphragmatic injuries from the perspective of thoracic and general surgery: analysis of patient management using the Injury Severity Score (ISS) and Modified Shock Index (MSI). Ulus Travma Acil Cerrahi Derg 2026;32:1337-1344.

Address for correspondence: Ersin Sapmaz
Department of Thoracic Surgery, Gülhane Training and Research Hospital, Ankara, Türkiye
E-mail: esapmaz@hotmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(11):1337-1344 DOI: 10.14744/tjtes.2026.54940
Submitted: 14.02.2025 Revised: 07.03.2025 Accepted: 18.03.2025 Published: 05.11.2026

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INTRODUCTION

Traumatic diaphragmatic injury (TDI) is a rare but serious clinical condition associated with high mortality following blunt or penetrating thoracoabdominal trauma. Early diagnosis and timely surgical intervention are critical determinants of patient outcomes.[1] The diagnosis of TDI is often challenging because the injury is not directly visible and its clinical manifestations may be masked by concomitant traumatic injuries. Previous studies have demonstrated that missed or delayed diagnosis of TDI is associated with significantly increased morbidity and mortality.[2] The heterogeneous clinical presentation of TDI, the need for a high degree of clinical suspicion, and the complexities of surgical management necessitate a meticulous approach throughout both the diagnostic and therapeutic processes.[3] If left undiagnosed, TDI may result in herniation and strangulation of abdominal organs within the thoracic cavity, further increasing morbidity and mortality.[1]

Surgical intervention is the cornerstone of treatment, with laparotomy and thoracotomy being the most commonly employed approaches.[4] In recent years, minimally invasive techniques have also been reported as effective treatment options.[5] Primary repair of the diaphragmatic laceration remains the fundamental principle of surgical management.[1] This study retrospectively analyzes patients who underwent surgical treatment for traumatic diaphragmatic rupture at our institution. The aim of the study was to evaluate the challenges encountered in the management of TDI and to contribute to the optimization of clinical practice in this field.

MATERIALS AND METHODS

This retrospective study included patients who underwent surgical treatment for TDI at our institution between 2016 and 2024. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Clinical Research Ethics Committee of Gülhane Faculty of Medicine, University of Health Sciences (Date: 08.10.2024, Decision no: 2024-447).

The inclusion criteria were: age ≥18 years, diagnosis of TDI resulting from blunt or penetrating trauma, and surgical treatment for the injury. Exclusion criteria included conservative management without surgery, death before surgical intervention, a diagnosis of malignancy, and pregnancy.

Demographic and clinical data were obtained from the hospital information management system, operative records, and imaging reports. Variables collected included trauma type (blunt or penetrating), injury laterality (right or left hemidiaphragm), mechanism of injury (traffic accident, fall, gunshot wound, etc.), diagnostic modality (computed tomography [CT], chest X-ray, intraoperative diagnosis, etc.), number and type of associated injuries, and timing of surgery. Surgical variables included operative approach (laparotomy, thoracotomy, minimally invasive surgery, etc.), diaphragmatic repair technique (primary suture, patch repair, etc.), operative duration, postoperative complications, and clinical outcomes. Injury severity was assessed using the Injury Severity Score (ISS) and the Modified Shock Index (MSI), which reflect the anatomical and physiological impact of trauma, respectively.

Diaphragmatic defects were repaired using non-absorbable sutures or patches when required. Intraoperative complications were recorded and analyzed.

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics, version 20 (Chicago, IL, USA). Continuous variables were presented as mean ± standard deviation (SD), median (minimum–maximum), and interquartile range (IQR). Categorical variables were presented as frequencies and percentages. The normality of continuous variables was assessed using the Shapiro–Wilk test. Comparisons of ISS and MSI scores between two groups were performed using the Mann–Whitney U test, whereas comparisons among three or more groups were conducted using the Kruskal–Wallis test. The specific group differences were identified using Kruskal–Wallis multiple-comparison testing. Associations between continuous variables and ISS and MSI scores were evaluated using Spearman's correlation coefficient. A p-value <0.05 was considered statistically significant.

RESULTS

Between October 2016 and October 2024, a total of 41 patients who underwent surgery for blunt or penetrating thoracoabdominal trauma and were found to have diaphragmatic injury intraoperatively were included in the study. The mean age of the patients was 32.12±13.22 years (range: 17–57 years). Of the patients, 97.6% (n=40) were male and 2.4% (n=1) were female. Overall, 56.1% (n=23) of the patients underwent surgery in the Thoracic Surgery Department, whereas 43.9% (n=18) were operated on in the General Surgery Department. The presenting symptoms at admission included dyspnea in 39% (n=16) of patients, chest pain in 29.3% (n=12), abdominal pain in 26.8% (n=11), and shock in 7.3% (n=3). Because some patients presented with more than one symptom, the total number of symptoms exceeded the number of patients. Additionally, several patients arrived at the emergency department unconscious because of shock, and their symptoms could not be recorded.

Patients were classified into three groups according to the diagnostic process. Group 1 consisted of clinically unstable patients who underwent surgery without prior imaging and were diagnosed with diaphragmatic injury intraoperatively. Group 2 included patients who underwent preoperative imaging, but whose diaphragmatic injury was detected only during surgery. Group 3 comprised patients with a preoperative diagnosis of diaphragmatic injury established by CT. Overall, 22% (n=9) of the patients were clinically unstable and underwent surgery without imaging.

Penetrating trauma was more common than blunt trauma, accounting for 68.2% (n=28) of cases. Among these patients, 34.1% (n=14) sustained gunshot wounds (GSW) and 34.1% (n=14) sustained stab wounds (SWs). The left hemidiaphragm was the most frequently injured side, accounting for 63.4% (n=26) of cases. The median number of associated organ injuries was two. A total of 70.8% (n=29) of patients were diagnosed within 72 hours of injury, and 51.2% (n=21) underwent surgery within the first 24 hours. Primary repair was performed in 92.5% of patients. Intraoperative mortality occurred in one patient.

Among the 41 patients, laparotomy was performed in 41.5% (n=17), thoracotomy in 29.3% (n=12), and a combined thoracoabdominal approach in 19.5% (n=8). Additionally, four patients (9.7%) were treated using minimally invasive techniques. The most common combination of associated organ injuries was concomitant lung and liver injury, observed in 14.6% (n=6) of patients. Postoperative complications occurred in 37.5% of patients, with atelectasis being the most common complication (26.7%). Recurrence of diaphragmatic injury was observed in only one patient.

Patients treated in the Thoracic Surgery Department had

Table 1. Comparison of Injury Severity Score (ISS) according to patient characteristics

		ISS		p
	n	Mean±SD	Median (Min-Max)	
Department				
Thoracic Surgery	23	11.09±8.11	9 (4-34)	0.014[b]
General Surgery	18	17.94±9.69	15 (4-34)	
Diagnostic method				
Group 1	9	23.44±8.48	18 (13-34)	<0.001[c]
Group 2	16	14.69±6.84	13 (5-13)	
Group 3	16	8.25±7.76	4 (4-34)	
Trauma type				
Penetrating	27	16.26±9.05	13 (4-34)	0.014[b]
Blunt	14	9.93±8.86	4.5 (4-34)	
Mechanism of injury				
Motor vehicle accident (MVA)	12	10.50±9.44	4.5 (4-34)	0.049[c]
Gunshot wound (GSW)	14	18.64±9.67	18 (4-34)	
Stab wound (SW)	14	13.00±8.02	13 (4-34)	
Injury laterality				
Right	15	17.33±10.13	13 (4-34)	0.114[b]
Left	26	12.23±8.57	11 (4-34)	
Blood pressure at admission				
Normotensive	29	10.52±6.99	9 (4-34)	<0.001[b]
Hypotensive	12	22.75±8.95	19 (9-34)	
Time from injury to diagnosis				
<72 hours	29	17.90±8.56	17 (5-34)	<0.001[b]
>14 days	11	4.55±1.50	4 (4-9)	
Time from injury to surgery				
<2 hours	21	18.57±7.61	18 (8-34)	<0.001[c]
2-24 hours	4	9.00±3.26	9 (5-13)	
>24 hours	16	9.50±9.89	4 (4-34)	
Postoperative complications				
Absent	25	10.92±5.50	13 (4-20)	0.053[b]
Present	15	18.07±11.68	18 (4-34)	

[b]Mann–Whitney U test; [c]Kruskal–Wallis test. ISS: Injury Severity Score; SD: Standard deviation.

Table 2. Comparison of Modified Shock Index (MSI) according to patient characteristics

	n	MSI		p
		Mean±SD	Median (Min-Max)	
Department				
Thoracic Surgery	23	1.19±0.43	1.08 (0.68-2.0)	0.046[b]
General Surgery	18	1.62±0.73	1.29 (0.83-3.0)	
Diagnostic method				
Group 1	9	2.13±0.43	2.0 (1.63-3.0)	<0.001[c]
Group 2	16	1.31±0.42	1.23 (0.83-2.69)	
Group 3	16	1.04±0.54	0.83 (0.68-2.87)	
Trauma type				
Penetrating	27	1.57±0.58	1.38 (0.68-3.0)	<0.001[b]
Blunt	14	1.03±0.55	0.83 (0.71-2.87)	
Mechanism of injury				
Motor vehicle accident (MVA)	12	1.04±0.60	0.82 (0.71-2.87)	0.005[c]
Gunshot wound (GSW)	14	1.59±0.43	1.65 (0.84-2.36)	
Stab wound (SW)	14	1.50±0.73	1.22 (0.68-3.0)	
Injury laterality				
Right	15	1.41±0.45	1.26 (0.71-2.0)	0.398[b]
Left	26	1.37±0.71	1.14 (0.68-3.0)	
Blood pressure at admission				
Normotensive	29	1.05±0.26	1.01 (0.68-1.63)	<0.001[b]
Hypotensive	12	2.20±0.48	2.0 (1.57-3.0)	
Time from injury to diagnosis				
<72 hours	29	1.60±0.61	1.38 (0.83-3.0)	<0.001[b]
>14 days	11	0.83±0.19	0.76 (0.68-1.34)	
Time from injury to surgery				
<2 hours	21	1.63±0.62	1.38 (0.83-3.0)	0.002[c]
2-24 hours	4	1.39±0.20	1.43 (1.15-1.57)	
>24 hours	16	1.05±0.55	0.83 (0.68-2.87)	
Postoperative complications				
Absent	25	1.26±0.59	1.08 (0.68-2.69)	0.074[b]
Present	15	1.55±0.66	1.34 (0.76-3.0)	

[b]Mann–Whitney U test; [c]Kruskal–Wallis test. MSI: Modified Shock Index; SD: Standard deviation.

significantly lower ISS scores than those treated in the General Surgery Department ($p<0.05$). Significant differences in ISS scores were also observed among the three diagnostic groups ($p<0.001$). Further analysis using the Kruskal–Wallis multiple-comparison test demonstrated that ISS scores were significantly higher in Groups 1 and 2 than in Group 3 ($p<0.001$ and $p<0.05$, respectively). However, no significant difference was found between Groups 1 and 2 (Table 1).

Patients with penetrating trauma had significantly higher ISS scores than those with blunt trauma ($p<0.05$). Analysis according to the injury mechanism excluded the single patient who sustained a fall-related injury. ISS scores differed significantly among patients injured in motor vehicle accidents (MVA), gunshot wounds, and stab wounds ($p<0.05$). Patients with GSWs had significantly higher ISS scores than those involved in MVAs ($p<0.05$), whereas no significant differences were observed among the other injury mechanisms (Table 1).

No significant difference in ISS scores was found between patients with right-sided and left-sided diaphragmatic injuries ($p>0.05$). However, ISS scores were significantly higher in hypotensive patients than in normotensive patients at admission ($p<0.001$). Patients diagnosed within 72 hours of injury

Table 3. Pre- and post-treatment radiographic analysis data for regenerative endodontic procedure (REP) and mineral trioxide aggregate (MTA) apical plug applied groups

	ISS		MSI	
	r*	p		
Age	-0.525	<0.001	-0.440	0.004
Number of associated organ injuries (r)	0.812	<0.001	0.758	<0.001

Spearman's correlation coefficient. ISS: Injury Severity Score; MSI: Modified Shock Index.

had significantly higher ISS scores than those diagnosed more than 14 days after injury (p<0.001). One patient diagnosed between 72 hours and 14 days after injury was excluded from this comparison because of the small sample size.

The interval between injury and surgery was categorized as <2 hours, 2–24 hours, and >24 hours. ISS scores differed significantly among these groups (p<0.001). Patients who underwent surgery within the first two hours had significantly higher ISS scores than those who underwent delayed surgery (p<0.001). No significant difference in ISS scores was observed between patients with and without postoperative complications (p>0.05) (Table 1).

Comparison of MSI scores between the Thoracic Surgery and General Surgery groups revealed significantly lower MSI scores among patients treated in the Thoracic Surgery Department (p<0.05). Significant differences in MSI scores were also observed among the three diagnostic groups (p<0.001). Patients in Group 1 had significantly higher MSI scores than those in Groups 2 and 3 (p<0.05 and p<0.001, respectively), whereas no significant difference was found between Groups 2 and 3 (Table 2).

Patients with penetrating trauma had significantly higher MSI scores than those with blunt trauma (p<0.05). MSI scores also differed significantly among patients with MVAs, GSWs, and SWs (p<0.01). Patients with GSWs had significantly higher MSI scores than those with MVAs (p<0.01), whereas no significant differences were found among the other injury mechanisms (Table 2).

No significant difference in MSI scores was observed between patients with right-sided and left-sided diaphragmatic injuries (p>0.05). MSI scores were significantly higher in patients diagnosed within 72 hours of injury than in those diagnosed more than 14 days after injury (p<0.001). One patient diagnosed between 72 hours and 14 days after injury was excluded from the analysis because of the small sample size. Significant differences in MSI scores were observed among patients who underwent surgery within the first 2 hours, between 2 and 24 hours, and after 24 hours (p<0.001). Patients operated on within the first 2 hours had significantly higher MSI scores than those who underwent surgery more than 24 hours after injury (p<0.01). No significant difference in MSI scores was found between patients with and without postoperative complications (p>0.05) (Table 2).

Analyses were performed to evaluate the associations between patient age and ISS and MSI scores. Correlation analyses demonstrated a negative correlation between age and ISS score (r=-0.525, p<0.001), indicating that ISS scores decreased with increasing age. A significant positive correlation was observed between the number of associated organ injuries and ISS score (r=0.812, p<0.001), indicating that ISS scores increased as the number of associated organ injuries increased. Similarly, MSI scores were negatively correlated with age (r=-0.440, p<0.01), indicating that MSI decreased with increasing age. A significant positive correlation was observed between the number of associated organ injuries and MSI scores (r=0.758, p<0.001), indicating that MSI increased as the number of associated organ injuries increased (Table 3).

One limitation of this study is its retrospective design, which may have introduced inherent biases in data collection and analysis. Future prospective studies with larger patient cohorts are needed to validate these findings.

DISCUSSION

Diaphragmatic injuries are rare but potentially life-threatening conditions that typically result from blunt or penetrating trauma. In the present study, the diagnosis, treatment, and outcomes of traumatic diaphragmatic injuries were retrospectively analyzed and compared with findings from the literature.

In our study, penetrating trauma was the most common mechanism of injury. While some authors have reported findings consistent with ours,[3,6-8] others have suggested that blunt trauma is more prevalent.[5,9,10] All patients who underwent immediate surgery because of hemodynamic instability and the absence of preoperative imaging had sustained penetrating injuries. Furthermore, most patients in whom TDI was not detected on preoperative imaging also had penetrating injuries. In such cases, TDI may only be identified during exploratory surgery or when a large defect is present. Particularly in penetrating injuries with small defects, diagnosis may be missed, potentially leading to serious complications.

[6,9,11,12] The true incidence of diaphragmatic injuries remains uncertain. However, current literature estimates an incidence of 1%–7% following blunt trauma and 10%–15% following penetrating trauma.[13]

The rarity of diaphragmatic injuries, together with the diaphragm's close anatomical relationship to adjacent structures and the presence of conditions such as liver injury, pulmonary contusion, hemothorax, and pleural effusion, can make diagnosis challenging. Over the past three decades, the sensitivity and specificity of CT have improved substantially compared with chest radiography.[8] Accordingly, all patients in our study except those in Group 1 underwent CT imaging. Although previous studies have reported a sensitivity of 56%–87% for multidetector CT in the diagnosis of acute TDI,[8] CT detected only 50% of TDIs in our study population. This discrepancy may reflect not only differences in imaging quality but also variability in radiological interpretation.

Blunt diaphragmatic injuries are more frequently observed on the left side because of the protective effect of the liver and the relative congenital weakness of the left diaphragm. [3,6] Consistent with previous reports, blunt TDI in our study occurred predominantly on the left side (71.4%). When both penetrating and blunt mechanisms were considered, left-sided injuries accounted for 63.4% of all cases. Among patients with penetrating trauma, particularly those with stab wounds, left-sided injuries were present in 85.7% of cases. This predominance of left-sided injuries may be related to the predominance of right-handed individuals in the population, potentially increasing the likelihood of injury to the left hemithorax during interpersonal violence.

Regarding the timing of diagnosis, 70.8% of patients were diagnosed within the first 72 hours after trauma, whereas 26.8% were diagnosed more than 14 days after injury. With respect to surgical timing, 51.2% of patients underwent surgery within the first 2 hours, and 61% underwent surgery within the first 24 hours. Although CT is an effective diagnostic modality for TDI, previous studies have reported that up to 57.1% of cases are diagnosed intraoperatively during surgery performed for associated injuries.[8] In our study, patients in Groups 1 and Group 2, who were diagnosed intraoperatively, accounted for approximately 61% of all cases, consistent with the literature. The diagnosis of TDI is frequently overlooked during the initial evaluation because attention is often focused on life-threatening concomitant injuries.

The most commonly performed surgical approach in our study was laparotomy (36.6%), followed by thoracotomy (26.8%). Among the minimally invasive techniques, video-assisted thoracoscopic surgery (VATS) was performed in 9.9% of cases, whereas laparoscopy was used in only 2.4%. The limited use of minimally invasive approaches may be attributable to the challenges associated with managing severe intra-abdominal solid organ injuries using these techniques. Primary repair was sufficient in 92.5% of patients, and the use of non-absorbable sutures is recommended for repair.[14] In chronic cases, a transthoracic approach is generally preferred because it facilitates the management of intrathoracic adhesions involving abdominal organs, enables diaphragmatic repair, and allows treatment of associated intrathoracic pathology.[1,9,15] When necessary, extension of the incision along the costal margin to include laparotomy provides a thoracoabdominal approach and greater operative flexibility.[1] In our series, this approach was required in 19.5% of cases. Consistent with our findings, previous studies have reported that VATS can be used successfully in selected patients.[16,17] However, a recognized limitation of VATS is the restricted visualization of the peritoneal cavity, which may result in missed intra-abdominal injuries.[1] In the acute setting, laparotomy is the preferred approach, particularly in patients with concomitant intra-abdominal injuries or hemodynamically instability. If herniation or strangulation of abdominal organs into the thoracic cavity is identified during laparotomy, or if cardiac or major vascular injury is suspected, thoracotomy or thoracoscopy may be required.[8]

Postoperative complications occurred in 37.5% of patients and ranged from anxiety disorders to acute renal failure. Atelectasis was the most common complication, occurring in 26.7% of cases.

Early mortality following TDI is largely attributable to associated visceral injuries. Previous studies have reported higher mortality rates following blunt trauma than penetrating trauma.[18] In our cohort, the median number of associated organ injuries was two, and the lungs, liver, and ribs were the most commonly injured structures. Among patients with multiple injuries, concomitant lung and liver injuries were the most frequent combination. Our study included only patients who arrived at the hospital alive; therefore, prehospital deaths could not be evaluated because relevant data were unavailable. Only one patient with a penetrating injury who underwent a thoracoabdominal approach died intraoperatively. This patient sustained severe liver and kidney injuries. Consistent with previous reports, liver injury has been associated with increased mortality compared with other associated organ injuries.[6]

The ISS is one of the strongest predictors of mortality in patients with acute TDI.[4,6,9] Previous studies have demonstrated a significant increase in mortality among patients with ISS values greater than 24.[6] The patient who died intraoperatively in our series had an ISS of 34. The predominant injuries in this case were abdominal, necessitating management by the General Surgery Department. Consistent with this finding, ISS scores were significantly higher among patients treated by General Surgery than among those treated by Thoracic Surgery ($p<0.05$). Furthermore, ISS scores were significantly higher in patients who required urgent intervention or whose TDI was not identified on initial CT imaging (Groups 1 and 2) than in clinically stable patients diagnosed preoperatively by CT (Group 3) ($p<0.05$). Deng et al.[9] reported motor vehicle

accidents as the most common mechanism of TDI, whereas gunshot wounds were the predominant mechanism in our series, representing a significantly different injury pattern ($p<0.05$). The relationship between ISS scores and patient characteristics is summarized in Table 1.

In addition to ISS, MSI was calculated to assess injury severity and predict mortality. The findings for MSI were largely consistent with those observed for ISS, and the relationship between MSI scores and patient characteristics is presented in Table 2. Correlation analyses demonstrated significant negative associations between age and both ISS and MSI scores, indicating that injury severity decreased with increasing age in our cohort. In contrast, higher numbers of associated organ injuries were associated with higher ISS and MSI scores (Table 3). The inverse relationship between age and ISS/MSI scores differs from previous reports.[9] This discrepancy may reflect the retrospective nature of the study and the potential exclusion of older patients with severe injuries who died before hospital admission.

In patients undergoing surgery for traumatic hemothorax, diaphragmatic injury may be detected incidentally during operative exploration. In this group, MSI values are generally lower because of the hemodynamic consequences of significant blood loss following trauma. In contrast, patients diagnosed preoperatively by CT generally presented with a more stable clinical condition and higher MSI values. However, ISS values were higher in patients diagnosed preoperatively via CT, likely due to the greater anatomical extent of trauma. These findings suggest that TDI diagnostic methods influence physiological and anatomical profiles differently across patient populations.

CONCLUSION

Despite advances in imaging technology, TDI is still frequently overlooked, particularly in patients with concomitant organ injuries and those requiring urgent intervention. TDI should always be considered in patients undergoing thoracic or abdominal surgery after trauma, close follow-up should be maintained in patients whose diagnosis is delayed. Although TDI may not represent the most immediate threat in the acute trauma setting, early recognition is essential for preventing potentially life-threatening long-term complications.

Ethics Committee Approval: This study was approved by the Clinical Research Ethics Committee of Gülhane Faculty of Medicine, University of Health Sciences (Date: 08.10.2024, Decision No: 2024-447).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: E.S., Ş.K., H.I.; Design: E.S., H.I., Ş.K., Ö.A.; Supervision: E.S., Ş.K.; Resource: H.I., Ö.A., E.E., R.Ş.; Materials: E.S., Ş.K., Ö.A.; Data collection and/or processing: E.S., R.Ş., Ö.A.; Analysis and/or interpretation: E.E., R.Ş.; Literature review: Ş.K., E.E., Ö.A., E.E.; Writing: E.S., Ş.K., Ö.A.; Critical review: E.S., E.E., R.Ş.

Informed Consent: This retrospective study.

Conflict of Interest: None declared.

Financial Disclosure: The author declared that this study has received no financial support.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Göğüs cerrahisi ve genel cerrahi perspektifinden travmatik diyafragma yaralanmaları: Yaralanma Şiddet Skoru ve Modifiye Şok İndeksi kullanılarak hasta yönetiminin analizi

AMAÇ: Travmatik Diyafragma Yaralanması (TDY), künt ve penetran torakoabdominal travmalar sonrası nadir görülen ancak yüksek mortalite riski taşıyan ciddi bir klinik tablodur. Tanı koyma süreci zor olup, eşlik eden yaralanmalar nedeniyle gözden kaçabilmektedir. Bu çalışma, travmatik diyafragma yaralanmalarının tanı süreci ve cerrahi yönetimini değerlendirmek amacıyla 2016-2024 yılları arasında tek merkezde gerçekleştirilen retrospektif bir analizdir.

GEREÇ VE YÖNTEM: Çalışmada, TDY nedeniyle cerrahi tedavi uygulanan 41 hastanın verileri incelenmiştir. Hastalar tanı süreçlerine göre üç gruba ayrılmıştır: görüntüleme yapılmadan intraoperatif tanı alanlar (Grup 1), görüntüleme yapılmış ancak intraoperatif tanı konulmuş hastalar (Grup 2) ve preoperatif dönemde bilgisayarlı tomografi (BT) ile tanı konulmuş hastalar (Grup 3). Hastaların demografik özellikleri, yaralanma mekanizmaları, cerrahi yaklaşımlar, komplikasyonlar ve prognostik skorlar (İnjury Severity Score [ISS] ve Modifiye Şok İndeksi [MŞİ]) değerlendirilmiştir.

BULGULAR: Hastaların çoğunluğunu erkekler oluşturmuş (%97.6) ve en sık etkilenen hemidiyafragmanın sol taraf olduğu tespit edilmiştir (%63.4). Penetran yaralanmalar (%68.2), künt travmalara kıyasla daha sık görülmüş olup, en yaygın yaralanma nedenleri ateşli silah yaralanmaları (%34.1) ve delici-kesici alet yaralanmalarıdır (%34.1). Cerrahi yaklaşım olarak en sık laparotomi uygulanmış (%41.5) ve hastaların %92.5'inde primer onarım gerçekleştirilmiştir. Postoperatif komplikasyon oranı %37.5 olup en yaygın komplikasyon atelektazi olarak belirlenmiştir (%26.7). ISS skorları, intraoperatif tanı alan hastalarda preoperatif görüntüleme ile tanı konulan hastalara göre anlamlı derecede yüksek bulunmuştur ($p<0.001$). Ayrıca, ilk 2 saat içinde cerrahi müdahale edilen hastaların ISS skorları, gecikmiş cerrahi uygulananlara kıyasla daha yüksek saptanmıştır ($p<0.001$). Genel Cerrahi kliniğinde opere edilen hastaların ISS skorları Göğüs Cerrahisi hastalarına göre anlamlı derecede yüksek bulunurken, hemotoraks nedeniyle acil opere edilen Göğüs Cerrahisi hastalarının MŞİ skorları Genel Cerrahi hastalarına kıyasla daha düşük bulunmuştur.

SONUÇ: TDY tanısı halen zor olmakla beraber, erken cerrahi müdahale mortaliteyi azaltmada kritik öneme sahiptir. Gelişmiş görüntüleme yöntemlerine rağmen, eşlik eden yaralanmalar nedeniyle bazı vakalar gözden kaçabilmektedir. Bu nedenle, TDY şüphesi klinik değerlendirme ile ön planda tutulmalı ve hastalar yakından izlenmelidir. Ayrıca, farklı disiplinlerce opere edilen hastaların ISS ve MŞİ skorlarındaki farklılıklar, travma şiddeti, cerrahi yönetim ve zamanlama açısından disiplinler arası farklılıkları ortaya koymaktadır.

Anahtar sözcükler: Cerrahi tedavi; Injury Severity Score; Modifiye Şok İndeksi; tanı; torakoabdominal travma; travmatik diyafram yaralanması.

Ulus Travma Acil Cerrahi Derg 2026;32(11):1337-1344 DOI: 10.14744/tjtes.2026.54940

ORIGINAL ARTICLE

Impact of frailty on acute kidney injury in patients followed-up in the intensive care unit

Zahide Şahin Yıldırım,[1] Mustafa Yıldırım,[1*] Mustafa Deniz[2]

[1]Department of Anesthesiology and Reanimation, Bolu Abant İzzet Baysal State Hospital, Bolu-*Türkiye*

[2]Department of Intensive Care Unit, Bolu İzzet Baysal State Hospital, Bolu-*Türkiye*

**Current affiliation: Department of Anesthesiology and Reanimation, Akdeniz University, Faculty of Medicine, Antalya-Türkiye*

ABSTRACT

BACKGROUND: Frailty in elderly patients is an important determinant of clinical outcomes in intensive care units, particularly in relation to acute kidney injury (AKI). This study investigated the association between frailty and AKI in the geriatric population.

METHODS: This prospective observational study included 120 patients. Frailty was assessed via the Clinical Frailty Scale (CFS) and the Edmonton Frail Scale (EFS). Patients were categorized according to the presence or absence of AKI. Demographic data, frailty scores, laboratory parameters, and clinical outcomes, including mortality, mechanical ventilation, and vasopressor use, were compared. Univariate and multivariate logistic regression analyses were used to identify factors associated with the development of AKI.

RESULTS: The mean age of the participants was 79.7±7.5 years. Comorbidities such as diabetes and hypertension were common, and AKI was observed in 29.1% of patients. The incidence of AKI was significantly higher among patients classified as frail according to the CFS (p=0.002). Patients with AKI presented increased mortality rates and an increased need for mechanical ventilation and vasopressors. The AKI group presented significantly lower hemoglobin, platelet, and albumin levels and higher baseline creatinine levels. Multivariate analysis revealed that elevated baseline creatinine was an important predictor of AKI.

CONCLUSION: Frailty assessed by the CFS was associated with AKI development in unadjusted analyses; however, this association was not maintained after multivariable adjustment. No significant association was observed between AKI and frailty assessed by the EFS. Baseline serum creatinine was the only independent predictor of AKI. These findings suggest that frailty assessment, particularly using the CFS, may serve as a complementary clinical tool for early risk recognition and patient stratification rather than an independent predictor of AKI. AKI development in critically ill older adults appears to be multifactorial.

Keywords: Acute kidney injury; frailty; geriatrics; intensive care unit; risk stratification.

INTRODUCTION

The risk of acute kidney injury (AKI) is substantially higher in older adults. This increased vulnerability is largely driven by progressive age-associated alterations in renal architecture and physiological performance. Aging leads to impaired renal perfusion, reduced filtration efficiency, loss of nephron mass, and diminished adaptive capacity, all of which weaken the kidney's response to acute systemic stress. In addition, the high prevalence of chronic conditions – such as cardiovascular disease, diabetes mellitus (DM), and hypertension (HT) – along with common exposure to polypharmacy further contributes to the development of AKI in this population.[1,2]

AKI represents one of the most frequent complications in critically ill patients and is linked to extended durations of intensive care treatment as well as higher mortality rates.[3-6] In clinical practice, the diagnosis and staging of AKI are generally established using the 2012 Kidney Disease: Improving Global

Cite this article as: Yıldırım ZS, Yıldırım M, Deniz M. Impact of frailty on acute kidney injury in patients followed-up in the intensive care unit. Ulus Travma Acil Cerrahi Derg 2026;32:1345-1352.

Address for correspondence: Zahide Şahin Yıldırım

Department of Anesthesiology and Reanimation, Bolu Abant İzzet Baysal University Faculty of Medicine, Bolu, Türkiye

E-mail: zhdshnyldrm@gmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(11):1345-1352 DOI: 10.14744/tjtes.2026.68115

Submitted: 08.01.2026 Revised: 31.07.2026 Accepted: 17.09.2026 Published: 05.11.2026

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Outcomes (KDIGO) framework, which defines the condition based on variations in serum creatinine (sCr) concentration and/or alterations in urine volume.[7]

Frailty is recognized as a central geriatric syndrome characterized by reduced physiological resilience and heightened susceptibility to external stress. In critically ill patients, frailty has repeatedly been linked to unfavorable clinical trajectories and poorer health-related outcomes.[8,9] It encompasses a complex, multidimensional construct that integrates physical performance, cognitive function, psychological status, and social factors.[10-12] Various validated assessment instruments – such as the Clinical Frailty Scale (CFS) and the Edmonton Frail Scale (EFS) – are widely applied to measure frailty severity and to estimate the risk of adverse outcomes.[9,13,14]

Considering the frequent overlap between frailty and AKI in older patients admitted to the intensive care unit (ICU), as well as their potentially intersecting pathophysiological mechanisms, we sought to explore whether frailty status was associated with the occurrence of AKI in a geriatric critical care cohort.

MATERIALS AND METHODS

A prospective, observational investigation was conducted in an adult mixed ICU and enrolled 120 consecutive patients aged 65 years and older over a 3-month period (July–September 2023). Demographic characteristics, clinical parameters, and laboratory findings were retrieved from the hospital's electronic database and structured ICU monitoring records. During the study period, 254 patients were admitted to the ICU. Patients younger than 65 years (n=116) and those with missing or incomplete datasets (n=18) were excluded from the analysis. In addition, individuals with pre-existing chronic kidney impairment or those undergoing renal replacement therapy before ICU admission were not eligible for inclusion. Approval from the institutional ethics committee was secured before patient enrollment. The study protocol was approved by the İzzet Baysal University Clinical Research Ethics Committee (approval date: June 06, 2023; decision no: 2023/189), and the study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained either from the participants themselves or, when necessary, from their legally authorized representatives. Information regarding frailty status was collected directly from patients whenever possible; otherwise, proxy data were obtained from relatives or caregivers. For analytical purposes, participants were stratified based on the occurrence of AKI during their ICU stay (AKI group vs. non-AKI group). sCr at ICU admission was accepted as the baseline value. Creatinine levels were measured using the kinetic Jaffe method. All laboratory parameters were analyzed by certified laboratory personnel and recorded daily.

Definitions

The diagnosis and severity grading of AKI were established using the 2012 KDIGO classification system, which determines AKI on the basis of variations in sCr concentration and/or urine volume compared with baseline values. For this study, baseline creatinine was accepted as the measurement obtained at the time of ICU admission.

Recorded clinical variables comprised patient demographics, including age and sex, as well as documented comorbid conditions such as DM, HT, coronary artery disease, chronic obstructive pulmonary disease (COPD), malignancy, and neurological disorders. Frailty assessments (CFS and EFS), presence and stage of AKI, time to AKI onset, and ICU-related interventions – specifically mechanical ventilation and vasoactive agent administration – were also documented.

Biochemical parameters analyzed included hemoglobin levels, total leukocyte and lymphocyte counts, platelet levels, serum albumin, total bilirubin, aspartate aminotransferase (AST), alanine aminotransferase (ALT), creatinine, sodium, potassium, magnesium, and C-reactive protein (CRP). Frailty status was evaluated using two established assessment tools: the CFS and the EFS. The CFS consists of a nine-level clinician-judged instrument that reflects overall functional capacity and dependence in daily activities, with higher scores corresponding to increased frailty severity. Consistent with previous reports, individuals scoring 1–4 were categorized as non-frail, whereas those with scores ≥5 were considered frail.[15] The EFS is an 18-point multidimensional instrument designed to assess domains such as cognitive status, overall health perception, functional autonomy, social resources, medication burden, nutritional status, mood, continence, and physical performance. Increasing scores indicate more pronounced frailty. Classification of EFS results followed conventional threshold values (non-frail 0–5, vulnerable 6–7, mild frailty 8–9, moderate frailty 10–11, severe frailty 12–18).[16]

Statistical analysis

Statistical analyses were carried out using Jamovi (version 2.3.28) and JASP (version 0.17.3). Continuous data were described according to their distributional properties: variables approximating a normal distribution were expressed as mean±standard deviation (SD), whereas non-normally distributed variables were summarized as median with minimum and maximum values. Categorical data were reported as frequencies and percentages. The assumption of normality was evaluated using the Shapiro–Wilk, Kolmogorov–Smirnov, and Anderson–Darling tests. For comparisons between groups, continuous variables were analyzed using the independent samples t-test when normality criteria were met; otherwise, the Mann–Whitney U test was applied. Associations between categorical variables were examined using the Pearson chi-square test when cell counts were sufficient. In cases of small expected frequencies, Fisher's exact test or the Fisher–Freeman–Halton test was employed as appropriate. Potential determinants of AKI were initially examined through univariable logistic regression analyses focusing on clinically meaningful parameters. Variables considered clinically important and/

or demonstrating statistical association were subsequently entered into a multivariable logistic regression model. Given the limited number of AKI events, variable selection was performed with consideration of clinical relevance and to minimize the risk of model overfitting. Although Sequential Organ Failure Assessment (SOFA) score was associated with AKI in univariate analysis, it was not included in the final model because of the limited number of outcome events and the potential overlap between disease severity indicators and other clinical variables. Results were presented as odds ratios with corresponding 95% confidence intervals. An alpha level of 0.05 (two-sided) was prespecified as the threshold for statistical significance.

RESULTS

This study included 120 patients admitted to the ICU. The cohort's mean age was 79.7 years (SD 7.5) and the sample consisted of 67 female (55.8%) and 53 male (44.2%) patients. Comorbidities were distributed as follows: DM (n=36 [30%]); HT (n=46 [38.3%]); coronary artery disease (n=29 [24.2%]); and COPD (n=29 [24.2%]). During follow-up in the ICU, 68 (56.7%) patients survived, and 52 (43.3%) patients died. Fifty-six (46.7%) patients required mechanical ventilation, and 53 (44.2%) patients required vasopressor medications. Malignancy was detected in 18 (15%) patients, and neurological disorders were detected in 47 (39.2%) patients. The median CFS and EFS scores were 5 and 7, respectively. Mortality, need for mechanical ventilation, and vasopressor support occurred significantly more often in the AKI group relative to the non-AKI group (p<0.001 for all comparisons). When stratified by CFS category, AKI occurred more frequently among individuals identified as frail (CFS≥5), demonstrating a statistically significant association (p=0.002). In contrast, no meaningful between-group differences were observed with respect to age, sex, DM, HT, COPD, malignancy status, neurological comorbidity, or EFS score (all p>0.05) (Table 1).

The median hemoglobin, leukocyte, lymphocyte, and platelet counts were 10.3 g/dL, 11.1×10⁹/L, 0.9×10⁹/L, and

Table 1. Demographic and clinical characteristics of intensive care unit patients and pairwise comparisons in terms of the development of acute kidney injury

	Overall (n=120)	Acute kidney injury		p
		Absent (n=85)	Present (n=35)	
Age†	79.7±7.5	79.7±7.4	79.7±7.9	0.987***
Gender‡				
Female	67 (55.8)	43 (50.6)	24 (68.6)	0.109*
Male	53 (44.2)	42 (49.4)	11 (31.4)	
Comorbidity‡				
Diabetes Mellitus, Present	36 (30.0)	21 (24.7)	15 (42.9)	0.080*
Hypertension, Present	46 (38.3)	29 (34.1)	17 (48.6)	0.203*
Coronary Heart Disease, Present	29 (24.2)	21 (24.7)	8 (22.9)	0.999*
Chronic Obstructive Pulmonary Disease, Present	29 (24.2)	20 (23.5)	9 (25.7)	0.984*
Final Status‡				
Alive	68 (56.7)	58 (68.2)	10 (28.6)	**<0.001***
Deceased	52 (43.3)	27 (31.8)	25 (71.4)	
Mechanical ventilation use, Yes‡	56 (46.7)	30 (35.3)	26 (74.3)	**<0.001***
Vasoactive drug use, Yes‡	53 (44.2)	27 (31.8)	26 (74.3)	**<0.001***
Presence of malignancy‡	18 (15.0)	12 (14.1)	6 (17.1)	0.888*
Neurological disorder‡	47 (39.2)	35 (41.2)	12 (34.3)	0.619*
SOFAs (range)	5 (4-8)	4 (3-6)	6 (5-9)	0,02
Clinical frailty scale index§	5.0 [2.0–9.0]	5.0 [2.0–8.0]	6.0 [3.0–9.0]	**0.017****
Edmonton frailty scale index§	7.0 [4.0–17.0]	7.0 [4.0–17.0]	7.0 [5.0–17.0]	0.198**

Table 1 presents the demographic and clinical characteristics of intensive care unit (ICU) patients, with a focus on the development of acute kidney injury (AKI). The table includes an overall group of 120 patients and is divided into two subgroups: those without AKI (n=85) and those with AKI (n=35). '‡' denotes categorical data expressed as "n (%)", "†" denotes the mean±standard deviation, and "§" denotes median values with a range [Minimum-Maximum]. The statistical significance is indicated by "p" values, where "*" denotes results from the Pearson Chi-square test, "**" indicates findings from the Mann–Whitney U test, and "***" represents results from the independent samples t-test. This table highlights the differences in demographic and clinical characteristics between ICU patients with and without acute kidney injury.

Table 2. Descriptive statistics of laboratory parameters in intensive care unit patients and pairwise comparisons in terms of the development of acute kidney injury

	Overall (n=120)	Acute kidney injury		p
		Absent (n=85)	Present (n=35)	
Hemoglobin§	10.3 [6.4–16.0]	10.7 [6.4–16.0]	9.4 [7.6–14.2]	**0.004***
Leukocytes§	11.1 [3.0–32.0]	11.0 [3.0–32.0]	12.0 [6.0–30.0]	0.285*
Lymphocytes§	0.9 [0.1–3.3]	1.0 [0.1–3.1]	0.8 [0.1–3.3]	0.786*
Platelets§	209.5 [65.0–527.0]	222.0 [65.0–519.0]	184.0 [75.0–527.0]	0.008*
Albumin§	24.5 [15.0–39.0]	25.3 [15.0–39.0]	22.1 [17.0–34.0]	0.004*
Total Bilirubin§	1.0 [0.3–5.0]	1.0 [0.3–5.0]	1.0 [0.5–2.2]	0.489*
ALT§	24.0 [3.0–238.0]	24.0 [3.0–238.0]	23.0 [5.0–170.0]	0.926*
AST§	25.5 [5.0–167.0]	23.0 [11.0–167.0]	33.0 [5.0–165.0]	0.057*
Baseline creatinine§	1.0 [0.3–2.9]	0.9 [0.3–2.9]	1.4 [0.5–2.4]	<0.001*
Sodium§	139.0 [126.0–166.0]	139.0 [126.0–166.0]	138.0 [126.0–150.0]	0.961*
Potassium†	3.9 ± 0.6	3.9 ± 0.5	3.8 ± 0.7	0.322**
Magnesium§	2.0 [1.2–4.0]	2.0 [1.2–4.0]	2.0 [1.3–2.4]	0.228*
C-reactive protein§	81.5 [2.4–169.0]	70.0 [2.4–169.0]	97.0 [5.0–152.0]	0.111*

Table 2 presents descriptive statistics of laboratory parameters in ICU patients and their correlation with the development of acute kidney injury (AKI). The study involved 120 patients, with AKI present in 35 patients and absent in 85 patients. The key laboratory parameters included hemoglobin, leukocytes, lymphocytes, platelets, albumin, total bilirubin, ALT, AST, creatinine, sodium, potassium, magnesium, and C-reactive protein (CRP). "†" indicates the mean±standard deviation, and "§" denotes median values with a range [Minimum - Maximum]. The table uses the Mann–Whitney U test (denoted by "*") and independent samples t test ("**") to evaluate differences between the groups, ALT: Alanine aminotransferase; AST: Aspartate aminotransferase.

Table 3. Acute kidney injury characteristics in a clinical setting: Staging, renal replacement therapy, and onset timing

	Patients with only acute kidney injury (n=35)
KDIGO criteria for acute kidney injury‡	
Stage 1	10 (28.6)
Stage 2	9 (25.7)
Stage 3	16 (45.7)
Renal Replacement Therapy, Yes‡	18 (51.4)
Day of Hospitalization When Injury Occurred§ 4.0 [2.0–15.0]	

Table 3 focuses on the characteristics of in relation to acute kidney injury (AKI) in a clinical setting among 35 patients. It examines the KDIGO criteria stages of AKI, the use of renal replacement therapy, and the day of hospitalization when the injury occurred. "‡" signifies categorical data as "n (%)", and "§" signifies median values with a range [Minimum - Maximum].

209.5×10^9/L, respectively. The median albumin and total bilirubin levels were 24.5 g/L and 1.0 mg/dL, respectively. The median ALT and AST levels were 24.0 U/L and 25.5 U/L, respectively. The median baseline creatinine, sodium, magnesium, and CRP levels were 1.0 mg/dL, 139.0 mmol/L, 2.0 mg/dL, and 81.5 mg/L, respectively. The mean potassium level was 3.9±0.6 mmol/L. Hemoglobin, platelet, and albumin levels were significantly lower in patients who developed AKI than in those who did not ($p<0.05$). In addition, baseline creatinine was significantly higher in the AKI group ($p<0.001$). No significant between-group differences were observed for leukocyte or lymphocyte counts, total bilirubin, ALT, AST, sodium, potassium, magnesium, or CRP (all $p>0.05$) (Table 2).

Among patients diagnosed with AKI, 10 (28.6%) were classified as stage 1, 9 (25.7%) as stage 2, and 16 (45.7%) as stage 3, according to the KDIGO criteria. Renal replacement therapy was administered to 18 (51.4%) patients with AKI. AKI developed at a median of 4 days after hospitalization (Table 3).

According to univariate analyses, AKI occurrence was signifi-

Table 4. Factors affecting the risk of developing acute kidney injury in intensive care unit patients

Logistic regression predicting "acute kidney injury"	Univariate logistic regression		Multiple logistic regression	
	OR. [95%CI]	p	OR. [95%CI]	p
Gender: Male versus Female	0.47 [0.21–1.08]	0.074	-	-
Diabetes Mellitus: Present versus Absent	2.29 [0.99–5.25]	0.051	1.89 [0.67–5.38]	0.227
Hypertension: Present versus Absent	1.82 [0.82–4.06]	0.141	-	-
Mechanical Ventilation Use: Yes versus No	5.3 [2.19–12.76]	<0.001	2.25 [0.75–6.73]	0.148
Vasoactive Drug Use: Yes versus No	6.21 [2.56–15.04]	**<0.001**	1.90 [0.59–6.11]	0.280
Hemoglobin	0.77 [0.63–0.94]	**0.012**	0.88 [0.68–1.15]	0.360
Platelets	0.99 [0.99–1.01]	0.086	-	-
Albumin	0.88 [0.79–0.96]	**0.006**	0.91 [0.80–1.04]	0.155
Aspartate Aminotransferase (AST)	1.01 [0.99–1.02]	0.327	-	-
Baseline creatinine	5.06 [2.10–12.17]	**<0.001**	4.57 [1.67–12.47]	**0.003**
C-Reactive Protein (CRP)	1.01 [0.99–1.02]	0.137	-	-
CFS Index (Clinical Frailty Scale Index)	1.47 [1.09–1.99]	**0.012**	1.26 [0.84–1.91]	0.269

Table 4 shows the factors affecting the risk of developing acute kidney injury (AKI) in ICU patients through logistic regression analysis. It includes variables such as sex, the presence of diabetes mellitus, hypertension, the use of mechanical ventilation, the use of vasoactive drugs, hemoglobin, platelets, albumin, AST, creatinine, CRP, and the Clinical Frailty Scale Index (CFS Index). The table presents odds ratios (ORs) with 95% confi-dence intervals (CIs) and p-values, and univariate and multiple logistic regression results were compared to iden-tify significant predictors of AKI in this population.

Table 5. Comparative analysis of clinical characteristics and scoring indices in patients with and without acute kidney injury

Variables	Acute kidney injury		p
	Absent (n=85)	Present (n=35)	
CFS index (Categorical) (%)			
<5	36 (42.4)	4 (11.4)	**0.002**
≥5	49 (57.6)	31 (88.6)	
EFS index (Categorical) (%)			
≤7	47 (55.3)	18 (51.4)	0.853
>7	38 (44.7)	17 (48.6)	

Pearson's Chi-square test was used. CFS: Clinical Frailty Scale; EFS: Edmonton Frail Scale.

cantly more frequent among patients who required mechanical ventilation and vasopressor support during ICU follow-up (p<0.001 for each). Accordingly, the use of mechanical ventilation increased the risk of AKI by 5.3 times, whereas the use of vasopressors increased the risk by 6.21 times. Each unit decrease in hemoglobin level increased the risk of AKI by 23%, whereas each unit decrease in albumin level increased the risk by 12%. A one-unit increase in creatinine was associated with a 5.06-fold higher odds of AKI, whereas each additional point in the CFS score corresponded to a 1.47-fold increase in risk. Sex, DM, HT, platelet count, and AST and CRP levels did not significantly affect the univariate analysis.

After multivariable analysis, baseline creatinine was the only variable independently associated with AKI (p=0.003). Accordingly, a one-unit increase in creatinine corresponded to a 4.57-fold increase in AKI risk. DM, HT, mechanical ventilation use, vasopressor use, and hemoglobin and albumin levels showed no independent association with AKI in the adjusted model (Table 4).

When the CFS and EFS frailty indices were compared, AKI occurred more frequently among patients classified as frail according to the CFS (≥5), whereas AKI incidence did not differ significantly across categories defined by the EFS (Table 5).

DISCUSSION

In critically ill patients, whose fragility increases and toler-

ance decreases with age, the risk of AKI increases owing to factors such as pathophysiological processes, inflammation, comorbidities, and medications, which in turn leads to increased mortality. In our analysis assessing the association between frailty status and AKI development, we found that frailty (according to the CFS scale) was associated with AKI. In addition, mortality (71%) was markedly elevated among patients who developed AKI compared with those who did not. Frailty is recognized as an important determinant of outcomes in the intensive care setting, particularly with respect to renal complications such as AKI. Küçük et al.,[9] in a study examining geriatric ICU patients aged ≥65 years with COVID-19, reported that frailty was an important risk factor for AKI (63.6%) and that the development of AKI in this geriatric population was associated with high mortality (97.6%).

A meta-analysis investigating the association between frailty and AKI in the elderly population revealed an association between frailty and AKI.[16] Xu et al.,[17] in their analysis of elderly hypertensive COVID-19 patients, reported that frailty was not found to be an independent risk factor for AKI. In our study, frailty was found to be significantly associated with AKI according to the CFS, but it was not identified as an independent risk factor. As noted in this study, our results are consistent with the finding that the CFS may guide clinical decision-making in elderly patients. Rose et al.[18] reported in their EFS study that frailty increases hospital stay and mortality. In a study conducted by Yucel et al.,[19] that used CFS and EFS, mortality, ICU stay duration, and emergency department stay duration were found to be significantly greater in the frail group on both scales.No significant association was observed between frailty assessed by the EFS and AKI in this cohort. The better performance of the CFS compared with the EFS may be explained by the practical characteristics of these instruments in critically ill patients. The CFS primarily evaluates global functional status and pre-admission independence, allowing relatively straightforward assessment even when direct communication with the patient is limited. In contrast, the EFS includes multiple domains, such as cognition, mood, social support, medication use, nutrition, and functional performance, many of which are difficult to assess accurately in critically ill or mechanically ventilated patients and often rely on proxy information obtained from family members. These practical differences may partly explain why the CFS demonstrated a stronger association with AKI than the EFS in our ICU population.

Bagshaw et al.,[13] in their investigation of critically ill patients over the age of 50, reported an independent association between frailty and intensive care mortality (32%). Beaubien-Souligny et al.,[20] examining frailty in elderly critically ill patients with severe AKI, identified preexisting frailty as an independent predictor of mortality in this population. In our cohort, mortality was significantly higher among patients who developed AKI (71%). Frail patients taking multiple medications due to infection, malnutrition, and comorbidities are highly susceptible to AKI. Considering the impact of AKI on mortality, we believe that the pre-identification of vulnerable patients prone to AKI would be beneficial in terms of early diagnosis and treatment guidance and reducing mortality Chen et al.[21] reported that elevated baseline sCr was associated with mortality among individuals aged ≥65 years with COVID-19. Li et al.[22] demonstrated that patients who developed AKI had higher baseline sCr at hospital admission. In our study, baseline sCr levels were higher in the AKI group than in the non-AKI group. Accurately identifying AKI in elderly and frail patients may present some challenges. In this patient group with reduced muscle mass, sCr levels may remain normal for some time. Therefore, AKI may be detected later. Owing to the delayed increase in sCr levels after a decrease in the GFR, AKI may progress and lead to irreversible damage. Considering that high baseline sCr levels at hospital admission are associated with the development of AKI and, consequently, an increased need for ICU admission and mechanical ventilation, we believe that baseline sCr levels are important for increasing AKI awareness in frail elderly patients. An additional methodological consideration is that baseline sCr served both as a predictor variable and as the reference value for KDIGO-based AKI diagnosis. Therefore, some degree of methodological dependency cannot be excluded. Nevertheless, baseline sCr reflects pre-existing renal reserve and remains a clinically relevant marker of AKI risk in older adults. Accordingly, our findings should be interpreted as demonstrating an association rather than a causal relationship. Xiong et al.[23] examined the association of the geriatric nutritional risk index (GNRI) with mortality among patients with AKI in the intensive care setting and reported that higher GNRI values, indicating better nutritional status, were associated with lower mortality. Another study revealed that AKI after CABG was strongly associated with malnutrition and frailty.[24] Comparable findings were described by Liao et al.[25] in their investigation of the prognostic value of the GNRI among elderly ICU patients with AKI. Hypoalbuminemia was associated with AKI occurrence in the present cohort. Hypoalbuminemia is frequently observed among frail individuals who often require hospitalization due to malnutrition and infection. Hypoalbuminemia reduces the effective arterial blood volume and increases the risk of AKI by causing long-term renal dysfunction due to hypoperfusion. These findings support the conclusion that a comprehensive frailty assessment, including assessment of the serum ALB concentration, a component of the GNRI, is important in predicting AKI outcomes. In a study by Zhang and colleagues, high vasoactive inotropic scores were positively correlated with the risk of AKI development.[26] Similarly, in our study, the need for vasopressors was greater in patients with AKI. In hypotensive patients requiring high inotropic support, renal perfusion may be inadequate, leading to AKI development. In routine ICU practice, several prognostic scoring tools are employed, including the SOFA score, APACHE, Logistic Organ Dysfunction System, Multiple Organ Dysfunction Score,

and SAPS-II.[27] However, no specific standard tests are used to predict outcomes in elderly and frail patients. Considering that frailty increases the risk of AKI, hospitalization, mechanical ventilation requirements, and mortality, it would be valuable to use different scoring systems in addition to the current assessments in this patient population. Our study contributes to the literature by highlighting the specific role of frailty indices in predicting AKI in intensive care patients. This addresses questions concerning the association between frailty and AKI, particularly within an aging population. In addition, it raises new questions about how frailty assessment can be integrated into routine clinical practice to improve the treatment and prognosis of critically ill patients, particularly elderly patients. Future research should investigate the implementation of frailty assessments in clinical workflows and explore how these assessments can be used to tailor treatment strategies for individual patients. Furthermore, longitudinal studies may provide insights into the long-term outcomes of frail patients who develop AKI in the ICU. Although frailty did not emerge as an independent determinant of AKI after multivariable adjustment, this finding reflects the complex and multifactorial nature of acute organ dysfunction in critically ill elderly patients. Frailty represents an aggregate vulnerability overlapping with comorbid conditions, hemodynamic instability, and inflammatory burden rather than a single isolated risk factor. Therefore, frailty assessment – particularly when performed using the CFS – should be regarded as a complementary bedside instrument to support early risk recognition and clinical stratification in acute and intensive care settings.

The present investigation has several limitations. First, it was conducted at a single center with a prospective design; therefore, the findings may not be broadly generalizable. Second, frailty-related information was obtained from relatives in cases where patients themselves could not be reached.

CONCLUSION

Frailty assessed by the CFS was significantly associated with AKI occurrence in elderly ICU patients; however, this association did not remain significant after multivariable adjustment. No significant association was observed between AKI occurrence and frailty assessed by the EFS. Baseline sCr was identified as the only independent predictor of AKI. These findings suggest that frailty assessment, particularly using the CFS, should be considered a complementary bedside clinical tool that may support early risk awareness and patient stratification rather than an independent predictor of AKI. The development of AKI in critically ill elderly patients is likely multifactorial and reflects the combined effects of baseline renal status, disease severity, and other clinical factors.

Ethics Committee Approval: This study was approved by the İzzet Baysal University Clinical Research Ethics Committee (Date: 06.06.2023, Decision No: 2023/189).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: Z.Ş.Y., M.Y., M.D.; Design: Z.Ş.Y., M.Y., M.D.; Supervision: Z.Ş.Y.; Resource: Z.Ş.Y., M.Y.; Materials: M.Y., M.D.; Data collection and/or processing: Z.Ş.Y., M.Y., M.D.; Analysis and/or interpretation: Z.Ş.Y., M.D.; Literature review: Z.Ş.Y., M.Y., M.D.; Writing: Z.Ş.Y.; Critical review: Z.Ş.Y., M.Y., M.D.

Conflict of Interest: None declared.

Financial Disclosure: The author declared that this study has received no financial support.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Yoğun bakım ünitesinde takip edilen hastalarda kırılganlığın akut böbrek hasarına etkisi

AMAÇ: Yaşlı hastalarda kırılganlık, özellikle akut böbrek yetmezliği (ABY) bağlamında, yoğun bakım ünitelerinde (YBÜ) klinik sonuçları etkileyen kritik bir faktördür. Bu çalışmada, geriatrik popülasyonda kırılganlık ile akut böbrek yetmezliği arasındaki ilişki araştırılmıştır.
GEREÇ VE YÖNTEM: Bu prospektif gözlemsel çalışmaya 120 hasta dahil edildi. Kırılganlık, Klinik Kırılganlık Ölçeği (CFS) ve Edmonton Kırılganlık Ölçeği (EFS) kullanılarak değerlendirildi. Hastalar, akut böbrek yetmezliği varlığına göre sınıflandırıldı. Demografik veriler, kırılganlık skorları, laboratuvar parametreleri, mekanik ventilasyon ve vazopresör kullanımı ile mortalite oranları karşılaştırıldı. Akut böbrek yetmezliği gelişimiyle ilişkili faktörleri belirlemek amacıyla tek değişkenli ve çok değişkenli lojistik regresyon analizleri kullanıldı.
BULGULAR: Katılımcıların ortalama yaşı 79.7±7.5 yıldı. Diyabet ve hipertansiyon gibi komorbiditeler yaygındı ve hastaların %29.1'inde akut böbrek yetmezliği gözlendi. Akut böbrek yetmezliği oranı, kırılgan grupta anlamlı derecede daha yüksekti (p=0.002). Akut böbrek yetmezliği olan hastalarda mortalite oranları ile mekanik ventilasyon ve vazopresör ihtiyacı artmıştı. Akut böbrek yetmezliği grubunda hemoglobin, trombosit ve albümin düzeyleri anlamlı derecede daha düşükken bazal kreatinin düzeyleri daha yüksekti. Çok değişkenli analiz, yüksek bazal kreatinin düzeyinin akut böbrek yetmezliği gelişiminin önemli bir belirleyicisi olduğunu ortaya koydu.
SONUÇ: Klinik Kırılganlık Ölçeği (CFS) ile değerlendirilen kırılganlık, yaşlı yoğun bakım hastalarında akut böbrek hasarı gelişimiyle anlamlı düzeyde ilişkili bulunmuştur; ancak bu ilişki, çok değişkenli analiz sonrasında anlamlılığını sürdürmemiştir. Akut böbrek hasarı için bağımsız belirleyici olarak yalnızca bazal serum kreatinin düzeyi saptanmıştır. Bu bulgular, kırılganlık değerlendirmesinin erken risk belirlemesine katkı sağlayabileceğini düşündürmekle birlikte, kritik hastalarda akut böbrek hasarının çok faktörlü bir süreç olduğunu göstermektedir.

Anahtar sözcükler: Akut böbrek hasarı; kırılganlık; risk sınıflaması; yaşlılık; yoğun bakım ünitesi.

Ulus Travma Acil Cerrahi Derg 2026;32(11):1345-1352 DOI: 10.14744/tjtes.2026.68115

ORIGINAL ARTICLE

Hepatectomy is associated with favorable long-term outcomes related to septic complications in patients with localized hepatolithiasis

Kürşat Rahmi Serin,[1] İnan Güden,[2] Beslen Göksoy,[1] İrem Karataş,[3] Görkem Uzunyolcu,[4] Semih Çakır,[5] Meryem Yanık,[1] Adem Bayraktar,[1] Feza Ekiz,[1] Yaman Tekant[1]

[1]Department of General Surgery, Istanbul University Faculty of Medicine, İstanbul-*Türkiye*
[2]Department of General Surgery, Beylikdüzü State Hospital, İstanbul-*Türkiye*
[3]Department of General Surgery, Prof. Dr. Cemil Tascioglu City Hospital, İstanbul-*Türkiye*
[4]Department of General Surgery, Arnavutköy State Hospital, İstanbul-*Türkiye*
[5]Department of Radiology, Istanbul University Faculty of Medicine, İstanbul-*Türkiye*

ABSTRACT

BACKGROUND: Hepatolithiasis can lead to the development of severe complications such as liver abscesses, secondary biliary cirrhosis, and intrahepatic cholangiocarcinoma. While major liver resection is under debate, conservative approaches may not be curative. In this report, long-term results of surgical treatment were presented.

METHODS: A retrospective analysis of patients who underwent surgical treatment for hepatolithiasis between September 1999 and August 2020 was conducted. Clinical symptoms, stone distribution, interventions, complications, residual and recurrent stone rates, and long-term outcomes were evaluated.

RESULTS: Fifty-two patients were identified. Twenty-eight were female, and 24 were male, with a mean age of 50 years (range: 22–75 years). Thirty-two patients had localized disease; 13 had stones in the right hepatic lobe and 19 in the left. Twenty patients had bilateral stones. In the localized disease group, patients underwent either liver resection (n=20) or conservative surgery (hepaticojejunostomy or T-tube drainage following stone clearance, n=12). In the bilateral disease group, only conservative surgical approaches were employed. The overall post-operative complication rate was 46%, and was higher after conservative surgery ($p<0.26$). However, bile leakage occurred more frequently following resection (15% vs. 6%). There was no mortality, and median post-operative hospital stay was 12 days (range: 5–55). Recurrence occurred in 5 patients (10%) during a mean follow-up period of 134 months (range; 25–275); all in the conservative treatment group, except one. Four patients developed hepaticojejunostomy strictures, whereas portal vein thrombosis and secondary biliary cirrhosis occurred in two patients each. Thirteen patients (25%) died during follow-up; two deaths were directly related to the disease. Ten-year disease-free survival was significantly better after resection compared to conservative surgery (85% vs 58%, $p<0.05$).

CONCLUSION: Liver resection offers superior outcomes compared to conservative surgery in patients with localized intrahepatic stones. However, in patients with bilateral involvement, treatment needs to be individualized.

Keywords: Bile ducts; cholangiocarcinoma; gallstone; hepatectomy; hepaticojejunostomy.

Cite this article as: Serin KR, Guden I, Goksoy B, Karataş I, Uzunyolcu G, Cakir S, et al. Hepatectomy is associated with favorable long-term outcomes related to septic complications in patients with localized hepatolithiasis. Ulus Travma Acil Cerrahi Derg 2026;32:1353-1359.

Address for correspondence: Kürşat Rahmi Serin
Department of General Surgery, Istanbul Faculty of Medicine, Istanbul University, Istanbul, Türkiye
E-mail: krserin@istanbul.edu.tr

Ulus Travma Acil Cerrahi Derg 2026;32(11):1353-1359 DOI: 10.14744/tjtes.2026.48905
Submitted: 28.03.2026 Revised: 21.04.2026 Accepted: 29.04.2026 Published: 05.11.2026
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INTRODUCTION

Hepatolithiasis is defined as the presence of stones within the intrahepatic bile ducts proximal to the hepatic hilum and is characteristically associated with recurrent episodes of cholangitis.[1] Its etiopathogenesis is multifactorial, with genetic, dietary, and environmental factors playing central roles. While this condition accounts for up to 20% of biliary stone disease in Southeast Asia, it remains exceedingly rare in Western countries with an estimated incidence of approximately 1%.[1-3] The primary objectives of treatment are complete removal of stones and resolution of biliary stasis, thereby preventing further episodes of cholangitis, complications such as liver abscess, biliary cirrhosis, or intrahepatic cholangiocarcinoma, and disease progression.[4,5] Therapeutic approaches are generally classified into three categories: surgical, percutaneous, and endoscopic. Surgical options vary widely, from bile duct exploration and stone extraction to liver resection.[1] Although surgical resection of all affected liver segments offers a theoretical cure, it is not always feasible in clinical practice, particularly in patients with diffuse or bilobar disease. On the other hand, endoscopic and percutaneous interventions have shown satisfactory rates of initial stone clearance in localized disease; however, recurrence rates are high, leading to late complications due to repeated cholangitis.[6,7]

Recently published series from Latin America indicate rising incidence outside Asia; however, the short duration of follow-up in these studies restricts conclusive evidence regarding long-term outcomes.[8,9] European reports are similarly limited and typically comprise small series.[10,11] Collectively, these observations lack sufficient data and experience regarding the management of this complex disease in non-Asian populations.

This study aimed to present the experience with surgical management and long-term outcomes of hepatolithiasis treated at a leading hepatopancreatobiliary referral center in Turkey, which constitutes one of the largest reported series in Europe.

MATERIALS AND METHODS

The medical records of patients who presented to the Hepatopancreatobiliary Surgery Unit, Department of General Surgery, Istanbul Faculty of Medicine, Istanbul University for surgical treatment of hepatolithiasis between September 1999 and August 2020 were reviewed retrospectively. Patients who were unfit for surgery, declined surgical treatment, had a follow-up period shorter than 24 months or were lost to follow-up before completing 2 years of surveillance were excluded from the study. The data collected included demographic characteristics, clinical findings, pre-operative interventions, stone location, type of surgery performed, postoperative complications, and follow-up results. The disease was categorized as localized (confined to either right or left hepatic lobe) or bilobar (involving both lobes).

Post-operative complications were classified as early (within the first 30 days) or late (after 30 days). Early complications were evaluated using the Clavien–Dindo classification.[12] Secondary interventions and long-term outcomes were analyzed.

Statistical Analysis

Descriptive statistics summarized demographics, clinical features, and outcomes. Categorical variables were compared using Chi-square or Fisher's exact tests; continuous variables were compared using the Mann–Whitney U test. Kaplan–Meier analysis estimated disease-free survival, with group differences assessed via the log-rank test. Significance was set at $p<0.05$. Analyses were conducted using the Statistical Package for the Social Sciences v25.0 (IBM Corp., Armonk, NY, USA).

RESULTS

The study included 52 patients (28 female and 24 male). Thirteen patients (four unfit for surgery, two who declined surgical treatment, and seven with either a follow-up period shorter than 24 months or who were lost to follow-up before completing 2 years of surveillance) were excluded from the study. Median age was 50 years (range, 22–75). At presentation, the most common symptoms were cholangitis (n=22, 41%), abdominal pain (n=21, 40%), and jaundice (n=7, 13%).

All patients underwent magnetic resonance cholangiopancreatography (MRCP) as part of the routine pre-operative evaluation. MRCP enabled high-resolution, non-invasive assessment of biliary anatomy and stone burden, and was superior to computed tomography (CT) in delineating the extent of disease in four patients in whom MRCP revealed bilobar involvement that had been underestimated by the initial CT.

Thirty-two patients had localized disease which was confined to the left lobe in 19 patients and to the right lobe in 13. Twenty patients had bilobar involvement. Concurrent common bile duct stones were identified in 40 patients. Before referral, interventions included endoscopic retrograde cholangiopancreatography in 35 patients, previous surgical procedures in 15 (9 bilioenteric anastomoses, 5 T-tube drainages, and 1 sphincterotomy), and cholecystectomy in 28 (Table 1).

Surgical Procedures and Outcomes

All patients with bilobar disease and 12 with localized disease underwent conservative surgery. Following stone clearance, 5 of these patients had T-tube drainage, whereas 27 underwent Roux-en-Y hepaticojejunostomy (RY-HJ) with or without extrahepatic bile duct resection. The remaining 20 patients with localized disease underwent liver resection: right hepatectomy in 4, left hepatectomy in 8, lateral sectionectomy in 6, and segmental resections in 2 patients. In 10 of these patients, biliary exploration with either T-tube drainage or RY-HJ was additionally performed.

The overall postoperative complication rate was 46%. Early postoperative complications occurred in 53% of patients who

Table 1. Symptoms at presentation and prior biliary interventions

Symptoms and Findings, n, (%)	Bilobar (n=20)	Localized (n=32)
Abdominal pain	5 (25)	16 (50)
Cholangitis	11 (55)	11 (34.4)
Jaundice	5 (25)	2 (6.3)
Concomitant choledocholithiasis	18 (90)	22 (68.8)
Pre-operative stricture	12 (60)	10 (31.3)
Pre-referral interventions		
Bilioenteric anastomosis/T-tube drainage	9 (45)	6 (18.8)
Cholecystectomy	14 (70)	14 (43.8)
Endoscopic retrograde cholangiography	16 (80)	19 (59.4)
Percutaneous biliary drainage	13 (65)	10 (31.3)

Table 2. Early post-operative complications

Complications	Conservative (n=32) (%)	Resection (n=20)(%)	p
Early complication (<30 days)	17 (53)	7 (35)	0.26
Surgical site infection	11 (35)	1 (5)	0.014
Intra-abdominal collection	2 (6)	2 (10)	0.63
Biliary stricture	1 (3)	0 (0)	1
Pericholangitic abscess	1 (3)	0 (0)	1
Pulmonary embolism	0 (0)	1 (5)	0.38
Bile leakage	2 (6)	3 (15)	0.36

Bold indicates statistical significance (p<0.05).

underwent conservative procedures and 35% of those who underwent liver resection; this difference was not statistically significant (p=0.26) (Table 2). Bile leakage occurred in 3 patients (15%) in the resection group and 2 patients (6%) in the conservative treatment group. All cases resolved without further intervention.The median post-operative hospital stay was 12 days (range 5–55); similar between both conservative surgery and resection groups.

Histopathological Findings

Histopathological evaluation of the resected liver specimens revealed chronic inflammatory changes, periductal fibrosis, and significant ductal strictures in most patients. No evidence of invasive malignancy or dysplasia was identified in any specimen. Similarly, no suspicious premalignant features were observed intraoperatively in patients who underwent conservative surgery without resection.

Follow-Up

The mean follow-up period of the cohort was 134 months (range, 25–275); 125 months (range, 25–275) after conservative surgery and 147 months (range, 25–262) after liver resection. Residual stones were found in 10 patients (19%), all after conservative surgical treatment. Recurrent stones occurred in a further 5 patients (10%), again all in the conservative surgery group, except one (Tables 3 and 4). Both residual and recurrent stone rates were significantly higher after conservative surgery (p<0.01).

Residual stones were cleared either endoscopically or with percutaneous transhepatic biliary drainage (PTBD) in 5 out of 10 patients. The remaining 5 patients were followed up with

Table 3. Success rates of surgical treatment in localized disease

Surgical approach	Residual stones (%)	Recurrent stones (%)
Resection (n=20, 100)	0 (0)	1 (5)
Conservative (n=32, 100)	10 (31)	4 (13)

Table 4. Type of surgical treatment, residual and recurrent stones

Outcome	Bilobar (n=20)		Localized (n=32)	
	C	R	C	R
Surgical method	20	0	12	20
Residual stones (Post-operative)	7	–	3	–
Recurrent stones	3	–	1	1

C: Conservative surgery; R: Liver resection.

medical therapy with ursodeoxycholic acid (UDCA); stones disappeared in one of them.

Recurrent hepatolithiasis (n=5) developed with a median of 44 months (range, 22–95). The only patient who experienced stone recurrence 12 years after liver resection was treated with hepatolithotomy followed by RY-HJ due to late-onset bile duct stricture from T-tube placement at the initial operation prior to referral. In the remaining four patients with recurrence after conservative surgery, one patient underwent anastomotic revision, and one other required PTBD due to persistent biliary obstruction. This latter patient was currently on the liver transplantation waiting list due to development of secondary biliary cirrhosis. All patients received high-dose UDCA therapy with 20 mg/kg/day for a minimum of 24 months (Table 5).

Two further patients underwent revision of RY-HJ due to development of anastomotic stricture. Other long-term complications were detailed in Table 6.

Overall, 13 patients (25%) died; two of these deaths were attributable to complications associated with hepatolithiasis. One of these patients died following liver transplantation for secondary biliary cirrhosis, and the other due to rupture of a pseudoaneurysm caused by PTBD. Other causes included development of hepatocellular carcinoma (n=1), ischemic heart disease (n=2), and senility (n=8).

Disease-free survival (DFS) rates in patients who underwent liver resection at 1, 3, 5, and 10 years were 100%, 100%, 95%, and 85%, respectively, with no residual stones and a recurrence rate of only 5%. In contrast, patients who underwent conservative surgical treatment (including both localized and bilobar disease; n=32) demonstrated significantly lower DFS rates of 97%, 88%, 75%, and 58% at 1, 3, 5, and 10 years, respectively (Fig. 1). The liver resection group demonstrated superior long-term outcomes, with significantly higher survival rates beyond 5 and 10 years ($p<0.05$).

Table 5. Outcome of treatment in patients with recurrence

Patient	Gender	Location	Surgery	Recurrences treatment	Result	Mortality	Reason
1	Male	Bilobar	HJ	PTBD	+	Yes	Cirrhosis
2	Female	Bilobar	HJ	Re-HJ	Disappeared	-	
3	Male	Bilobar	HJ	-	+	Yes	HCC
4	Male	Left	HJ	-	+	Yes	IHD
5	Female	Left	Resection	HJ	+	-	

HJ: Hepaticojejunostomy; PTBD: Percutaneous transhepatic biliary drainage; Re-HJ: Revision hepaticojejunostomy; IHD: Ischemic heart disease; HCC: Hepatocellular carcinoma; +: Stone persistence.

Table 6. Late (>30 days) post-operative complications

Late postoperative complications	Conservative (n=32)	Resection (n=20)	p
Patients with late complications, n (%)	18 (56%)	5 (25%)	0.0143
Incisional hernia, n	10	4	
Anastomotic stricture, n	4	–	
Portal vein-Superior mesenteric vein thrombosis, n	2	–	
Secondary biliary cirrhosis, n	2	–	
Intestinal obstruction, n	–	1	

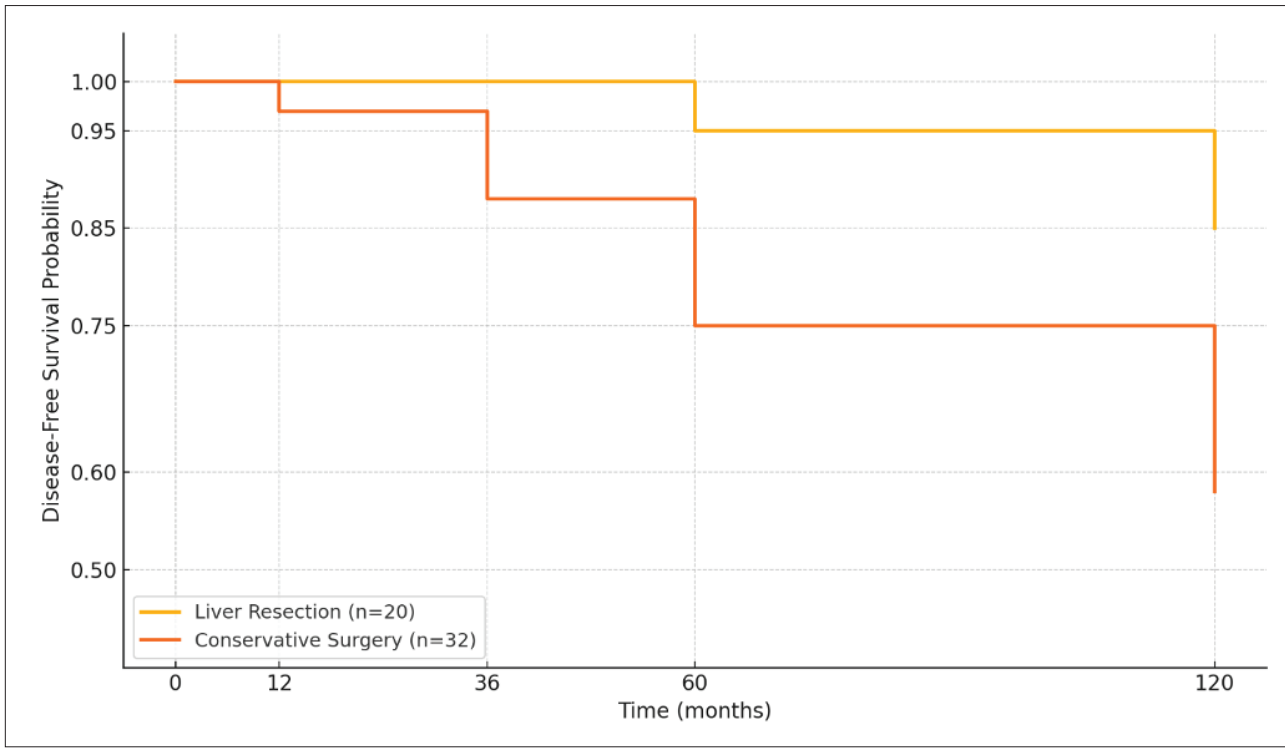


Figure 1. Kaplan–Meier curve showing disease-free survival probabilities for patients treated with liver resection (n=20) versus conservative surgery (n=32).

DISCUSSION

Despite being classified as a benign disease, hepatolithiasis may lead to serious complications both in the early and late post-operative periods: recurrent cholangitis, biliary strictures, hepatic abscesses, and secondary biliary cirrhosis, often resulting in chronic liver dysfunction.[13,14] Residual stones remain in 10–20% of patients even after surgical intervention, and recurrence rates of up to 30–40% have been reported.[4,6,7] Prolonged inflammation and bile stasis also elevate the risk of malignant transformation, with cholangiocarcinoma reported in 5–10% in some series.[15-17] In this context, our study provides a remarkable outcome in patients with localized hepatolithiasis undergoing hepatic resection, with no residual stones and only a 5% recurrence rate during long-term follow-up.

Advances in imaging techniques over the past decades have significantly improved the diagnosis and management of hepatolithiasis. Non-invasive modalities such as MRCP provide high-resolution visualization of both biliary stones and anatomical structures. These tools enable earlier diagnosis and comprehensive pre-operative assessment, particularly in detecting associated complications such as biliary strictures, ductal dilatation, and segmental atrophy.[18,19] In this cohort, routine pre-operative MRCP allowed for more accurate assessment of the extent and distribution of stone disease compared to CT, which was available in a subset of patients. In several cases, initial CT imaging suggested unilateral or segmental involvement, whereas MRCP revealed bilobar or more extensive disease, directly influencing surgical planning and the choice between resection and conservative approaches.

Significant geographical variation in the prevalence of hepatolithiasis has led to varying management strategies. While Eastern centers, where the disease is endemic, often favor liver resection for definitive treatment, Western centers tend to approach surgical treatment more cautiously. Although the decision to perform major hepatectomy for a benign disease may raise concerns, the potential for malignant transformation must not be overlooked. Chronic inflammation and bile stasis are the key pathogenic factors involved in the development of malignancy within the biliary system. Numerous studies have reported significantly increased risk of cholangiocarcinoma in patients with long-standing hepatolithiasis.[16,17,20] Our findings support the performance of liver resection in patients with structural pathology.[15,21,22] Histopathological analysis of the resected specimens confirmed the presence of chronic inflammation and ductal strictures, although no malignancy was detected.

Invasive malignancy also did not develop during long-term follow-up of patients with bilobar disease without biliary strictures who were treated with intrahepatic stone clearance and biliary drainage. Treatment strategies were individualized based on the distribution of stones and extent of pathological

changes. Hepatic resection has been demonstrated to have reduced complication rates,[23,24] and it can be a safe and effective option even in low-prevalence settings.[25-27] In this series, major hepatectomy was performed without mortality in selected patients.

Studies have frequently indicated a predominance of disease in the left lobe of the liver. This distribution may be due to the anatomical features that predispose the left hepatic ducts to bile stasis. In these patients, a left hepatectomy or lateral sectionectomy may be curative. However, the presence of bilobar stones significantly complicates management strategy. In this situation, the potential for severe complications such as recurrent cholangitis, biliary fistulas, and post-operative liver failure should be carefully considered. Extensive hepatectomies are generally not recommended in these patients,[28-30] but may be considered in patients with irreversible liver damage (e.g., biliary stenosis, severe fibrosis, or atrophy) in a single liver lobe. In such patients, the diseased lobe is resected, residual stones on the contralateral side are intraoperatively cleared, and a biliary drainage procedure in the form of a hepaticojejunostomy is performed if necessary.[26,27,31] This multimodal approach reduces stone burden and helps prevent complications.

Minimally invasive techniques, such as percutaneous transhepatic cholangioscopy and endoscopic lithotripsy, have shown efficacy in patients with limited stone burden or those unfit for surgery. However, their efficacy significantly decreases in patients with extensive disease, particularly in those harboring multiple or large stones with associated biliary strictures. In such scenarios, these approaches are not only technically challenging but also associated with a higher likelihood of incomplete stone clearance and increased recurrence rates.[31,32]

CONCLUSION

Hepatolithiasis is a rare and complex disease. Our findings support hepatic resection as the most effective approach in localized disease, offering complete stone clearance and a low recurrence rate. Conservative surgery, typically employed in bilobar disease, carries higher risks of residual and recurrent stones. Treatment should be tailored based on stone distribution, liver function, and associated complications.

Ethics Committee Approval: This study was approved by the the Istanbul University Ethics Committee (Date: 2026, Decision No: 572).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: K.R.S., İ.G., B.G., G.U., Y.T.; Design: K.R.S., İ.G., G.U., M.Y.; Supervision: K.R.S., A.B., F.E., Y.T; Resource: İ.G., G.U., İ.K., M.Y.; Materials: K.R.S., B.G., F.E.; Data collection and/or processing: İ.G., M.Y., G.U., İ.K.; Analysis and/or interpretation: K.R.S., İ.G., S.Ç.; Literature review: K.R.S., İ.G., G.U.; Writing: K.R.S., İ.G., Y.T.; Critical review: A.B., F.E., Y.T.

Conflict of Interest: None declared.

Financial Disclosure: The author declared that this study has received no financial support.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Lokalize hepatolitiazisli hastalarda hepatektomi, septik komplikasyonlarla ilişkili olumlu uzun dönem sonuçlar sağlamaktadır

AMAÇ: Hepatolithiazis; karaciğer apsesi, sekonder biliyer siroz ve intrahepatik kolanjiyokarsinom gibi ciddi komplikasyonların gelişimine yol açabilmektedir. Majör karaciğer rezeksiyonu tartışmalı bir konu olmaya devam ederken, konservatif yaklaşımlar her zaman küratif sonuç vermeyebilir. Bu çalışmada, cerrahi tedavinin uzun dönem sonuçları sunulmuştur.
GEREÇ VE YÖNTEM: Eylül 1999 ile Ağustos 2020 tarihleri arasında hepatolithiazis nedeniyle cerrahi tedavi uygulanan hastalar retrospektif olarak analiz edildi. Klinik semptomlar, taş lokalizasyonu, uygulanan girişimler, komplikasyonlar, rezidüel ve nüks taş oranları ile uzun dönem sonuçlar değerlendirildi.
BULGULAR: Toplam 52 hasta tanımlandı. Hastaların 28'i kadın, 24'ü erkek olup ortalama yaş 50 (min-maks: 22–75) idi. Otuz iki hastada lokalize hastalık saptandı; taşlar 13 hastada sağ, 19 hastada ise sol hepatik lobda yerleşmişti. Yirmi hastada bilateral taş mevcuttu. Lokalize hastalık grubundaki hastalara ya karaciğer rezeksiyonu (n=20) ya da konservatif cerrahi (taş temizliğini takiben hepatikojejunostomi veya T-tüp drenajı, n=12) uygulandı. Bilateral grupta ise yalnızca konservatif cerrahi yaklaşımlar tercih edildi. Genel postoperatif komplikasyon oranı %46 olup, bu oran konservatif cerrahi sonrası daha yüksekti ($p<0.26$). Öte yandan, safra kaçağı rezeksiyon sonrası daha sık görüldü (%15'e karşılık %6). Mortalite izlenmedi ve medyan postoperatif hastanede yatış süresi 12 gün (min-maks: 5–55) idi. Ortalama 134 aylık (min-maks: 25–275) takip süresince, biri hariç tamamı konservatif grupta olmak üzere 5 hastada (%10) nüks gelişti. Dört hastada hepatikojejunostomi darlığı, 2 hastada portal ven trombozu ve 2 hastada sekonder biliyer siroz gelişimi gözlendi. Takip sürecinde 13 hasta (%25) kaybedildi; bu ölümlerden ikisi doğrudan hastalıkla ilişkiliydi. On yıllık hastalıksız sağkalım oranı, rezeksiyon grubunda konservatif cerrahiye göre anlamlı derecede daha yüksek bulundu (%85'e karşılık %58, $p<0.05$).
SONUÇ: Lokalize intrahepatik taşları olan hastalarda karaciğer rezeksiyonu, konservatif cerrahiye kıyasla daha üstün sonuçlar sunmaktadır. Ancak bilateral tutulum gösteren hastalarda tedavi stratejisi bireyselleştirilmelidir.

Anahtar sözcükler: Hepatektomi; hepatikojejunostomi; kolanjiyokarsinom; safra taşı; safra yolları.

Ulus Travma Acil Cerrahi Derg 2026;32(11):1353-1359 DOI: 10.14744/tjtes.2026.48905

ORIGINAL ARTICLE

Prediction of mortality in patients with Fournier's gangrene: Importance of time to surgery

Mert Hamza Özbilen,[1] Mahmut Can Karabacak,[2] Eyyüp Tekin,[3] Ulaş Can Erdoğan,[3] Mehmet Çağlar Çakıcı,[4] Mehmet Yoldaş,[3] Adem Altunkol,[5] Ergün Alma,[5] Mehmet Zeynel Keskin[3]

[1]Department of Urology, Uşak University Faculty of Medicine, Uşak-*Türkiye*
[2]Department of Urology, Kahramanmaras State Hospital, Kahramanmaraş-*Türkiye*
[3]Department of Urology, Health Sciences University Izmir Tepecik Training and Research Hospital, İzmir-*Türkiye*
[4]Department of Urology, Istanbul Medeniyet University, İstanbul-*Türkiye*
[5]Department of Urology, Health Sciences University Adana City Training and Research Hospital, Adana-*Türkiye*

ABSTRACT

BACKGROUND: Considering the complex structure and severity of Fournier's Gangrene (FG), it is important to identify prognostic factors to develop treatment strategies and predict clinical outcomes. Early diagnosis of FG patients may result in reducing damage to patients' health, increasing treatment success and survival rates. Our study aims to evaluate the clinical and laboratory findings that predict mortality, the role of five scoring systems in mortality prediction, and the importance of the time from admission to emergency department to surgery in FG patients.

METHODS: A total of 354 patients who were diagnosed with FG were divided into survivors (n=293) and non-survivors (n=61). Multivariate logistic regression analysis was applied for variables that were statistically significant in the univariate analysis regarding factors predicting mortality in patients with FG. Fournier Gangrene Severity Index (FGSI) score, Uludağ Fournier Gangrene Severity Index (UFGSI) score, Age-adjusted Charlson Comorbidity Index (ACCI), Laboratory Risk Indicator for Necrotizing Fasciitis (LRINEC) index, and the Combined Urology and Plastics Index (CUPI) were analyzed with receiver operating characteristic (ROC) curves for predicting the mortality of FG.

RESULTS: The mortality rate due to FG was found to be 17.2%. Advanced age, increased respiratory rate, high serum chloride, low serum bicarbonate, low serum albumin, and the time between hospital admission and surgery are independent predictors of FG mortality in the multivariate analysis. The area under the ROC curve values of FGSI score, UFGSI score, ACCI, LRINEC index, and CUPI were found to be 0.719, 0.751, 0.641, 0.636, and 0.751, respectively. Mortality was 13.3% in patients with a time of up to 12 h until surgery, and 24.2% in patients with a time of more than 12 h until surgery. Furthermore, a time to surgery longer than 12 h was associated with a longer length of hospital stay (p=0.001).

CONCLUSION: Considering the scoring systems, our results showed that UFGSI and CUPI significantly outperformed ACCI and LRINEC, while FGSI, UFGSI, and CUPI did not differ significantly from one another. One of the most important aspects of reducing mortality is complete debridement within 12 h of hospital admission.

Keywords: Emergency; Fournier's gangrene; mortality; scoring systems; time to surgery.

INTRODUCTION

Fournier's Gangrene (FG) is the form of necrotizing fasciitis that affects the superficial and deep tissues of the genital, scrotal, perineal, and perianal regions.[1] In other words, FG is a subgroup of necrotizing soft tissue infection (NSTI). FG causes obliterative endarteritis. Necrosis occurs due to microvascular obstruction and impaired blood circulation. The

Cite this article as: Özbilen MH, Karabacak MC, Tekin E, Erdoğan UC, Çakıcı MÇ, Yoldaş M, et al. Prediction of mortality in patients with Fournier's gangrene: Importance of time to surgery. Ulus Travma Acil Cerrahi Derg 2026;32:1360-1370.

Address for correspondence: Mert Hamza Özbilen
Department of Urology, Uşak University Faculty of Medicine, Uşak, Türkiye
E-mail: merthozbilen@hotmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(11):1360-1370 DOI: 10.14744/tjtes.2026.95219
Submitted: 22.06.2026 Revised: 31.08.2026 Accepted: 06.10.2026 Published: 05.11.2026

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existing hypoxic environment provides the basis for bacterial proliferation.[2] FG is associated with severe tissue damage, necrosis, and potential systemic complications following spread of infection through soft tissues. It usually presents with signs of sepsis. It can progress to multiple organ failure and septic shock.[3]

In the systematic review covering the years 1993–2018, it was emphasized that mortality due to FG was around 40%.[4] However, another review conducted between 2000 and 2021 found that although the mortality rate due to FG was still high at 7.3%, it had decreased compared to previous years thanks to advances in both the recognition and treatment of the disease.[5]

Considering the complex structure and severity of FG, it is important to identify prognostic factors to develop treatment strategies and predict clinical outcomes. Various scoring systems have been developed to predict the morbidity and mortality of FG patients. Fournier Gangrene Severity Index (FGSI)[6] and Uludağ Fournier Gangrene Severity Index (UFGSI)[7] are scoring systems developed to predict the mortality probability of FG patients. Age-adjusted Charlson Comorbidity Index (ACCI) is a scoring system used to evaluate comorbidities and predict mortality.[8] Laboratory Risk Indicator for Necrotizing Fasciitis (LRINEC) index is used to differentiate necrotizing fasciitis from other soft tissue infections based on laboratory findings.[9] The Combined Urology and Plastics Index (CUPI) is a scoring system used to predict length of hospital stay (LOS) and morbidity in patients with FG.[10]

Early diagnosis of FG patients may result in reducing the damage to patients' health, increasing treatment success and survival rates. Based on this idea, we aimed to evaluate the clinical and laboratory findings that predict mortality, the role of five existing scoring systems in mortality prediction, and the importance of the time from admission to emergency department to surgery in FG patients.

MATERIALS AND METHODS

This study was approved by the Health Sciences University Izmir Tepecik Training and Research Hospital (Date: 05.02.2025, Decision no: 2025/01-33). Written consent was obtained from all patients during hospitalization, and their clinical data could be used in future studies. This study was conducted in accordance with the ethical standards set forth in the 1964 Declaration of Helsinki. Data of patients diagnosed with FG between 2007 and 2023 in one of the tertiary reference centers in our country were retrospectively examined. Diagnosis was made by physical examination, taking into account the presence of erythema, induration, tenderness, blackness, subcutaneous crepitation, necrosis, and repulsive fecaloid odor. Individuals with perianal, periurethral, or scrotal abscesses without necrosis and soft tissue extension were excluded. As a result of the review, a total of 354 patients over the age of 18 who were diagnosed with FG and had no missing data were included in the study.

A total of 354 patients who met the inclusion criteria were divided into survivors (n=293) and non-survivors (n=62). The following data were collected from FG patients admitted to hospital and compared between the two groups: Patient demographics (age, gender, comorbidities), pulse, respiratory rate (RR), body temperature, disease extent, serum laboratory results (hematocrit, leukocyte, lymphocyte, neutrophil lymphocyte ratio (NLR), albumin, international normalized ratio (INR), procalcitonin, c-reactive protein (CRP), scoring system scores (FGSI score, UFGSI score, ACCI, LRINEC index, CUPI), microbial growth in wound culture, wound culture sterilization time, time to surgery, vacuum-assisted closure (VAC) of a wound, VAC duration, definitive wound closure type, number of debridement in the operating room, need for intensive care unit (ICU), LOS, length of stay in the ICU. Time to surgery was defined as the time from the patient's application to the emergency department to surgical intervention.

Multivariate logistic regression analysis was applied for variables that were statistically significant in the univariate analysis regarding factors predicting mortality in patients with FG. Patients who had a time to surgery of more than 12 h and less were compared in terms of mortality, need for ICU, number of debridements performed in the operating room, LOS, and length of stay in the ICU. FGSI score, UFGSI score, ACCI, LRINEC index and CUPI were analyzed with receiver operating characteristic (ROC) curve for the predicting the severity of FG.

After the vital signs of all patients were stabilized, the patient was evaluated by the infectious diseases clinic and empirical antibiotics were started in the emergency room. Antibiotic treatment was changed if deemed necessary by the infectious diseases department based on the patient's wound culture results, clinical and laboratory findings. Surgical intervention was performed by debridement of infected and necrotic tissues until healthy tissues were reached. Depending on the progression of the infection, debridement was repeated in the operating room when the surgeon deemed it necessary. All patients who did not receive VAC treatment were followed up with conventional wound dressing. In patients receiving VAC treatment, the dressing was changed every 72 h. Conventional wound dressing was changed daily with appropriate saline-soaked gauze by the surgeon and nurse.

The FGSI score is a numerical value created by combining clinical and laboratory values. It is created based on body temperature, pulse, RR, serum sodium, potassium, creatinine, hematocrit, leukocyte, and bicarbonate values. A score between 0 and 4 is given for each parameter. The overall score is calculated by summing the points given to each parameter. It has been reported that it is strongly associated with mortality rates.[6] The UFGSI score is another scoring system cre-

ated by adding disease extent and patient age to the FGSI score.[7] ACCI is one of the widely used comorbidity scoring systems. It has 20 parameters. It is used to evaluate the mortality risk based on the severity and number of diseases that the patient has.[8] The LRINEC index is a laboratory-based scoring system that can be used to detect early clinical cases of necrotizing fasciitis. It was created based on serum CRP, leukocyte, hemoglobin, sodium, creatinine, and glucose values. A maximum of 13 points can be obtained by giving points to each parameter.[9] CUPI is a scoring system used for LOS of FG patients. In addition to age, serum hematocrit, calcium, alkaline phosphatase (ALP), albumin, INR, bicarbonate, total bilirubin, and blood urea nitrogen values are taken into account. A total score of up to 15 is obtained from the parameters.[10]

Statistical Analysis

One-sample Kolmogorov–Smirnov test was used to control whether the data showed a normal distribution for numerical variables. Mean ± standard deviation was found in the data with a normal distribution, and median interquartile range values were recorded in the data without a normal distribution. Numerical variables were compared with Student's t test when parametric test criteria were found. In the absence of these criteria, the Mann–Whitney U test was used. In addition, the Mann-Whitney U test was used to compare ordinal categorical variables. Pearson Chi-Square Test was used to determine whether there was a difference between the percentages of categorical variables. Candidate predictors of mortality were first screened using univariable logistic regression; variables with $p<0.05$ were entered into a multivariable logistic regression model using the enter method. Multicollinearity among the final predictors was assessed using the variance inflation factor (VIF), with VIF <5 considered acceptable. Model calibration was evaluated using the Hosmer–Lemeshow goodness-of-fit test, and model discrimination was quantified using the C-statistic (area under the ROC curve), with 95% confidence intervals (CIs) calculated by the DeLong method.

The 12-h interval from presentation to surgical debridement was defined a priori, based on time intervals commonly used in the surgical-delay literature for necrotizing soft tissue infections, and was not derived post hoc from the study outcome data.

The optimal cut-off value for each scoring system was determined using the Youden index (J=sensitivity+specificity−1), identifying the threshold that maximized combined sensitivity and specificity for predicting mortality. At each optimal cut-off, sensitivity, specificity, positive and negative predictive values (PPV, NPV), and positive likelihood ratio (LR+) and negative likelihood ratios were calculated. Ninety-five percent CIs for sensitivity, specificity, PPV, and NPV were estimated using the Wilson score method; the 95% CI for each area under the curve (AUC) was estimated using the DeLong method. Pointwise 95% confidence bands for the ROC curves were obtained by bootstrap resampling (1,000 resamples with replacement, stratified on outcome). Internal validation was performed using bootstrap resampling (1,000 resamples) to estimate optimism-corrected model performance. The apparent C-statistic (0.907) was adjusted for optimism (mean=0.014), yielding an optimism-corrected C-statistic of 0.893.

Pairwise comparisons of the AUC between scoring systems were performed using the DeLong method for correlated ROC curves derived from the same patient cohort. A two-sided $p<0.05$ was considered statistically significant. For all tests, the probability of first-type error was $\alpha=0.05$. Statistical analysis of the study was performed using the IBM Statistical Package for the Social Sciences 22.0 package program.

RESULTS

Considering the inclusion and exclusion criteria, a total of 354 patients followed up due to FG were included in the study. Of these, 293 patients were defined as survivors and 61 patients as non-survivors. Demographic, clinical, and laboratory findings of both groups are compared in Table 1. The mortality rate due to FG was found to be 17.2%. The mean age was 55.3 in survivors and 65.6 in non-survivors, and a statistically significant difference was found ($p<0.001$). While the mean RR was 19.5 in survivors, it was 22.5 in non-survivors, and a statistically significant difference was observed ($p<0.001$). Female gender, comorbidities, increased pulse rate, and advanced disease extent were more common in deceased patients. When laboratory findings were evaluated, serum NLR ($p=0.046$), chloride ($p=0.025$), INR ($p=0.001$), and procalcitonin ($p<0.001$) were found to be, while hematocrit ($p=0.004$), bicarbonate ($p<0.001$), albumin ($p<0.001$), and calcium ($p=0.003$) were found to be low-high in non-survivors. No significant difference was found between the two groups in terms of serum leukocyte ($p=0.951$), sodium ($p=0.934$), potassium ($p=0.544$), CRP ($p=0.309$), and ALP ($p=0.505$) values.

The mean FGSI score, UFGSI score, ACCI, LRINEC index, and CUPI were 3.5, 5.7, 1.8, 5.5, and 4.3 in survivors and 6.9, 10.5, 2.9, 7.1, and 5.9 in non-survivors, respectively. All of these scores were statistically higher in deceased patients ($p<0.001$ for all). In the comparison of both groups, the median time to surgery was 8 h in surviving patients and 12.5 h in those who died ($p=0.016$). Time to surgery longer than 12 h was associated with increased mortality ($p=0.009$).

The results of multivariate logistic regression analysis of factors predicting mortality in FG patients are shown in Table 2. According to multivariate analysis, advanced age ($p=0.001$), increased RR ($p=0.003$), high serum chloride level ($p=0.027$), low serum bicarbonate level ($p<0.001$), low serum albumin level ($p<0.001$), and prolonged time to surgery ($p=0.005$) were found to be independent factors predicting mortality in FG. All six independent predictors showed VIF values below 1.3, indicating no evidence of multicollinearity. The multivari-

Table 1. Grouping of demographic, clinical, and laboratory data according to mortality

	Survivors (n=293)	Non-survivors (n=61)	p
Age, years, mean±SD	55.3±13.5	65.6±13.5	<0.001[T]
Gender, n (%)			
Female	82 (28)	27 (44.3)	0.012[P]
Male	211 (72)	34 (55.7)	
Presence of risk factors, n (%)	247 (84.3)	56 (91.8)	0.129[P]
Pulse (beats per min), mean±SD	92.3±15.9	100.4±17.5	<0.001[T]
Respiratory rate (breaths per min), mean±SD	19.5±4.9	22.6±5.3	<0.001[T]
Body temperature (°C), median (min–max)	36.6 (36.0–39.6)	37 (36.4–41.0)	<0.001[M]
Comorbidities, n (%)			
No	46 (15.7)	5 (8.2)	0.003[P]
Diabetes mellitus	81 (27.6)	8 (13.1)	
Cancer	21 (7.2)	3 (4.9)	
Immunosuppression	5 (1.7)	3 (4.9)	
Obesity	24 (8.2)	1 (1.6)	
Trauma/Surgery	45 (15.4)	13 (21.3)	
Cardiovascular	60 (20.5)	24 (39.3)	
Chronic kidney disease	11 (3.8)	4 (6.6)	
Disease extend, n (%)			
Urogenital	82 (28)	13 (21.3)	0.005[P]
Anorectal	108 (36.9)	13 (21.3)	
Extending into the pelvis	26 (8.9)	7 (11.5)	
Extending outside the pelvis	48 (16.4)	22 (36.1)	
Anogenital	29 (9.9)	6 (9.8)	
Hematocrit (%), mean±SD	34.2±7.0	31.5±5.3	0.004[T]
Leukocyte (103/µL), mean±SD	16.9±7.9	16.8±8.5	0.951[T]
Lymphocyte (103/µL), median (min–max)	1.3 (0.2–9.8)	1 (0.1–8.3)	0.005[M]
Neutrophil lymphocyte ratio, median (min–max)	12.1 (0.8–119.5)	16.8 (1.3–133)	0.046[M]
Sodium (mmol/L), median (min–max)	134 (115–148)	134 (117–176)	0.934[M]
Potassium (mmol/L), mean±SD	4.3±0.7	4.3±0.9	0.544[T]
Chloride (mmol/L), median (min–max)	99 (79–112)	101 (78–144)	0.025[M]
Bicarbonate (venous) (mmol/L), mean±SD	22.9±2.8	19.1±4.2	<0.001[T]
Calcium (mg/dL), mean±SD	8.6±0.7	8.3±0.7	0.003[T]
Albumin (g/dL), mean±SD	2.9±0.7	2.2±0.7	<0.001[T]
INR, median (min–max)	1.1 (0.1–2.2)	1.2 (0.12–52)	0.001[M]
Procalcitonin (µg/L), median (min–max)	0.4 (0–75)	1.1 (0.03–63)	<0.001[M]
CRP (mg/dL), mean±SD	165.5±136.7	185.0±130.9	0.309[T]
FGSI score, mean±SD	3.5±3.7	6.9±4.8	<0.001[T]
UFGSI score, mean±SD	5.7±4.3	10.5±5.7	<0.001[T]
ACCI, mean±SD	1.8±1.6	2.9±2.3	<0.001[T]
LRINEC index, mean±SD	5.5±3.4	7.1±3.4	<0.001[T]
CUPI, mean±SD	4.3±1.8	5.9±1.7	<0.001[T]
Microbial growth in wound cul-ture, n (%)	163 (60.8)	34 (59.6)	0.869[P]
Wound culture sterilization time (days)	17.6±18.4		
Time to surgery (hours), median (min–max)	8 (0.5–168)	12.5 (1–480)	0.016[T]

Surgery after 24 h, n (%)	50 (17.1)	15 (24.6)	0.167[P]
Surgery after 12 h, n (%)	97 (33.1)	31 (50.8)	0.009[P]
Surgery after 6 h, n (%)	176 (60.1)	40 (65.6)	0.422[P]
Surgery after 3 h, n (%)	241 (82.3)	52 (85.2)	0.573[P]
Surgery after 1 h, n (%)	274 (93.5)	58 (95.1)	0.645[P]
VAC of a wound, n (%)	83 (28.3)	16 (26.2)	0.740 [P]
VAC duration, median (min–max)	15 (3–60)	13.5 (1–85)	0.875[M]
Definitive wound closure type, n (%)			
Primary	121 (41.3)	2 (3.3)	<0.001[P]
Secondary	111 (37.9)	2 (3.3)	
Graft-Flap	61 (20.8)	-	
Exitus	-	57 (93.4)	
Number of debridements in the operating room, median (min–max)	1 (1–13)	1 (1–20)	0.966M
Need for ICU, n (%)	109 (37.2)	56 (91.8)	<0.001[P]
Length of hospital stay, days, median (min–max)	15 (1–93)	14 (1–120)	0.374[M]
Length of stay in the ICU, days, median (min–max)	3 (1–35)	6 (1–90)	0.001[M]

SD: Standard deviation; n: Number; min: Minute; INR: International normalized ratio; CRP: C-reactive protein; FGSI: Fournier Gangrene Severity Index; UFGSI: Uludağ Fournier Gangrene Severity Index; ACCI: Age-adjusted Charlson Comorbidity Index; LRINEC: Laboratory risk indicator for necrotizing fasciitis; CUPI: The Combined Urology and Plastics Index; VAC: Vacuum-assisted closure; ICU: Intensive care unit; TStudent T test; MMann-Whitney U test; PPearson's Chi-square test.

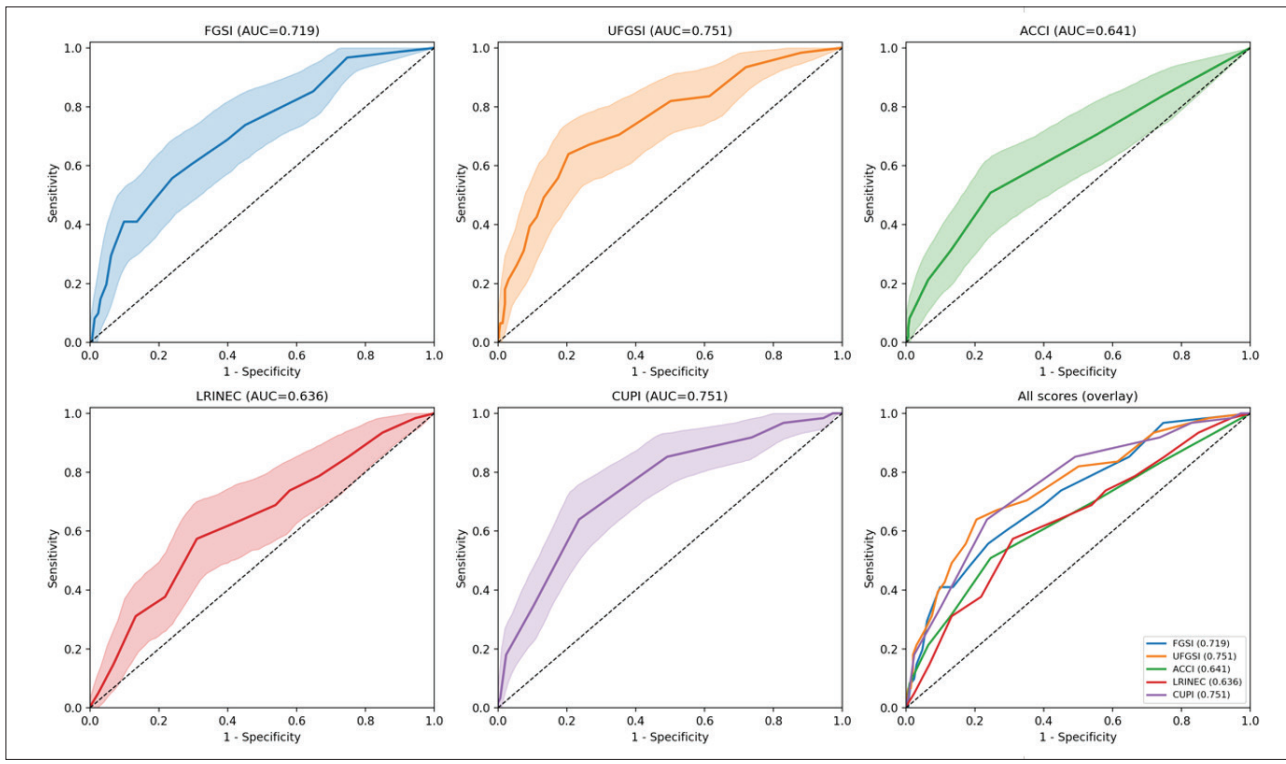


Figure 1. ROC curves for FGSI, UFGSI, ACCI, LRINEC, and CUPI predicting mortality, with 95% bootstrap confidence bands (shaded area); bottom-right panel shows all curves overlaid for comparison. ROC: Receiver operating characteristic; FGSI: Fournier Gangrene Severity Index; UFGSI: Uludağ Fournier Gangrene Severity Index; ACCI: Age-adjusted Charlson Comorbidity Index; LRINEC: Laboratory risk indicator for necrotizing fasciitis; CUPI: The Combined Urology and Plastics Index.

Table 2. Multivariate logistic regression analysis of factors predicting mortality in patients with Fournier gangrene

Binary logistic regression (n=354)

	Univariate model			Multivariate model		
	OR	95% CI	p	OR	95% CI	p
Age	1.065	1.039–1.092	<0.001	1.055	1.022–1.090	0.001
Gender (refer-ence: Female)	0.489	0.278–0.862	0.013			
Presence of risk factors	2.086	0.793–5.488	0.136			
Pulse	1.029	1.012–1.046	0.001			
Respiratory rate	1.113	1.055–1.173	<0.001	1.107	1.035–1.185	0.003
Body tempera-ture (°C)	2.235	1.569–3.185	<0.001			
Disease extent (reference: Urogenital)	1.302	1.063–1.594	0.011			
Hematocrit	0.945	0.907–0.984	0.006			
Leukocyte	0.999	0.965–1.034	0.951			
Lymphocyte	0.905	0.681–1.204	0.494			
Neutrophil lymphocyte ra-tio	1.023	1.006–1.040	0.008			
Sodium	1.016	0.970–1.063	0.509			
Potassium	1.123	0.772–1.634	0.543			
Chloride	1.060	1.012–1.110	0.014	1.075	1.008–1.146	0.027
Bicarbonate	0.731	0.668–0.801	<0.001	0.776	0.700–0.860	<0.001
Calcium	0.557	0.378–0.821	0.003			
Albumin	0.186	0.109–0.317	<0.001	0.245	0.125–0.478	<0.001
INR	6.274	1.184–20.888	0.003			
Procalcitonin	1.027	1.000–1.055	0.047			
CRP	1.001	0.999–1.003	0.308			
FGSI score	1.193	1.119–1.271	<0.001			
UFGSI score	1.201	1.135–1.271	<0.001			
ACCI	1.331	1.156–1.531	<0.001			
LRINEC Index	1.151	1.056–1.255	0.001			
CUPI	1.775	1.460–2.158	<0.001			
Time to surgery (hours)	1.012	1.006–1.019	<0.001	1.014	1.004–1.024	0.005
Δ-hours >12	2.088	1.195–3.647	0.010			
Number of deb-ridements	1.069	0.980–1.167	0.131			
VAC	0.900	0.482–1.680	0.740			
VAC duration	1.026	0.995–1.058	0.097			

n: Number; INR: International normalized ratio; CRP: C-reactive protein; OR: Odds ratio; FGSI: Fournier Gangrene Severity Index; UFGSI: Uludağ Fournier Gangrene Severity Index; ACCI: Age-adjusted Charlson Comorbidity Index; LRINEC: Laboratory risk indicator for necrotizing fasciitis; CUPI: The Combined Urology and Plastics Index; VAC: Vacuum assisted closure; ICU: Intensive care unit.

able model demonstrated good calibration (Hosmer–Lemeshow χ^2=7.95, degrees of freedom=8, p=0.438) and excellent discrimination (C-statistic=0.907, 95% CI 0.863–0.950).

When the survivors and the deceased were compared in Table 1, it was determined that the time to surgery exceeding 12 h was a statistically significant difference between the two groups. For this reason, patients whose time to surgery exceeded 12 h and those who did not exceed 12 h were evaluated separately in Table 3. In Table 3, patients with a time to surgery of up to 12 h (n=226) and patients with a time to surgery of more than 12 h (n=128) were compared with each other. Accordingly, mortality was 13.3% in patients with a time of up to 12 h until surgery, and 24.2% in patients with a time of more than 12 h until surgery (p=0.009). Furthermore, a time to surgery longer than 12 h was associated with longer LOS (p=0.001) and longer length of stay in the

Table 3. Effect of time to surgery longer than 12 h on mortality and length of hospital stay

	Δ-hours <12 (n=226)	Δ-hours >12 (n=128)	p
Mortality, n (%)	30 (13.3)	31 (24.2)	0.009[P]
Need for ICU, n (%)	102 (45.1)	63 (49.2)	0.459[P]
Number of deb-ridements in the operating room, medi-an (min–max)	1 (1–20)	1 (1–18)	0.774[M]
Length of hospital stay, days, median (min–max)	14 (1–103)	19 (1–120)	0.001[M]
Length of stay in the ICU, days, me-dian (min–max)	3 (1–64)	6 (1–90)	0.044[M]

n: Number; ICU: Intensive care unit; [M]Mann–Whitney U test; [P]Pearson's Chi-square test.

Table 4. Pairwise DeLong comparisons

Comparison	AUC 1	AUC 2	Difference	SE	Z	95% CI (diff)/p-value
FGSI versus UFGSI	0.719	0.751	−0.032	0.018	−1.804	(−0.067, 0.003); p=0.071
FGSI versus ACCI	0.719	0.641	0.078	0.044	1.775	(−0.008, 0.163); p=0.076
FGSI versus LRINEC	0.719	0.636	0.083	0.033	2.522	(0.019, 0.148); p=0.012
FGSI versus CUPI	0.719	0.751	−0.032	0.035	−0.924	(−0.099, 0.036); p=0.356
UFGSI versus ACCI	0.751	0.641	0.110	0.046	2.394	(0.020, 0.200); p=0.017
UFGSI versus LRINEC	0.751	0.636	0.116	0.035	3.283	(0.047, 0.185); p=0.001
UFGSI versus CUPI	0.751	0.751	0.000	0.035	0.010	(−0.068, 0.069); p=0.992
ACCI versus LRINEC	0.641	0.636	0.006	0.048	0.123	(−0.087, 0.099); p=0.902
ACCI versus CUPI	0.641	0.751	−0.109	0.041	−2.675	(−0.190, -0.029); p=0.008
LRINEC ver-sus CUPI	0.636	0.751	−0.115	0.043	−2.661	(−0.200, -0.030); p=0.008

Bold p-values indicate statistically significant differences (p<0.05). CI: Confidence interval; SE: Standard error of the AUC difference; Z: DeLong test statistic; FGSI: Fournier Gangrene Severity Index; UFGSI: Uludağ Fournier Gangrene Severity Index; ACCI: Age-adjusted Charlson Comorbidity Index; LRINEC: Laboratory risk indicator for necrotizing fasciitis; CUPI: The Combined Urology and Plastics Index; AUC: Area under the curve.

Table 5. Diagnostic performance at the optimal (Youden-Index) cut-off

Score	Cut-off (≥)	AUC (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	LR+/LR−	Youden index (J)
FGSI	≥6	0.719 (0.649–0.790)	55.7 (43.3–67.5)	76.1 (70.9–80.6)	32.7 (24.4–42.2)	89.2 (84.7–92.5)	2.33/0.58	0.318
UFGSI	≥9	0.751 (0.681–0.821)	63.9 (51.4–74.8)	79.5 (74.5–83.7)	39.4 (30.3–49.2)	91.4 (87.3–94.2)	3.12/0.45	0.435
ACCI	≥3	0.641 (0.561–0.722)	50.8 (38.6–62.9)	75.4 (70.2–80.0)	30.1 (22.1–39.5)	88.0 (83.5–91.5)	2.07/0.65	0.262
LRINEC	≥8	0.636 (0.557–0.714)	57.4 (44.9–69.0)	68.9 (63.4–74.0)	27.8 (20.7–36.2)	88.6 (83.8–92.1)	1.85/0.62	0.263
CUPI	≥6	0.751 (0.684–0.818)	63.9 (51.4–74.8)	76.5 (71.3–80.9)	36.1 (27.7–45.5)	91.1 (86.8–94.0)	2.71/0.47	0.404

AUC: Area under the curve; CI: Confidence interval; PPV: Positive and predictive values; NPV: Negative predictive values; LR+: Positive likelihood ratios; LR−: Negative likelihood ratios; FGSI: Fournier Gangrene Severity Index; UFGSI: Uludağ Fournier Gangrene Severity Index; ACCI: Age-adjusted Charlson Comorbidity Index; LRINEC: Laboratory risk indicator for necrotizing fasciitis; CUPI: The Combined Urology and Plastics Index.

ICU (p=0.044). No significant difference was found in need for ICU (p=0.459) and number of debridement in the operating room (p=0.774).

Details of the ROC analysis of the scoring systems predicting FG mortality were shown in Figure 1. Individual AUC values (DeLong 95% CI) of FGSI score, UFGSI score, ACCI, LRINEC index, CUPI found to be (0.719, 95% CI 0.649–0.790, 0.751, 95% CI 0.681–0.821, AUC = 0.641, 95% CI 0.561–0.722, 0.636, 95% CI 0.557–0.714, 0.751, 95% CI 0.684–0.818)

Pairwise comparison of the AUC values using the DeLong

test for correlated ROC curves demonstrated that UFGSI and CUPI had significantly higher discriminative ability for mortality than ACCI (p=0.017 and p=0.008, respectively) and LRINEC (p=0.001 and p=0.008, respectively). FGSI also showed superior discrimination compared with LRINEC (p=0.012). No statistically significant differences were observed between FGSI and UFGSI (p=0.071), FGSI and ACCI (p=0.076), FGSI and CUPI (p = 0.356), UFGSI and CUPI (p=0.992), or ACCI and LRINEC (p=0.902) (Table 4).

Using Youden-index-derived optimal cut-offs (Table 5), UFGSI (≥9) and CUPI (≥6) showed the best overall diagnostic performance, each with a sensitivity of 63.9% and specificity of 79.5% and 76.5%, respectively, and the highest Youden indices (J=0.435 and 0.404). FGSI (≥6) demonstrated a specificity of 76.1% with a Youden index of 0.318, while ACCI (≥3) and LRINEC (≥8) showed comparatively lower discriminative performance (J=0.262 and 0.263, respectively). NPV were uniformly high across all five scores (88.0–91.4%), reflecting the relatively low overall mortality rate in this cohort (17.2%), whereas PPV remained modest (27.8–39.4%), as expected for a low-prevalence outcome. The LR+ was highest for UFGSI (LR+=3.12), indicating the greatest increase in the post-test probability of mortality among patients scoring above the optimal threshold.

DISCUSSION

FG treatment is mainly based on hemodynamic stabilization, regulation of fluid and electrolyte balance, early extensive debridement of infected and necrotic tissues, and parenteral broad-spectrum antibiotics.[11] In a disease with high mortality rates, such as FG, determining the factors that will affect the course of the disease is one of the most important elements. By determining these factors, it is possible to prevent the morbidity and mortality that accompany FG.[12]

Advancing age causes a decrease in physiological functions and a weakening of the immune system. This can mean both an increased risk of infection and a reduced ability to fight infection. At the same time, comorbidities that may occur due to advanced age can cause a more dramatic course of FG.[13] While age is not included in the FGSI score and LRINEC index, it is one of the parameters in the UFGSI and CUPI scores. Although there are studies claiming the contrary,[14,15] many studies have stated that advanced age is associated with mortality due to FG.[13,16] In the regression analysis of mortality due to FG in the study by Sugihara et al.,[17] advanced age was found to be an independent risk factor, similar to our study.

Although RR is one of the parameters of the two most commonly used scoring systems for FG (FGSI and UFGSI), there are studies showing that RR is higher in the group of patients who deceased,[15,18] as well as studies showing that there is no significant difference between survivors and non-survivors.[19,20] In our study, multivariate regression analysis showed that increased RR was one of the independent factors predicting mortality (p=0.003).

Chloride is an electrolyte that is often overlooked but has important effects on the patient, which can lead to many disorders, including disorders of hemostasis, acid-base balance, and immunomodulation.[21] Increased serum chloride levels may lead to metabolic acidosis, renal failure, and hemodynamic instability.[22] Although the literature indicates that mortality rates increase in patients with hyperchloremia, it is not yet clear whether the effect of chloride levels on mortality is direct or indirect.[23] In our study, high serum chloride level was found to be an independent predictor of FG-related mortality. With this result, our study suggests there may be a link between serum chloride levels and FG-related mortality.

Low serum bicarbonate is an indicator of metabolic acidosis. In metabolic acidosis, interleukin production is stimulated by macrophages and lymphocyte function is suppressed. This leads to increased inflammation and impaired immune response.[24] Studies have generally reported that serum bicarbonate levels were statistically significantly lower in patients who died of FG.[20,25] In our study, low serum bicarbonate level was found to be one of the independent predictors of FG-related mortality (p<0.001).

Serum albumin is known as a negative acute phase reactant. Hypoalbuminemia may be observed in patients with metabolic stress. Serum albumin levels may reflect the patient's nutritional status and immune function.[26] Low serum albumin levels may play a role in the progression of the disease, and advanced disease may cause a decrease in serum albumin levels. Although it was also stated that there were similar results regarding serum albumin levels between patients who survived and died after FG,[18] low serum albumin level was found to be an independent risk factor for mortality related to FG in the multivariate regression analysis in the study of Çomçalı et al.[27] and in the study of Shin et al.,[28] as in our study.

More than 10 scoring systems, both specific and non-specific to FG, have been investigated in the literature to predict mortality in FG.[15] Scoring systems should be easy to calculate, relatively less time-consuming, and have high sensitivity and specificity. There is no clear consensus in the literature on whether scoring systems are useful in FG and, if so, which system should be used first.[29]

The FGSI is the first and most commonly used FG-specific scoring method, but it is time-consuming to calculate. The threshold value for FGSI was found to be 9. It was stated that if it was higher than 9, the mortality rate would be 75%, and if it was lower than 9, the mortality rate would drop to 22%.[6] In the meta-analysis of El-Qushayri et al.,[30] it was stated that comorbidities should also be included in the FGSI scoring. The threshold value for the UFGSI score was accepted as 9, as in the FGSI score. The authors stated that the predictive power was higher and emphasized that if the score was high-

er than 9, the mortality rate would be 94%, while when it was 9 or less, this rate would drop to 18%.[7] The calculation is time-consuming. Although ACCI is not a scoring system specific to FG, it is used to evaluate the mortality risk based on the severity and number of diseases the patient has. It is easy to calculate and has validation for a large number of diseases. In the study by Sugihara et al.,[17] it was stated that increased ACCI was an independent risk factor for FG-related mortality in multivariate regression analysis. LRINEC index is an easy-to-calculate scoring system. It is not specific to FG and was developed for diagnostic purposes. In the LRINEC index, patients are divided into three risk categories for NSTIs: Low (LRINEC index ≤5), intermediate (LRINEC index 6–7), and high (LRINEC index ≥8). A LRINEC index of 6 and above increases suspicion of necrotizing fasciitis, and a score of 8 and above is a strong predictor of this disease.[9] Some studies suggest that the LRINEC index is helpful in the diagnosis of necrotizing fasciitis, but clinical evaluation and radiological methods should also be used in the diagnosis.[31,32] CUPI is specific for FG and is the first scoring system that prioritizes morbidity and LOS in FG patients. The threshold value for CUPI was found to be 5. For values 5 and below, the mean LOS was 25 days, while for values above 5, the mean LOS was 71 days.[10] CUPI is a scoring system that has not been studied much. It is a complement to the existing prognosis prediction model. Identifying high-risk FG patients in CUPI may shorten LOS and improve prognosis.[33]

If we evaluate the studies comparing the scoring systems predicting FG-related mortality, in the meta-analysis conducted by Tufano et al.[34] investigating the predictive values of FGSI and UFGSI scores for mortality in patients with FG, they stated that mortality increased as scores increased in both scoring systems, but the accuracy rate of UFGSI was higher. Among the studies comparing FGSI, UFGSI, and ACCI, Tuncel et al.[35] reported that only UFGSI has predictive value for mortality. In the study by Azmi et al.[15] comparing FGSI, UFGSI, ACCI, and LRINEC scores, all scoring systems were found to be significantly higher in non-survivors, but among these, FGSI was found to be superior to the other 3 scoring systems. In the study by Arıkan et al.,[36] where they compared FGSI, UFGSI, ACCI, and LRINEC, it was found that FGSI and UFGSI scores were superior to others in multivariate analysis, and among these, UFGSI was stated to be the most accurate and LRINEC the least accurate in mortality prediction. In our study, although all 5 scoring systems were found to be statistically higher in the non-survivors ($p<0.001$). To formally compare the discriminative performance of the five scoring systems, we performed pairwise DeLong tests for correlated ROC curves. This analysis showed that UFGSI and CUPI significantly outperformed ACCI and LRINEC (all $p<0.02$), while FGSI, UFGSI, and CUPI did not differ significantly from one another.

The general consensus among surgeons is that the earlier the necrotic tissue is debrided, the better the outcome. However, how early is early enough is not well defined.[37] Studies on this subject mainly cover NSTIs, which are a more general definition. In the meta-analysis by Nawijn et al.,[38] they noted that the time from the onset of NSTI symptoms to hospital admission or surgery did not affect mortality. It was stated that surgical treatment within 12 h of hospital admission is necessary to reduce mortality rate, but surgical treatment within 6 h may further improve outcomes. Patients with severe sepsis may undergo delayed surgery because they require initial stabilization. Conversely, the sickest patients may undergo surgery immediately. It should be kept in mind that such confounding factors can affect time-to-surgery outcomes. In the study by Gelbard et al.,[39] in patients with NSTI, mortality was found to be 14% and 25.8% in patients with a time to surgery of less than and more than 12 h, respectively. In a systematic review evaluating patients with necrotizing fasciitis, it was found that the survival rate decreased from 93.2% to 75.2% when the time from admission to surgery was increased from 24 to 48 h.[40] Lin et al.[41] found that the only significant factor in comparing surviving and deceased patients with FG was time to surgery. It has been stated that the appropriate time for surgical debridement of FG is the first 14 h, and any delay is associated with increased mortality. In our study, in the multivariate regression analysis investigating the factors affecting mortality in patients with FG, the time to surgery was found to be an independent predictor ($p=0.005$). When the time to surgery was compared between survivors and non-survivors, the median time to surgery was 8 h in survivors and 12.5 h in non-survivors ($p=0.016$). In our study, mortality was 13.3% in patients with a time of up to 12 h until surgery, and 24.2% in patients with a time of more than 12 h until surgery ($p=0.009$).

Although our study includes a certain population, it includes a larger number of patients compared to similar studies. One of the limitations of the study is that not all scoring systems were used. In addition, the lack of detailed information on the type of microorganism isolated in the wound culture, the antibiotic therapy administered, and the antibiotic resistance pattern of patients with FG is among the limitations of the study. In addition, data regarding "time from symptom onset to hospital admission" and "time from symptom onset to surgery" were not available in our study. The retrospective, single-center nature is a potential source of bias and another limitation that prevents generalization of the study results. Furthermore, there is no external validation available for our study. A multicenter prospective study with a larger sample size is needed for further confirmation.

CONCLUSION

There are various clinical, laboratory findings, and scoring systems that help us predict the relationship between FG and mortality. According to our study, advanced age, increased RR, high serum chloride, low serum bicarbonate, low serum albumin, and the time between hospital admission and surgery are independent predictors of FG mortality. Consider-

ing the scoring systems, our results showed that UFGSI and CUPI significantly outperformed ACCI and LRINEC, while FGSI, UFGSI, and CUPI did not differ significantly from one another. Prompt, complete debridement is the basis for patient survival. One of the most important aspects of reducing mortality is complete debridement within 12 h of hospital admission.

Ethics Committee Approval: This study was approved by the Health Sciences University Izmir Tepecik Training and Research Hospital (Date: 05.02.2025, Decision No: 2025/01-33).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: M.H.Ö., M.Y., M.Z.K.; Design: M.H.Ö., M.Ç.Ç., M.Y.; Supervision: M.Z.K.; Resource: M.C.K., E.T., U.C.E.; Materials: A.A.; Data collection and/or processing: M.C.K., E.T., U.C.E.; Analysis and/or interpretation: M.Ç.Ç., A.A.; Literature review: M.H.Ö., M.Ç.Ç., E.A.; Writing: M.H.Ö., M.Ç.Ç., E.A.; Critical review: M.Z.K.

Conflict of Interest: None declared.

Financial Disclosure: The author declared that this study has received no financial support.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Fournier gangreni olan hastalarda ölüm oraninin tahmini: Ameliyata kadar geçen sürenin önemi

AMAÇ: Fournier gangreninin (FG) karmaşık yapısı ve ciddiyeti göz önüne alındığında, tedavi stratejileri geliştirmek ve klinik sonuçları tahmin etmek için prognostik faktörleri belirlemek önemlidir. FG hastalarının erken teşhisi, hastaların sağlık durumlarına verilen zararı azaltabilir, tedavi başarısını ve hayatta kalma oranlarını artırabilir. Çalışmamızın amacı, FG hastalarında mortaliteyi öngören klinik ve laboratuvar bulgularını, mortalite tahmininde beş puanlama sisteminin rolünü ve acil servise başvuru anından ameliyat anına kadar geçen sürenin önemini değerlendirmektir.
GEREÇ VE YÖNTEM: FG tanısı konulan toplam 354 hasta, hayatta kalanlar (n=293) ve hayatını kaybedenler (n=61) olmak üzere iki gruba ayrıldı. FG hastalarında mortaliteyi öngören faktörlere ilişkin tek değişkenli analizde istatistiksel anlamlı bulunan değişkenler için çok değişkenli lojistik regresyon analizi uygulandı. Fournier Gangren Şiddet İndeksi (FGSI) skoru, Uludağ Fournier Gangren Şiddet İndeksi (UFGSI) skoru, Yaşa Göre Ayarlanmış Charlson Komorbidite İndeksi (ACCI), Nekrotizan Fasiit için Laboratuvar Risk Göstergesi (LRINEC) İndeksi ve Kombine Üroloji ve Plastik Cerrahi İndeksi (CUPI); FG'nin mortalitesini tahmin etmek için ROC eğrisi ile analiz edildi.
BULGULAR: FG'ye bağlı ölüm oranı %17.2 olarak bulunmuştur. İleri yaş, artmış solunum hızı, yüksek serum klorür, düşük serum bikarbonat, düşük serum albümin ve hastaneye yatış ile ameliyat arasındaki süre, çok değişkenli analizde FG mortalitesinin bağımsız belirleyicileridir. FGSI skoru, UFGSI skoru, ACCI, LRINEC indeksi ve CUPI'nin ROC eğrisi altındaki alan (AUC) değerleri sırasıyla 0.719, 0.751, 0.641, 0.636 ve 0.751 olarak bulunmuştur. Ölüm oranı ameliyata kadar geçen süre 12 saate kadar olan hastalarda %13.3, ameliyata kadar geçen süre 12 saatten fazla olan hastalarda ise %24.2 idi. Ayrıca, ameliyata kadar geçen sürenin 12 saatten uzun olması, hastanede kalış süresinin de uzamasıyla ilişkiliydi (p=0.001).
SONUÇ: Skorlama sistemlerini dikkate aldığımızda, sonuçlarımız UFGSI ve CUPI'nin ACCI ve LRINEC'ten önemli ölçüde daha iyi performans gösterdiğini, FGSI, UFGSI ve CUPI arasında ise anlamlı bir fark olmadığını ortaya koymuştur. Ölüm oranını azaltmanın en önemli yönlerinden biri, hastaneye yatıştan sonraki 12 saat içinde tam debridmanın yapılmasıdır.

Anahtar sözcükler: Acil; ameliyata kadar geçen süre; Fournier gangreni; ölüm oranı; skorlama sistemleri.

Ulus Travma Acil Cerrahi Derg 2026;32(11):1360-1370 DOI: 10.14744/tjtes.2026.95219

ORIGINAL ARTICLE

Clinical findings of thoracic injuries in forensic trauma and their importance in medico-legal evaluation

Emre Gürkan Bulutluöz,[1] Burak Kaya[2]

[1]Department of Forensic Medicine, Çankırı State Hospital, Çankırı-*Türkiye*

[2]Department of Forensic Medicine, University pf Health Sciences, Gülhane Faculty of Medicine, Ankara-*Türkiye*

ABSTRACT

BACKGROUND: Trauma remains one of the leading causes of mortality worldwide. Thoracic injuries constitute a frequently encountered group of injuries, particularly among young adult trauma patients. This study aimed to examine thoracic trauma of forensic relevance from a medico-legal perspective and to determine the demographic characteristics, clinical findings, and the relationship of these findings with forensic reporting.

METHODS: A total of 254 patients presenting with traumatic thoracic injuries to a secondary care hospital between 2023 and 2025 were retrospectively analyzed. The patients' age, sex, origin of the incident, clinical characteristics, and medico-legal outcomes were evaluated.

RESULTS: Of the cases, 75.2% were male, and the mean age was 48 years. Blunt trauma accounted for 86.2% of injuries, with in-vehicle road traffic accidents representing the most common cause (49.2%). According to current Turkish medico-legal guidelines, all cases were classified as injuries that could not be treated with simple medical intervention; 83.1% involved bone fractures, and 79.9% were considered life-threatening. Rib fractures were identified in 70.5% of cases, whereas intrathoracic injuries were detected in 71.3%. The most frequently observed pathologies were pneumothorax (70.2%) and hemothorax (50.8%). The frequencies of pneumothorax and hemothorax were significantly increased in cases of assault-related injury ($p<0.05$), whereas parenchymal contusion was more frequently observed in accidental injuries. The mortality rate was 6.7%.

CONCLUSION: Although thoracic trauma is relatively uncommon in secondary healthcare institutions, it carries a high risk of life-threatening complications and the potential for complex medico-legal consequences. Standardized and detailed medical documentation is essential to ensure consistency in legal processes and criminal sanctions. Focusing medico-legal evaluations not only on the trauma mechanism but also on anatomical injury and associated complications may improve the standardization and objectivity of forensic reports.

Keywords: Forensic medicine; thoracic trauma; wounds and injuries.

INTRODUCTION

Trauma remains the third leading cause of death worldwide after cardiovascular diseases and cancer.[1] Thoracic injuries represent the third most common type of traumatic injury after head and extremity trauma. They are particularly prominent among young adult populations, in whom trauma is the leading cause of death.[2,3] Available data indicate that approximately one in four traumatic deaths occurs directly as a result of thoracic injuries or their associated complications.[1,4] Owing to its anatomical structure, which contains vital organs such as the heart, lungs, and major vessels, any trauma affecting the thoracic region carries a substantial risk of mortality and morbidity.[2,5]

Cite this article as: Bulutluöz EG, Kaya B. Clinical findings of thoracic injuries in forensic trauma and their importance in medico-legal evaluation. Ulus Travma Acil Cerrahi Derg 2026;32:1371-1379.

Address for correspondence: Emre Gürkan Bulutluöz

Department of Forensic Medicine, Çankırı State Hospital, Çankırı, Türkiye

E-mail: gbulutluoz@yahoo.com.tr

Ulus Travma Acil Cerrahi Derg 2026;32(11):1371-1379 DOI: 10.14744/tjtes.2026.38499

Submitted: 24.03.2026 Revised: 05.05.2026 Accepted: 10.05.2026 Published: 05.11.2026

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Thoracic trauma is broadly classified into two main categories: Blunt and penetrating injuries.[1,2] Blunt trauma most commonly occurs as a result of high-energy road traffic accidents, falls from height, and physical assault, whereas penetrating injuries are typically caused by firearms or sharp objects.[5,6] From a forensic medicine perspective, traumatic thoracic injuries represent not only a medical emergency but also forensic cases in which physicians have a legal obligation to notify the authorities and where accurate documentation of medical findings plays a decisive role in shaping the judicial process.[2]

Forensic medicine specialists and clinicians must accurately determine the severity of these injuries, as this is critical both for appropriate medical management and for the functioning of the legal system.[7] Under the Turkish Penal Code, determining whether an injury constitutes a life-threatening condition, assessing the impact of bone fractures on vital functions, and establishing whether the injury can be treated with simple medical intervention are factors that directly influence the criminal sanctions imposed on the accused.[8] Consequently, establishing a clear correlation between clinical findings and forensic medical parameters is essential to ensure that medico-legal reporting is based on objective and standardized criteria.[5] Therefore, the medico-legal evaluation of thoracic injuries is not limited to identifying the injury itself but represents a complex process in which medical findings are translated into legal terminology.[9]

This study aims to analyze thoracic trauma of forensic relevance from a medico-legal perspective. The primary objectives are to determine the demographic characteristics of patients exposed to thoracic trauma, including age, sex, and mechanism of injury; to identify the frequency and distribution of accompanying clinical and radiological findings such as rib fractures, pneumothorax, hemothorax, and pulmonary contusion; and to examine the relationship between trauma severity and medico-legal reporting parameters, particularly life-threatening injury and the grading of bone fractures.

MATERIALS AND METHODS

Between January 1, 2023, and December 31, 2025, a total of 21,573 cases presenting to Çankırı State Hospital and reported as forensic cases were retrospectively reviewed, and 254 cases with thoracic injuries were included in the study. Data were obtained from the hospital's electronic patient record system (Hospital Information Management System), the forensic report archive, and relevant clinical unit records. Forensic examination reports, patient discharge summaries, laboratory results, operative notes, and radiological imaging records were examined in detail. Variables including age, sex, mechanism and origin of injury, intrathoracic and extrathoracic organ injuries, bone fractures, vascular injuries, blood ethanol levels, treatment protocols, and medico-legal outcomes were recorded using a structured data collection form developed by the research team. Data entries were verified using a double-check method, and potential errors were corrected through cross-validation.

The inclusion criteria were defined as follows: having a forensic case notification within the specified study period, presence of traumatic injury involving the thoracic region, and confirmation of the injury through clinical evaluation and/or radiological examination. In this study, "thoracic trauma" was defined as injuries occurring in the thoracic region consistent with the history of trauma and including at least one of the following: physical examination findings (e.g., tenderness, deformity, and respiratory distress), radiologically confirmed pathologies (e.g., rib fracture, pneumothorax, hemothorax, and pulmonary contusion), or clinically significant traumatic injuries affecting thoracic organs.

The legal classification of injuries was performed in accordance with the provisions of the Turkish Penal Code and the "Guide for the Forensic Medical Evaluation of Offences Defined as Bodily Injury in the Turkish Penal Code."[10] Due to the retrospective design, missing data were present for certain variables; no statistical imputation methods were applied, and analyses were conducted based on available data, with the sample size specified separately for each relevant variable.

Statistical Analysis

Statistical analyses were performed using IBM Statistical Package for the Social Sciences Statistics version 26 (IBM Corp., Armonk, NY, USA). Descriptive statistics were presented as frequencies, percentages, means, standard deviations, minimum, and maximum values. Differences between categorical variables were analyzed using the Pearson Chi-square test and Fisher's exact test. A $p<0.05$ was considered statistically significant.

Ethics

This study was approved by the Çankırı Karatekin University Health Sciences Ethics Committee (Date: 04-03-2026, Decision no: 28) and was conducted in accordance with the principles of the Declaration of Helsinki.

RESULTS

Out of a total of 21,573 forensic cases, 254 patients were identified as having traumatic chest injury, which corresponds to 1.2% of all cases.

Demographic Characteristics and Temporal–Spatial Distribution

Of the 254 patients, 191 (75.2%) were male, and 63 (24.8%) were female. The mean age was 48.04±18.3 years (range: 15–88 years). The highest proportion of cases occurred in patients aged ≥60 years (n=79, 31.1%), followed by those aged 50–59 years (n=49, 19.3%) and 19–29 years (n=48, 18.9%). The lowest frequency was observed in the 0–18-year age group (n=6, 2.4%).

Thoracic injuries occurred most frequently during autumn (n=84, 33.1%), on weekdays (n=184, 72.4%), between 08:01 and 16:00 h (n=103, 40.6%), and in urban settings (n=174, 68.5%) (Table 1).

Trauma Type, Origin of Injury, and Injury Mechanisms

Blunt trauma accounted for the majority of injuries (n=219, 86.2%), while penetrating trauma was observed in 34 cases (13.4%). One patient (0.4%) sustained both blunt and penetrating trauma. A statistically significant association was identified between sex and trauma type (χ^2=10.49, p=0.005). Among male patients, 82.2% sustained blunt trauma, and 17.3% sustained penetrating trauma, whereas blunt trauma accounted for 98.4% of injuries among female patients.

When evaluated according to the origin of injury, accidents constituted the predominant cause (n=216, 85%), followed by assault-related injury (n=36, 14.2%) and suicide attempts (n=2, 0.8%). A significant association was observed between sex and the origin of injury (χ^2=11.84, p=0.008). Assault-related injuries were more frequently observed among males, accounting for 18.3% of male cases, whereas the vast majority of injuries among females were accident-related (96.8%) (Table 2).

Table 1. Demographic, temporal, and spatial distribution of the cases

	n	%
Gender		
Male	191	75.2
Female	63	24.8
Age group (years)		
0–18	6	2.4
19–29	48	18.9
30–39	34	13.4
40–49	38	15.0
50–59	49	19.3
60+	79	31.1
Place		
Urban areas	174	68.5
Rural areas	80	31.5
Time		
08:01–16:00	103	40.6
00:01–08:00	53	20.9
Day		
Weekday	184	72.4
Weekend	70	27.6
Season		
Spring	65	25.6
Summer	73	28.7
Autumn	84	33.1
Winter	32	12.6

A statistically significant association was also found between age group and origin of injury (χ^2=39.25, p=0.001). Although accident-related injuries predominated in all age groups, assault-related injuries were relatively more common among patients aged 19–29 years (29.2%) and 30–39 years (29.4%). In contrast, accident-related injuries were markedly predominant among patients aged 50–59 years (95.9%) and ≥60 years (97.5%) (Table 2).

Regarding injury mechanisms, in-vehicle road traffic accidents were the most frequent cause (n=125, 49.2%). This was followed by falls from height (n=34, 13.4%), sharp object injuries (n=31, 12.2%), motorcycle accidents (n=27, 10.6%), and out-of-vehicle road traffic accidents (n=21, 8.3%). Other mechanisms included assault related blunt trauma (n=6, 2.4%), compression/crush injuries (n=6, 2.4%), firearm injuries (n=3, 1.2%), and animal attack (n=1, 0.4%). A significant association was identified between sex and injury mechanism (χ^2=22.41, p=0.004) (Table 3).

Among males, injuries most commonly resulted from in-vehicle traffic accidents (41.9%), sharp object injuries (15.7%), falls from height (13.6%), and motorcycle accidents (12.6%). Among females, the majority of injuries were caused by in-vehicle traffic accidents (71.4%) and falls from height (12.7%). Sharp object injuries and motorcycle accidents were rare among female patients, and no cases of assault related blunt trauma or firearm injury were recorded in this group.

A statistically significant association was also observed between age group and injury mechanisms (χ^2=94.93, p<0.001). Sharp object injuries and motorcycle accidents were more common among younger patients, particularly in the 19–29-year age group. Conversely, in-vehicle traffic accidents predominated among older age groups, particularly in patients aged ≥50 years (Table 3).

Clinical, Radiological, and Laboratory Findings

At admission, Glasgow Coma Scale (GCS) scores indicated mild trauma (GCS 13–15) in 91.3% of patients, moderate trauma (GCS 9–12) in 2.8%, and severe trauma (GCS 3–8) in 5.9%.

Rib fractures were identified in 179 patients (70.5%), of which 58.3% were multiple fractures. Among patients with rib fractures, displaced fractures were observed in 52.5%, combined displaced and non-displaced fractures in 30.2%, and non-displaced fractures in 17.3%.

Other thoracic skeletal injuries included clavicle fractures in 14.2% of patients, scapular fractures in 11.8%, thoracic vertebral fractures in 11.8%, and sternal fractures in 7.5% (Table 4).

Intrathoracic injuries were identified in 71.3% of patients. Pneumothorax was the most frequent pathology (70.2%), followed by hemothorax (50.8%) and pulmonary parenchymal

Table 2. The relationship of injury origins with age, gender, and intrathoracic injuries

	Injury origins						χ^2	p
	Assault-related		Accident		Suicide			
	n	%	n	%	n	%		
Gender								
Man	35	18.3	155	81.1	1	0.5	11.84	0.008*
Woman	1	1.6	61	96.8	1	1.6		
Age groups								
0–18	1	16.7	5	83.3	-	-	39.25	0.001*
19–29	14	29.2	33	68.8	1	2.1		
30–39	10	29.4	24	70.6	-	-		
40–49	7	18.4	30	78.9	1	2.6		
50–59	2	4.1	47	95.9	-	-		
≥60	2	2.5	77	97.5	-	-		
Pneumothorax								
Present	28	22	98	75.4	1	0.8	14.16	0.003*
Absent	8	6.3	118	92.9	1	0.8		
Hemothorax								
Present	26	28.3	65	70.7	1	1.1	25.99	<0.001*
Absent	10	6.2	151	93.2	1	0.6		
Parenchymal contusion								
Present	2	2.4	82	96.5	1	1.2	15.45	0.001*
Absent	34	20.1	134	79.3	1	0.6		
Total	36	14.2	216	85	2	0.8		

*Because more than one intrathoracic injury can be present in a single case, the sum of the percentages exceeds 100%. *The percentages presented show the overall distributions calculated across all cases.

contusion (47%). Less frequent injuries included parenchymal laceration (3.9%), diaphragmatic injury (2.8%), cardiac injury (1.7%), and thoracic vascular injury (1.7%) (Table 4).

The origin of injury showed a significant association with the development of pneumothorax, hemothorax, and pulmonary contusion (χ^2=14.16, p=0.003; χ^2=25.99, p<0.001; χ^2=15.45, p=0.001, respectively). Pneumothorax and hemothorax were significantly more frequent in assault-related injury cases, whereas pulmonary contusion was more commonly observed in accident-related trauma (Table 2). (This comparison is based on within-group percentage distributions. The percentages presented in Table 2 show the overall distributions calculated across all cases).

Extrathoracic fractures were identified in 109 patients (42.9%). Among these, pelvic and lower extremity fractures were the most common (45.9%), followed by vertebral fractures outside the thoracic region (40.4%), upper extremity fractures (34.9%), facial bone fractures (22%), and skull fractures (13.8%) (Table 4).

Extrathoracic internal organ injuries were detected in 48 patients (18.9%). Among these, abdominal organ injuries were the most frequent (55.3%), followed by intracranial injuries (34%), whereas 10.6% involved injuries affecting multiple anatomical regions (Table 4).

Blood ethanol analysis showed negative results in 57.9% of patients, whereas ethanol levels above 50 mg/dL were detected in 11.8%. Ethanol levels below 50 mg/dL were observed in 2% of cases, whereas ethanol testing had not been performed in 28.3% of patients.

Medico-Legal Evaluation

Since all included patients had either thoracic bone fractures or intrathoracic organ injuries, all injuries were classified as not treatable by simple medical intervention (100%). At least one bone fracture was present in 83.1% of cases, and 79.9% of injuries were classified as life-threatening.

No statistically significant association was identified between trauma type or injury mechanism and the occurrence of life-threatening injury (χ^2=5.24, p=0.073; χ^2=8.96, p=0.346).

Table 3. Distribution of the injury mechanism by gender and age groups

	Injury mechanism									χ^2	p
	IVTA	OVTA	MC	Assault related blunt trauma	Fall from height	SOI	FAI	Crush	Animal attack		
Age groups											
0–18											<0.001*
n	1	1	1	1	1	-	-	1	-	94.93	
%	16.7	16.7	16.7	16.7	16.7	-	-	16.7	-		
19–29											
n	19	3	10	-	2	14	-	-	-		
%	39.6	6.3	20.8	-	4.2	29.2	-	-	-		
30–39											
n	15	1	3	2	1	9	2	1	-		
	44.1	2.9	8.8	5.9	2.9	26.5	5.9	2.9	-		
40–49											
n	16	3	1	2	8	5	1	1	1		
%	42.1	7.9	2.6	5.3	21.1	13.2	2.6	2.6	2.6		
50–59											
n	34	1	3	1	7	1	-	2	-		
%	69.4	2	6.1	2	14.3	2		4.1	-		
≥60											
n	40	12	9	-	15	2	-	1	-		
%	50.6	15.2	11.4	-	19	2.5	-	1.3	-		
Gender											
Man											0.004*
n	80	16	24	6	26	30	3	5	1	22.41	
%	41.9	8.4	12.6	3.1	13.6	15.7	1.6	2.6	0.5		
Woman											
n	45	5	3	-	8	1	-	1	-		
%	71.4	7.9	4.8	-	12.7	1.6	-	1.6	-		
Total											
n	125	21	27	6	34	31	3	6	1		
%	49.2	8.3	10.6	2.4	13.4	12.2	1.2	2.4	0.4		

IVTA: In-vehicle traffic accident; OVTA: Out-of-vehicle traffic accident; MC: Motorcycle crash; SOI: Sharp object ınjury; FAI: Firearm injury.

Treatment Modalities and Mortality

Among the patients, 37.7% were admitted to inpatient wards, 23% underwent surgical intervention, and 10.3% required admission to the intensive care unit. In addition, 22.2% of patients were referred to a higher-level hospital for further management, whereas 6.7% of patients were treated on an outpatient basis.

Among the 182 hospitalized patients, the mean length of hospital stay was 7.68±7.44 days (range: 0–63 days).

Overall survival analysis demonstrated that 237 patients (93.3%) survived, whereas 17 patients (6.7%) died.

DISCUSSION

This study demonstrates that although traumatic thoracic injuries of forensic relevance are relatively uncommon in secondary care hospitals, they are associated with substantial clinical severity and significant medico-legal consequences. In the present cohort, thoracic trauma accounted for only 1.2% of all trauma presentations, yet these injuries had a disproportionately high impact on both clinical course and medico-legal outcomes. Although previous studies have reported higher rates (5–6%),[5,11] the lower frequency observed here likely reflects the inclusion of mild-to-moderate trauma cases

Table 4. Thoracic, extrathoracic injuries, and fractures

	n	%
Thoracic internal organ injury		
Present	181	71.3
Absent	73	28.7
Pneumothorax	127	70.2
Hemotoraxs	92	50.8
Parenchymal contusion	85	47
Parenchymal laceration	7	3.9
Diaphragm	5	2.8
Cardiac	3	1.7
Vascular	3	1.7
Thoracic bone fracture		
Present	199	78.3
Absent	55	21.7
Rib	179	70.5
Clavicle	36	14.2
Scapula	30	11.8
Thoracic vertebra	30	11.8
Sternum	19	7.5
Extrathoracic internal organ injury		
Present	48	18.9
Absent	206	81.1
Abdominal	26	55.3
Intracranial	16	34
Multiple	5	10.6
Extrathoracic bone fracture		
Present	109	42.9
Absent	145	57.1
Pelvis and lower extremity	50	45.9
Non-thoracic vertebra	44	40.4
Upper extremity	38	34.9
Facial bone	24	22
Skull	15	13.8

*Since more than one fracture and injury can be present together in a single case, the total of the percentages exceeds 100%.

and the referral of severe cases to higher-level centers.

Male patients constituted 75.2% of cases, consistent with literature reporting male predominance (70–85%) in thoracic trauma, attributed to greater exposure to high-risk occupations, motor vehicle use, and physically hazardous environments.[5,12] The mean age was 48 years, with a notable concentration in individuals aged ≥60 years (31.1%), supporting evidence that thoracic trauma risk increases with age due to factors such as bone fragility.[13]

Injuries occurred most frequently during autumn (33.1%), on weekdays (72.4%), between 08:01 and 16:00 h (40.6%), and in urban areas (68.5%). These findings corroborate the study by Slovic et al.,[4] which highlighted the sociodemographic and temporal characteristics of traumatic injuries. Taken together, these data suggest that thoracic trauma peaks during time periods and in environments characterized by increased human mobility, when individuals spend more time traveling or outdoors.

The vast majority of thoracic injuries resulted from blunt trauma (86.2%), whereas penetrating trauma accounted for 13.4% of cases. This distribution accords with previous reports, in which blunt thoracic injuries are generally reported to account for 80–90% of cases and penetrating injuries for 10–20%.[12,14] In our study, the association between sex and trauma type was significant. Male patients had a higher proportion of penetrating trauma (17.3%), whereas almost all female patients had blunt trauma (98.4%). This difference likely reflects men's greater exposure to violent incidents, assaults, or occupational risks leading to penetrating injuries.

In our study, the great majority of thoracic injuries were accident-related (85%), followed by assault-related injury cases (14.2%). This distribution mirrors the general pattern reported in the literature, which indicates that thoracic trauma most commonly results from high-energy accidents, such as traffic collisions, falls, and occupational accidents.[5,12] The significant association between sex and origin of injury showed that males were more frequently exposed to assault-related injury (18.3%). This observation may reflect the higher likelihood of men being involved in interpersonal assault and other risk-prone situations. The literature likewise indicates that males are significantly more likely than females both to be victims of interpersonal assault and to be involved in violent incidents.[13]

In our study, the most common mechanism of injury was in-vehicle road traffic accidents (49.2%), followed by falls from height (13.4%), sharp object injuries (12.2%), and motorcycle accidents (10.6%). This finding parallels international reports identifying road traffic accidents as the most common etiological factor in thoracic trauma. In a study conducted in China, 41.4% of thoracic trauma cases were reported to be related to road traffic accidents, with such cases occurring mainly in middle-aged men.[15] Similarly, studies from India and Nepal found that accidents accounted for 60–70% of thoracic injuries.[1,16] The association between sex and injury mechanism indicates that gender roles are closely linked to injury patterns. The higher frequency of sharp object injuries (15.7%) and motorcycle accidents (12.6%) among men may be associated with both their greater representation among active drivers and their greater tendency towards risk-taking behavior.

At least one rib fracture was identified in 70.5% of cases, with 58.3% having multiple rib fractures and 12.2% having a single rib fracture. The fact that more than half of rib fractures

(52.5%) were displaced indicates that the injuries in this cohort were associated with high-energy mechanisms. Similarly, Lundin et al.[17] reported rib fractures in 68% of patients with thoracic trauma, with these fractures usually being multiple in nature (≥3 ribs). Ariyaratnam et al.[18] found rib fractures in 70.3% of cases and showed that mortality increased significantly with the number of fractured ribs. Zhang et al.[15] also reported rib fractures in 70.3% of patients with thoracic trauma.

Intrathoracic organ injuries were identified in 71.3% of thoracic trauma cases, a rate that broadly corresponds to the general average reported in the literature (60–80%).[17,19] More than half of the patients had more than one intrathoracic pathology. The most common injury was pneumothorax (70.2%), followed by hemothorax (50.8%) and pulmonary parenchymal contusion (47%). Similarly, in a study of thoracic injuries by Beshay et al.,[19] pneumothorax (64.1%) and hemothorax (69.4%) were the most frequent complications, whereas Lundin et al.[17] reported pneumothorax in 35%, hemothorax in 23%, and parenchymal contusion in 18% of cases. The relatively high rate of pulmonary contusion in our study (47%) may reflect the fact that a substantial proportion of injuries resulted from blunt trauma. It is well established that contusions are more frequent in blunt trauma, whereas penetrating injuries more commonly lead to pneumothorax and hemothorax.[20,21] Indeed, in our study, the association between the origin of injury and the development of pneumothorax, hemothorax, and contusion was significant. While pneumothorax (77.8%) and hemothorax (72.2%) were more common in assault-related injury cases, parenchymal contusions were markedly more prominent in accidents than in assault-related injuries.

At least one extrathoracic fracture was identified in 42.9% of thoracic trauma cases. This finding is largely compatible with international data showing the frequency of multisystem injuries associated with chest trauma. Ariyaratnam et al.[18] reported an extrathoracic skeletal injury rate of 44.2% in patients with thoracic trauma; among these patients, 48% had pelvic or long-bone fractures, and 39% had vertebral fractures. Similarly, Beshay et al.[19] reported extrathoracic bone fractures in 46% of thoracic trauma cases, most commonly involving the pelvis and lower extremities. In their analysis, Lundin et al.[17] identified extrathoracic skeletal fractures in 41.5% of cases and reported a significant correlation between these injuries and mortality.

Extrathoracic internal organ injury was detected in 18.9% of cases. This rate is largely comparable to the reported frequency of extrathoracic organ damage in patients with thoracic trauma, which is approximately 15–25%.[18,21] Most of these injuries consisted of abdominal organ injuries (55.3%) and intracranial injuries (34%), whereas multisystem trauma was present in 10.6%. As reported in previous studies,[18,21] abdominal organ injuries were the most common group of extrathoracic injuries in our study. This finding is associated with the fact that thoracic trauma frequently results from blunt, high-energy mechanisms. In such events, thoracoabdominal energy transfer can produce damage at both diaphragmatic and visceral levels.[20]

At least one bone fracture was identified in 83.1% of cases in our study, which is comparable to the 83% fracture rate reported by Chapagain et al.[16] The bone fracture frequency of 78.4% reported by Şişman and Şimşek[5] also supports our findings. However, Karbeyaz et al.[2] reported an overall fracture rate of 51.6%, which is markedly lower than that observed in our study. This discrepancy may be attributable to the fact that our sample consisted of a more homogeneous group of relatively severe trauma cases. The high rate observed in our study likely reflects the fact that forensic trauma generally results from high-energy blunt mechanisms, with the rib cage fracturing while absorbing this energy.[22] In 79.9% of cases, the injury was found to have caused a life-threatening condition, which is comparable to the rate of 69.3% reported by Karbeyaz et al.[2] In both studies, the majority of thoracic injuries were life-threatening; however, no association was found between trauma type and the occurrence of life-threatening injury. Chapagain et al.[16] likewise reported no association between trauma mechanism and mortality, noting that injury severity depends not only on trauma type but also on the amount of energy transferred to the body and the specific anatomical region affected. This finding suggests that medico-legal evaluation should focus less on the label of the trauma and more on the severity of the anatomical damage it produces.

CONCLUSION

This retrospective study shows that thoracic injuries of forensic relevance, although relatively infrequent in secondary care hospitals, have substantial clinical and medico-legal implications. Most cases involved male and middle-aged patients, and injuries were predominantly caused by accident-related blunt trauma; however, assault-related injuries and penetrating mechanisms were relatively more common among young adults. Clinically, rib fractures and intrathoracic pathologies were frequently observed. Pneumothorax and hemothorax were more prominent in assault-related injuries, whereas pulmonary parenchymal contusion was more commonly associated with accident-related trauma. In addition, the presence of extrathoracic fractures and non-thoracic organ injuries demonstrated that thoracic trauma frequently represents a component of multisystem trauma.

From a medico-legal perspective, the fact that all cases were classified as injuries not treatable by simple medical intervention under the applicable medico-legal framework, together with the high rates of bone fractures and life-threatening injuries, highlights the critical importance of detailed and standardized medical documentation. Such documentation, supported by radiological findings, is essential for accurate criminal classification and causality assessments in thoracic trauma.

Study Limitations

This study has several limitations. First, its retrospective design inherently carries risks of selection bias and missing data bias. Because the study was based on previously recorded forensic and medical documentation, the included cases were limited to individuals who presented to the hospital and were registered as forensic trauma cases. Therefore, minor thoracic injuries that did not result in hospital admission, cases managed in other institutions, or patients directly referred to tertiary trauma centers may not have been captured. This may have led to selection bias and limited the representativeness of the study population.

In addition, the reliance on routine patient records may have resulted in incomplete or heterogeneous documentation for certain variables. Some clinical details, injury mechanisms, radiological findings, treatment processes, and medico-legal parameters may not have been recorded with equal precision in all cases. Accordingly, missing data bias may have affected the evaluation of specific variables and limited the depth of subgroup analyzes.

The single-center design also limits the generalizability of the findings. Since the study was conducted in a secondary healthcare institution, more severe thoracic trauma cases, particularly those involving complex vascular or cardiac injuries, may have been referred to tertiary centers. This may have resulted in an underrepresentation of the most critical thoracic injuries. Furthermore, long-term functional outcomes, permanent disability rates, and delayed medico-legal consequences could not be assessed.

Ethics Committee Approval: This study was approved by the Çankırı Karatekin Universıty Health Sciences Ethics Committee (Date: 04.03.2026, Decision No: 28).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: E.G.B., B.K.; Design: E.G.B., B.K.; Supervision: E.G.B., B.K.; Resource: E.G.B., B.K.; Materials: E.G.B., B.K.; Data collection and/or processing: E.G.B., B.K.; Analysis and/or interpretation: E.G.B., B.K.; Literature review: E.G.B., B.K.; Writing: E.G.B., B.K.; Critical review: E.G.B., B.K.

Informed Consent: This retrospective study.

Conflict of Interest: The authors and/or their family members have no scientific or medical committee memberships, affiliations with members of such committees, consultancy roles, expert witness positions, employment, shareholding, or any similar potential conflicts of interest related to this study.

Financial Disclosure: During this study, no financial or moral support was received from any pharmaceutical company, medical device, equipment, or supply provider or manufacturer, or any other commercial entity directly associated with the research topic that could negatively influence the decision-making process regarding the study's evaluation.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Adli nitelikli travmalarda toraks yaralanmalarının klinik bulguları ve adli tıbbi değerlendirmedeki önemi

AMAÇ: Travmalar dünya genelinde önde gelen ölüm nedenlerinden biridir. Toraks yaralanmaları özellikle genç erişkin travma olgularında sık karşılaşılan bir yaralanma grubunu oluşturmaktadır. Bu çalışma, adli nitelikli toraks travmalarını adli tıbbi bir yaklaşımla incelemeyi ve bu olguların demografik özelliklerini, klinik bulgularını ve söz konusu bulguların adli raporlama ile ilişkisini ortaya koymayı amaçlamaktadır.
GEREÇ VE YÖNTEM: 2023-2025 yılları arasında ikinci basamak bir hastaneye başvuran travmatik toraks yaralanmalı 254 olgu retrospektif olarak incelenmiştir. Olguların yaş, cinsiyet, olay kökeni, klinik özellikleri ve adli sonuçları analiz edilmiştir.
BULGULAR: Olguların %75.2'si erkek olup yaş ortalaması 48 yıl olarak saptanmıştır. Yaralanmaların %86.2'sinin künt travma kaynaklı olduğu ve en sık nedenin araç içi trafik kazaları olduğu belirlenmiştir (%49.2). Mevcut Türk adli-tıbbi rehberlere göre vakaların tümünün basit tıbbi müdahale ile giderilemeyecek nitelikte olduğu, %83.1'inde kemik kırığı saptandığı ve %79.9'unun yaşamı tehlikeye sokan nitelikte olduğu belirlenmiştir. Olguların %70.5'inde kot kırığı, %71.3'ünde ise intratorasik yaralanma saptanmış; en sık gözlenen patolojilerin pnömotoraks (%70.2) ve hemotoraxs (%50.8) olduğu görülmüştür. Kasten yaralama olgularında pnömotoraks ve hemotoraxs sıklığının anlamlı düzeyde arttığı ($p<0.05$), buna karşılık kaza olgularında parankimal kontüzyonun daha sık izlendiği saptanmıştır. Mortalite oranı %6.7 saptanmıştır.
SONUÇ: İkinci basamak sağlık kuruluşlarında düşük sıklıkta görülse de toraks travmaları yüksek oranda yaşamsal tehlike riski ve karmaşık adli tıbbi sonuç potansiyeli taşımaktadır. Standart ve ayrıntılı tıbbi dökümantasyon, hukuki süreçler ve cezai yaptırımların tutarlılığı için elzemdir. Adli değerlendirmelerin sadece travma mekanizmasına değil, anatomik hasar ve komplikasyonlara odaklanması raporların standardı ve objektifliğini artıracaktır.

Anahtar sözcükler: Adli tıp; toraks travmaları; yaralar ve yaralanmalar.

Ulus Travma Acil Cerrahi Derg 2026;32(11):1371-1379 DOI: 10.14744/tjtes.2026.38499

ORIGINAL ARTICLE

Endoscopic management of selected post-cholecystectomy bile duct injuries: A multicenter retrospective cohort from Türkiye

Emre Balli,[1] Esat Taylan Ugurlu,[2] Mehlika Bilgi Kirmaci,[1] Ali Kocatas,[3] Kemal Dolay,[3] Yasin Kara,[4] Yahya Kemal Caliskan,[4] Candas Ercetin,[5] Hakan Yigitbas,[5] Turan Pehlivan,[5] Mustafa Ormeci,[6] Alpaslan Fedayi Calta,[6] Ali Haldun Ozcan,[6] Sercan Yuksel,[7] Mehmet Saban Korkmaz,[7] Yusuf Emre Aytin,[8] Dogan Albayrak,[8] Mahmut Said Degerli,[3] Alpen Yahya Gumusoglu,[3] Nurettin Sahin,[3] Hamit Ahmet Kabuli,[3] Nezih Zengin,[9] Ozkan Yunuk,[9] Emrah Akin,[10] Emine Sena Cunuk,[10] Ahmet Surek,[3] Ihsan Tumkaya,[2] Sezgin Yilmaz[1]

[1]Department of General Surgery, Afyonkarahisar Health Sciences University Faculty of Medicine, Afyonkarahisar-*Türkiye*
[2]Department of General Surgery, Mehmet Akif İnan Training and Research Hospital, University of Health Sciences, Şanlıurfa-*Türkiye*
[3]Department of General Surgery, Dr. Sadi Konuk Training and Research Hospital, University of Health Sciences, İstanbul-*Türkiye*
[4]Department of General Surgery, Kanuni Sultan Süleyman Training and Research Hospital, University of Health Sciences, İstanbul-*Türkiye*
[5]Department of General Surgery, Bagcılar Training and Research Hospital, University of Health Sciences, İstanbul-*Türkiye*
[6]Department of General Surgery, Bandırma Onyedi Eylül University Faculty of Medicine, Balikesir-*Türkiye*
[7]Department of General Surgery, Başaksehir Cam and Sakura City Hospital, İstanbul-*Türkiye*
[8]Department of General Surgery, Trakya University Faculty of Medicine, Edirne-*Türkiye*
[9]Department of General Surgery, Bursa State Hospital, Bursa-*Türkiye*
[10]Department of General Surgery, Sakarya University Faculty of Medicine, Sakarya Training and Research Hospital, Sakarya-*Türkiye*

ABSTRACT

BACKGROUND: Endoscopic retrograde cholangiopancreatography (ERCP) is a specialized endoscopic procedure that has an essential role in the diagnosis and treatment of biliary tract diseases, especially post-cholecystectomy bile duct injuries (BDIs). This study aims to demonstrate the classification of biliary tract injuries after cholecystectomy, ERCP application patterns, and short-term clinical success in selected patients in a multicenter retrospective cohort from Türkiye.

METHODS: Patients who have undergone ERCP for iatrogenic BDIs of participant centers after laparoscopic cholecystectomy were included in this study. The demographic characteristics, classification of BDI, the efficacy of endoscopic treatment, the management of the patients, the factors associated with the success of ERCP, length of hospital stay, and mortality were retrospectively evaluated.

RESULTS: A total of 26798 cholecystectomies were performed at 10 general surgery clinics participated into the study and 139 iatrogenic BDIs (0.51%) developed between January 2021 and December 2025. Eighteen patients underwent surgery either intraoperatively or in the early post-operative period. Nine patients with BDI recovered spontaneously with supportive treatment. ERCP was performed in the remaining 112 patients, and 108 of them were treated successfully with ERCP. The treatment efficacy was 96.4%. Four patients were scheduled to surgery following failed ERCP. Clinical presentation of the patients with BDI was bile leakage through abdominal drain (87.5%), obstructive jaundice (1.8%), mixed scenario (10.7%), and abdominal pain (44.6%). The results of the study revealed that the radiological and endoscopic methods were usually used together to diagnose the BDI. The minor injuries (Strasberg A

Cite this article as: Balli E, Ugurlu ET, Kirmaci MB, Kocatas A, Dolay K, Kara Y, et al. Endoscopic management of selected post-cholecystectomy bile duct injuries: A multicenter retrospective cohort from Türkiye. Ulus Travma Acil Cerrahi Derg 2026;32:1380-1388.

Address for correspondence: Emre Balli
Department of General Surgery, Afyonkarahisar Health Sciences University Faculty of Medicine, Afyonkarahisar, Türkiye
E-mail: balliemre_88@hotmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(11):1380-1388 DOI: 10.14744/tjtes.2026.93889
Submitted: 17.08.2026 Revised: 25.09.2026 Accepted: 03.10.2026 Published: 05.11.2026
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and D) were the most commonly observed BDI in patients. The presence of sepsis was associated with increased hospital stay and mortality. Abdominal pain and biloma showed an association with increased hospital stay. Bile drainage through the drain also showed an association with increased success of the endoscopic procedure. Endoscopic sphincterotomy without stent placement was noticed to decrease the endoscopic treatment success.

CONCLUSION: In selected patients with minor post-cholecystectomy BDIs, particularly cystic duct stump leaks and lateral duct injuries, ERCP-based treatment was associated with a high short-term clinical success rate in this multicenter retrospective cohort.

Keywords: Bile duct injury; biliary fistula; cholecystectomy; endoscopic retrograde cholangiopancreatography; endoscopic treatment; multicenter study.

INTRODUCTION

Endoscopic retrograde cholangiopancreatography (ERCP) is a specialized invasive endoluminal procedure that uses both endoscopic and fluoroscopic equipment. It has an essential role in the diagnosis and treatment of biliary tract diseases, especially post-cholecystectomy bile duct injuries (BDIs).[1]

Laparoscopic cholecystectomy (LC) is one of the most common operations performed by surgeons throughout the world and accepted as "gold standard" for symptomatic gallstone diseases.[2] Because laparoscopy results in faster recovery after surgery, lesser pain, better cosmetic results and shorter hospital stay.[3]

However, there is still a substantial risk of BDI accounting between 0.4% and 1.2% with high morbidity and mortality. LC is the most frequent cause of BDI, and the clinical scenarios of the patients vary from a quiet, silent picture to catastrophic consequences. In addition, BDI occurs 2 times more common as compared to open cholecystectomy, and also the BDIs occurred are more severe.[4]

It is estimated that around 200,000 cholecystectomies are performed each year in Türkiye and approximately 600–2000 BDIs occur annually. However, there is no national comprehensive study demonstrating the BDI rate after LC and the endoscopic treatments utilized.[5]

Critical view of safety is the basic principle of safe cholecystectomy and should be ensured in all cases to prevent the BDI.[5] If the critical view of safety can't be achieved, conversion to open surgery or any other modalities, such as cholecystostomy or subtotal cholecystectomy are strongly recommended.[6,7] Intra-operative recognition of BDI usually necessitates conversion to laparotomy and intraoperative cholangiography. If the center has hepatopancreatobiliary (HPB) experience, proper repair should be done with ligation of the cystic duct remnant or small biliary radicals or with hepaticojejunostomy for more complex injuries, once the injury site is located.[8] Otherwise, the patient should be transferred to an experienced center.

The post-operative identification of BDIs is more complex and can occur early (<48 h) or late settings (>48 h). The presence of bile within the drains, jaundice, fluid accumulation in abdominal cavity, elevation of liver enzymes, abdominal pain, and unexplained sepsis are the findings considering the BDI. Appropriate radiological examination is crucial to determine if the BDI is amenable to endoscopic or surgical treatment. Although computerized tomography and magnetic resonance imaging cholangiopancreatography (MRCP) are the principal diagnostic methods, if their results are inconclusive, ERCP should be performed for diagnosis. The algorithm that we recommend for BDI suspicion is presented in Figure 1. This algorithm was not derived from the present cohort but represents a literature-based practical approach proposed by the authors.

Strasberg classification is the most commonly used system to identify the location of BDI.[9] Strasberg A and D types are the injuries that benefit most from ERCP. Fortunately, the majority of BDIs occurring after LC are type A injuries, including bile leak from the cystic duct stump, subvesicular, and hepatocystic ducts. The leakage from the cystic duct stump usually occurs due to misapplication of metal clips, slippage following necrosis, and metal clips applied to a thick, edematous, and swollen cystic duct.[10] Sub-vesicular biliary ducts are actually anatomical variants of small biliary radicals that traverse from the right lobe of the liver directly to the gallbladder. If hook diathermy is used during gallbladder dissection, these ducts can easily be injured. Most of the time, pre-operative or intraoperative identification is impossible. The hepatocystic duct is a duct from the liver to the cystic duct. If it is not recognized at the operation and transected, bile leak occurs thereafter.[10,11]

Endoscopic treatment in appropriate cases prevents the high morbidity and mortality of otherwise surgical treatment.[12,13] The fistula presentation, low fistula output (daily output <200 mL), and the absence of jaundice are the findings suggesting that the endoscopic treatment may be applicable. ERCP has a fundamental value not only in the treatment of BDI but also in confirming the diagnosis. Endoscopic sphincterotomy (ES) and stent placement are therapeutic for most cases of small biliary radicals or cystic stump leaks.[14] However, if ERCP fails, conservative treatment can also be undertaken once the bile leakage is well drained. The main target of endoscopic treatment is to decrease the intraductal pressure of the biliary system. There are several reports noting that biliary stenting with ES is more effective in terms of decreasing the intrabiliary pressure than ES alone.[15,16] Endoscopic stenting encourages enteric flow of bile and allows the fistula to heal by diverting the bile away from the injury site. So it can also be considered in situations where there is minimal tear or laceration of the choledochus (Strasberg type D), in which the stent will bridge the laceration area.

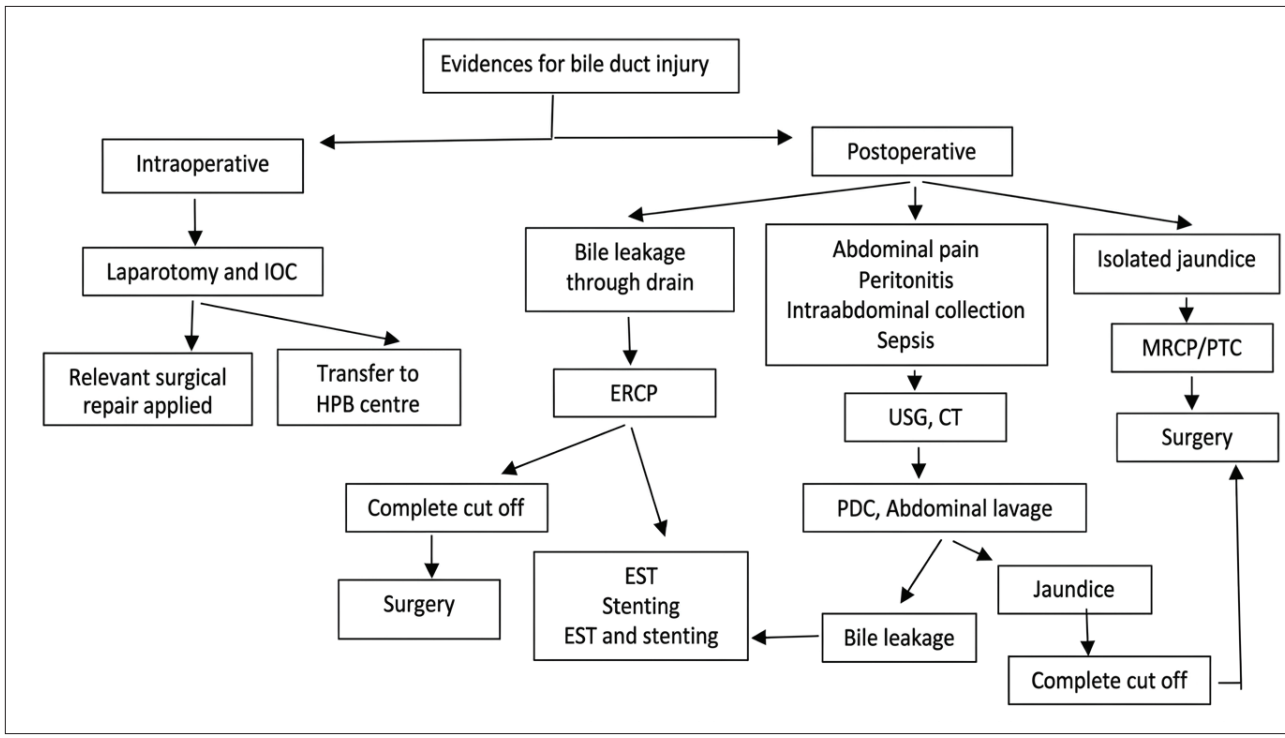


Figure 1. Proposed literature-based approach for suspected bile duct injury after cholecystectomy. IOC: Intraoperative cholangiography; PDC: Percutaneous drainage catheterization; EST: Endoscopic sphincterotomy; USG: Ultrasonography; CT: Computerized tomography; MRCP: Magnetic resonance cholangiography; ERCP: Endoscopic retrograde cholangiopancreatography; PTC: Percutaneous trans-hepatic cholangiography.

The patients treated endoscopically should be examined closely and monitored daily for fistula output and the presence of jaundice, taking into account the possibility of stent occlusion.

Type E injuries deserve special attention while determining the endoscopic treatment. Because a Strasberg Type E injury involves a complete transection or total occlusion of the main bile duct, ERCP cannot provide definitive, curative treatment in an acute setting. However, it isn't completely useless since certain E types of chronic strictures can be treated occasionally with ERCP-assisted interventions, such as magnet compression anastomosis with the help of interventional radiology.[17]

However, the initial management of the patient should be controlling the sepsis and stabilizing the patient before any kind of treatment. If the experience of the center is inadequate, it is mandatory to transfer the patient to an experienced HPB unit. In such instances, early referral without doing any surgical intervention has significant role in decreasing morbidity and mortality.[2]

In this retrospective observational study, we examined the endoscopic treatment of BDIs that occurred after LC at 10 surgical centers in Türkiye. Ten centers experienced in HPB surgery, where cholecystectomy is performed extensively and who have the ability to intervene endoscopically or surgically in cases when a BDI occurs after their own cases were invited to the study. Thus, we designed a large cohort study determining the classification of biliary tract injuries after cholecystectomy, ERCP application patterns, and short-term clinical success in selected patients in a multicenter retrospective manner from Türkiye. To our knowledge, this is one of the largest series on BDIs occurring after cholecystectomy.

MATERIALS AND METHODS

The study was conducted with the contribution of ten surgical clinics that are tertiary referral centers. These centers perform LC extensively and could also perform endoscopic or surgical treatment when their own BDI occurred. Afyonkarahisar Health Sciences University Local Ethics Committee approved the study design with approval number of 2026/2, date: 06.02.2026.

Study Concept

The primary endpoint of the study was to evaluate the clinical success of ERCP-based treatment in selected patients with post-cholecystectomy BDI. The secondary end-points were to determine the distribution of BDI types, types of endoscopic interventions, ERCP-related complications, length of hospital stay, need for surgery after failed ERCP, and in-hospital mortality.

Participating Centers

The centers included into the study were 10 university and research/education hospitals in which cholecystectomy was performed extensively, and the endoscopic and surgical treatment of BDI occurred after cholecystectomy could be carried out at their own facilities. The ERCP procedures in this study were performed by experienced general surgeons who have an annual volume of more than 100 ERCP procedures.

Data Obtain

These centers were invited to send the data of their own cholecystectomy numbers, the numbers of their BDI complications, and endoscopic and surgical treatments between January 1, 2021 and December 31, 2025. The responsible researchers were identified from all centers, and the data were obtained under the responsibility of the individual authors. The data of all centers were combined in an Excel file, and cumulative results were analyzed. We didn't obtain the daily fistula output, stent-related complications, and long-term results of BDIS as strictures.

Statistical Methods

The study data were analyzed by using the Statistical Package for the Social Sciences (SPSS) software package program. The categorical variables were expressed as numbers and percentages. The continuous variables were expressed

Table 1. Exploratory univariate analysis of variables associated with endoscopic treatment success, length of hospital stay, and mortality (n=112)

	Success of endoscopic treatment[a]		Length of hospital stay (day)[b]	Mortality[c]		p
	Yes	No		Yes	No	
Operation type						
Laparoscopy	75	2	8.61	0	77	0.610[a]
Laparoscopy to open	30	2	10.78	1	31	0.278[b]
Open	3	0	5.33	0	3	0.283[c]
Drain placement						
Yes	104	4	10.82	1	107	0.695[a]
No	4	0	7.79	0	4	0.440[b]
						0.847[c]
Abdominal pain						
Yes	48	2	10.8	0	50	0.826[a]
No	60	2	7.6	1	61	0.037[b]
						0.554[c]
Presence of sepsis						
Yes	15	0	14.33	1	14	0.423[a]
No	93	4	8.34	0	97	0.004[b]
						0.011[c]
Biloma						
Yes	22	2	12.83	0	24	0.156[a]
No	86	2	8.13	1	87	0.007[b]
						0.600[c]
Clinic after cholecystectomy						
Drainage through drain	97	1	8.93	1	91	0.004[a]
Jaundice	1	1	5	0	2	0.535[b]
Mixed scenario	10	2	11.75	0	12	0.983[c]
Type of endoscopic treatment						
EST	15	2	9.4	0	17	0.034[a]
EST and stent placement	92	2	9.29	1	93	0.554[b]
Stent placement alone	1	0	6	0	1	0.977[c]

EST: Endoscopic sphincterotomy.

as mean±standart deviation. It was our intention to identify variables associated with treatment outcomes in a univariate exploratory analysis. Table 1 was arranged for interpretation as descriptive rather than inferential. Because of the retrospective design, the low number of unsuccessful treatments (n=1, 2, 4, etc.), only one mortality event, and the very small size of several subgroups, a univariate analysis was used to prevent unstable estimates and potentially misleading conclusions.

Variables Discussed

The data obtained from the centers included the demographic features of the patients, the number of cholecystectomies (laparoscopic, laparoscopic to open, open), BDI cases, and the patients treated with endoscopic or surgical repair.

The post-operative period after the cholecystectomy, including clinical scenarios of the patients, the status of the drain placement or percutaneous catheterization (PDC), presence of abdominal pain, sepsis, or jaundice, the type of the BDI, and presentation (leakage from drain, PDC, or paracentesis, etc.) were also noted.

The success of the endoscopic treatment was defined as cessation of the bile flow from the drain or percutaneous catheter drain, absence of any intra-abdominal fluid collection or biloma, and general improvement of the patient's clinical and laboratory parameters.

For these purposes, the type of endoscopic treatment, the success rate, ERCP-related complications, total length of hospital stay, and cure rate were included into data file.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 26.0 (Armonk, NY, USA: IBM Corp.).

RESULTS

A total of 26798 cholecystectomies were performed at 10 general surgery clinics that participated in the study between January 2021 and December 2025, and 139 iatrogenic BDIs (0.51%) occurred. Among 139 patients with BDI, the ratio of female/male was 71/68, and the mean age of the patients was 53.87±1.35.

BDIs occurred after LC in 95 patients (68.3%), after conversion from laparoscopic to open surgery in 39 patients (28.1%), and after open cholecystectomy in 5 patients (3.6%). The minor injuries (Strasberg A [74.1%] and D [15.8%]) were the most commonly observed BDI in patients (Table 2).

Eighteen patients (2 in type A, 1 in type B, 1 in type C, 2 in type D, 12 in type E groups, respectively) underwent surgery either intraoperatively or at early post-operative period for definitive reconstruction (Cystic duct ligation in two, bile duct repair over T-tube in five, and hepaticojejunostomy or similar operations in eleven patients).

Table 2. The features of the patients with bile duct injury

Total (n=139)		
Parameters	**n**	**Years±mean**
Patients	139	53.87±1.35
Parameters	**n**	**Percentage**
Sex		
Female	71	51.1
Male	68	48.9
Type of cholecystectomy		
Laparoscopic	95	68.3
Laparoscopic to open	39	28.1
Open	5	3.6
The type of bile duct injury (Strasberg)		
A		
Cystic stump leakage	99	71.22
Leakage from Luschka duct, etc.	4	2.88
B	1	0.72
C	1	0.72
D	22	15.83
E	12	8.63
Treatment		
Symptomatic supportive treatment	9	6.5
Successful endoscopic treatment	108	77.7
Surgery after failed ERCP	4	2.9
Initial intraoperative or early post-operative surgery	18	12.9

ERCP: Endoscopic retrograde cholangiopancreatography.

Nine patients with BDI recovered spontaneously with supportive treatment. These patients had low fistula output and a gradually decreasing trend in fistula flow.

ERCP was performed in the remaining 112 patients, and short-term clinical success was achieved in 108 patients. The short-term clinical success rate was 96.4%. Four patients were scheduled to surgery following failed ERCP (Cystic duct ligation in one, ligation of aberrant duct in one, and bile duct repair over T-tube in two patients). The flow chart of the patients is shown in Figure 2.

The ERCP procedures were performed by experienced general surgeons; all have more than 100 procedure volume annually. Endoscopic treatment was determined according to the surgeon's preferences. If necessary, Amsterdam-type plastic biliary stents were used (7–10 Fr, 10–12 cm depending on the duct diameter) usually and kept in place until the cessation of fistula.

Clinical presentation of the patients with BDI in whom ERCP was performed were bile leakage through abdominal drain

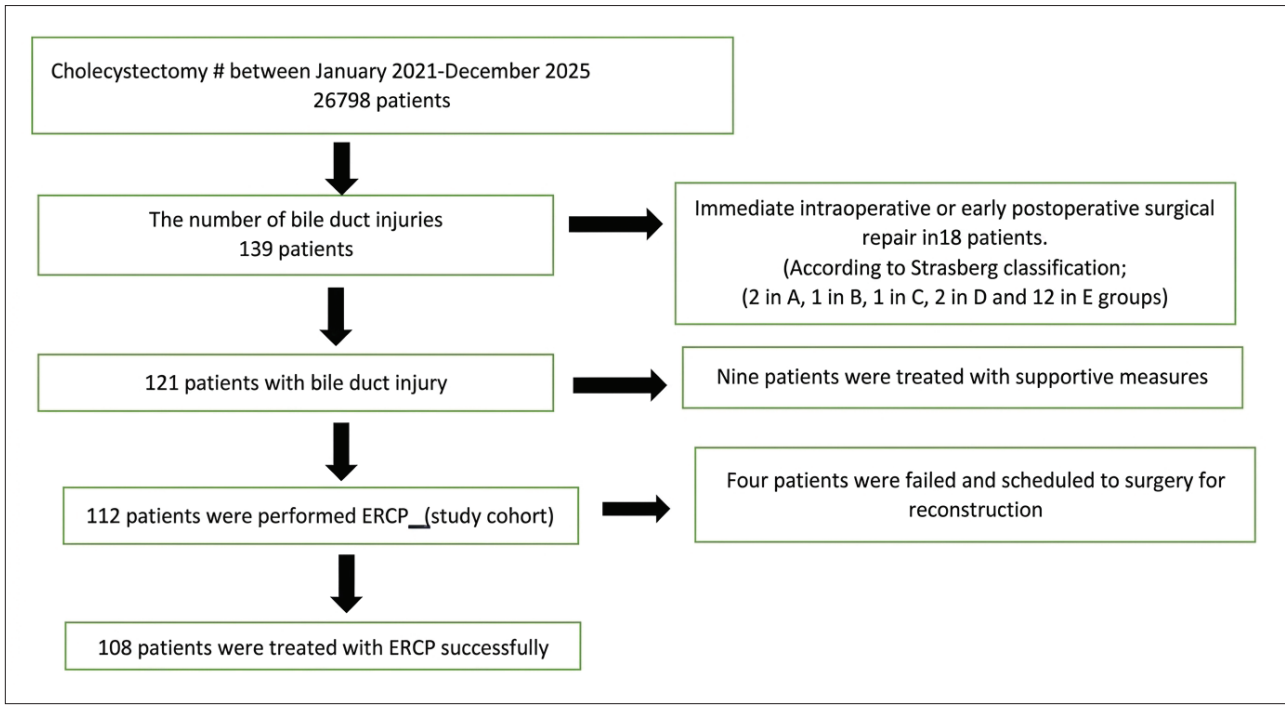


Figure 2. Flow chart of the patients.

Table 3. The clinical presentation of the patients undergoing endoscopic retrograde cholangiopancreatography

Clinical presentation (n=112)	n	Percentage
Bile leakage	98	87.5
Obstructive jaundice	2	1.8
Mixed scenario	12	10.7
Abdominal pain	50	44.6
Sepsis	15	13.4
Biloma	24	21.4

Table 4. The endoscopic treatments applied to patients with bile duct injury

Endoscopic treatment applied‡ (n=112 patients)	n	Percentage
Endoscopic sphincterotomy	17	15.2
Endoscopic sphincterotomy and stent placement	94	83.9
Stent placement alone	1	0.9

‡Four patients were scheduled to surgery after failed endoscopic treatment.

(87.5%), obstructive jaundice (1.8%), mixed scenario (10.7%), and abdominal pain (44.6%). Sepsis and associated clinical deterioration were present in 13.4% of patients. The rate of biloma was also 21.4% at admission (Table 3). Abdominal lavage was required in 7 patients (5%) who developed peritonitis after cholecystectomy. The radiological and endoscopic methods were usually used together to diagnose the BDI. The radiological methods were frequently used in patients presenting with obstruction, while ERCP was more commonly used in those presenting with bile leakage for diagnosing the BDI. The rate of percutaneous transhepatic cholangiography (PTC) before ERCP was 2.7%, while PTC was performed in 0.9% of patients after ERCP.

Ninety-four patients (83.9%) received EST with stent placement, whereas 17 patients (15.2%) received EST and one patient (0.9%) received stent placement alone (Table 4). Amsterdam-type plastic biliary stents were used (7–10 Fr, 10–12 cm depending on the duct diameter) usually and kept in place until the cessation of fistula. The mean time from BDI to ERCP intervention was 4.1 days. The mortality rate among patients who underwent ERCP was 0.9%. The complication rate of ERCP was 9.8%, as follows: Pancreatitis in 5.4%, sepsis in 2.6%, and bleeding in 1.8% of the patients. They were usually treated with supportive measures, and no surgical intervention was required. There was no perforation observed.

The overall mortality rate after all procedures was 5.03%. The mean length of hospital stay after the procedure was 6.6 days. The discharge rate with recovery was 94.96%. When the factors associated with the success of endoscopic treatment, length of hospital stay, and mortality were analyzed, it

was found that the presence of sepsis was found to be associated with increased hospital stay and mortality. Abdominal pain and biloma were also found to be associated with increased hospital stay. Bile drainage through the drain seems to be an important factor to increase the success of the endoscopic procedure. There was also an association between the EST alone and decreased endoscopic treatment success as compared to stent usage after EST (Table 1).

DISCUSSION

BDIs occurring after LC may cause to life threatening problems as increased morbidity and mortality, impaired life quality, as well as exposure of the clinicians to legal issues.[18] The treatment strategy of BDI depends on the clinical presentation, experience of the center, injury type, and time to diagnosis.

There are large data in the literature supporting the use of endoscopic procedures for both diagnosis and treatment once the major injury is excluded. However, it is our personal observation at the referral center that some clinicians are still performing surgery as the first-line treatment of BDIs despite the wide availability of ERCP and supporting data advocating its usage.

Endoscopic treatment should be encouraged for BDIs in case of Strasberg A and D type injuries following initial management for stabilizing the patient with biloma, abdominal collection, peritonitis, or general sepsis. These can be ensured with PDC for biloma and collection, abdominal lavage for peritonitis, or sometimes biliary drainage with PTC.

In case of major injuries (Strasberg type E), there is usually complete loss of the bile duct and endoscopic treatments offer no clinical therapeutic approach, instead early aggressive surgical approach should be planned to prevent onset of sepsis and related clinical problems. In the present study, there were 12 patients with type E injury, and all of them were treated with an intraoperative or early post-operative surgical approach (hepaticojejunostomy in 9 pts and bile duct repair over T-tube in one pt.).

The patients with the clinical presentation of bile drainage from drains or percutaneous catheters are more amenable to endoscopic treatment. However, patients without bile fistula but with obstructive jaundice are more prone to surgical interventions, such as hepaticojejunostomy.

MRCP is valuable to categorize the patients with bile duct obstruction; however, it has a limited value in patients with bile fistula or combined scenario. In such cases, ERCP is the first choice for diagnosing the BDIs because it also provides stent placement to bridge the laceration area at the same session.[19] It also allows to manage the predisposing issues, such as removal of any stones and stenting the strictures that may cause increased intrabiliary pressure.

The clinical presentation of patients with BDI is diverse. The common findings in patients undergoing ERCP are abdominal pain, fever, bile drainage from drains, PDC or paracentesis, biloma, and jaundice. However, we believe that severe abdominal pain that is gradually increasing and incompatible with surgery is the most important finding.[19,20] In the present study, although abdominal pain did not affect the endoscopic success and mortality, it was associated with increased hospital stay. The presence of high CRP and leukocyte values accompanied by this issue is an alarming symptom and requires radiological evaluation of the patient, preferably with ultrasonography initially. Patients with low-output fistula can be managed conservatively only after if there is no abdominal collection or biloma and no evidenced findings of sepsis. We also found that sepsis has an association with increased hospital stay and mortality in patients.

The BDI injuries that benefit most from endoscopic treatment are type A and D injuries, in which there is leakage from the cystic stump, subvesical or hepatocystic bile duct, and lateral laceration of the common bile duct.[10] We also found that the cystic duct stump is the most common site of bile fistula in the present study. Subvesical ducts and hepatocystic ducts are actually anatomical variants and vulnerable to injury during gallbladder dissection from the liver bed. These injuries are more related to the surgeon's attention and meticulous dissection. However, the injury to cystic duct is occurred mainly after erroneous clipping due to severe fibrosis around Calot triangle, cautery damage, dislodgement of clips due to ischemia of stump that are the situations mainly encountered during difficult cholecystectomies.[16]

Biliary stenting with endoscopic sphincterotomy decreases the pressure gradient between the common bile duct and the duodenum and permits the healing of the cystic stump by diverting the bile flow through the duodenum.[15,21] Although the use of biliary stenting depends of the endoscopist's preference, Dolay et al.[22] have previously reported that if there is not bile duct dilatation, biliary stenting seems to be more effective than EST alone in the management of patients with bile leakage after cholecystectomy. The cessation of bile flow from the drain or percutaneous catheter, resolution of the biloma and the other intra-abdominal collections, and the improvement of sepsis are the signs of successful endoscopic treatment. The effectiveness of ERCP in BDI is determined by daily amount of fistula, bile stone accompanying the injury, stricture formation, type and localization of fistula on cholangiography.[23] We have found that endoscopic sphincterotomy without stent placement decreased the endoscopic treatment success.

Actually, the efficacy of ERCP for post-cholecystectomy BDI leading to biliary fistula is reported between 85% and 95%.[14] In the present study, 96.4% of patients have benefitted from endoscopic treatment. However, given the small number of unsuccessful ERCPs and mortality events in the present study, statistical findings related to these outcomes should be interpreted cautiously and should not be generalized to

broader patient populations. There is not enough data in the literature reporting the size, length, and type of stent and the efficiency on ERCP treatment. Hence, it should be tailored individually according to bile duct stone, stricture, localization of injury, and preference of endoscopist. However, repeat ERCP for stent removal, re-exposure to anesthesia, migration, and well-known complications of ERCP are disadvantages of endoscopic treatments.[14]

On the other hand, ERCP should not be insisted for therapeutic purposes, especially in patients with suspicious complete transection, complete obstruction, or loss of continuity in the major bile duct; instead, they should be referred to an experienced HPB center after appropriate imaging.

Biliary stricture is an infrequent but serious complication of BDI at long-term if it is not treated properly. Serial stenting or dilatations may be required in such instances. In refractory cases, bilio-enteric bypass, including mainly hepaticojejunostomy, is recommended.[24]

CONCLUSION

BDIs are severe complications with high morbidity and mortality if left missed and untreated. Fortunately, most of them are treatable with endoscopic procedures with high success. Our results showed that in selected patients, especially in Strasberg Type A and D injuries, particularly cystic stump leaks and lateral duct injuries, ERCP-based treatment was associated with a high short-term clinical success. Hence, when a minor biliary injury is encountered after cholecystectomy, endoscopic treatment may be considered as an initial therapeutic option in appropriately selected patients. If there is technical inadequacy, these patients should be referred to advanced ERCP centers without doing any surgical procedure. However, in patients with radiological findings of a completely occluded or transected bile duct, surgical repair is still the first-line treatment, and endoscopic treatments should not be attempted.

However, the present study has several limitations. (1) Since there is limited short-term follow-up data in this study, there are no data documenting the long-term results of endoscopic treatment, such as stricture formation and stent-related complications. (2) There aren't any standardized ERCP protocols between the centers, and cholangiographic views are also lacking. (3) The effects of different types of stents were not analyzed in this study. (4) The present study is designed in a retrospective manner, and there are no comparative data regarding the patients treated with endoscopic and surgical treatment. Therefore, the present findings cannot establish the superiority of endoscopic treatment over surgical treatment or support definitive conclusions regarding its role as a first-line treatment. (5) The monitorization of daily fistula output is also lacking. Hence, these limitations should be considered when interpreting the results of the present study. We believe that these topics are subjects of further studies, including more centers and larger data, allowing more accurate interpretations. However, the extensive data of the present study is one of the largest series to date, and with these characteristics, it serves as an important guide for surveillancing the BDIs occurring after cholecystectomy in Türkiye.

Ethics Committee Approval: This study was approved by the Afyonkarahisar Health Sciences University Local Ethics Committee (Date: 06.02.2026, Decision No: 2026/2).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: E.B., S.Y.; Design: E.B., S.Y., K.D.; Supervision: S.Y.; Resource: E.T.U., M.B.K., A.K., K.D., Y.K., Y.K.C., C.E., H.Y., T.P., M.O., A.F.C., A.H.O., S.Yüksel., M.S.K., Y.E.A., D.A., M.S.D., A.Y.G., N.S., H.A.K., N.Z., O.Y., E.A., E.S.C., A.S., I.T., E.B., S.Y.; Materials: M.B.K., E.T.U.; Data collection and/or processing: E.T.U., M.B.K., A.K., K.D., Y.K., Y.K.C., C.E., H.Y., T.P., M.O., A.F.C., A.H.O., S.Yüksel., M.S.K., Y.E.A., D.A., M.S.D., A.Y.G., N.S., H.A.K., N.Z., O.Y., E.A., E.S.C., A.S., I.T., E.B., S.Y.; Analysis and/or interpretation: E.T.U., M.B.K., A.K., K.D., Y.K., Y.K.C., C.E., H.Y., T.P., M.O., A.F.C., A.H.O., S.Yüksel., M.S.K., Y.E.A., D.A., M.S.D., A.Y.G., N.S., H.A.K., N.Z., O.Y., E.A., E.S.C., A.S., I.T., E.B., S.Y.; Literature review: E.B., S.Y., K.D.; Writing: E.B., S.Y.; Critical review: E.B., S.Y.

Informed Consent: This is retrospective study.

Conflict of Interest: None declared.

Financial Disclosure: The author declared that this study has received no financial support.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Kolesistektomi sonrası seçilmiş safra yolu yaralanmalarının endoskopik yönetimi: Türkiye'den çok merkezli retrospektif bir kohort çalışması

AMAÇ: Endoskopik retrograd kolanjiyopankreatografi (ERCP), özellikle kolesistektomi sonrası gelişen safra yolu yaralanmaları (SY yaralanmaları) olmak üzere, safra yolu hastalıklarının tanı ve tedavisinde önemli bir role sahip olan özelleşmiş bir endoskopik işlemdir. Bu çalışmanın amacı, Türkiye'den çok merkezli retrospektif bir kohortta kolesistektomi sonrası gelişen safra yolu yaralanmalarının sınıflandırmasını, ERCP uygulama özelliklerini ve seçilmiş hastalardaki kısa dönem klinik başarıyı ortaya koymaktır.

GEREÇ VE YÖNTEM: Çalışmaya, katılımcı merkezlerde laparoskopik kolesistektomi sonrası gelişen iyatrojenik safra yolu yaralanması nedeniyle ERCP uygulanan hastalar dahil edildi. Hastaların demografik özellikleri, safra yolu yaralanmasının sınıflandırması, endoskopik tedavinin etkinliği, hasta yönetimi, ERCP başarısı ile ilişkili faktörler, hastanede yatış süresi ve mortalite retrospektif olarak değerlendirildi.

BULGULAR: Ocak 2021–Aralık 2025 tarihleri arasında çalışmaya katılan 10 genel cerrahi kliniğinde toplam 26.798 kolesistektomi gerçekleştirildi ve 139 hastada (%0.51) iyatrojenik safra yolu yaralanması gelişti. On sekiz hastaya intraoperatif veya erken postoperatif dönemde cerrahi tedavi uygulandı. Safra yolu yaralanması bulunan dokuz hasta destek tedavisi ile spontan olarak iyileşti. Geriye kalan 112 hastaya ERCP uygulandı ve bunların 108'i ERCP ile başarılı şekilde tedavi edildi. Endoskopik tedavi başarı oranı %96,4 olarak bulundu. ERCP'nin başarısız olduğu dört hasta cerrahi tedaviye yönlendirildi. Safra yolu yaralanması olan hastaların klinik başvuru bulguları; abdominal drenden safra drenajı (%87,5), obstrüktif sarılık (%1.8), kombine klinik tablo (%10.7) ve karın ağrısı (%44.6) idi. Çalışma sonuçları, safra yolu yaralanmasının tanısında radyolojik ve endoskopik yöntemlerin genellikle birlikte kullanıldığını gösterdi. Minör yaralanmalar (Strasberg A ve D), hastalarda en sık gözlenen safra yolu yaralanmalarıydı. Sepsis varlığı, daha uzun hastanede yatış süresi ve artmış mortalite ile ilişkiliydi. Karın ağrısı ve biloma varlığı da daha uzun hastanede yatış süresi ile ilişkili bulundu. Abdominal drenden safra drenajının bulunması, endoskopik işlem başarısının artmasıyla ilişkiliydi. Stent yerleştirilmeden yalnızca endoskopik sfinkterotomi uygulanmasının ise endoskopik tedavi başarısını azalttığı görüldü.

SONUÇ: Seçilmiş minör kolesistektomi sonrası safra yolu yaralanması olan hastalarda, özellikle sistik kanal güdük kaçakları ve lateral safra yolu yaralanmalarında, ERCP temelli tedavi bu çok merkezli retrospektif kohortta yüksek kısa dönem klinik başarı oranı ile ilişkili bulunmuştur.

Anahtar sözcükler: Endoskopik retrograd kolanjiyopankreatografi, endoskopik tedavi, kolesistektomi, multisentrik çalışma, safra fistülü, safra yolu yaralanması.

Ulus Travma Acil Cerrahi Derg 2026;32(11):1380-1388 DOI: 10.14744/tjtes.2026.93889

ORIGINAL ARTICLE

Suicide and accidental deaths in railway incidents: A 10-year retrospective regional autopsy study

Emre Nuri Igde,[1] Fatma Tugba Erkman,[1] Bekir Dincer,[2] Burak Tastekin[3]

[1]Department of Autopsy, Ankara Group Chairmanship, The Council of Forensic Medicine, Ankara-*Türkiye*
[2]Department of Forensic Medicine, Samsun University Faculty of Medicine, Samsun-*Türkiye*
[3]Department of Forensic Medicine, Hacettepe University Faculty of Medicine, Ankara-*Türkiye*

ABSTRACT

BACKGROUND: Railway-related deaths represent an important public health issue, emphasizing the value of preventive strategies. This study aimed to provide a regional perspective on railway-related fatalities in Ankara to contribute to the development and implementation of preventive measures by evaluating crime scene findings and autopsy reports.

METHODS: A retrospective review was conducted of autopsies performed at Ankara Group Chairmanship, The Council of Forensic Medicine between 2015 and 2024. Among 67 cases in which death occurred at a train station or railway, 48 traumatic railway-related deaths were included in the study. For each case, demographic and incident-related variables were collected, including age, sex, date of incident, location, manner of death, type of incident, type of railway transport, and specific scene characteristics. Comparative analyses were performed according to manner of death and type of incident.

RESULTS: The majority of railway-related fatalities were suicides. Both suicide and accident cases were predominantly male; suicide cases were most frequent in the 30–39 age group, whereas accident cases were most frequent in the 40–49 age group. Temporal analysis showed that suicides peaked in autumn and during the 12:00–17:59 time interval, whereas accidental deaths were most frequent in winter and during the 06:00–11:59 interval. Nearly all suicides took place in subway stations. Compared with accidents, suicide victims were younger and more frequently sustained skull fractures, spinal injuries, and dismemberment, whereas sternum fractures and liver injuries were more common in accidents. These findings highlight differences in injury patterns between suicide and accident cases, together with a marked concentration of suicide deaths in subway settings.

CONCLUSION: Preventive and regulatory measures may help reduce railway-related fatalities, including both accidents and suicides. Public awareness campaigns, installation of physical barriers, and the integration of automated video-based early warning systems may play a key role in decreasing subway suicides. From a forensic medicine perspective, the distinct injury patterns may have practical implications for forensic interpretation, particularly in cases with limited scene information.

Keywords: Autopsy; forensic medicine; forensic traumatology; railway; suicide.

INTRODUCTION

Railway transport remains a widely used mode of travel due to its extensive network, substantial passenger capacity, and reliability. Following the establishment of the Republic, railway construction in Türkiye was prioritized; however, from the 1950s onward, road transport gradually emerged as the predominant mode of transportation.[1] Political agendas, economic pressures, and global events, such as the oil crisis of the 1970s, renewed interest in sustainable railway initiatives.[1] By 2024, Türkiye had a railway network of 13,919 km, predominantly comprising conventional lines, 2023 km

Cite this article as: Igde EN, Erkman FT, Dincer B, Tastekin B. Suicide and accidental deaths in railway incidents: A 10-year retrospective regional autopsy study. Ulus Travma Acil Cerrahi Derg 2026;32:1389-1399.

Address for correspondence: Emre Nuri İğde
Department of Autopsy, Ankara Group Chairmanship, The Council of Forensic Medicine, Ankara, Türkiye
E-mail: emre.nuri.igde@gmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(11):1389-1399 DOI: 10.14744/tjtes.2026.32746
Submitted: 10.02.2026 Revised: 07.05.2026 Accepted: 11.05.2026 Published: 05.11.2026
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of which were complemented by high-speed rail introduced in the 2000s. Ankara's distinctive geographic position, along with its rapidly expanding population, has necessitated the development of subway and commuter rail systems to address transportation needs.[2-4]

Although railway transport is generally regarded as safe, it remains linked to significant accidental injuries and fatalities. Within the European Union (EU), accident numbers declined by 30% over the past decade; however, 841 railway-related deaths were still documented in 2023.[5] The causes of these incidents are multifactorial and include human error (such as operational errors or trespassing), mechanical or equipment failures, and track defects (e.g., broken rails or wide gauge), as well as adverse weather conditions.[6,7] Furthermore, the level of national socioeconomic development and the robustness of regulatory frameworks significantly influence the frequency and severity of accidents. In Türkiye, although the overall number of railway accidents has shown a downward trend, mortality rates remain above the EU average.[8,9]

Suicides on railways represent an even greater burden. In Europe, railway suicides have exceeded accidental railway deaths.[5] Different countries have different percentages of suicides that occur on railways. In the Netherlands, 10.8% of suicides occur on railways, compared to 7.3% in Germany and 4% in the United Kingdom.[10] These occurrences not only result in severe injuries, but they also cause family members, railway personnel, and witnesses to suffer severe psychological trauma.[11] To implement targeted preventive strategies, it is essential to identify high-risk groups through regional studies.

Ankara is the second most populous city in Türkiye and a major transport hub, providing an important setting for analyzing railway fatalities. This study aimed to examine railway-related deaths in Ankara using autopsy and scene investigation data, focusing on causes of death, type of transportation, temporal distribution, and injury patterns by manner of death (suicide vs. accident) and type of incident (train–train vs. train–pedestrian).

MATERIALS AND METHODS

Study Design and Data Collection

This retrospective study included autopsies performed between January 1, 2015, and December 31, 2024, at the Ankara Group Chairmanship, The Council of Forensic Medicine. The cases in which death occurred at a train station, on the tracks, or near the railway, as well as cases in which the body was found at these locations, were reviewed, and a total of 67 cases were identified. We excluded natural deaths, deaths from external causes unrelated to the railway (e.g., car–pedestrian collisions outside the railway and firearm injuries), and intoxication-related deaths. After applying these exclusion criteria, 48 traumatic railway-related fatalities were included in the study.

For each case, demographic and incident-related data were collected, including age, sex, date of the incident, location (urban vs. rural), manner of death, type of incident, type of railway transport, and specific characteristics of the scene. The manner of death was determined using prosecutor's office investigation files and categorized as suicide, accident, or undetermined. The type of incident was classified into five subgroups: train–pedestrian collision, train–train collision, train–vehicle collision, fall from the platform, and isolated electrocution. Railway transport was categorized into three systems used in Ankara: mainline, commuter, and subway. Mainline trains were not further subdivided into conventional or high-speed trains due to the small sample size. All information was obtained from crime scene investigation files and autopsy reports.

The study was approved by The Council of Forensic Medicine Education and Scientific Research Committee (Date: August 06, 2024, Decision No: 21589505/2024/915) and the Hacettepe University Health Sciences Research Ethics Committee (Date: February 18, 2025, Decision No: 2025/05-39) and was conducted in accordance with the Declaration of Helsinki.

Statistical Analysis

Descriptive statistics were presented as frequencies and percentages. For overall descriptive analyses, all cases, including those classified as "undetermined," were included. For subgroup analyses (e.g., manner of death and type of incident), percentages were calculated within each subgroup. Cases classified as "undetermined" (n=5) were excluded from comparative statistical analyses to prevent misclassification bias. The distribution of continuous variables was assessed using the Shapiro–Wilk test and visual inspection of Q–Q plots. Due to minor deviations from normality, non-parametric tests were used. Continuous variables were presented as mean (standard deviation [SD]) or median (interquartile range [IQR]). Group comparisons were made using the Chi-square test or Fisher's exact test for categorical variables and the Mann–Whitney U test for continuous variables. Comparisons for manner of death were performed only between suicide and accident cases, while comparisons by type of incident were limited to train–pedestrian and train–train collisions, as the number of cases in the other groups was insufficient for statistical analysis. Statistical significance was defined as $p<0.05$ (two-sided). All analyses were performed using the Statistical Package for the Social Sciences version 23.0 (IBM Corp., Armonk, NY, USA). Figures were created using R software version 4.5.3.

RESULTS

Between 2015 and 2024, a total of 18,521 autopsies were performed, of which 48 (0.3%) were related to railway-related deaths. Among these cases, 39 were male (81.2%), and 9 were female (18.8%), with ages ranging from 16 to 84 years (mean: 38.46, SD: 16.92; median: 36, IQR: 26-49). The major-

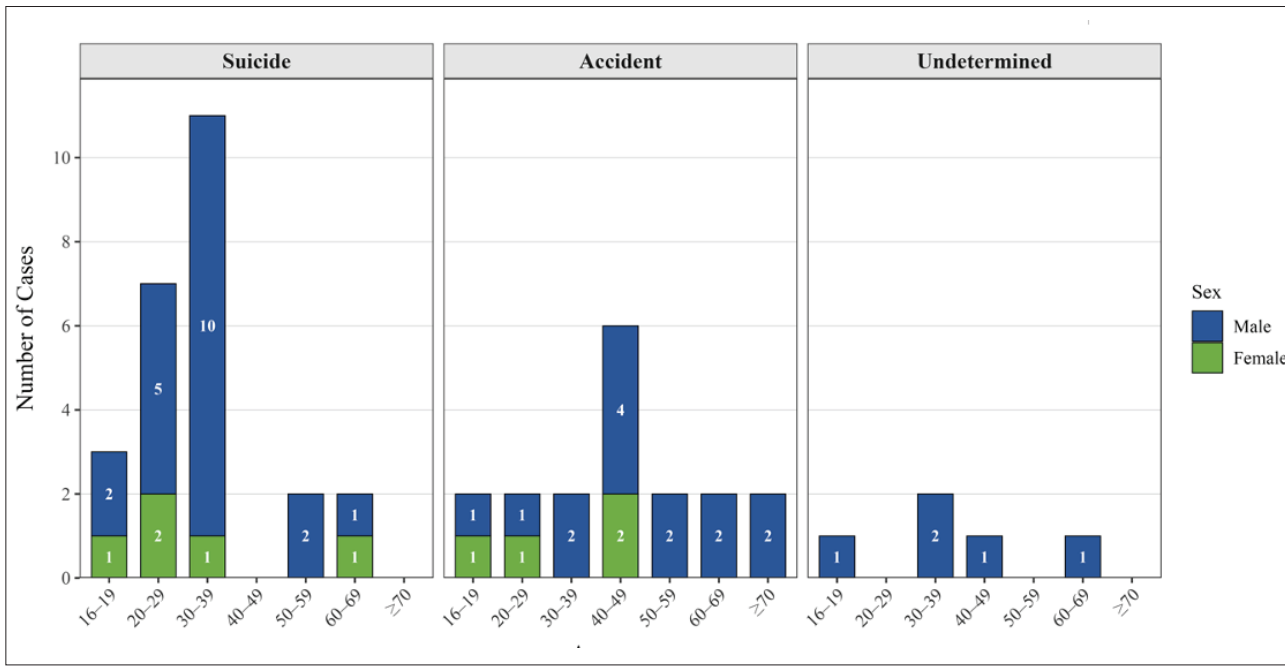


Figure 1. Distribution of railway-related deaths by age group, sex, and manner of death. Values represent the number of cases.

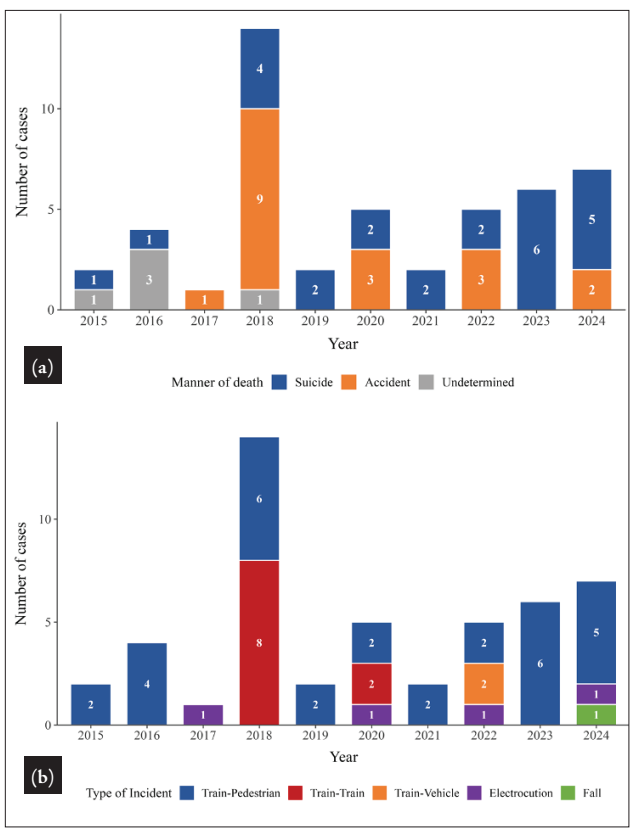


Figure 2. Annual distribution of railway-related deaths. **(a)** Manner of death and **(b)** type of incident. Values represent the number of cases.

ity of cases were within the 30–39 age group (n=15). According to the prosecutor's files, the manner of death was classified as suicide in 25 cases, accident in 18 cases, and undetermined in 5 cases; none of them were homicide. The median age was 31 (IQR: 22–37) years in suicide cases and 43.5 (IQR: 30–60) years in accident cases (Mann–Whitney U=130.500, p=0.02). The 30–39 age group represented the largest subgroup among suicide cases, whereas accident cases were most frequent in the 40–49 age group. Of the suicide cases, 20 were male, and 5 were female (Fig. 1). No statistically significant difference in sex distribution was observed between suicide and accident cases.

Regarding the type of incidents, 31 were due to train–pedestrian collisions, 10 were as a result of train–train collisions, 2 deaths occurred due to train–vehicle collisions, 1 was due to a fall onto the tracks, and 4 were due to electrocution. Geographically, 15 incidents occurred in rural areas and 33 in urban areas. In terms of transportation systems, 26 deaths occurred in the subway, 20 deaths in the mainline railway, and 2 deaths on commuter trains. Nearly all suicides occurred in the subway system (n=22, 88%), whereas 14 (77.8%) of accident-related deaths took place on the mainline railway (p<0.001).

When evaluated by year, the highest number of railway-related deaths in the overall sample was recorded in 2018 (n=14, 29.2%) (Fig. 2). Temporal distributions were further analyzed by manner of death. Among suicide cases (n=25), the most frequent day was Wednesday (n=6, 24%), and the most common time interval was 12:00–17:59 (n=11, 44%). Seasonally, the highest number of suicides occurred in autumn (n=10, 40%), followed by spring (n=6, 24%), winter (n=5, 20%), and summer (n=4, 16%). In contrast, among accident cases

Table 1. Distribution of cases by time of occurrence. n (%)

	Manner of Death				Type of Incident				
	Total n=48	Suicide n=25	Accident n=18	Undetermined n=5	Train-Pedestrian n=31	Train-Train n=10	Train-Vehicle n=2	Fall n=1	Electrocution n=4
Days									
Monday	9 (18.8)	5 (20)	3 (16.7)	1 (20)	6 (19.4)	0	2 (100)	0	1 (25)
Tuesday	2 (4.2)	2 (8)	0	0	2 (6.5)	0	0	0	0
Wednesday	8 (16.7)	6 (24)	1 (5.6)	1 (20)	8 (25.8)	0	0	0	0
Thursday	15 (31.3)	5 (20)	9 (50)	1 (20)	6 (19.4)	8 (80)	0	0	1 (25)
Friday	5 (10.4)	1 (4)	2 (11.1)	2 (40)	3 (9.7)	0	0	1 (100)	1 (25)
Saturday	5 (10.4)	3 (12)	2 (11.1)	0	3 (9.7)	2 (20)	0	0	0
Sunday	4 (8.3)	3 (12)	1 (5.6)	0	3 (9.7)	0	0	0	1 (25)
Seasons									
Winter	17 (35.4)	5 (20)	11 (61.1)	1 (20)	7 (22.6)	8 (80)	2 (100)	0	0
Spring	11 (22.9)	6 (24)	2 (11.1)	3 (60)	9 (29)	0	0	1 (100)	1 (25)
Summer	7 (14.6)	4 (16)	2 (11.1)	1 (20)	5 (16.1)	0	0	0	2 (50)
Autumn	13 (27.1)	10 (40)	3 (16.7)	0	10 (32.3)	2 (20)	0	0	1 (25)
Incident Time									
00.00-05.59	5 (10.4)	2 (8)	2 (11.1)	1 (20)	3 (9.7)	0	0	0	2 (50)
06.00-11.59	18 (37.5)	4 (16)	13 (72.2)	1 (20)	6 (19.4)	10 (100)	2 (100)	1 (100)	1 (25)
12.00-17.59	15 (31.3)	11 (44)	3 (16.7)	1 (20)	12 (38.8)	0	0	0	1 (25)
18.00-23.59	10 (20.8)	8 (32)	0	2 (40)	10 (32.3)	0	0	0	0

Values are presented as n (%). Percentages were calculated within each subgroup.

(n=18), incidents occurred most frequently on Thursdays (n=9, 50.0%), during the 06:00–11:59 time interval (n=13, 72.2%), and in the winter season (n=11, 61.1%). Detailed time distributions based on the manner of death and the type of incident are presented in Table 1 and Fig. 3.

All cases exhibited some form of external injury. Abrasions and ecchymoses were identified in 46 (95.8%) cases, lacerations in 41 (85.4%), and second-to-third degree burns in 3 (6.3%). Excluding superficial injuries, the most frequently affected anatomical regions were the thorax (n=36, 75%) and

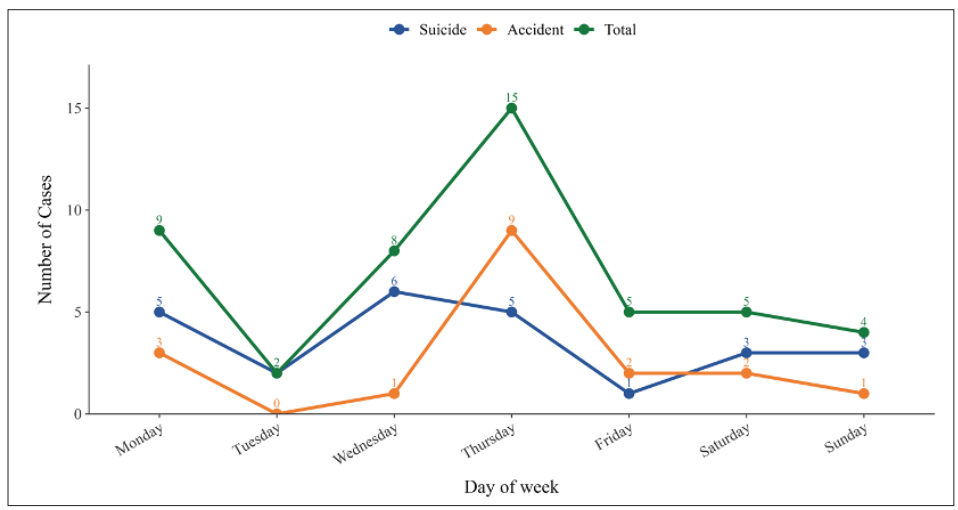


Figure 3. Distribution of railway-related deaths by day of the week according to manner of death. Cases classified as undetermined are not presented separately and are included in the total case count. Values represent the number of cases.

Table 2. Distribution of injured anatomical regions according to manner of death and type of incident

Anatomical Region	Manner of Death					Type of Incident					
	Total n=48	Suicide n=25	Accident n=18	Undetermined n=5	p	Train-Pedestrian n=31	Train-Train n=10	Train-Vehicle n=2	Fall n=1	Electrocution n=4	p
Head	33 (68.8)	22 (88)	7 (38.9)	3 (60)	0.001	26 (83.9)	4 (40)	2 (100)	0	0	0.013¥
Neck	9 (18.8)	7 (28)	1 (5.6)	1 (20)	0.111¥	8 (25.8)	1 (10)	0	0	0	0.410¥
Face	16 (33.3)	10 (40)	3 (16.7)	3 (60)	0.100	13 (41.9)	2 (20)	0	0	1 (25)	0.277¥
Thorax	36 (75)	19 (76)	12 (66.7)	5 (100)	0.501	25 (80.6)	8 (80)	2 (100)	1 (100)	0	1¥
Abdomen	23 (47.9)	8 (32)	10 (55.6)	5 (100)	0.122	14 (45.2)	7 (70)	2 (100)	0	0	0.277¥
Spine	22 (45.8)	16 (64)	4 (22.2)	2 (40)	0.007	18 (58.1)	3 (30)	1 (50)	0	0	0.159¥
Upper extremity	19 (39.6)	12 (48)	3 (16.7)	4 (80)	0.033	17 (54.8)	1 (10)	1 (50)	0	0	0.025¥
Lower extremity	17 (35.4)	11 (44)	4 (22.2)	2 (40)	0.139	13 (41.9)	3 (30)	1 (50)	1 (100)	2 (50)	0.713¥

Values are presented as n (%). Percentages were calculated within each subgroup. Column percentages are not expected to sum to 100%, as more than one pathological finding could be present in the same case. Comparisons of manner of death were restricted to suicide vs. accident cases, and comparisons of incident type were limited to train–pedestrian vs. train–train collisions, due to the small number of cases in the remaining groups. Comparisons were performed using the chi-square test. ¥: Fisher's exact test test was performed. p<0.05 was considered statistically significant.

Table 3. Distribution of bone fractures according to manner of death and type of incident

	Manner of Death					Type of Incident					
	Total n=48	Suicide n=25	Accident n=18	Undetermined n=5	p	Train-Pedestrian n=31	Train-Train n=10	Train-Vehicle n=2	Fall n=1	Electrocution n=4	p
Skull Bone	31 (64.6)	22 (88)	6 (33.3)	3 (60)	<0.001	25 (80.6)	4 (40)	2 (100)	0	0	0.04¥
Vault	29 (60.4)	21 (84)	5 (27.8)	3 (60)	<0.001	24 (77.4)	3 (30)	2 (100)	0	0	0.017¥
Base	30 (62.5)	22 (88)	5 (27.8)	3 (60)	<0.001	25 (80.6)	3 (30)	2 (100)	0	0	0.005¥
Linear	8 (16.7)	7 (28)	1 (5.6)	0	0.111	7 (22.6)	1 (10)	0	0	0	0.653¥
Displaced	26 (54.2)	18 (72)	5 (27.8)	3 (60)	0.004	21 (67.7)	3 (30)	2 (100)	0	0	0.063¥
Comminuted	22 (45.8)	18 (72)	1 (5.6)	3 (60)	<0.001	21 (67.7)	1 (10)	0	0	0	0.002¥
Face	16 (33.3)	10 (40)	3 (16.7)	3 (60)	0.1	13 (41.9)	2 (20)	0	0	1 (25)	0.277¥
Rib	34 (70.8)	17 (68)	12 (66.7)	5 (100)	0.927	23 (74.2)	8 (80)	2 (100)	1 (100)	0	1¥
Sternum	18 (37.5)	6 (24)	10 (55.6)	2 (40)	0.035	9 (29)	7 (70)	1 (50)	1 (100)	0	0.03¥
HB and/or TC	9 (18.8)	7 (28)	1 (5.6)	1 (20)	0.111¥	8 (25.8)	1 (10)	0	0	0	0.41¥
Spinal Fracture	22 (45.8)	16 (64)	4 (22.2)	2 (40)	0.007	18 (58.1)	3 (30)	1 (50)	0	0	0.159¥
Cervical	12 (25.0)	10 (40)	2 (11.1)	0		10 (32.3)	1 (10)	1 (50)	0	0	
Thoracic	8 (16.7)	6 (24)	0	2 (40)		8 (25.8)	0	0	0	0	
Lumbar	6 (12.5)	5 (20)	0	1 (20)		6 (19.4)	0	0	0	0	
Extremity	28 (58.3)	18 (72)	6 (33.3)	4 (80)	0.012	23 (74.2)	4 (40)	1 (50)	0	0	0.064¥
Upper	19 (39.6)	12 (48)	3 (16.7)	4 (80)	0.033	17 (54.8)	1 (10)	1 (50)	0	0	0.025¥
Lower	17 (35.4)	11 (44)	4 (22.2)	2 (40)	0.139	13 (41.9)	3 (30)	1 (50)	0	0	0.712¥

Values are presented as n (%). Percentages were calculated within each subgroup. Column percentages are not expected to sum to 100%, as more than one pathological finding could be present in the same case. Comparisons of manner of death were restricted to suicide vs. accident cases, and comparisons of incident type were limited to train–pedestrian vs. train–train collisions, due to the small number of cases in the remaining groups. Comparisons were performed using the chi-square test. ¥: Fisher's exact test was performed. p<0.05 was considered statistically significant. HB: Hyoid Bone; TC: Thyroid cartilage.

the head (n=33, 68.8%). Multisystem trauma (≥3 systems) was observed in 29 (60.4%) cases. Anatomical regions affected by trauma according to the type of incident and manner of death are detailed in Table 2.

Table 4. Distribution of organ injuries according to manner of death and type of incident

	Manner of Death					Type of Incident					
	Total	Suicide	Accident	Undetermined	p	Train-Pedestrian	Train-Train	Train-Vehicle	Fall	Electrocution	p
	n=48	n=25	n=18	n=5		n=31	n=10	n=2	n=1	n=4	
Brain	31 (64.6)	22 (88)	6 (33.3)	3 (60)	<0.001	26 (83.9)	3 (30)	2 (100)	0	0	0.003¥
SAH	26 (54.2)	18 (72)	5 (27.8)	3 (60)	0.006	22 (71)	2 (20)	2 (100)	0	0	0.008¥
EDH	5 (10.4)	4 (16)	0	1 (20)	0.134¥	5 (16.1)	0	0	0	0	0.31¥
SDH	11 (22.9)	9 (36)	2 (11.1)	0	0.151¥	10 (32.3)	1 (10)	0	0	0	0.238¥
IVH or IPH	5 (10.4)	5 (20)	0	0	0.070¥	5 (16.1)	0	0	0	0	0.31¥
contusion	12 (25)	9 (36)	2 (11.1)	1 (20)	0.151¥	10 (32.3)	1 (10)	1 (50)	0	0	0.238¥
laceration	18 (37.5)	15 (60)	1 (5.6)	2 (40)	<0.001	17 (54.8)	1 (10)	0	0	0	0.025¥
Lung c/l	31 (64.6)	18 (72)	8 (44.4)	5 (100)	0.102	24 (77.4)	6 (60)	1 (50)	1 (100)	0	0.413¥
Liver c/l	19 (39.6)	5 (20)	9 (50)	5 (100)	0.026	11 (35.5)	6 (60)	2 (100)	0	0	0.27¥
Spleen l	14 (29.2)	4 (16)	7 (38.9)	3 (60)	0.086¥	8 (25.8)	5 (50)	1 (50)	0	0	0.241¥
Other organs c/l	18 (37.5)	8 (32)	6 (33.3)	4 (80)	0.824	13 (41.9)	3 (30)	2 (100)	0	0	0.712¥
Dismemberment	16 (33.3)	11 (44)	2 (11.1)	3 (60)	0.021	14 (45.2)	2 (20)	0	0	0	0.265¥
Decapitation	5 (10.4)	4 (16)	0	1 (20)		5 (16.1)	0	0	0	0	
Upper extremity amputation	5 (10.4)	1 (4)	1 (5.6)	3 (60)		4 (12.9)	1 (10)	0	0	0	
Lower extremity amputation	7 (14.6)	5 (20)	1 (5.6)	1 (20)		6 (19.4)	1 (10)	0	0	0	
Abdominal transection	2 (4.2)	2 (8)	0	0		2 (6.5)	0	0	0	0	
Major vascular injuries	20 (41.7)	13 (52)	3 (16.7)	4 (80)	0.018	17 (54.8)	3 (30)	0	0	0	0.277¥
Spinal cord injury	12 (25)	9 (36)	1 (5.6)	2 (40)	0.231¥	11 (35.5)	1 (10)	0	0	0	0.231¥

Values are presented as n (%). Percentages were calculated within each subgroup. Column percentages are not expected to sum to 100%, as more than one pathological finding could be present in the same case. Comparisons of manner of death were restricted to suicide vs. accident cases, and comparisons of incident type were limited to train–pedestrian vs. train–train collisions, due to the small number of cases in the remaining groups. Comparisons were performed using the chi-square test. ¥: Fisher's exact test was performed. p<0.05 was considered statistically significant. HB: Hyoid Bone; TC: Thyroid cartilage.

Upon examination of bone fractures, rib fractures were identified as the most frequent type, accounting for 34 (70.8%) cases. Skull fractures represented the second most common injury (n=31, 64.6%). Spinal fractures were documented in 22 (45.8%) cases, most frequently involving the cervical vertebrae. Extremity fractures were also common, observed in 28 (58.3%) cases, and included 19 (39.6%) fractures of the upper extremities and 17 (35.4%) fractures of the lower extremities. Fractures of the hyoid bone and/or laryngeal cartilaginous structures were found in 9 (18.8%) cases. Then the distribution of fractures was analyzed by manner of death; fractures of the skull, spine, and upper extremities were statistically more frequent among suicide cases. With regard to the type of incident, head injuries, as well as sternum and upper extremity fractures, were more commonly associated with train–pedestrian collisions. Additional details and the overall distribution of fracture patterns are presented in Table 3.

Intracranial injuries were present in 31 (64.6%) cases. Subarachnoid hemorrhage was noted in 26 (54.2%) cases, and cerebral lacerations due to severe head trauma in 18 (37.5%) cases. Pulmonary laceration or contusion was found in 31 (64.6%) cases. Among intra-abdominal organs, the liver was the most commonly injured. Severe mutilating injuries such as decapitation, major amputations, or complete abdominal transections were noted in 16 (33.3%) cases. Major vascular injuries were identified in 20 (41.7%) cases and spinal cord injury in 12 (25%) cases. Details on internal organ injuries are presented in Table 4.

Of the 48 cases, 38 (79.2%) were declared dead at the scene. Four (8.3%) died in hospital despite ongoing cardiopulmonary resuscitation efforts, and the remaining 6 (12.5%) died during in-hospital treatment between 1 and 32 days after the incident.

Toxicological analyses of blood and urine revealed no substances in 33 (68.8%) cases. Blood ethanol was detected in 9 cases, with an average concentration of 117 mg/dL (range: 15–256 mg/dL). One of these cases also tested positive for morphine. Among the alcohol-positive cases, 3 were suicides, 3 were accidents (including 1 train–vehicle collision), and 3 were of undetermined intent. Therapeutic drugs were detected in 8 cases (antidepressants in 6, antiepileptics in 2, and antipsychotics in 1), with some cases showing more than one drug class. Seven of these deaths were suicides, and one was an accident. After evaluation of the medical history of each case, an affective disorder (e.g., depression and bipolar disorder) was found in 24% (n=6) of suicide cases. There was no documented history of psychiatric illness among the accident fatalities.

Cause-of-death analysis revealed that 3 individuals died due to cardiorespiratory arrest (probable cardiac arrhythmia) secondary to electrocution, and one high-voltage electrocution case resulted in fatal burns involving 65–70% of total body surface area. In 4 cases of train–train collisions, death was attributed to traumatic asphyxia. In the remaining 40 (83.3%) cases, death resulted from internal and/or external hemorrhage due to multisystem trauma involving vital organs and/or major vessels.

DISCUSSION

This study provides a regional forensic perspective on railway-related deaths and may contribute to the development of preventive strategies through the analysis of temporal patterns, demographic characteristics, and autopsy findings. A particularly important aspect of the study is the demonstration of distinct injury patterns between suicide and accident cases, together with the marked concentration of suicide deaths in subway settings.

The incidence of railway-related accidents has significantly declined worldwide over the years, primarily due to preventive actions and regulatory enhancements.[5,12] A comparable reduction in serious accidents has been noted in Türkiye since 2015. According to the official Railway Accident Statistics, the number of deaths reported in the past 5 years has markedly declined compared with the preceding 5-year period.[9] In our study, accidents represented 37.5% of all cases, with the majority of these deaths resulting from two catastrophic train-to-train collisions in 2018 and 2020. Despite the overall decline in accident rates, such collisions demonstrate the capacity to produce high mortality and large-scale casualty events.

Railway suicides also constitute a major concern, causing a considerable psychological burden on families, railway personnel, and witnesses.[13] From 2014 to 2023, the EU reported an annual average of 2416 railway suicides, surpassing deaths from other railway-related causes. Germany, the Czech Republic, France, and the Netherlands have reported notably higher numbers of railway suicides relative to other countries within the EU.[5] This phenomenon is partially explained by the considerable length of railway networks in those countries.[14] The percentage of railway suicides compared to all suicides varies greatly across countries, from 1.3% to 12.3%.[11] In general, suicides that occur on railways have a very high mortality rate. Railway suicides involving mainline trains can have mortality rates as high as 92%. In contrast, subway systems, where trains slow down as they enter stations, have lower mortality rates, ranging from 42% to 64%.[11] Our findings align with EU statistics, with 52.1% of cases classified as suicides. Nearly all suicide cases (n=22, 88%) took place in subway stations. This finding may be related to the accessibility of subway systems and the relative distance of mainline and commuter railways. In this context, subway systems may represent a particularly important setting for both forensic evaluation and preventive interventions.

Prior studies have shown that railway-related injuries predominantly involve males,[15-17] with male-to-female ratios in suicide cases ranging from 1.55:1 to 3.78:1.[11] In our study, males constituted the majority of suicide cases, with a male-to-female ratio of 4:1, consistent with previous findings showing male predominance in more lethal suicidal behaviors.[18]

Differences in the age groups affected by railway-related incidents have been noted across countries. In the United States, the majority of victims were aged between 16 and 45, whereas a study from southwest China indicated a greater prevalence of cases among individuals over the age of 70.[16,19] In suicide on the railway, the average age was found to be lower than in other suicide methods.[20] In the Netherlands, suicides were most frequently observed among individuals younger than 20 years and those aged 20-30 years, whereas in the United Kingdom, the highest rates occurred among persons below 25 years of age.[10,20] In Munich, subway suicides mainly occurred within the 20–29 age group.[21] Regional studies conducted in Türkiye have indicated mean ages varying from 37 to 43 years.[22-24] Our results showed a mean age of 38.5 years. Compared with reports from some other countries, our series showed a somewhat older age profile; this difference may reflect regional variation[25] in factors such as the distribution of suicide methods.

Multiple studies have examined the temporal distribution of railway suicides. In the United Kingdom, Norman et al.[10] found that the highest number occurred on Fridays and most frequently between 12:00 and 18:00. In a study of the Munich subway, Ladwig et al.[21] reported suicide peaks on Saturdays and between 06:00 and 12:00, as well as during the spring and summer months. Research on subway-related deaths in New York City showed that the majority of suicides took place on Tuesdays and between 08:00 and 12:00.[26] In Türkiye, studies demonstrated that suicides on railways occurred predominantly in the autumn season.[22] Our study revealed that suicides most frequently occurred on Wednesdays and within the 12:00–17:59 time interval. These findings may be

associated with increased accessibility to subway systems during these hours. Consistent with prior studies, seasonal variation was also evident, with the highest frequency in autumn, followed by spring.[27] The higher frequency of suicides in autumn should be interpreted cautiously, as the underlying factors were not evaluated in the present study. Most fatal accidents in our study resulted from a single major incident; therefore, a detailed temporal analysis of accident-related deaths was not undertaken.

Railway fatalities are often characterized by injuries involving multiple organ systems. Train–pedestrian collisions tend to cause extensive trauma to several anatomical regions because of the high velocity of the train. Among fatal railway incidents, head and chest trauma are most frequently encountered.[17,23,26] Consistent with prior research, most cases in our study also showed head and thoracic injuries. Overall, fractures and internal organ injuries were more common in suicides, whereas sternum fractures and liver contusions or lacerations were observed more frequently in accident cases. The presence of sternum and liver injuries may be related to train–train or train–vehicle collisions, in which anteroposterior compression forces predominate. Taken together, these findings suggest that certain injury patterns may provide useful forensic clues in the classification of suicide and accident, particularly in cases with limited scene information. In addition, injury patterns such as head–thorax trauma predominance and severe mutilating injuries, including dismemberment, may also assist in the reconstruction of level-crossing incidents, particularly when differentiation between train-related and vehicle-related trauma is required. Further comparative studies are needed to clarify the practical value of these findings.

In our study, most suicides took place in subway systems, typically when individuals suddenly jumped in front of trains entering the station at considerable speed. Such events generally caused an initial impact, followed by projection or collapse onto the tracks and subsequent crushing between the wheels and rails.[28] Compared with accidents, subway suicides have been reported to involve amputations and decapitations with higher frequency.[26] The present study identified dismemberment in 33.3% of cases, which was more common in suicides (n=11, 44%) than in accidents (n=2, 11.1%). In a study conducted in India, decapitation was reported in 40% of railway suicides,[28] whereas the corresponding rate in our study was 16%. This finding was more consistent with previously published data on subway suicides.[26] A possible explanation for the lower rate of decapitation in our series is the type of train involved. Mainline train suicides often involve individuals lying down or stepping onto the tracks in front of high-speed trains, which may produce extensive dismemberment due to the much greater kinetic energy involved. By contrast, subway suicides usually occur when individuals jump in front of trains decelerating while entering stations, which may lead predominantly to blunt trauma from projection rather than complete crushing, which may account for the relatively lower frequency of decapitation observed in subway cases.

Alcohol use has been associated with higher mortality in railway accidents and is also regarded as a contributing factor in suicidal behavior. Previous investigations of railway suicides have reported alcohol positivity in 13–48% of cases.[26,29] In our study, alcohol was identified in 12% of suicide cases. Although this proportion was lower than those reported in the literature, this difference may reflect sociocultural patterns of alcohol use in the study region.

Another critical risk factor in suicide is the presence of psychiatric illness. The prevalence of psychiatric disorders among railway suicide cases has been reported to range from 34% to 77%.[11] In New York City subway suicides, antidepressants were detected in the blood of 21% of victims.[26] Our study, in line with previous literature, identified psychiatric disorders or antidepressant use in 24% of suicide cases. Affective disorders – marked by symptoms such as hopelessness, feelings of worthlessness, social isolation, and reduced coping capacity – are well established as major contributors to suicidal ideation and behavior. These findings imply that individuals with psychiatric illness may be more likely to select easily accessible methods, including subway suicides. Consequently, preventive measures should focus on reducing stigma, improving access to mental health care, implementing public awareness initiatives, ensuring regular and sustained clinical follow-up, and strengthening family support networks.

Implications for Policy and Prevention

Our findings show that death occurred at the scene in most cases due to internal and/or external hemorrhage resulting from multisystem trauma, consistent with previous literature.[24] This underscores the need for comprehensive preventive strategies to reduce railway-related deaths. As accidents and suicides represent distinct manners of death, different preventive approaches are required. Preventive measures should therefore prioritize the implementation of modern automatic train protection systems (e.g., positive train control, European rail traffic management system/European train control system), traffic–railway segregation, and technical or physical interventions at level crossings, together with fatigue management programs and training for personnel, supported by modern, evidence-based regulations and legislation in line with international standards.[30,31]

The psychological impact of suicides on families, witnesses, and railway employees is considerable. Early identification of individuals at high risk and the implementation of tailored preventive strategies are essential. At the community level, initiatives should emphasize awareness campaigns and the establishment of crisis hotlines to improve access to support services. Restricting access to railway tracks has demonstrated effective results. The installation of platform screen doors in Hong Kong was associated with a 60% reduction in annual railway suicides over a 5-year period.[32] Further measures, including the installation of blue lights and suicide pits, have

been examined for their potential preventive effectiveness.[33] Identifying hotspots, monitoring risky behaviors through cameras and sensors, and employing computer vision-based real-time closed-circuit television systems to detect suicidal actions and notify subway or train personnel may improve prevention efforts.[34] Ongoing investment in research and development is advised to facilitate these innovations. Railway suicides are recognized as a significant global public health issue. The Global Railway Alliance for Suicide Prevention, involving countries with higher suicide rates, establishes a significant framework for experience sharing and the formulation of preventive strategies.

Limitations

There were several limitations to our study. First, the retrospective design of the study may have introduced some degree of information bias. Second, the study was conducted at a single center, which may limit the generalizability of the findings to other populations. Third, the classification of the manner of death was based on prosecutors' files, which are routinely used in forensic practice; however, some degree of misclassification cannot be entirely excluded. Fourth, information on psychiatric history was derived from prosecutors' files and available medical records and may have been incomplete or underreported. Finally, the relatively small number of cases in certain subgroups (e.g., specific accident types and undetermined cases) limits the statistical power of the comparative analyses and increases the risk of Type II errors. Therefore, findings derived from these small subgroup comparisons should be interpreted with caution. Despite these limitations, the study provides a detailed forensic perspective on railway-related deaths and offers meaningful insight into the temporal and injury-related patterns of railway-related deaths.

CONCLUSION

Railway-related deaths represent an important public health issue, emphasizing the value of preventive strategies. This study provides a regional perspective on railway-related fatalities, revealing several noteworthy findings. Accidental railway-related deaths were less frequent in the region; despite their lower frequency, the findings highlight their considerable potential to cause mass casualties. To prevent accidents, especially train–train collisions, comprehensive system-based approaches addressing human error and equipment failures are essential. In our study, most railway-related deaths were of suicidal origin and occurred in subway stations. A substantial proportion of these suicide cases involved a history of psychiatric illness, and they most often occurred during the 12:00–17:59 time interval when stations were crowded. Injuries were mostly located in the head and chest regions, and the severity was sufficient to result in death at the scene. These findings highlight the importance of preventive health policies. Accordingly, regulatory interventions and effective monitoring by central authorities and municipalities are critical. Public awareness programs, improved access to mental health services, the establishment of crisis hotlines, and the installation of physical barriers are all necessary preventive strategies. Moreover, integrating automated recognition systems into video surveillance and supporting research on computer vision-based technologies may further enhance prevention. In addition, the findings of this study highlight differences in injury distribution between suicide and accident cases, and these differences may have practical implications for the manner of death.

Further regional and national research is required, and interdisciplinary projects involving forensic medicine, psychiatry, and public health should investigate predisposing factors for suicide, including family and social dynamics, socioeconomic conditions, and barriers to treatment access. The development of shared databases and the implementation of psychological autopsies could provide valuable insights for prevention and policymaking.

Ethics Committee Approval: The study was approved by Hacettepe University Health Sciences Research Ethics Committee (Date: 18.02.2025, Decision No: 2025/05-39).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: E.N.I.; Design: E.N.I.; Supervision: B.T.; Data collection and/or processing: E.N.I., F.T.E.; Analysis and/or interpretation: E.N.I., F.T.E., B.D., B.T.; Literature review: E.N.I., F.T.E.; Writing: E.N.I., F.T.E., B.D., B.T.; Critical review: E.N.I., F.T.E., B.D., B.T.

Informed Consent: This retrospective study.

Conflict of Interest: None declared.

Financial Disclosure: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Use of AI for Writing Assistance: The authors used a language model created by OpenAI using the GPT-5 architecture to improve the readability and language refinement of the manuscript. All content was subsequently reviewed and verified by the authors.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Demiryolu ilişkili intihar ve kaza ölümleri: 10 yıllık retrospektif bölgesel otopsi çalışması

AMAÇ: Demiryolu kaynaklı ölümler önemli bir halk sağlığı sorun olup bu konuda önleyici tedbirlerin uygulanmasını gerekli kılmaktadır. Bu çalışma, Ankara bölgesinde demiryolunda meydana gelen ölümlü olayların otopsi ve olay yeri raporları inceleyerek, önleyici stratejilerin geliştirilmesine yönelik bölgesel bir perspektif sunmayı amaçlamıştır.

GEREÇ VE YÖNTEM: Adli Tıp Kurumu Ankara Grup Başkanlığı'nda 2015-2024 yılları arasında gerçekleştirilen otopsiler retrospektif olarak incelendi. Demiryolu hattı veya tren istasyonunda ölen 67 olgu içerisinde 48 travmatik ölüm olgusu çalışmaya dahil edildi. Olguların yaş, cinsiyet gibi sosyodemografik verileri ile ölüm yeri, ölüm orijini, yaralanma türü, tren türü gibi olay ilişkili değişkenler değerlendirildi. Ölüm orijini ve olay türleri arasında karşılaştırmalı analiz yapıldı.

BULGULAR: Demiryolu kaynaklı ölümlerin çoğunluğu intihar olgularından oluşmuştur. Hem intihar hem de kaza olguları ağırlıklı olarak erkek cinsiyetten olup, intiharların en sık 30–39 ve kazaya bağlı ölümlerin ise 40-49 yaş aralığında olduğu görülmüştür. İntiharların zamansal analiz sonucunda en sık sonbahar mevsiminde ve gün içerisinde en sık 12.00-17.59 saatleri arasında gerçekleştiği saptanırken; kaza olgularının en sık kış mevsiminde ve 06.00-11.59 saatleri arasında meydana geldiği görülmüştür. İntiharların neredeyse tamamı metro istasyonlarında meydana gelmiştir. Kaza ve intihar olguları karşılaştırıldığında, intihar olguları daha genç yaş grubundaki kişilerden oluşmuştur. Kafatası kırıkları, omurga yaralanmaları ve uzuv kopması bulguları intihar olgularında daha sık görülmüştür. Bununla birlikte, sternum kırıkları ve karaciğer yaralanmaları kazalarda daha yaygın olarak saptanmıştır. Bu bulgular intihar ve kaza ölümleri arasındaki yaralanma paterni farklılığını ve intiharların metro istasyonlarında yoğunlaştığını göstermektedir.

SONUÇ: Önleyici ve düzenleyici tedbirler demiryolu kaynaklı hem kaza hem intihar ölümlerini azaltabilir. Toplumsal farkındalık kampanyaları, fiziksel bariyerlerin yerleştirilmesi ve otomatize video analiz tabanlı erken uyarı sistemleri özellikle metro intiharlarının azaltılmasında önemli bir rol oynayabilir. Adli tıp perspektifinden incelendiğinde, çalışmada saptanan yaralanma paterni farklılığı özellikle olay yeri bulgularının yetersiz olduğu olgularda ölüm orijini değerlendirilmesinde pratik katkı sağlayabilir.

Anahtar sözcükler: Adli tıp; adli travmatoloji; demiryolu; intihar; otopsi.

Ulus Travma Acil Cerrahi Derg 2026;32(11):1389-1399 DOI: 10.14744/tjtes.2026.32746

ORIGINAL ARTICLE

Emergency department evaluation of injuries caused by falls from horses: A retrospective study

Tuhan Kurtulmus, Sercan Oktar, Hakan Eskara, Yusuf Demir, Osman Yuksel Yavuz

Department of Orthopedic Surgery, Sancaktepe Martry Prof. Dr. Ilhan Varank Education and Research Hospital, İstanbul-*Türkiye*

ABSTRACT

BACKGROUND: Since their domestication, horses have played an important role in human life. Today, horseback riding is widely practiced for recreational and therapeutic purposes. Despite this, horseback riding–related injuries remain an underreported public health problem in the emergency medicine literature. The aim of this study was to evaluate the injury patterns, management strategies, and clinical outcomes of patients presenting to the emergency department after falls from horses.

METHODS: This retrospective study included patients who presented to the emergency department of Sancaktepe Martry Prof. Dr. Ilhan Varank Education and Research Hospital between 2019 and 2024 following falls from horses. Patient data were obtained from the hospital information system and Picture Archiving and Communication System. Demographic characteristics, injury location, treatment modality, length of hospital stay, and clinical outcomes were recorded and analyzed statistically.

RESULTS: A total of 86 patients were included in the study, of whom 43 (50%) were male and 43 (50%) were female. The mean age was 34±12.1 years (range: 7–69 years). Eight patients (9.3%) were under 18 years of age, while 78 patients (90.7%) were adults. Eighteen patients (20.9%) required hospital admission, whereas 68 patients (79.1%) were managed on an outpatient basis in the emergency department. Injury severity was assessed using the Injury Severity Score, with a mean value of 7.6. The majority of patients had minor injuries. The most commonly injured body region was the upper extremity, observed in 39 patients (45.3%). Surgical intervention was required in 18 patients (20.9%). Pelvic and spinal injuries were significantly more common among female riders, whereas lower extremity injuries predominated among male riders ($p<0.05$). Five patients (5.8%) required post-operative intensive care. One patient with severe head trauma (Glasgow Coma Scale 5) who was not using protective equipment died during follow-up.

CONCLUSION: Horseback riding–related injuries frequently involve multiple organ systems and may present to the emergency department with varying levels of severity. Although many patients sustain high-energy trauma, most are managed within the scope of orthopedic and traumatology services, with a considerable proportion requiring surgical or conservative intervention. This study represents the first comprehensive evaluation in Turkey of patients presenting to the emergency department after falls from horses. Given the potential risk of severe injury and mortality, the absence of protective equipment in the fatal case suggests a possible role of safety measures; however, further studies are needed to better define their impact.

Keywords: Emergency department; equestrian injuries; falls, horse-related trauma; surgery.

INTRODUCTION

Since their domestication, horses have played a significant role in human life. Throughout history, particularly in Central Asia, nomadic lifestyles as well as wars and conquests placed horseback riding at the center of daily human activity. In recent years, beyond recreational use, horses have also been increasingly utilized for therapeutic purposes due to their morphological, physiological, sensory, emotional, and social benefits. For these reasons, horseback riding continues to attract individuals of all ages as a recreational activity. In developed countries, equestrian sports are often introduced

Cite this article as: Kurtulmus T, Oktar S, Eskara H, Demir Y, Yavuz OY. Emergency department evaluation of injuries caused by falls from horses: A retrospective study. Ulus Travma Acil Cerrahi Derg 2026;32:1400-1406.

Address for correspondence: Tuhan Kurtulmus

Department of Orthopedic Surgery, Sancaktepe Martyr Prof. Dr. Ilhan Varank Training and Research Hospital, Istanbul, Türkiye

E-mail: drtuhan@gmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(11):1400-1406 DOI: 10.14744/tjtes.2026.47554

Submitted: 19.01.2026 Revised: 12.04.2026 Accepted: 05.05.2026 Published: 05.11.2026

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during childhood, and participation has been associated with benefits such as increased responsibility and greater respect for animals.[1,2]

Despite these benefits, horseback riding is associated with a considerable risk of injury. In the United States, approximately 100,000 emergency department visits annually are attributed to horse-related injuries.[3] A Swedish epidemiological study reported 1,756 horseback riding–related injuries, including three fatalities. Horseback riding has been identified as a sport with high morbidity and has been associated with advanced age, vertebral fractures, and thoracic injuries.[4] Several studies have demonstrated that horseback riding injuries occur frequently in children and adolescents.[5]

Although the overall risk of injury during horseback riding has been reported to be comparable to that of other common sports such as soccer and ice hockey, the severity of equestrian-related injuries is disproportionately higher.[5,6] In pediatric populations, equestrian injuries have been shown to result in more severe trauma compared with injuries sustained in most other sports.[6,7]

The mechanisms of injury in horseback riding, whether recreational or competitive, are often complex and high-energy. Sudden deceleration of the horse may cause the rider to be thrown forward while remaining unprotected and unbalanced. During a fall, the rider may undergo rotational motion around the horse, a mechanism that has been reported as one of the most fatal scenarios in equestrian sports.[8]

Previous studies have identified head injuries and long bone fractures as the most common types of horse-related trauma. In addition, horse-related injuries have been reported to occur more frequently in females, with the highest incidence observed around 14 years of age.[7] The clinical outcomes of these injuries vary widely, affecting hospital length of stay, treatment modality, and time to return to normal activities. In one large analysis evaluating hospitalization time across different sports-related injuries, equestrian activities accounted for 33.3% of all hospital days, exceeding those associated with motorsports, soccer, and skiing.[4,9]

Horseback riding–related injuries constitute an important subset of trauma admissions to emergency departments, often resulting from high-energy mechanisms and requiring prompt evaluation. These injuries are associated with a higher likelihood of hospitalization and surgical intervention compared with many other recreational activities.[3,4,10]

The present study was conducted to evaluate the frequency and patterns of injuries associated with horseback riding, to analyze injury mechanisms, and to investigate the relationships between age, sex, and trauma characteristics among patients presenting to the emergency department.

MATERIALS AND METHODS

This retrospective study included patients who presented to the emergency department of Sancaktepe Martry Prof. Dr. Ilhan Varank Education and Research Hospital between 2019 and 2024 following falls from horses. A horseback riding–related injury was defined as any injury sustained as a direct result of riding or falling from a horse that required medical evaluation in the hospital. Patients who presented to the emergency department with horse-related injuries not caused by riding or falling from a horse, including injuries due to being bitten or kicked by a horse or sustained during horse feeding, were excluded from the study. Patients of all age groups were eligible for inclusion.

Patients were categorized according to the clinical specialties consulted in the emergency department. This study was approved by the Sancaktepe Martyr Prof. Dr. Ilhan Varank Education and Research Hospital, İstanbul-Türkiye (Date: 17.02.2025, Decision no: 2025/49) and was conducted in accordance with the principles of the Declaration of Helsinki. As this was a retrospective study using anonymized data, the requirement for informed consent was waived.

Medical records were retrospectively reviewed using the hospital Health Information System, and radiologic images were evaluated through the Picture Archiving and Communication System. Following admission, patients were classified according to their hospitalization status as either ward admission or intensive care unit (ICU) admission. ICU admissions were further categorized as preoperative or post-operative. Data collected included patient age, sex, injury location, type of injury, treatment modality, length of hospital stay, and need for intensive care.

Injury locations were defined as follows: upper extremity injuries included injuries from the shoulder to the fingertips; lower extremity injuries included injuries from the hip to the toes; spinal injuries involved the cervical, thoracic, or lumbar spine; thoracic injuries were defined as non-spinal injuries to the thoracic region; pelvic injuries included osseous and non-osseous injuries of the pelvic region; and head injuries encompassed injuries to the head and facial regions. Each injury was classified as either a fracture or a soft-tissue injury.

Data regarding helmet use and protective equipment were extracted from medical records when available.

Statistical Analysis

Microsoft® Office Excel© was used for data collection, and statistical analyses were performed using the Statistical Package for the Social Sciences version 21.0 (IBM Corp., Chicago, IL, USA). Continuous variables were analyzed using the independent samples t-test. Normality of continuous variables was assessed using the Shapiro–Wilk and Kolmogorov-Smirnov tests. Categorical variables were analyzed using the Chi-square test. A $p<0.05$ was considered statistically significant, and p-values were reported to three decimal places.

RESULTS

A total of 86 patients who presented to the emergency department following falls from horses during the study period

Table 1. The sex distribution of the patients

Sex	Number	Percentage
Male	43	50
Female	43	50
Total	86	100

Table 2. The treatment distribution of the patients

Treatment options	Number	Percentage
Outpatient treatment	68	79.1
Inpatient treatment	18	20.9
Total	86	100

Table 3. Distribution of injury severity according to ISS

ISS category	Number	Percentage
Minor (<9)	51	59.3
Moderate (9–15)	12	14
Severe (16–24)	19	22.1
Critical (≥25)	4	4.7
Total	86	100

ISS: Injury severity score.

Table 4. The distribution of the affected anatomical site of the patients

Trauma site	Number	Percentage
Upper extremity	39	45.3
Lower extremity	9	10.5
Spine /spinal	10	11.6
Cranial/head	13	15.1
Pelvis/abdomen	11	12.8
Thorax	4	4.7
Total	86	100

Table 5. The length of hospitalization of patients

Length of hospitalization	Number	Percentage
1 Day	4	22.2
2–6 Days	6	33.3
7 Days and over	8	44.5

Table 6. The types of treatment of patients

Treatment options	Number	Percentage
Rest	35/86	40.7
Surgery	18	20.9
Plaster/Cast	14	16.3
Velpau/Shoulder strap	11	12.8
Suture	5	5.8
Brace/Corset	3	3.5

were included. Of these, 43 patients (50%) were male, and 43 patients (50%) were female. The mean age was 34 ± 12.04 years (range: 7–69 years). Eight patients (9.3%) were younger than 18 years, while 78 patients (90.7%) were adults. No statistically significant association was found between sex and overall trauma distribution ($p>0.05$). Eighteen patients (20.9%) required hospital admission, whereas 68 patients (79.1%) were treated on an outpatient basis (Tables 1 and 2). Injury severity was evaluated using the Injury Severity Score (ISS). The majority of patients had minor injuries (ISS <9), accounting for 59.3% (n=51) of the cohort. Moderate injuries (ISS 9–15) were observed in 14.0% (n=12) of patients, while 22.1% (n=19) had severe injuries (ISS 16–24). Critical injuries (ISS ≥25) were present in 4.7% (n=4) of patients (Table 3). The mean ISS was 7.6, indicating that most injuries were of low severity.

Data on helmet and protective equipment use were available for 36 patients. Of these, 21 patients (58.3%) were using protective equipment at the time of injury, whereas 15 patients (41.7%) were not. Information on protective equipment use was not available for the remaining patients.

Trauma Sites

The distribution of trauma sites was as follows: Upper extremity injuries in 39 patients (45.3%), head/cranial injuries in 13 patients (15.1%), pelvis/abdominal injuries in 11 patients (12.8%), spinal injuries in 10 patients (11.6%), lower extremity injuries in 9 patients (10.5%), and thoracic injuries in 4 patients (4.7%) (Table 4).

When trauma sites were evaluated according to sex, spinal and cranial injuries were more frequent in female patients (65.2%), as were pelvis/abdominal/thoracic injuries (66.7%) compared with males ($p<0.05$). In contrast, lower extremity injuries were more common in male patients (77.8%) ($p<0.05$).

Treatment Modalities and Hospitalization

Of the total cohort, 68 patients (79.1%) were managed on an outpatient basis, while 18 patients (20.9%) required inpatient treatment. The mean length of hospital stay among admitted patients was 5.05 days. Hospitalization duration was 1 day in 4 patients (22.2%), 2–6 days in 6 patients (33.3%), and 7 days or longer in 8 patients (44.5%) (Table 5).

Table 7. Trauma sites and surgical procedures of surgically treated patients

	Age (years)	Sex	Trauma Site/Injury	Surgical Procedure
1	42	M	Tibial plateau fracture	Plate and screw osteosynthesis
2	42	F	Distal radius fracture	Plate and screw osteosynthesis
3	31	M	Distal radius fracture	Plate and screw osteosynthesis
4	25	M	Distal radius fracture	Plate and screw osteosynthesis
5	30	F	Both-bone forearm fracture	Plate and screw osteosynthesis
6	33	F	Scaphoid fracture	Screw osteosynthesis
7	33	F	Femur fracture+pelvic ring fracture	Femur IMN osteosynthesis
8	38	M	Lateral malleolus fracture	Plate and screw osteosynthesis
9	25	F	Lumbar vertebral fracture	T11-L3 posterior instrumentation
10	21	F	Lumbar vertebral fracture	L2-L4 posterior instrumentation
11	24	F	Humerus fracture	Plate and screw osteosynthesis
12	25	F	Humerus fracture	Plate and screw osteosynthesis
13	26	M	Humerus fracture	Plate and screw osteosynthesis
14	35	F	AC joint separation	Hook plate
15	25	F	AC joint separation	Hook plate
16	36	F	Subdural hematoma	Decompression
17	47	M	Intra-abdominal free fluid/ retroperitoneal hematoma	Laparoscopy
18	36	F	Intra-abdominal free fluid/ retroperitoneal hematoma	Laparoscopy

Among outpatients, 34 were female, and 34 were male, whereas hospitalized patients included 9 females and 9 males; this difference was not statistically significant ($p>0.05$). No patients under 18 years of age required hospitalization. All admitted patients were adults.

Eighteen patients (20.9%) underwent surgical intervention. Conservative treatments included shoulder slings in 11 patients (12.8%), splints in 14 patients (16.3%), primary suturing in 5 patients (5.8%), and brace or corset application in 3 patients (3.5%). Thirty-five patients (39%) did not require any medical intervention beyond evaluation and were discharged with recommendations (Table 6).

Surgical Diagnoses and Outcomes

Among surgically treated patients, distal radius fractures and humerus fractures were each observed in three patients, lumbar vertebral fractures and acromioclavicular joint separations in two patients each, and intra-abdominal perforation in two patients. Tibial plateau fracture, bilateral forearm fracture, scaphoid fracture, femoral fracture, lateral malleolus fracture, and subdural hematoma were each observed in one patient. Detailed diagnoses and surgical procedures are summarized in Table 7.

No patients were admitted directly from the emergency department to the ICU. However, following surgical intervention, 5 patients (5.8%) required post-operative ICU care.

One patient died during follow-up after undergoing decompressive surgery for severe head trauma. The patient was a 36-year-old female who sustained a subdural hematoma following a fall from a horse. On admission, the Glasgow Coma Scale (GCS) score was 5, consistent with severe neurological injury. It was documented that the patient was not using a helmet or any protective equipment at the time of injury.

Surgical Consultations

Analysis of surgical consultations revealed that orthopedics and traumatology was the most frequently consulted specialty, involving 56 patients (65.1%). Neurosurgery consultations were requested for 21 patients (24.5%), general surgery for 2 patients (2.3%), and gynecology and obstetrics for 1 patient (1.2%). Orthopedics and traumatology consultations were statistically predominant ($p<0.05$) (Table 8).

Table 8. The distribution of surgical units where patients were consulted by the emergency department

Surgical units consulted in the emergency department	Number	Percentage
Orthopedics and traumatology	56	65.1
Brain and nerve surgery	21	24.5
Thoracic surgery	6	7
General surgery	2	2.3
Gynecology and obstetrics	1	1.2

When consultations were analyzed by trauma site, orthopedics and traumatology was the most frequently consulted specialty for upper and lower extremity injuries, whereas neurosurgery was most commonly consulted for head and cranial injuries ($p<0.05$). Evaluation of hospitalization duration by trauma site showed that hospital stays of 7 days or longer occurred in 4 patients with upper extremity injuries and in two patients with lower extremity injuries; this difference was not statistically significant ($p>0.05$) (Table 5).

DISCUSSION

In this study, the distribution of male and female patients presenting to the emergency department after falls from horses was equal. Previous studies have reported varying sex distributions in equestrian-related trauma. An Australian study reported that 59% of injured riders were female, whereas studies from the Netherlands demonstrated female predominance rates of up to 81%.[11-13] The equal sex distribution observed in our cohort differs from much of the existing literature and suggests that sex-related injury patterns in equestrian trauma may vary according to regional and cultural factors. Therefore, definitive conclusions regarding gender predilection in equestrian-related emergency department admissions cannot be established.

Regarding age distribution, the majority of patients presenting to the emergency department were adults, with 90.7% being older than 18 years. This finding is consistent with previous studies reporting a higher incidence of emergency department admissions among adult riders.[1,11] In contrast, a Swedish study reported that riders younger than 18 years accounted for 51% of equestrian-related injuries.[7] This discrepancy may be attributed to differences in demographic characteristics and riding practices, particularly the higher participation of children in organized equestrian activities in Scandinavian countries. As most available data originate from limited geographic regions, further emergency department–based studies from different populations are needed to better define age-related risk factors.

In contrast to previous studies that estimate injury severity based solely on treatment requirements or hospitalization status, our study provides an objective assessment of trauma severity using the ISS, allowing for a more standardized and comparable evaluation. The majority of patients in our cohort had low ISS values, suggesting that most injuries were of mild to moderate severity despite the high-energy mechanism of trauma. However, the presence of severe and critical cases highlights the potential for life-threatening injuries associated with horseback riding.

Evaluation of injury patterns among emergency department presentations demonstrated that upper extremity injuries were the most common (45.3%), followed by head/cranial injuries (15.1%) and pelvis/abdominal injuries (12.8%). These findings are consistent with previous emergency medicine–focused studies identifying these regions as the most frequently injured anatomical sites in horseback riding–related trauma.[7,11,14] The predominance of upper extremity injuries likely reflects defensive mechanisms during falls, whereas head and axial injuries emphasize the high-energy nature of equestrian trauma.

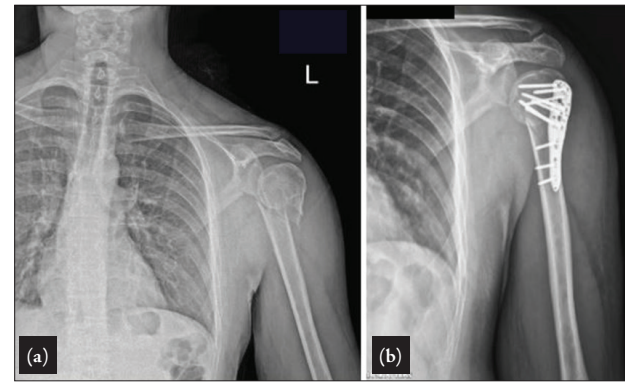


Figure 1. Proximal humerus (a) fracture and (b) post-operative radiograph.

When trauma sites were analyzed according to sex, male riders more frequently sustained upper and lower extremity injuries, whereas female riders were more commonly affected by spinal, cranial, pelvic, abdominal, and thoracic injuries. These differences were statistically significant. One possible explanation is that male riders may attempt to break their fall using their extremities, whereas female riders may sustain more axial injuries due to differences in fall mechanics. However, this interpretation remains speculative, as there is limited evidence addressing biomechanical differences during falls. Further emergency department–based observational studies are required to clarify these mechanisms (Fig. 1).

Analysis of emergency department consultation patterns revealed that orthopedics and traumatology was the most frequently consulted specialty, accounting for 65.1% of cases, followed by neurosurgery at 24.5%. This finding is consistent with previous studies reporting that equestrian-related injuries presenting to the emergency department often require musculoskeletal and neurological evaluation due to high-energy trauma mechanisms.[3,7,11,15] These results highlight the importance of a multidisciplinary approach in the acute management of equestrian-related injuries.

In terms of treatment outcomes, most patients presenting to the emergency department were managed on an outpatient basis, whereas approximately one-fifth required hospitalization. Surgical intervention was necessary in 20.9% of cases, a rate that lies between those reported in previous studies, which range from 7% to 43%.[1,2,4,7] This variability may be related to differences in injury severity, patient selection, and referral patterns. The observed need for surgical intervention further supports the classification of horseback riding–related injuries as high-energy trauma.

Hospital length of stay varied according to injury type and

severity. In our cohort, the mean duration of hospitalization was 5.05 days. Although no patients were admitted directly from the emergency department to the ICU, 5.8% required post-operative intensive care. One patient died during follow-up after undergoing decompressive surgery for severe intracranial injury. This fatal case involved a patient with a GCS score of 5 on admission who was not using protective equipment, highlighting the potential role of helmet use in reducing the severity of head injuries.

These findings suggest that equestrian-related injuries presenting to the emergency department may result in significant morbidity and, in rare cases, mortality, supporting their classification as potentially life-threatening high-energy trauma.

This study has several limitations. First, its retrospective and single-center design may limit the generalizability of the findings to other populations and healthcare settings. Second, the analysis relied on medical records obtained from hospital information systems, which may be subject to incomplete documentation or coding inaccuracies. Third, detailed information regarding rider experience, use of protective equipment, helmet compliance, and exact injury mechanisms was not consistently available and therefore could not be systematically evaluated. In addition, long-term functional outcomes and return-to-activity data were not assessed. Despite these limitations, injury severity was objectively assessed using the ISS for all patients. GCS scores were not consistently available for all patients due to the retrospective design of the study.

CONCLUSION

Approximately one-fifth of patients presenting to the emergency department with equestrian-related injuries require hospital admission, reflecting the potential severity of these traumas. Although most patients had low ISS values, indicating generally mild to moderate injuries, the presence of severe cases and a fatal outcome highlights the risk of life-threatening complications. Upper and lower extremity injuries, as well as pelvic and spinal trauma, were among the most commonly affected regions. These findings suggest that equestrian-related injuries may present with a wide spectrum of severity. Emergency physicians should maintain a high index of suspicion and perform careful evaluation of these anatomical regions. The absence of protective equipment in the fatal case further suggests a potential role of safety measures; however, further studies are needed to better define their impact.

Ethics Committee Approval: This study was approved by the Sancaktepe Martry Prof. Dr. Ilhan Varank Education and Research Hospital Ethics Committee (Date: 17.02.2025, Decision No: 2025/49).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: T.K.; Design: S.O.; Supervision: O.Y.Y.; Resource: S.O., Y.D.; Materials: H.E.; Data collection and/or processing: S.O.; Analysis and/or interpretation: S.O.; Literature review: O.Y.Y.; Writing: S.O., Y.D.; Critical review: H.E.

Conflict of Interest: None declared.

Informed Consent: As this was a retrospective study using anonymized data, the requirement for informed consent was waived.

Financial Disclosure: The author declared that this study has received no financial support.

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ORİJİNAL ÇALIŞMA - *ÖZ*

At düşmelerine bağlı yaralanmaların acil serviste değerlendirilmesi: Retrospektif bir çalışma

AMAÇ: Atlar tarih boyunca insan yaşamında önemli bir yer edinmiştir. Günümüzde at biniciliği hem rekreasyonel hem de terapötik amaçlarla giderek yaygınlaşmaktadır. Buna rağmen, attan düşmeye bağlı yaralanmalar literatürde sınırlı olarak ele alınmıştır. Bu çalışmanın amacı, at biniciliği sırasında meydana gelen travmaları değerlendirmektir.

GEREÇ VE YÖNTEM: Bu retrospektif çalışma, 2019–2024 yılları arasında Sancaktepe Şehit Prof. Dr. İlhan Varank Eğitim ve Araştırma Hastanesi acil servisine attan düşme şikayeti ile başvuran hastaları kapsamaktadır. Veriler hastane otomasyon sistemi ve görüntüleme arşiv sistemi (PACS) üzerinden elde edilmiştir. Isırılma, tekmelenme veya at bakımı sırasında gelişen yaralanmalar çalışma dışı bırakılmıştır. Yaş, cinsiyet, travma bölgesi, tedavi yöntemi ve hastanede yatış süresi analiz edilmiştir.

BULGULAR: Toplam 86 hasta değerlendirilmiştir. Hastaların %50'si erkek, %50'si kadındır ve ortalama yaş 34±12.1 (7–69) yıldır. Hastaların %20.9'u hastaneye yatırılırken, %79.1'i ayaktan tedavi edilmiştir. Ortalama ISS değeri 7.6 olup, çoğunluk hafif yaralanma grubundadır. En sık yaralanan bölge üst ekstremitedir (%45.3). Hastaların %20.9'unda cerrahi tedavi uygulanmıştır. Kadınlarda pelvis ve omurga, erkeklerde alt ekstremite yaralanmaları daha sık saptanmıştır ($p<0.05$). Beş hastada yoğun bakım ihtiyacı gelişmiş, GKS 5 olan ve koruyucu ekipman kullanmayan bir hasta eksitus olmuştur.

SONUÇ: At biniciliğine bağlı yaralanmalar hafif travmalardan yaşamı tehdit eden durumlara kadar geniş bir spektrumda seyretmektedir. Çoğu hasta ortopedi ve travmatoloji kapsamında yönetilmektedir. Ağır olgularda koruyucu ekipman kullanımının önemli olabileceği düşünülmekle birlikte, bu ilişkinin netleştirilmesi için ileri çalışmalara ihtiyaç vardır.

Anahtar sözcükler: Acil servis; atla ilişkili travma; binicilik yaralanmaları; cerrahi; düşmeler.

Ulus Travma Acil Cerrahi Derg 2026;32(11):1400-1406 DOI: 10.14744/tjtes.2026.47554

ORIGINAL ARTICLE

Clinical outcomes and risk factors for complications after closed reduction and internal fixation of pediatric femoral neck fractures

Erman Öğümsöğütlü,[1] Sezgin Bahadır Tekin,[2] Bahri Bozgeyik[3]

[1]Department of Orthopaedics and Traumatology, Yalova Training and Research Hospital, Yalova-*Türkiye*
[2]Clinic of Orthopaedics and Traumatology, Medical Point Hospital, Gaziantep-*Türkiye*
[3]Department of Orthopaedics and Traumatology, Gaziantep University Faculty of Medicine, Gaziantep-*Türkiye*

ABSTRACT

BACKGROUND: Pediatric femoral neck fractures are rare but may lead to severe complications. This study aimed to evaluate clinical outcomes after closed reduction and internal fixation in pediatric femoral neck fractures and to identify risk factors associated with post-operative complications.

METHODS: A retrospective analysis was performed on 41 pediatric patients (mean age, 10.6 years) treated with closed reduction and internal fixation. The mean follow-up period was 64 months (25–160). Demographic variables, fracture type, displacement, time to surgery, reduction quality, fixation method, and physeal penetration were analyzed as potential risk factors. Recorded complications included avascular necrosis (AVN), premature physeal closure (PPC), non-union, limb shortening, coxa vara, and coxa valga. Clinical outcomes were evaluated according to the Ratliff classification.

RESULTS: Fracture union was achieved in 95.1% of patients. Initial displacement and reduction quality were significantly associated with both clinical outcomes and complication rates ($p<0.05$). Delayed surgery was linked to a higher incidence of AVN ($p=0.013$). Physeal penetration was associated with worse clinical outcomes, especially an increased risk of PPC ($p=0.002$) and AVN ($p=0.031$).

CONCLUSION: Pediatric femoral neck fractures remain associated with high complication rates. Initial displacement, inappropriate reduction, prolonged time to surgery, and physeal penetration were found to be risk factors for complications. Early anatomical reduction and physeal-sparing fixation are key to improving outcomes.

Keywords: Clinical outcomes; complications; pediatric femoral neck fractures; risk factors.

INTRODUCTION

Pediatric femoral neck fractures represent a rare but serious injury, accounting for approximately 1% of all pediatric fractures.[1,2] Despite their low incidence, these fractures carry a high risk of devastating complications, including avascular necrosis (AVN) of the femoral head, coxa vara, coxa valga, non-union, premature physeal closure (PPC), and limb-length discrepancy.[3-5] Reported incidences of AVN following pediatric femoral neck fractures vary widely in the literature, ranging from 0% to 92%.[5] Coxa vara rates following pediatric femoral neck fractures have been reported to range from 5.2% to 54.5%.[6,7] The vascular supply to the femoral head in children is both fragile and variable, and developmental changes in the proximal femoral circulation further increase the susceptibility of the epiphysis to vascular compromise following trauma.[8,9] As a result, affected patients may experience persistent pain, limited range of motion, gait disturbances, and often require additional surgical procedures.[10]

Cite this article as: Öğümsöğütlü E, Tekin SB, Bozgeyik B. Clinical outcomes and risk factors for complications after closed reduction and internal fixation of pediatric femoral neck fractures. Ulus Travma Acil Cerrahi Derg 2026;32:1407-1415.

Address for correspondence: Erman Öğümsöğütlü
Department of Orthopaedics and Traumatology, Yalova Training and Research Hospital, Yalova, Türkiye
E-mail: eogumsogutlu@gmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(11):1407-1415 DOI: 10.14744/tjtes.2026.63828
Submitted: 18.11.2025 Revised: 06.04.2026 Accepted: 20.04.2026 Published: 05.11.2026
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Numerous factors – including patient age, fracture type, displacement, treatment, and timing of surgery – have been proposed to influence the development of these complications.[11] While numerous studies have addressed pediatric femoral neck fractures, few have focused exclusively on closed-reduction cases and detailed analysis of physeal penetration as a risk factor.

Closed reduction and internal fixation aim to restore anatomical alignment while preserving vascular integrity, thereby reducing the likelihood of iatrogenic injury. The present study focused exclusively on patients treated with closed reduction and internal fixation, allowing for a more homogeneous analysis of patient- and fracture-related prognostic factors. However, few studies have focused exclusively on cases managed with closed reduction, which limits the understanding of prognostic factors specific to this less invasive approach.

Therefore, the present study aimed to evaluate the mid- to long-term clinical and radiological outcomes of pediatric femoral neck fractures treated with closed reduction and internal fixation and to identify the prognostic factors associated with post-operative complications.

MATERIALS AND METHODS

Study Design and Population

This retrospective single-center study included pediatric patients who underwent surgical treatment for femoral neck fractures between 2009 and 2020 at our clinic. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Gaziantep University (Date: 09.11.2022 / No: 2022/406).

Inclusion criteria were: (1) Radiologically confirmed femoral neck fracture, (2) age ≤16 years, (3) open proximal femoral physis with growth potential, (4) a minimum clinical and radiological follow-up of 24 months, and (5) closed reduction and internal fixation performed. Patients who required open reduction were excluded to ensure a homogeneous study population. Exclusion criteria included: (1) Pathological fractures, (2) absence of adequate imaging, and (3) incomplete or insufficient (<24 months) follow-up data.

Of the 64 patients, 13 underwent open reduction, 5 underwent surgery more than 24 h later, 4 had short follow-up, and 1 had a pathological fracture and was excluded from the study. A total of 41 patients who met the criteria were included and evaluated in the study. For each patient, demographic and clinical variables were recorded, including age, sex, side, mechanism of injury, fracture type, initial displacement, time to surgery, fixation method, and presence of physeal penetration. Mechanisms of injury included falls from height, traffic accidents, and sports-related trauma. Demographic characteristics and treatment details are summarized in Table 1.

Surgical Technique

All surgeries were performed following a standardized institutional protocol. In situ fixation was performed for non-displaced fractures. For all displaced fractures, closed reduction and internal fixation were performed under fluoroscopic guidance. In our institutional treatment algorithm, closed reduction is considered the first-line approach for all displaced pediatric femoral neck fractures to minimize additional vascular insult to the femoral head. Open reduction is reserved for cases in which acceptable alignment cannot be achieved by closed reduction or when adequate stability cannot be ensured. For study purposes, residual displacement >2 mm was categorized as unacceptable reduction. However, intraoperative decision-making regarding conversion to open reduction was not based solely on this threshold. In some borderline cases, residual step-off remained below 4 mm, which has been considered a good reduction in previous reports, and these reductions were therefore accepted without proceeding to open reduction.[12-14] Cases treated with open reduction or plate fixation were excluded from the study, as this study was specifically designed to evaluate outcomes following closed reduction and internal fixation.

Fixation methods included smooth Kirschner wires and partially threaded cannulated screws. The choice of fixation method was based on patient age, body weight, femoral neck size, and fracture stability. In general, smooth Kirschner wires were preferred in younger children (typically under 6 years of age) to reduce the risk of physeal injury. In contrast, partially threaded cannulated screws were used in older children to provide stronger fixation and compression across the fracture site. Patients with Delbet Type IV fractures treated with plate fixation were not included in this study, as all such cases were managed with open reduction and were therefore excluded in accordance with the study design focusing on closed reduction. K-wires were left outside the skin to facilitate removal without the need for a second surgical procedure. To minimize the risk of migration, wires were appropriately positioned under fluoroscopic guidance and bent externally after insertion.

Physeal penetration was avoided whenever possible. However, in selected cases – particularly when the proximal fragment was small or sufficient stability could not otherwise be achieved – crossing the physis was considered necessary. In our series, physeal penetration was performed selectively based on intraoperative stability requirements. None of the Delbet Type IV fractures in our series required physeal penetration. Routine decompression of the fracture hematoma was not performed during the surgical procedures. Casts were applied in addition to fixation only in children under 10 years of age, in whom adequate communication and cooperation could not be ensured, which is consistent with the existing literature.[5] Post-operative immobilization was applied in all patients for 8 weeks.

Radiological and Clinical Evaluation

Fractures were classified on anteroposterior pelvic radio-

Table 1. Demographic characteristics and treatment details of the patients (n=41)

Variable	n (%) or Mean±SD
Age	10.56±4.55
Sex	
Male	25 (61)
Female	16 (39)
Side of injury	
Left	18 (43.9)
Right	23 (56.1)
Fracture mechanism (n/%)	
Fall from height	18 (43.9)
Traffic accident	9 (22)
Sports-related injury	14 (34.1)
Delbet classification (n/%)	
2	28 (68.3)
3	10 (24.4)
4	3 (7.3)
Initial displacement (n/%)	
Yes	24 (58.5)
No	17 (41.5)
Time to surgery (n/%)	
<8 h	24 (58.5)
8–16 h	12 (29.3)
16–24 h	5 (12.2)
Reduction quality	
Unacceptable	7 (17.1)
Acceptable	34 (82.9)
Type of fixation	
Kirschner wire	12 (29.3)
Cannulated screw	29 (70.7)
Physis penetration	
No	21(51.2)
Yes	20 (48.8)

SD: Standard deviation.

graphs according to the Delbet classification popularized by Colonna,[15,16] as follows: Type I, transphyseal (epiphyseal separation); Type II, transcervical; Type III, cervicotrochanteric (basicervical); and Type IV, intertrochanteric.

The quality of reduction was assessed according to the criteria described by Song.[17] A residual displacement of <2 mm and angulation of <20° were defined as an acceptable reduction; all other cases were categorized as unacceptable reduction.

At the final follow-up, clinical and radiological outcomes were evaluated using the Ratliff criteria,[3] which classify results as good, fair, or poor. Physeal penetration is defined as visible crossing of the growth plate on AP or lateral radiographs. Complications – including coxa vara, coxa valga, non-union, AVN, PPC, and limb shortening were documented and summarized in Table 2.

Table 2. Recorded post-operative complications

Complication	n	%
Premature physis closure	15	36.6
Avascular necrosis	12	29.3
Shortening	11	26.8
Coxa vara	4	9.8
Non-union	2	4.9
Coxa valga	1	2.4
Overall	18	43.9

Statistical Analysis

Numerical variables were expressed as mean±standard deviation, and categorical variables as frequencies and percentages. Intergroup comparisons were performed using the Chi-square test, Student's t-test, one-way analysis of variance, and Mann–Whitney U test, as appropriate. Logistic regression analysis was conducted to identify independent risk factors associated with complications. All statistical analyses were performed using IBM Statistical Package for the Social Sciences Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY, USA). A $p<0.05$ was considered statistically significant. A post hoc power analysis was performed to evaluate the association between initial fracture displacement and the development of AVN. Based on the observed AVN rates in the non-displaced (1/17, 5.9%) and displaced (11/24, 45.8%) groups, the estimated statistical power was >80% at $\alpha=0.05$, indicating adequate sensitivity to detect the observed difference.

RESULTS

A total of 41 pediatric patients met the inclusion criteria for this study. The mean age at the time of injury was 10.6 years (range, 2–16 years), and the mean follow-up duration was 64 months (range, 25–160 months). All patients underwent closed reduction and internal fixation. Acceptable reduction was achieved in 34 patients (82.9%), whereas 7 patients (17.1%) had unacceptable reduction. Overall, 18 of 41 patients (43.9%) experienced at least one post-operative complication. While complications developed in 6 of 7 patients (85.7%) with unacceptable reduction, only 1 patient did not experience any complications. Based on the Ratliff clinical and radiological criteria, outcomes were rated as good in 29 patients (70.7%), fair in 6 (14.6%), and poor in 6 (14.6%). No cases of secondary loss of reduction requiring revision surgery were observed during follow-up.

Table 3. Patient and fracture characteristics according to the occurrence of complications and clinical outcomes

	Ratliff Classification			p	Avascular necrosis		p	Premature physis closure		p	Shortening		p
	Poor (n=6)	Fair (n=6)	Good (n=29)		No (n=29)	Yes (n=12)		No (n=26)	Yes (n=15)		No (n=30)	Yes (n=11)	
	X̄±SD	X̄±SD	X̄±SD		X̄±SD	X̄±SD		X̄±SD	X̄±SD		X̄±SD	X̄±SD	
Age (mean±SD)	14.17±2.64	11.0±3.01	9.72±4.81	0.088¥	9.79±4.83	12.42±3.29	0.094§	9.08±4.86	13.13±2.45	0.010*ϕ	9.93±4.72	12.27±3.74	0.147§
	n (%)	n (%)	n (%)		n (%)	n (%)		n (%)	n (%)		n (%)	n (%)	
Sex				0.192			1.000			0.570			1.000
Male	5 (83.3)	2 (33.3)	18 (62.1)		18 (62.1)	7 (58.3)		15 (57.7)	10 66.7)		18 (60)	7 (63.6)	
Female	1 (16.7)	4 (66.7)	11 (37.9)		11 (37.9)	5 (41.7)		11 (42.3)	5 (33.3)		12 (40)	4 (36.4)	
Side				0.096			0.059			0.355			1.000
Left	2 (33.3)	5 (83.3)	11 (37.9)		10 (34.5)	8 (66.7)		10 (38.5)	8 (53.3)		13 (43.3)	5 (45.5)	
Right	4 (66.7)	1 (16.7)	18 (62.1)		19 (65.5)	4 (33.3)		16 (61.5)	7 (46.7)		17 (56.7)	6 (54.5)	
Injury mechanism				0.213			0.120			0.583			0.426
Fall from height	1 (16.7)	2 (33.3)	15 (51.7)		15 (51.7)	3 (25)		13 (50)	5 (33.3)		14 (46.7)	4 (36.4)	
Traffic accident	2 (33.3)	3 (50)	4 (13.8)		4 (13.8)	5 (41.7)		5 (19.2)	4 (26.7)		5 (16.7)	4 (36.4)	
Sports-related injury	3 (50)	1 (16.7)	10 (34.5)		10 (34.5)	4 (33.3)		8 (30.8)	6 (40)		11 (36.7)	3 (27.3)	
Delbet type				0.104			0.748			0.411			0.836
2	6 (100)	2 (33.3)	20 (69)		19 (65.5)	9 (75)		16 (61.5)	12 (80)		20 (66.7)	8 (72.7)	
3	0	3 (50)	7 (24.1)		8 (27.6)	2 (16.7)		8 (30.8)	2 (13.3)		8 (26.7)	2 (18.2)	
4	0	1 (16.7)	2 (6.9)		2 (6.9)	1 (8.3)		2 (7.7)	1 (6.7)		2 (6.7)	1 (9.1)	
Initial displacement				0.006*			0.006*			0.005*			0.085
No	1 (16.7)	0	16 (55.2)		16 (55.2)	1 (8.3)		15 (57.7)	2 (13.3)		15 (50)	2 (18.2)	
Yes	5 (83.3)	6 (100)	13 (44.8)		13 (44.8)	11 (91.7)		11 (42.3)	13 (86.7)		15 (50)	9 (81.8)	

*Indicates significant difference (p<0.05); ¥One way analysis of variance, §Independent sample t-test, ϕMann–Whitney U test.

Table 4. Treatment characteristics according to the occurrence of complications and clinical outcomes

	Ratliff Classification			p	Avascular necrosis		p	Premature physis closure		p	Shortening		p
	Poor (n=6) n (%)	Fair (n=6) n (%)	Good (n=29) n (%)		No (n=29) n (%)	Yes (n=12) n (%)		No (n=26) n (%)	Yes (n=15) n (%)		No (n=30) n (%)	Yes (n=11) n (%)	
Time to surgery				0.177			0.013*			0.524			0.557
<8	4 (66.7)	3 (50)	17 (58.6)		17 (58.6)	7 (58.3)		16 (61.5)	8 (53.3)		17 (56.7)	7(63.6)	
8–16	0	2 (33.3)	10 (34.5)		11 (37.9)	1 (8.3)		8 (30.8)	4 (26.7)		10 (33.3)	2 (18.2)	
16–24	2 (33.3)	1 (16.7)	2 (6.9)		1 (3.4)	4 (33.3)		2 (7.7)	3 (20)		3 (10)	2 (18.2)	
Reduction quality				0.001*			0.016*			0.006*			<0.001*
Unacceptable	4 (66.7)	2 (33.3)	1 (3.4)		2 (6.9)	5 (41.7)		1 (3.8)	6 (40)		1 (3.3)	6 (54.5)	
Acceptable	2 (33.3)	4 (66.7)	28 (96.6)		27 (93.1)	7 (58.3)		25 (96.2)	9 (60)		29 (96.7)	5 (45.5)	
Fixation material				0.059			0.073			0.001*			0.128
K-wire	0	1 (16.7)	11 (37.9)		11 (37.9)	1 (8.3)		12 (46.2)	0		11 (36.6)	1 (9.1)	
Screw	6 (100)	5 (83.3)	18 (62.1)		18 (62.1)	11 (91.7)		14 (53.8)	15 (100)		19 (63.4)	10 (90.9)	
Physis penetration				0.003*			0.031*			0.002*			0.063
No	0	2 (33.3)	19 (65.5)		18 (62.1)	3 (25)		18 (69.2)	3 (20)		18 (60)	3 (27.3)	
Yes	6 (100)	4 (66.7)	10 (34.5)		11 (37.9)	9 (75)		8 (30.8)	12 (80)		12 (40)	8 (72.7)	

*Indicates significant difference (p<0.05).

No statistically significant association was observed between gender, side, or mechanism of injury and either the occurrence of complications or Ratliff outcome scores (p>0.05). PPC was found to increase with advancing age (p=0.01). Although all patients with poor outcomes according to the Ratliff classification sustained Delbet Type II (transcervical) fractures, no statistically significant correlation was found between fracture type and either complications or Ratliff scores (p>0.05).

Initial displacement demonstrated a significant association with both clinical outcomes and the development of complications. The presence of displacement correlated with worse Ratliff scores (p=0.006) and increased incidence of AVN (p=0.006) and PPC (p=0.005). According to multivariate logistic regression analysis, initial displacement was identified as an independent predictor of both AVN and PPC. Each unit increase in displacement increased the risk of AVN by 22.41 times (95% confidence interval [CI], 1.509–332.829; p=0.024) and the risk of PPC by 11.56 times (95% CI, 1.704–78.395; p=0.012). Patient and fracture characteristics according to the occurrence of complications and clinical outcomes are summarized in Table 3.

The time interval from injury to surgery was also significantly associated with the development of AVN (p=0.013), indicating that delayed surgical intervention correlated with a higher risk of AVN. Furthermore, the quality of reduction was significantly associated with both Ratliff clinical scores and complication rate (p<0.05). Patients with anatomical or acceptable reductions exhibited superior outcomes and fewer complications compared to those with unacceptable reductions.

Physeal penetration was correlated with poorer outcomes and was significantly associated with worse Ratliff scores (p=0.003), AVN (p=0.031), and PPC (p=0.002). Logistic regression identified physeal penetration as an independent predictor of PPC, increasing its risk by 11.47 times (95% CI, 2.019–65.173; p=0.006). An illustrative case of a patient who developed AVN following fixation with physeal penetration is shown in Figure 1. Treatment characteristics according to the occurrence of complications and clinical outcomes are summarized in Table 4.

DISCUSSION

The main findings of the present study indicate that initial fracture displacement, reduction quality, surgical delay, and physeal penetration are significant predictors of post-operative complications following closed reduction and internal fixation of pediatric femoral neck fractures. Although pediatric femoral neck fractures are uncommon, they remain a challenging condition due to their potential for serious and lasting complications. To minimize these adverse outcomes, orthopedic surgeons must have a thorough understanding of the distinctive anatomical and physiological features of these



Figure 1. (a) Male, 14 years, Delbet Type II femoral neck fracture. **(b)** The fracture was treated with closed reduction and internal fixation using cannulated screws. An immediate post-operative radiograph is shown. **(c)** After 61 months post-surgery, the examination revealed avascular necrosis of the femoral head, along with deformity of the hip joint.

fractures. Despite numerous studies, consensus is still lacking regarding the prognostic factors that influence clinical outcomes. The present study evaluated the mid- to long-term clinical outcomes of pediatric femoral neck fractures and identified risk factors associated with the development of complications.

Although there are studies reporting that open and closed reduction do not make a difference in post-operative complications,[18,19] in the present study, only patients treated with closed reduction were included to minimize surgical variability and focus on patient- and fracture-related prognostic factors. This design enabled a more homogeneous evaluation of prognostic determinants while minimizing potential confounding factors. As this study did not include predefined comparative groups, all subgroup analyses were exploratory and aimed to identify potential associations rather than establish causal relationships. Although residual displacement >2 mm was defined as an unacceptable reduction for radiographic assessment in the present study, this threshold may be stricter than those used in some previous reports. Previous studies have suggested that residual displacement below 4 mm may still be considered a good reduction. In several cases, the residual displacement remained below 4 mm and was considered clinically acceptable intraoperatively. In these borderline cases, open reduction was not pursued in order to avoid additional soft tissue dissection and possible vascular compromise to the femoral head.

Consistent with previous reports, high-energy trauma – particularly falls from height and motor vehicle accidents – was the predominant cause of fractures in this series.[20,21] Several studies have demonstrated that the incidence of AVN increases with age;[11,22] however, this association remains controversial. While Spence et al.[13] found no significant relationship between age and osteonecrosis, Kay et al.[23] reported a higher incidence among patients older than 10 years. In the present study, although AVN occurred more frequently in patients aged ≥10 years, the difference did not reach statistical significance.

The role of initial fracture displacement in predicting complications after pediatric femoral neck fractures has been extensively debated. Dai et al.[24] and İnan et al.[25] reported no correlation between displacement and AVN, whereas Wang et al.[22] and Spence et al.[13] identified displacement as a major risk factor, with displaced fractures showing up to a nine-fold higher incidence of osteonecrosis. This relationship may be explained by greater vascular and soft-tissue disruption at the time of injury. In agreement with these findings, our study demonstrated that initial displacement was significantly associated with poorer clinical outcomes. Moreover, we identified a novel association between initial displacement and PPC, emphasizing the prognostic importance of displacement in the management of pediatric femoral neck fractures.

No statistically significant association was found between fracture type and complications or Ratliff scores in this study. The effect of the Delbet classification on post-operative complications remains a subject of debate. Some authors have reported that Type I and II fractures are associated with a higher risk of AVN,[22,26] whereas others have suggested that fracture type is not an independent risk factor.[22] These divergent findings underscore the need for further studies to clarify the impact of fracture classification on outcomes.

The influence of the timing of surgery on complication rates has also been widely discussed. Several studies reported that AVN incidence is independent of surgical timing within the first 24 h,[27,28] whereas others have shown that early surgery reduces complications.[12,26,29] In the present study, AVN was more frequent in patients treated more than 16 h after injury, highlighting the importance of timely surgical intervention. Collectively, these data reinforce the critical role of early anatomical reduction and support further prospective research to determine the optimal timing for surgical fixation.

The quality of reduction has been consistently identified as one of the most important factors influencing outcomes. Patients with inadequate reductions exhibited poorer functional and radiographic results, along with higher rates of AVN, PPC, non-union, and shortening. Previous studies have emphasized that achieving an anatomical or acceptable reduction is essential for treatment success and for minimizing post-operative

complications.[14,30,31] Our findings are in agreement with this evidence, confirming the strong correlation between reduction quality and both clinical and radiological outcomes. Interestingly, a small subset of patients with unacceptable reduction did not develop major complications such as AVN or PPC. Although definitive conclusions are precluded by the limited sample size, potential explanations include differences in initial trauma severity and individual biological variability. Similarly, Wang et al.[22] reported an incidence of unacceptable reduction of approximately 9.7% in patients treated with closed reduction; however, AVN developed in only about 20% of these cases. Likewise, Dai et al.[24] reported a high rate of reduction success (up to 91%); 10 out of 14 patients who developed AVN in their series had undergone open reduction.[24] Taken together, these findings suggest that the quality of reduction is not the only factor influencing complications and that residual displacement may not always be entirely avoidable.

The effect of physeal penetration on post-operative complications has been evaluated in relatively few studies. Previous reports suggested that PPC may result from direct trauma to the physis, vascular compromise, or iatrogenic injury during fixation, with an incidence of approximately 20–25%.[26] Nayeemuddin et al.[32] highlighted the risk associated with screw penetration across the physis and recommended stable fixation methods that preserve the growth plate whenever feasible. Similarly, Forlin et al.[10] observed that the majority of patients who developed PPC had undergone fixation involving physeal violation. In our study, the rate of PPC was significantly higher in patients with physeal penetration, and AVN was also more frequent in this group. These findings suggest that physeal penetration may adversely affect bone healing and predispose patients to post-operative complications; however, in certain fracture patterns, crossing the physis may be unavoidable to ensure stability. Although PPC was observed in 15 patients, limb shortening developed in only 11. This discrepancy is likely related to residual growth potential and the inclusion of patients approaching skeletal maturity. The average age of individuals who had PPC but did not experience shortening was relatively high, 13.2 years, suggesting that they were approaching skeletal maturity with limited remaining growth potential. Therefore, physeal closure in these patients may not have resulted in clinically significant limb length discrepancy. This finding highlights the importance of considering skeletal maturity when interpreting growth-related complications.

The influence of fixation type on outcomes remains controversial. Spence et al.[13] found no significant association between fixation method and osteonecrosis. Recent reviews have suggested that the increased use of multiple cannulated screws in older patients may contribute to higher complication rates due to age-related biological factors rather than the fixation technique itself.[33] In our series, PPC was more frequent among patients treated with cannulated screws, which may reflect their preferential use in older patients. This age-related trend, observed in multiple studies,[34] highlights the complexity of interpreting fixation outcomes and calls for further comparative research to isolate the independent effects of fixation method. No patients with a Delbet Type IV fracture were treated with plate fixation in this study, as all such cases were managed with open reduction and were therefore excluded in accordance with the study design focusing on closed reduction. In addition, the limited number of Delbet Type IV fractures in our series also influenced this approach.

Limitations

This study has several limitations. First, its retrospective design inherently restricts the level of evidence and introduces potential selection bias, as data were derived from existing medical records. Wide confidence intervals reflect the limited sample size and should be interpreted cautiously. Second, the relatively small sample size limits the generalizability of the findings. Third, variations in follow-up duration may have affected the detection of late complications. Fourth, because only patients treated with closed reduction were included, the findings may not be generalizable to all pediatric femoral neck fractures, particularly those requiring open reduction. Fifth, the inclusion of patients approaching skeletal maturity may have affected the interpretation of PPC and may have introduced confounding in establishing its association with the development of limb length discrepancy. Finally, although the inclusion of patients with unacceptable reductions may appear to bias outcomes toward worse prognoses, we believe it more accurately reflects real clinical practice and underscores the prognostic impact of modifiable treatment factors such as reduction quality. Future multicenter prospective studies with standardized follow-up protocols are warranted to validate these results and further clarify prognostic factors.

CONCLUSION

Pediatric femoral neck fractures remain associated with high complication rates. The present findings indicate that initial displacement, inadequate reduction, surgical delay, and physeal penetration are significant predictors of adverse outcomes. Early anatomical reduction, achieved through stable yet physeal-sparing fixation whenever possible, appears to be crucial for optimizing prognosis and minimizing long-term complications.

Ethics Committee Approval: This study was approved by the Ethics Committee of Gaziantep University (Date: 09.11.2022, Decision No: 2022/406).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: E.Ö.; Design: E.Ö., S.B.T.; Supervision: S.B.T.; Resource: S.B.T.; Materials: E.Ö.; Data collection and/or processing: E.Ö., S.B.T.; Analysis and/or interpretation: E.Ö., B.B.; Literature review: B.B., E.Ö.; Writing: E.Ö., B.B.; Critical review: B.B.

Informed Consent: This is retrospective study.

Conflict of Interest: The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Financial Disclosure: The author declared that this study has received no financial support.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Pediatrik femur boyun kırıklarının kapalı redüksiyon ve internal fiksasyonu sonrası klinik sonuçları ve komplikasyonlar için risk faktörleri

AMAÇ: Pediatrik femur boyun kırıkları nadir görülmekle birlikle ciddi komplikasyonlara yol açabilir. Bu çalışmada, pediatrik femur boyun kırıklarında kapalı redüksiyon ve internal fiksasyon sonrası klinik sonuçların değerlendirilmesi ve postoperatif komplikasyonlarla ilişkili risk faktörlerinin belirlenmesi amaçlanmıştır.

GEREÇ VE YÖNTEM: Kapalı redüksiyon ve internal fiksasyon uygulanan 41 pediatrik hasta (ortalama yaş 10.6) üzerinde retrospektif bir analiz gerçekleştirildi. Ortalama takip süresi 64 ay (25-160) idi. Demografik değişkenler, kırık tipi, kırık deplasmanı, ameliyata kadar geçen süre, redüksiyon kalitesi, fiksasyon yöntemi ve fiz penetrasyonu potansiyel risk faktörleri olarak analiz edildi. Kaydedilen komplikasyonlar arasında avasküler nekroz (AVN), prematür epifiz kapanması (PEK), kaynamama, ekstremite kısalığı, koksa vara ve koksa valga yer aldı. Klinik sonuçlar Rattliff sınıflamasına göre değerlendirildi.

BULGULAR: Hastaların %95.1'inde kırık kaynaması sağlandı. Başlangıç deplasmanı ve redüksiyon kalitesi, hem klinik sonuçlar hem de komplikasyon oranları ile anlamlı şekilde ilişkili bulundu ($p<0.05$). Gecikmiş cerrahi, daha yüksek AVN insidansı ile ilişkiliydi ($p=0.013$). Fiz penetrasyonu, özellikle PEK ($p=0.002$) ve AVN ($p=0.031$) riskinde artış olmak üzere, daha kötü klinik sonuçlarla ilişkili olarak bulundu.

SONUÇ: Pediatrik femur boyun kırıkları yüksek komplikasyon oranlarıyla ilişkili olmaya devam etmektedir. Başlangıç deplasmanı, uygunsuz redüksiyon, cerrahiye kadar geçen sürenin uzaması ve fiz penetrasyonunun komplikasyonlar için risk faktörleri olduğu bulunmuştur. Erken anatomik redüksiyon ve fiz koruyucu fiksasyon, sonuçların iyileştirilmesinde anahtar rol oynamaktadır.

Anahtar sözcükler: Klinik sonuçlar; komplikasyonlar; pediatrik femur boyun kırıkları; risk faktörleri.

Ulus Travma Acil Cerrahi Derg 2026;32(11):1407-1415 DOI: 10.14744/tjtes.2026.63828

ORIGINAL ARTICLE

Short-segment fixation including the fractured vertebra versus long-segment fixation in thoracolumbar fractures a ≥10-year comparative study

Serkan Aydin, Halil Gok

Department of Orthopediscs and Traumatology, Etlik City Hospital, Ankara-*Türkiye*

ABSTRACT

BACKGROUND: The aim is to compare the long-term clinical and radiological outcomes of posterior long-segment fixation (LS) versus short-segment fixation (SSIF) involving the fractured vertebra in patients with thoracolumbar fractures, based on a follow-up period of at least 10 years.

METHODS: Patients who underwent surgical treatment for thoracolumbar fractures between 2002 and 2013 were retrospectively reviewed. Neurologically intact patients with a AO Spine thoracolumbar fractures classification system A2, A3, and A4 and a minimum follow-up of 10 years were included in the study. Exclusion criteria included osteoporotic, pathological, multilevel fractures, and prior thoracolumbar surgery. Forty-six patients met the inclusion criteria (LS fixation, n=22; SSIF İncluding The Fractured vertebra, n=24). All procedures were performed at a single center by the same senior spine surgeon. Clinical outcomes were assessed using the Oswestry disability ındex (ODI) and visual analog scale (VAS). Radiological evaluation included Sagittal Cobb Angle (SCA) and anterior central vertebral body height (ACVBH). Complications and revision surgeries were recorded.

RESULTS: Operative time was shorter in the SSIF group than in the LS group (138±8 minutes vs. 149±9 min; p<0,001, p<0.05 for both) and post-operative hospital stay was shorter in the SSIF group than LS group (4.3±1.2 days vs. 5.0±1.1 days; p=0.045, p<0.05 for both). Both groups showed post-operative improvement in ODI (p=0.312), VAS (p=0.083), SCA (p=0.418), and ACVBH (p=0.421), with no statistically significant between-group differences at final follow-up ODI (p=0.496), VAS (p=0.597), SCA (p=0.694), and ACVBH (p=0.512) (p>0.05 for all). No statistically significant differences were observed between groups in implant-related complications, junctional pathology, or revision surgery rates (p>0.05 for all).

CONCLUSION: SSIF including the fractured vertebra yields long-term clinical and radiological outcomes comparable to those of LS fixation in thoracolumbar fractures. In suitable patients, this approach is a reliable surgical option for a shorter instrumented segment and a more mobile vertebral segment.

Keywords: Long-segment fixation; long-term follow-up; short-segment fixation; thoracolumbar fracture.

INTRODUCTION

Most thoracolumbar fractures are localized within the T11-L2 region, a vulnerable zone characterized by the mechanical shift from the rigid thoracic to the mobile lumbar spine. These injuries are commonly associated with spinal instability and sagittal deformity.[1,2] The ideal extent of posterior instrumentation continues to be a subject of debate, although surgical stabilization of unstable thoracolumbar injuries is commonly achieved through posterior pedicle screw fixation.[3,4] Consequently, treatment decision-making continues to vary among surgeons, although classification-based algo-

Cite this article as: Aydin S, Gök H. Short-segment fixation including the fractured vertebra versus long-segment fixation in thoracolumbar fractures a ≥10-year comparative study. Ulus Travma Acil Cerrahi Derg 2026;32:1416-1424.

Address for correspondence: Serkan Aydın

Department of Orthopediscs and Traumatology, Etlik City Hospital, Ankara, Türkiye

E-mail: drsaydin2003@yahoo.com

Ulus Travma Acil Cerrahi Derg 2026;32(11):1416-1424 DOI: 10.14744/tjtes.2026.58887

Submitted: 06.02.2026 Revised: 16.04.2026 Accepted: 11.05.2026 Published: 05.11.2026

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rithms such as the AO Spine Thoracolumbar Injury Severity Score and the Thoracolumbar Injury Classification and Severity Score are commonly used to guide operative indications.[5] Long-segment (LS) fixation provides strong initial stability but requires fusion of multiple motion segments and may be associated with increased operative morbidity as well as higher stress on adjacent segments. In contrast, short-segment fixation (SSIF) preserves motion segments but has historically been linked to increased incidences of implant failure and loss of correction.[6] To address these limitations, SSIF including the fractured vertebra has been introduced. Both clinical data and biomechanical analyses have indicated that this approach improves construct stability and better maintains sagittal alignment compared with conventional SSIF.[1,3,7]

Evidence from various comparative investigations suggests that short-segment constructs augmented at the fracture level yield clinical and radiological results equivalent to those of LS fixation in the short-to-mid-term.[6,8,9] However, most available evidence is limited by follow-up durations of <5 years, and data regarding very long-term outcomes remain scarce.[10] Because correction loss and junctional complications may develop over time, long-term comparative analyses are warranted.

From a biomechanical perspective, the inclusion of pedicle screws at the fractured vertebra has been proposed as a strategy to enhance fracture reduction and improve construct stability in SSIF. By facilitating lordotic correction, fracture-level screws may help reposition the fractured vertebral body anterior to the gravitational axis, thereby improving anterior column load sharing. This configuration has been suggested to create a supportive effect that allows fracture healing to occur before construct collapse, potentially reducing correction loss and implant-related complications.[11]

Given that classification-based operative indications primarily address initial injury severity, long-term comparative data remain essential to understand the durability of different posterior fixation strategies.[5] Moreover, treatment recommendations in neurologically intact AO Spine A3/A4 burst fractures may still show meaningful variability between expert recommendations and real-world practice, underscoring the need for robust long-term outcome data.[12] Experimental and biomechanical studies further support this concept. According to Anekstein et al.,[13] the addition of intermediate screws at the fracture level significantly increases construct stiffness and reduces stress on adjacent pedicle screws, thereby improving load distribution across the fixation construct. Similarly, Ye et al.[14] reported that fracture-level screw augmentation enhances resistance to kyphotic deformation and decreases implant strain in short-segment constructs when compared with conventional configurations. Finite element analyses have also demonstrated that incorporating the fractured vertebra into the fixation construct results in a more homogeneous stress distribution and improved stability, particularly under axial loading conditions.[15]

This study is based on the hypothesis that the SSIF technique, which involves fixing the fractured vertebrae in the surgical treatment of thoracolumbar fractures, preserves spinal mobility by fixing fewer vertebrae compared to traditional LS fixation, while providing equivalent structural stability and deformity control in follow-ups of at least 10 years.

MATERIALS AND METHODS

Study Design and Patient Selection

A retrospective comparative cohort design was employed at a single institution to examine surgical interventions for thoracolumbar fractures between 2002 and 2013. Following an eligibility assessment of 594 patients, the study proceeded under the ethical framework of the Declaration of Helsinki. The protocol received official approval from the Etlik City Hospital ethics board (February 18, 2026; Ref: AEŞH-BADEK1-2026-145).

Patients without pre-operative neurological deficits and with AO spine thoracolumbar fractures classification system A2, A3, and A4 were considered eligible for inclusion. Exclusion criteria included osteoporotic fractures (T-score <−2.5), pathological fractures, multilevel spinal fractures, prior thoracolumbar spine surgery, multiple trauma, or incomplete clinical or radiological data. Patients younger than 18 years of age, those with <10 years of post-operative follow-up, and missing data was also excluded.

After screening the patients based on the pre-established selection criteria, 46 patients constituted the final study cohort. The process of selecting patients is outlined in Figure 1.

Group Distribution and Surgical Technique

Posterior pedicle screw fixation was performed on all patients, who were then split into two study arms based on the instrumentation range. In the LS fixation group, surgical stabilization was performed by instrumenting two vertebra above and two vertebrae below the fracture level (Fig. 2). The SSIF involving the fractured vertebra arm consisted of patients whose treatment involved one level of fixation above and below the fractured segment, with the addition of fracture-level screws (Fig. 3). This approach to SSIF involves the fractured vertebra and is considered effective in promoting load sharing while minimizing the span of spinal instrumentation.[16]

Each procedure was performed at the same medical center by a single senior spine surgeon chosen as randomly cases and utilizing a standardized posterior technique. No anterior reconstruction procedures were performed. Posterior fixation was considered sufficient to restore and maintain spinal stability, and no progressive collapse requiring anterior reconstruction was observed during follow-up. Posterior decompression was carried out only when deemed necessary based on intraoperative findings.

Clinical Assessment

Clinical assessment included the use of the Oswestry disabil-

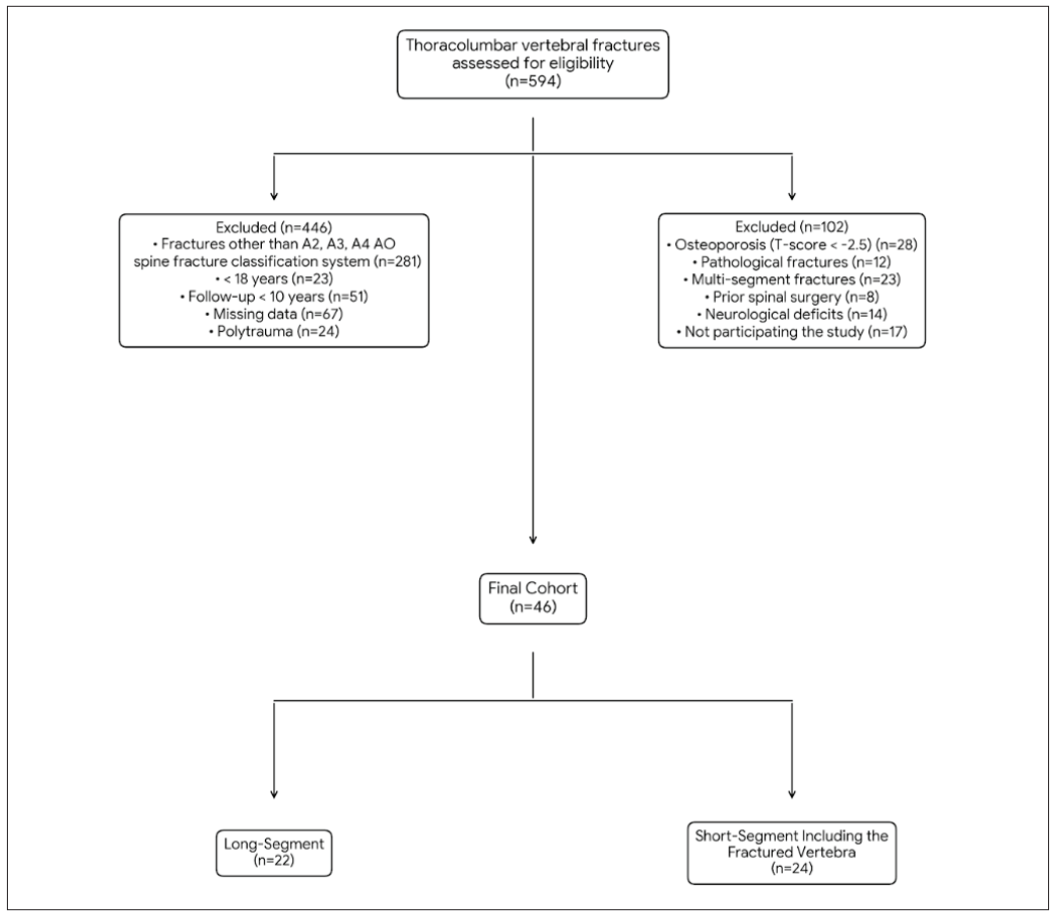


Figure 1. Flowchart of patient selection and allocation to study groups. A total of 594 patients with thoracolumbar vertebral fractures were assessed for eligibility. After application of the inclusion and exclusion criteria, 46 patients were included in the final cohort and allocated to either the long-segment fixation group (LS, n=22) or the short-segment fixation including the fractured vertebra group (SSIF, n=24).

ity index (ODI) along with the visual analog scale (VAS) for pain measurement. Assessments were performed preoperatively, during the early post-operative period, and at the final follow-up. ODI and VAS scores were recorded for all patients at each time point.

Radiological Evaluation

Radiological assessment involved measurement of the sagittal Cobb angle (SCA) and anterior central vertebral body height (ACVBH). These parameters were measured using standardized lateral radiographs taken preoperatively, postoperatively, and at the final follow-up. ACVBH was expressed as a percentage relative to the mean height of the vertebral bodies located above and below the fractured level.

Pre-operative and Post-operative Data and Complications

Pre-operative and post-operative data included operative time, intraoperative blood loss, and post-operative length of hospital stay.

In our study, perioperative blood loss was meticulously calculated using a combination of clinical and mathematical measurement techniques. To determine intraoperative visible blood loss, a volumetric method was applied, based on subtracting the volume of irrigation fluid used during surgery from the total fluid volume collected in the suction device. In addition, the gauze and compresses used in the surgical field were weighed, and the values obtained by calculating the difference between their dry and blood-soaked wet weights were included in the blood loss calculation using the gravimetric method. Postoperatively, patients Hemovac drains were monitored regularly, and the amounts of post-operative bleeding were recorded and added to the total visible blood loss.

Throughout the follow-up period, post-operative complications were documented, including rod or screw breakage, surgical site infection, and junctional problems such as proximal junctional kyphosis, proximal junctional failure, distal junctional kyphosis (DJK), and distal junctional failure (DJF), along with any revision procedures.

Statistical Analysis

Statistical analyses were performed using IBM Statistical Package for the Social Sciences Statistics software (version

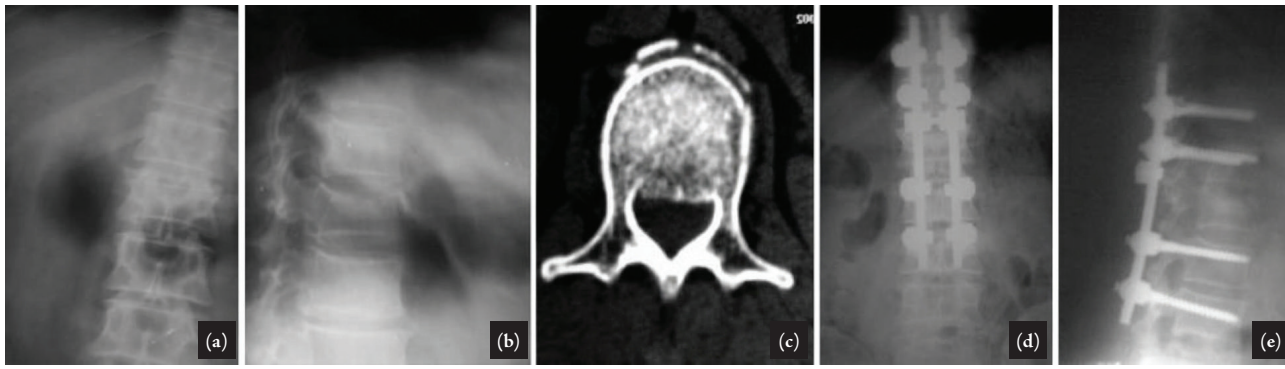


Figure 2. Preoperative (a) Anteroposterior X-ray, (b) Lateral X-ray, (c) Axial Computed Tomography (CT); Postoperative (d) Anteroposterior X-ray, (e) Lateral X-ray.

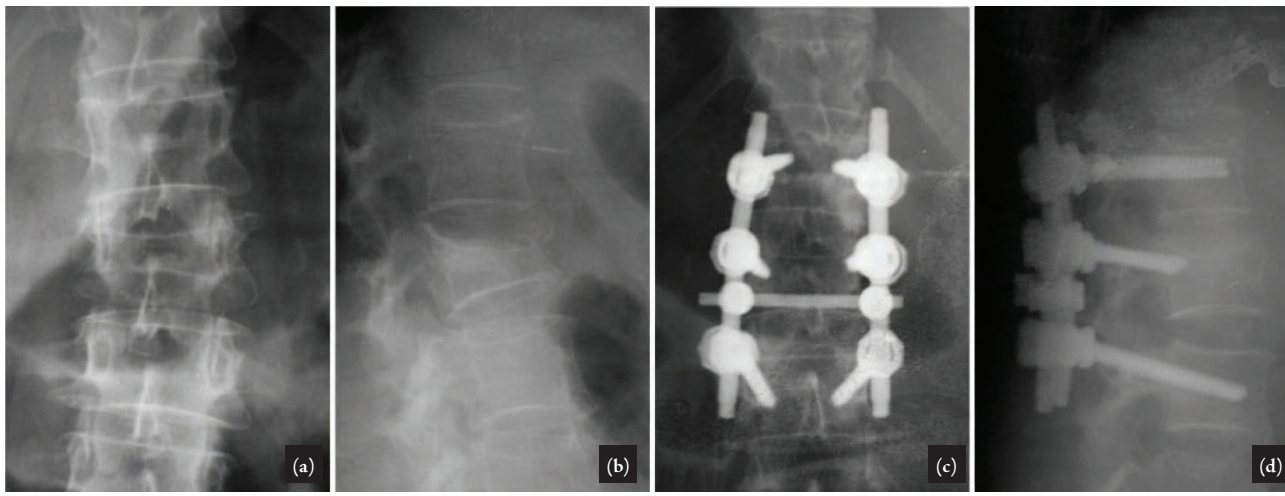


Figure 3. (a) Preoperative Anteroposterior X-ray, **(b)** Preoperative Lateral X-ray, **(c)** Postoperative Anteroposterior X-ray, **(d)** Lateral X-ray.

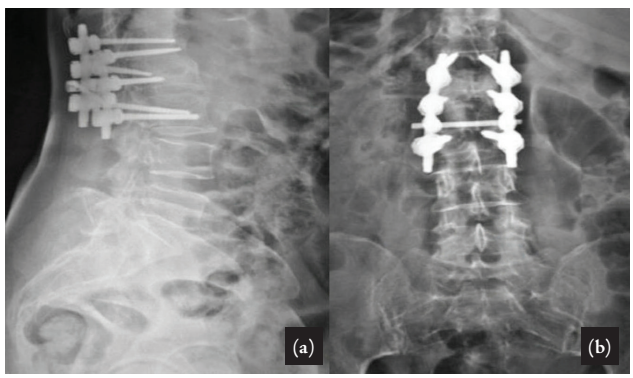


Figure 4. (a) Preoperative Anteroposterior X-ray, **(b)** Preoperative Lateral X-ray, **(c)** Postoperative Anteroposterior X-ray, **(d)** Lateral X-ray.

25; IBM Corp., Armonk, NY, USA). Continuous variables are presented as mean ± standard deviation. The normality of the data distribution was assessed using the Shapiro–Wilk test. Differences in continuous variables between groups were analyzed with the independent-samples t-test. Categorical variables are reported as frequencies and percentages, and group comparisons were conducted using the chi-square test. When the expected cell counts were fewer than five, Fisher's exact test was applied. In addition, the Fisher–Freeman–Halton test was used to evaluate r×c contingency tables when appropriate. $p<0.05$ was considered statistically significant.

Ethical Considerations

The study was conducted in accordance with the principles of the Declaration of Helsinki. Approval was obtained from the Local Institutional Review Board before data collection, and written informed consent was obtained from all patients.

RESULTS

Patient Demographics and Injury Characteristics

A total of 46 patients who met the inclusion criteria were included in the final analysis. Of these, 22 patients underwent LS fixation, while 24 were treated with SSIF including the fractured vertebra. The demographic data, mechanisms of injury, fracture levels, AO fracture classification, and duration of follow-up are presented in Table 1.

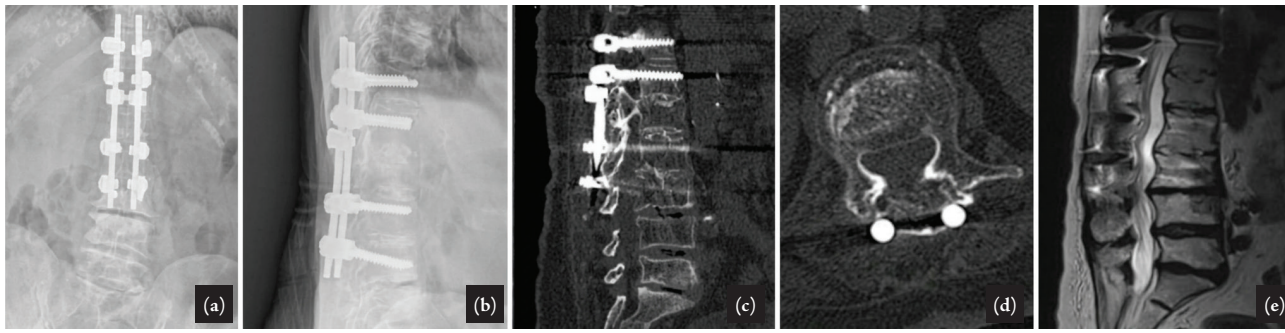


Figure 5. After 23 years LS surgery **(a)** Anteroposterior X-ray, **(b)** Lateral X-ray, **(c)** Sagittal Computed Tomography (CT), **(d)** Axial Computed Tomography (CT), **(e)** Sagittal Magnetic Resonance.

Regarding demographic and follow-up data, the LS and SSIF cohorts showed no important differences in age (p=0.646), gender distribution (p=0.606), body mass index (p=0.166), or the length of follow-up (p>0.05 for all variables). Similarly, the distribution of injury mechanisms, fracture levels (p=0.897), and AO fracture classification (p=0.450) did not differ remarkable between the two groups (p>0.05 for all).

Operative and Perioperative Data

Operative and perioperative data are summarized in Table 2. The duration of surgery was significantly shorter in the SSIF group (149±9 min vs. 138±8 min; p<0,001; p<0.05) compared with the LS group (5.0±1.1days vs. 5.0±1.1days; p=0.045; p<0.001). Although intraoperative blood loss was lower in the SSIF group, this difference did not reach statistical significance (p=0.059). Post-operative hospital stay, however, was significantly reduced in patients treated with SSIF relative to those in the LS group (p=0.045).

Clinical Outcomes

Clinical outcomes, as evaluated using the ODI and VAS, are presented in Table 3. Pre-operative ODI (p=0.418) and VAS

Table 1. Demographic characteristics, injury features, and follow-up duration of the patients

Variable	LS (n=22)	SSIF (n=24)	p-value
Demographic data			
Age (years), mean±SD	40.4±14.1	42.4±14.8	0.646
Sex (Male/Female), n	14/8	18/6	0.606
Body mass index (kg/m²), mean±SD	29.1±3.5	27.5±4.3	0.166
Follow-up duration (years), mean±SD	15.6±3.8	15.7±3.7	0.978
Injury mechanism, n (%)			
Traffic accident	10 (45.5)	9 (37.5)	
Fall from a height	9 (40.9)	9 (37.5)	0.688
Other	3 (13.6)	6 (25.0)	
Fracture level, n (%)			
T11	2 (9.1)	4 (16.7)	
T12	6 (27.3)	6 (25.0)	0.897
L1	10 (45.5)	11 (45.8)	
L2	4 (18.2)	3 (12.5)	
AO fracture classification†, n (%)			
A2	2 (9.1)	5 (20.8)	
A3	9 (40.9)	11 (45.8)	0.450
A4	11 (50.0)	8 (33.3)	

Values are presented as mean±standard deviation or number (percentage), as appropriate. Comparisons between groups were performed using the independent-samples t-test for continuous variables and the chi-square test or Fisher's exact test (including Fisher-Freeman-Halton exact test for r×c tables), as appropriate, for categorical variables. †According to the AO spine thoracolumbar fracture classification, only A2, A3, and A4 fracture types were included in the study. LS: Long-segment fixation; SSIF: Short-segment fixation including the fractured vertebra; SD: Standard deviation.

Table 2. Operative and perioperative data

Variable	LS (n=22)	SSIF (n=24)	p
Operative time (min), mean±SD	149±9	138±8	<0.001
Blood loss (mL), mean±SD	420±63	386±55	0.059
Post-operative hospital stay (days), mean±SD	5.0±1.1	4.3±1.2	0.045

Values are presented as mean±standard deviation. Comparisons between groups were performed using the independent-samples t-test or the Mann-Whitney U test, as appropriate. LS: Long-segment fixation; SSIF: Short-segment fixation including the fractured vertebra; SD: Standard deviation.

Table 3. Clinical outcomes (ODI and VAS scores)

Variable	LS (n=22)	SSIF (n=24)	p
Oswestry Disability Index (ODI)			
Pre-operative ODI, mean±SD	67.1±5.6	68.3±6.2	0.418
Post-operative ODI, mean±SD	20.1±7.4	18.4±7.1	0.332
Final follow-up ODI, mean±SD	27.4±14.6	24.9±13.8	0.496
Visual Analog Scale (VAS)			
Pre-operative VAS, mean±SD	8.6±1.1	8.4±1.2	0.481
Post-operative VAS, mean±SD	2.9±1.1	2.4±1.0	0.083
Final follow-up VAS, mean±SD	3.1±1.4	2.9±1.3	0.597

Values are presented as mean±standard deviation. Between-group comparisons were performed using the independent-samples t-test or the Mann–Whitney U-test, as appropriate. LS: Long-segment fixation; SSIF: Short-segment fixation including the fractured vertebra; ODI: Oswestry disability index; VAS: Visual analog scale; SD: Standard deviation.

Table 4. Radiological outcomes

Variable	LS (n=22)	SSIF (n=24)	p
Sagittal Cobb Angle (SCA, °)			
Pre-operative SCA, mean±SD	25.1±6.8	26.4±7.2	0.523
Post-operative SCA, mean±SD	3.7±2.4	3.3±2.1	0.418
Final follow-up SCA, mean±SD	6.8±3.9	6.4±3.6	0.694
Anterior Central Vertebral Body Height (ACVBH, %)			
Pre-operative ACVBH, mean±SD	66.8±9.7	68.2±10.1	0.588
Post-operative ACVBH, mean±SD	86.9±6.4	88.1±6.0	0.421
Final follow-up ACVBH, mean±SD	79.1±7.5	80.4±7.2	0.512

Values are presented as mean±standard deviation. Between-group comparisons were performed using the independent-samples t-test or the Mann–Whitney U-test, as appropriate. LS: Long-segment fixation; SSIF: Short-segment fixation including the fractured vertebra; SCA: Sagittal Cobb angle; ACVBH: Anterior central vertebral body height; SD: Standard deviation.

(p=0.481) scores were similar between the LS and SSIF groups (p>0.05). Both groups demonstrated developments in ODI (p=0.332) and VAS (p=0.083) scores postoperatively and at the final follow-up in ODI (p=0.496) and VAS (p=0.597), with no statistically important differences observed between the two groups at any time point (p>0.05 for all comparisons).

Radiological Outcomes

Radiological parameters, including SCA and ACVBH, are summarized in Table 4. Pre-operative, post-operative, and final follow-up measurements; pre-operative SCA (p=0.523) post-operative SCA (p=0.418) final follow-up SCA (p=0.694); and pre-operative ACVBH (p=0.588) post-operative ACVBH (p=0.421) final follow-up ACVBH (p=0.512) indicated no

Table 5. Complications and reoperation

Complication	LS (n=22)	SSIF (n=24)	p
Screw breakage, n (%)	3 (13.6)	1 (4.2)	0.255
Rod fracture, n (%)	2 (9.1)	1 (4.2)	0.486
Surgical site infection, n (%)	1 (4.5)	0 (0.0)	0.311
Proximal junctional kyphosis (PJK), n (%)	2 (9.1)	1 (4.2)	0.486
Proximal junctional failure (PJF), n (%)	1 (4.5)	0 (0.0)	0.311
Distal junctional kyphosis (DJK), n (%)	2 (9.1)	1 (4.2)	0.486
Distal junctional failure (DJF), n (%)	1 (4.5)	0 (0.0)	0.311
Revision surgery, n (%)	1 (4.5)	0 (0.0)	0.311

Values are presented as number (percentage). Comparisons between groups were performed using Fisher's exact test. One patient in the LS group developed a post-operative surgical site infection associated with subsequent proximal and distal junctional failure, requiring revision surgery. LS: Long-segment; SSIF: Short-segment fixation.

statistically important differences between the LS and SSIF groups for either parameter (p>0.05 for all).

Complications and Reoperations

Post-operative complications and reoperation rates are summarized in Table 5. The incidence of screw (p=0.255) or rod fractures (p=0.486), proximal and DJK (p=0.846 and p=0.486), proximal and DJF (p=0.311and p=0.311), as well as revision surgeries (p=0.311), was similar between the two groups, with no statistically significant differences observed (p>0.05 for all).

One patient in the LS group developed a post-operative surgical site infection, which was associated with subsequent proximal and DJF and required revision surgery (p=0.311).

DISCUSSION

This study suggests that posterior SSIF including the fractured vertebra yields long-term clinical and radiological outcomes comparable to those of LS fixation in patients with thoracolumbar fractures, with a minimum follow-up of 10 years. The present study demonstrated the long-term durability of the SSIF technique in the post-operative period (Fig. 4); similarly, stability was maintained over the very long-term in the LS group (Fig. 5). At the final follow-up, no significant differences were identified between the two groups in terms of pain levels, functional outcomes, sagittal alignment, vertebral body height restoration, or complication rates. Previous clinical series evaluating posterior fixation have similarly reported significant immediate post-operative correction followed by partial loss of correction over time, while maintaining improvements compared with pre-operative alignment.[16] These findings suggest that, when appropriately applied, SSIF, including the fractured vertebra, can achieve durable stability and deformity control comparable to LS constructs while preserving additional motion segments.

Taken together, these biomechanical findings provide a reasonable explanation for the durable radiological outcomes observed in the present study and suggest that fracture-level screw placement may compensate for the reduced number of fixation segments in short-segment constructs while preserving spinal mobility.

Our long-term findings not only corroborate but also expand on previous comparative studies investigating SSIF involving the fractured level versus traditional LS stabilization for thoracolumbar fractures. For instance, Park et al.[6] demonstrated comparable clinical and radiological results when comparing two-level and three-level posterior constructs over at least 5 years, noting no substantial disparities in functional scores or the maintenance of kyphotic correction. Correspondingly, Martin-Somoza et al.[8] and Suer et al.[9] observed no significant clinical or radiological disparities between LS constructs and fractured-level included SSIF within short- to medium-term assessment windows.[8]

Other authors have reported comparable findings using different short-segment configurations. Kapoen et al.[17,18] showed that SSIF strategies incorporating the fractured vertebra provide satisfactory sagittal alignment and clinical outcomes while preserving motion segments, although their follow-up duration was limited to the early post-operative period. Comparable results have also been reported in regional series, including those by El Behairy et al.,[19] Başaran et al.,[20] and Cetin and Oner,[21] which demonstrated acceptable radiological correction and functional improvement following SSIF, involved the fractured vertebra, although with relatively short follow-up durations.

Unlike previous studies that mainly focused on short- to mid-term outcomes, the present study observed no statistically substantial differences in clinical or radiological outcomes between SSIF including the fractured vertebra and LS fixation over a minimum follow-up of 10 years. This finding suggests

that the durability of fracture-level screw augmentation extends beyond the early post-operative period and supports its role as a long-term stabilization strategy in appropriately selected patients.

Regarding complications, no important difference was observed between the LS and SSIF groups in terms of implant-related failures or junctional problems during long-term follow-up. Although it is often assumed that LS fixation reduces mechanical complications by distributing stress to more segments, it may also increase the risk of junctional pathology due to the longer lever arm created by extended instrumentation.[13,22] In this study, a single patient in the LS group developed a post-operative surgical site infection that was associated with subsequent proximal and DJF, requiring revision surgery. No revision procedure was required in the SSIF group. These findings show that extending the fixation length does not necessarily eliminate long-term mechanical or junctional complications, and that SSIF, involving the fractured vertebra, does not increase the risk of adverse events during long-term follow-up.

The present study has several strengths. Most notably, it provides a direct comparison of LS fixation and SSIF, including the fractured vertebra, with a minimum follow-up of 10 years, which is longer than that reported in the majority of previously published studies. In addition, all procedures were carried out at a single center by the same senior spine surgeon using a standardized posterior technique, thereby minimizing variability related to surgical approach and experience. The use of consistent clinical and radiological outcome measures further enhances the internal validity of the findings. Limitations of this study include its retrospective framework, which may introduce selection bias, and a sample size that, while comparable to existing long-term data, is still somewhat restricted; however, the absence of statistically significant differences was not associated with clinically meaningful differences between the groups. Furthermore, patients with severe neurological deficits and osteoporotic fractures were excluded, which might limit the generalizability of the results to these populations. Despite these limitations, the extended follow-up period and the homogeneous study population offer important insights into the long-term durability of SSIF incorporating the fractured vertebra compared with LS fixation in thoracolumbar fractures.

Perioperative findings indicate that the SSIF technique significantly reduces both operative and hospital stay durations; while blood loss was lower in volume compared to the LS group, it did not result in a statistically significant difference between the groups.

When the study's results are combined with biomechanical principles and literature data, it is confirmed that the screw placed at the fracture level optimizes the load distribution of the anterior column, compensates for the fixation deficit in the short segment, and thus both groups achieve similar success in the long-term regarding ODI, VAS, radiographic healing (SCA and ACVBH), and complication rates.

CONCLUSION

The findings suggest that for patients with thoracolumbar fractures, short-segment posterior fixation including the fractured level achieves clinical and radiographic outcomes equivalent to those of LS stabilization over a minimum 10-year period. These results demonstrate that, when applied to suitable cases, this approach ensures lasting spinal stability and successful deformity management while minimizing the loss of motion segments. Consequently, incorporating the fractured vertebra into short-segment constructs stands as a reliable and effective long-term surgical alternative.

Ethics Committee Approval: This study was approved by the Etlik City Hospital Ethics Committee (Date: 18.02.2026, Decision No: AEŞH-BADEK1-2026-145).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: S.A., H.G.; Design: S.A., H.G.; Supervision: S.A., H.G.; Resource: S.A., H.G.; Materials: S.A., H.G.; Data collection and/or processing: S.A., H.G.; Analysis and/or interpretation: S.A., H.G.; Literature review: S.A., H.G.; Writing: S.A., H.G.; Critical review: S.A., H.G.

Informed Consent: Written informed consent was obtained.

Conflict of Interest: None declared.

Financial Disclosure: The author declared that this study has received no financial support.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Torakolomber kırıklarda kırık omurga dahil kısa segment fiksasyonu ile uzun segment fiksasyonu karşılaştırması ≥10 yıllık karşılaştırmalı çalışma

AMAÇ: Torakolomber kırığı olan hastalarda posterior uzun segment fiksasyon (LS) ile kırık vertebrayı içeren kısa segment fiksasyonun (SSIF), en az 10 yıllık takip süresindeki uzun dönem klinik ve radyolojik sonuçlarını karşılaştırmaktır.

GEREÇ VE YÖNTEM: 2002 ile 2013 yılları arasında torakolomber kırıklar nedeniyle cerrahi tedavi gören hastalar retrospektif olarak incelenmiştir. AO omurga torakolomber kırık sınıflandırma sistemine göre A2, A3 ve A4 sınıfında yer alan ve en az 10 yıllık takip süresi olan, nörolojik açıdan sağlam hastalar çalışmaya dahil edilmiştir. Dışlama kriterleri arasında osteoporotik, patolojik ve çok seviyeli kırıklar ile daha önce geçirilmiş torakolomber cerrahi yer almıştır. Dahil edilme kriterlerini karşılayan 46 hasta vardı (uzun segment fiksasyonu (LS), n=22; kırık omuru içeren kısa segment fiksasyonu (SSIF), n=24). Tüm işlemler tek bir merkezde aynı kıdemli omurga cerrahı tarafından gerçekleştirildi. Klinik sonuçlar, Oswestry Engellilik İndeksi (ODI) ve Görsel Analog Skalası (VAS) kullanılarak değerlendirildi. Radyolojik değerlendirme, Sagital Cobb Açısı (SCA) ve Anterior Merkezi Vertebra Gövdesi Yüksekliğini (ACVBH) içeriyordu. Komplikasyonlar ve revizyon ameliyatları kaydedildi.

BULGULAR: SSIF grubunda ameliyat süresi LS grubuna göre daha kısaydı (138±8 dakika karşı 149±9 dakika; p<0.001, her ikisi için de p<0.05) ve SSIF grubunda ameliyat sonrası hastanede kalış süresi LS grubuna göre daha kısaydı (4.3±1.2 gün karşı 5.0±1.1 gün; p=0.045, her ikisi için de p<0.05). Her iki grupta da ODI (p=0.312), VAS (p=0.083), SCA (p=0.418) ve ACVBH (p=0.421) açısından ameliyat sonrası iyileşme görülmüştür; son takipte ODI (p=0.496), VAS (p=0.597), SCA (p=0.694) ve ACVBH (p=0.512) değerlerinde istatistiksel olarak anlamlı bir fark gözlenmemiştir (tümü için p>0.05). Gruplar arasında implantla ilişkili komplikasyonlar, birleşme yeri patolojisi veya revizyon cerrahisi oranlarında istatistiksel olarak anlamlı bir fark gözlenmemiştir (tümü için p>0.05).

SONUÇ: Kırık omuru içeren kısa segment fiksasyonu, torakolomber kırıklarda uzun segment fiksasyonuna benzer uzun vadeli klinik ve radyolojik sonuçlar sağlar. Uygun hastalarda, bu yaklaşım daha kısa enstrümanlı segment ve daha hareketli vertebral segment için güvenilir bir cerrahi seçenektir.

Anahtar sözcükler: Kısa segment fiksasyon; torakolomber kırık;, uzun segment fiksasyon; uzun dönem takip.

Ulus Travma Acil Cerrahi Derg 2026;32(11):1416-1424 DOI: 10.14744/tjtes.2026.58887

ORIGINAL ARTICLE

The association between Vitamin D metabolites and low-energy distal radius fractures in non-elderly adults

Berk Koncalıoğlu,[1] Batuhan Gencer,[2] Ufuk Arzu,[2] Seyyid Necmeddin Çevik,[2] İhsan Özdamar,[2] Deniz Gulabi[2]

[1]Orthopaedics and Traumatology Clinic, Sultanbeyli State Hospital, İstanbul-*Türkiye*

[2]Department of Orthopaedics and Traumatology, Marmara University Faculty of Medicine, İstanbul-*Türkiye*

ABSTRACT

BACKGROUND: This study aimed to evaluate Vitamin D metabolism in non-elderly adults with low-energy distal radius fractures (DRFs). Serum 25-hydroxyvitamin D [25-(OH)D] and 1,25-dihydroxyvitamin D [1,25-(OH)D] levels were compared with those of age- and sex-comparable healthy controls. In addition, the relationship between Vitamin D metabolites, other biochemical parameters, and articular involvement patterns was investigated in patients with low-energy DRFs.

METHODS: This observational case–control study included 102 patients aged 18–60 years with low-energy DRFs and 138 age- and sex-comparable healthy controls in the same age range. Serum 25-(OH)D and 1,25-(OH)D levels were compared between the fracture and control groups. In the fracture group, Frykman fracture type was used to assess articular involvement, and its relationship with alkaline phosphatase (ALP), calcium (Ca), phosphate (P), parathyroid hormone, and Vitamin D metabolite levels was analyzed.

RESULTS: A total of 240 participants were included in the final analysis. Age and sex distribution were similar between the fracture and control groups (p=0.285 and p=0.855, respectively). Serum 25-(OH)D levels did not differ significantly between groups (p=0.557), whereas serum 1,25-(OH)D levels were significantly lower in the low-energy DRF group than in controls (p<0.001). Among Frykman fracture subgroups, significant differences were found in 25-(OH)D, ALP, and Ca levels (p=0.009, p=0.001, and p=0.002, respectively). Extra-articular fractures were associated with lower 25-(OH)D and higher ALP levels compared with other fracture subgroups, while Ca levels were lower than in selected intra-articular fracture subgroups.

CONCLUSION: Non-elderly adults with low-energy DRFs had lower serum 1,25-(OH)D levels despite having serum 25-(OH)D levels comparable to those of healthy controls. These findings suggest that alterations in active Vitamin D metabolism may be associated with low-energy DRFs in this population. Assessment of active Vitamin D metabolites together with conventional biochemical parameters may provide a more comprehensive understanding of the metabolic profile of non-elderly adults presenting with low-energy DRFs.

Keywords: 1,25-dihydroxyvitamin D; distal radius fracture; frykman classification; low-energy fracture; vitamin D metabolism.

INTRODUCTION

Distal radius fractures (DRFs) are among the most common fractures in orthopedic practice and are typically associated with low-energy trauma in older adults with osteoporotic bone.[1] In contrast, DRFs in non-elderly adults are usually related to high-energy mechanisms, most often motor vehicle accidents or sports-related injuries.[2] Therefore, the occurrence of a DRF after a low-energy mechanism in a non-elderly adult may suggest the presence of underlying systemic or metabolic factors associated with impaired bone quality, rather than being solely attributable to mechanical trauma.[3]

Among the metabolic determinants of skeletal integrity, Vitamin D plays an essential role in bone health by regulat-

Cite this article as: Koncalıoğlu B, Gencer B, Arzu U, Çevik SN, Özdamar İ, Gülabi D. The association between Vitamin D metabolites and low-energy distal radius fractures in non-elderly adults. Ulus Travma Acil Cerrahi Derg 2026;32:1425-1434.

Address for correspondence: Berk Koncalioğlu

Orthopedics and Traumatology Clinic, Sultanbeyli State Hospital, İstanbul,Türkiye

E-mail: berkkoncalioglu@gmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(11):1425-1434 DOI: 10.14744/tjtes.2026.06812

Submitted: 12.05.2026 Revised: 06.09.2026 Accepted: 16.09.2026 Published: 05.11.2026

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ing calcium and phosphate homeostasis, promoting bone mineralization, and preserving microarchitectural stability.[4] Evaluation of Vitamin D status is primarily based on serum 25-hydroxyvitamin D [25-(OH)D], which reflects the main circulating and storage form of Vitamin D. However, this metabolite does not directly represent the biologically active component of Vitamin D metabolism. The active form, 1,25-dihydroxyvitamin D [1,25-(OH)D], is involved in intestinal calcium absorption, osteoblast activity, and bone matrix regulation.[5]

Although most previous studies have focused on serum 25-(OH)D levels in patients with low-energy or fragility fractures, emerging evidence suggests that alterations in Vitamin D metabolism may also be reflected by changes in active Vitamin D metabolites. Specifically, reduced circulating 1,25-(OH)D levels in the presence of comparable 25-(OH)D concentrations may indicate altered Vitamin D activation and may be associated with impaired skeletal metabolism. Given that low-energy DRFs are less expected in non-elderly adults, evaluation of both 25-(OH)D and 1,25-(OH)D may provide additional insight into the metabolic profile of this patient group. Nevertheless, data addressing this relationship in non-elderly adults presenting with low-energy DRFs remain limited.[6,7]

Beyond Vitamin D metabolites, biochemical markers such as serum alkaline phosphatase (ALP), calcium (Ca), phosphate (P), and parathyroid hormone (PTH) are also important components of bone metabolism assessment.[8] The primary aim of this study was to compare serum 25-(OH)D and 1,25-(OH)D levels between non-elderly adults with low-energy DRFs and age- and sex-comparable healthy controls. The secondary aim was to evaluate whether ALP, Ca, P, and PTH levels, in addition to Vitamin D metabolites, were associated with articular involvement patterns in low-energy DRFs.

MATERIALS AND METHODS

Study Design and Participants

This retrospective observational case–control study was conducted at Marmara University Faculty of Medicine. The study protocol was approved by the Marmara University Faculty of Medicine Non-Interventional Clinical Research Ethics Committee (Protocol No.09.2025.25-0481; approval date: June 01, 2025). The study was conducted in accordance with the principles of the Declaration of Helsinki.

The fracture cohort consisted of patients aged 18–60 years who presented with low-energy DRFs between January and June 2025. These patients were identified retrospectively from the institution's electronic medical records, and their demographic characteristics, fracture-related data, and laboratory results were retrieved from the hospital database. As the study was based exclusively on retrospectively collected clinical data and no research-specific interventions were performed, the Institutional Ethics Committee waived the requirement for written informed consent from the patient cohort.

Patients were eligible if they sustained a DRF following a low-energy mechanism (e.g., a fall from standing height). Exclusion criteria included high-energy trauma, a previous diagnosis of osteoporosis (established by previous bone mineral density assessment or clinical diagnosis, or current pharmacological treatment for osteoporosis), metabolic bone diseases (including osteomalacia and hyperparathyroidism), chronic kidney or liver disease, malignancy, glucocorticoid use, or Vitamin D supplementation within 6 months before enrollment.

Following ethics approval, healthy controls were prospectively recruited from volunteers attending the outpatient clinic between June and December 2025, including patients' relatives, hospital staff and other volunteers. Eligibility was assessed according to predefined inclusion and exclusion criteria, and written informed consent was obtained from all participants prior to enrolment. Controls were recruited using a frequency-matching strategy to achieve an age and sex distribution comparable to that of the fracture cohort. According to the inclusion and exclusion criteria, a total of 102 patients met the eligibility criteria, and 138 healthy volunteers were included in the control group.

Fracture Classification

The Frykman Fracture Classification System was used to assess articular involvement patterns in low-energy DRFs. Although the AO/OTA classification is widely used for DRFs, the Frykman classification was selected in the present study because the primary objective of the subgroup analysis was not to guide treatment strategy or to provide a detailed morphologic fracture classification, but rather to evaluate biochemical parameters according to radiographic joint involvement. The Frykman classification provides a practical distinction between extra-articular fractures, radiocarpal joint involvement, distal radioulnar joint involvement, combined joint involvement, and the presence of an associated ulnar styloid fracture.

According to this classification system, extra-articular DRFs are classified as Type I, while radiocarpal joint involvement is categorized as Type III. Distal radioulnar joint involvement is designated as Type V, and involvement of both the radiocarpal and distal radioulnar joints is classified as Type VII. In cases with a concomitant ulnar styloid fracture, the corresponding fracture types are classified as Type II, IV, VI, or VIII, respectively.

The Frykman fracture type of each low-energy DRF was determined by two independent orthopedic surgeons who were blinded to the biochemical results. Anteroposterior and lateral radiographs obtained at the initial presentation were evaluated. Any discrepancies between the two observers were resolved by consensus.

Because the aim of this study was to evaluate the relationship

between biochemical parameters and fracture involvement patterns, treatment modality was not included as an analytical variable. Therefore, closed reduction and casting, closed reduction and percutaneous pinning, and open reduction and internal fixation were not evaluated separately.

Biochemical Analysis

At the study institution, venous blood sampling is routinely performed as part of the etiological evaluation of young adults presenting with low-energy DRFs that are inconsistent with the reported injury mechanism. This is done to investigate potential underlying metabolic or endocrine disorders. Venous blood samples were collected from all patients in the fracture group the morning after their initial presentation to the emergency department, after an overnight fast. Thus, biochemical measurements in the fracture group were obtained after the fracture occurred and before definitive treatment, whenever possible. In the control group, venous blood samples were collected under the same fasting conditions.

Serum 25-hydroxyvitamin D [25-(OH)D] and 1,25-(OH)D levels were measured using a Beckman Coulter UniCel DxI Access immunoassay analyzer (Beckman Coulter, USA) with the corresponding manufacturer-specific Vitamin D assays. Serum total calcium, phosphate, and ALP concentrations were measured by colorimetric methods using an automated biochemical analyzer. PTH levels were analyzed using an electrochemiluminescence immunoassay.

All biochemical analyses were performed in the central biochemistry laboratory of the study hospital according to standard laboratory procedures. Reference ranges were based on the calibration values and reporting standards of the same laboratory.

Study Outcomes

The primary outcome of this study was the comparison of serum 25-(OH)D and 1,25-(OH)D levels between young adults with low-energy DRFs and a healthy control group. A comparative analysis was conducted between the fracture and control groups, including demographic characteristics (age and sex) and serum Vitamin D metabolite levels. To assess the consistency of the primary findings across different age groups, a predefined sensitivity analysis was performed using three age categories (18–30, 31–45, and 46–60 years). Secondary outcomes encompassed comparisons of serum ALP, Ca, P, and PTH levels according to fracture severity. Fracture severity was categorized according to the predefined Frykman groups to examine the association between biochemical markers and the degree of fracture fragmentation.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics, version 25.0 (IBM Corp., Armonk, NY, USA). The final dataset included 102 patients with low-energy DRFs and 138 age- and sex-comparable healthy controls aged 18–60 years. The normality of data distribution was assessed using both analytical methods, including the Kolmogorov–Smirnov test, and visual methods, including histograms and probability plots.

Descriptive statistics were presented as mean±standard deviation (SD) for normally distributed continuous variables and as median with interquartile range and minimum–maximum values for non-normally distributed continuous variables. Categorical variables were summarized as frequencies and percentages.

For comparisons between two independent groups, the Independent-samples t-test was used for normally distributed variables, whereas the Mann–Whitney U test was used for non-normally distributed variables. When comparisons were required among more than two independent groups, one-way analysis of variance was used for normally distributed variables, and the Kruskal–Wallis test was used for non-normally distributed variables. Post hoc pairwise comparisons were performed when a statistically significant overall difference was detected. Given the relatively small sample size of some fracture subgroups, these post hoc analyses were considered exploratory and interpreted accordingly.

Categorical variables were analyzed using the Chi-square test. When the assumptions of the Chi-square test were not met, Fisher's exact test was applied. A $p<0.05$ was considered statistically significant.

To determine whether serum 1,25-(OH)D was independently associated with low-energy DRFs, a multivariable binary logistic regression analysis was performed with fracture status as the dependent variable and age, sex, and serum 1,25-(OH)D level as independent variables. Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were reported. Serum 25-hydroxyvitamin D was not included in the multivariable model because it was not significantly associated with fracture status in the univariable analysis.

An a priori sample size calculation was performed during the study planning phase using G*Power software (version 3.1.9.7, Heinrich Heine University Düsseldorf, Germany) to determine whether the anticipated recruitment period would provide an adequate sample size for the primary analysis. Because no previous study had specifically compared serum 1,25-(OH)D levels between young adults with low-energy DRFs and healthy controls, a medium-to-large standardized effect size (Cohen's d=0.65) was assumed. Using a two-sided α level of 0.05, a statistical power of 80%, and an allocation ratio of 1.35, the minimum required sample size was calculated as 80 participants (34 patients and 46 controls). The final study population comprised 240 participants (102 patients and 138 controls), exceeding the calculated minimum sample size.

RESULTS

A total of 240 participants were included in the final analysis, consisting of 102 patients with low-energy DRFs and 138 age- and sex-comparable healthy controls aged 18–60 years.

There was no statistically significant difference between the fracture and control groups in terms of age, age-group distribution, or sex distribution (p=0.285, p=0.648, and p=0.855, respectively). Overall serum total 25-(OH)D levels were similar between the fracture and control groups (p=0.557). However, overall serum 1,25-(OH)D levels were significantly lower in the fracture group than in the control group (mean difference, −11.87 pg/mL; 95% CI, −16.57–−7.17; p<0.001). Age-stratified sensitivity analysis demonstrated that this difference remained consistent across the predefined age categories, although statistical significance was not reached in the 18–30-year subgroup. The detailed demographic characteristics and Vitamin D metabolite levels are summarized in Table 1.

Given the significant association observed in the univariable analysis, serum 1,25-(OH)D, the primary biochemical variable of interest in the present study, was further evaluated using multivariable binary logistic regression. After adjustment for age and sex, lower serum 1,25-(OH)D levels remained independently associated with fracture status (adjusted OR, 0.965; 95% CI, 0.951–0.980; p<0.001). The findings revealed that neither age (p=0.628) nor sex (p=0.871) exhibited independent associations with fracture status. The findings of the multivariable analysis are presented in Table 2.

The median 25-(OH)D level was 17.58 ng/mL, and the mean 1,25-(OH)D level was 44.1±19.60 pg/mL in patients with low-energy DRFs. These values were within the laboratory reference range, although 25-(OH)D levels were close to the lower limit. Median or mean values of serum ALP, calcium, phosphate, and PTH were within the laboratory reference ranges. The descriptive statistics of the biochemical parameters in the fracture group are presented in Table 3.

Extra-articular DRFs (Frykman types I–II) were detected in 16 patients (15.69%), while the most common intra-articular involvement pattern was radiocarpal extension (Frykman types III–IV), observed in 34 patients (33.33%). No significant association was found between Frykman fracture type and age or sex distribution (p>0.05). However, significant differences were observed among Frykman subgroups in terms of 25-(OH)D, ALP, and calcium levels (p=0.009, p=0.001, and p=0.002, respectively) (Table 4).

Post hoc pairwise analyses showed that 25-(OH)D levels were lower in Frykman types I-II fractures compared with the other fracture subgroups (Table 5). ALP levels were higher in Frykman Types I-II fractures compared with the other fracture subgroups (Table 6). Calcium levels also differed between selected Frykman subgroups, with lower values in Frykman Types I-II fractures compared with Frykman Types III-IV and

Table 1. Demographic characteristics and Vitamin D metabolite levels of the fracture and control groups

	Fracture group (n=102)	Control group (n=138)	p
Age (years)	43 (22) (18–60)	45 (24) (18–60)	0.285*
Age groups, n (%)		0.648**	
18–30 years of age	26 (25.5%)	36 (26.1%)	
31–45 years of age	32 (31.4%)	36 (26.1%)	
46–60 years of age	44 (43.1%)	66 (47.8%)	
Sex, n (%)		0.855**	
Female	52 (51%)	72 (52.2%)	
Male	50 (49%)	66 (47.8%)	
25-hydroxyvitamin D (ng/mL)			
Overall	17.58 (21.5) (3–115)	18.40 (10.69) (4.5–66.36)	0.557*
18–30 years	17.58 (30.92) (6.92–72.9)	16.78 (9.86) (4.5–36.87)	0.954*
31–45 years	16.47 (48.79) (6.92–115)	17 (15.46) (7.40–46.60)	0.325*
46–60 years	17.33 (17.09) (3–63.9)	20.30 (11.27) (6.49–66.36)	0.092*
1,25-dihydroxyvitamin D (pg/mL)			
Overall	44.1±19.60	55.97±17.22	<0.001***
18–30 years	48.09±21.42	54.65±18.07	0.197***
31–45 years	41.66±18.13	50.93±17.15	0.034***
46–60 years	43.52±19.61	59.44±16.24	<0.001***

n: Number of participants; p: Statistical significance value. *p value was calculated using the Mann–Whitney U test. **Categorical variables were analyzed using the Chi-square test or Fisher's exact test, as appropriate. ***p value was calculated using the independent-samples t-test. Age subgroup analyses were performed as a sensitivity analysis to evaluate the consistency of the primary findings across narrower age categories.

Table 2. Multivariable logistic regression analysis adjusted for age and sex

Variable	Adjusted OR	95% CI	p
Age (per year)	0.994	0.972–1.017	0.628
Male sex	1.051	0.578–1.909	0.871
1,25-dihydroxyvitamin D (per pg/mL)	0.965	0.951–0.980	<0.001

Data are presented as adjusted odds ratios (ORs) with 95% confidence intervals (CIs). A multivariable binary logistic regression model was constructed including serum 1,25-dihydroxyvitamin D as the primary biochemical variable and adjusted for age and sex. Only variables demonstrating a significant association in the univariable analysis were entered into the multivariable model.

Table 3. Vitamin D metabolites and other biochemical parameters in patients with low-energy distal radius fractures

Parameter	Low-energy distal radius fractures (n=102)	Normal range
25-hydroxyvitamin D (ng/mL)	17.58 (21.5) (3–115)	15–80 ng/mL
1,25-dihydroxyvitamin D (pg/mL)	44.1±19.60	20–80 pg/mL
ALP (IU/L)	79.4 (29.6) (44–133.8)	33–98 IU/L
Calcium (mg/dL)	9.8 (0.6) (7.33–10.9)	8.8–10.6 mg/dL
Phosphate (mg/dL)	3.41±0.49	2.8–4.0 mg/dL
Parathyroid hormone (pg/mL)	38.1 (28.2) (7–365)	12–88 pg/mL

n: Number of patients.

Table 4. Parameters related to articular involvement in distal radius fractures

	Articular involvement of DRFs–Frykman classification				
	Types I–II (n=16)	Types III–IV (n=34)	Types V-VI (n=30)	Types VII-VIII (n=22)	p
Age (years)	50 (22) (23–59)	40 (26) (18–60)	43 (21) (18–59)	41 (15) (27–52)	0.496*
Sex, n (%)		0.081**			
Female	10 (62.5%)	22 (64.7%)	12 (40%)	8 (36.4%)	
Male	6 (37.5%)	12 (35.3%)	18 (60%)	14 (63.6%)	
25-(OH)D (ng/mL)	10.71 (10.74) (5.95–21.45)	21.9 (15.12) (8.5–115)	17.58 (39.95) (3–72.9)	14.82 (53.5) (8.84–73.5)	0.009*
1,25-(OH)D (pg/mL)	47.57±18.069	49.85±22.560	38.54±17.932	40.28±15.774	0.081***
ALP (IU/L)	98.1 (13.33) (83–104)	72.3 (23.47) (59.3–127.1)	78 (34.1) (44–133.8)	75 (35.2) (55.9–118.7)	0.001*
Calcium (mg/dL)	9.52 (0.47) (9–10.1)	9.9 (0.4) (8.9–10.9)	9.9 (0.7) (7.33–10.7)	9.7 (0.5) (8.96–10.2)	0.002*
Phosphate (mg/dL)	3.49±0.612	3.49±0.600	3.23±0.413	3.47±0.200	0.131***
PTH (pg/mL)	53.75 (33.78) (7–365)	37.1 (22.18) (16.5–157)	38.1 (28.1) (11–82)	40.6 (29.8) (20.5–65.4)	0.822*

n: Number of patients; p: Statistical significance value; ALP: Alkaline phosphatase; PTH: Parathormone. *p value was calculated using the Kruskal-Wallis test. **Categorical variables were analyzed using the chi-square test or Fisher's exact test, as appropriate. ***P value was calculated using one-way analysis of variance (ANOVA).

V-VI fractures, and higher values in Frykman Types III-IV fractures compared with Frykman Types VII-VIII fractures (Table 7). Because of the relatively small number of patients in the Frykman Types I-II subgroup and the use of multiple pairwise comparisons, these subgroup findings should be interpreted as exploratory.

DISCUSSION

The present study investigated the relationship between Vitamin D metabolism and low-energy DRFs in non-elderly adults and evaluated biochemical parameters associated with fracture characteristics. In non-elderly adults, cortical bone is typically thicker and bone mineral density is higher; conse-

Table 5. *Post hoc* analysis of 25-hydroxyvitamin D levels among Frykman fracture types

25-hydroxyvitamin D levels	Frykman types I-II	Frykman types III-IV	Frykman types V-VI	Frykman types VII-VIII
Frykman types I-II	—	<0.001	0.047	0.009
Frykman types III-IV	<0.001	—	0.404	0.867
Frykman types V-VI	0.047	0.404	—	0.282
Frykman Types VII-VIII	0.009	0.867	0.282	—

The values contained within the cells of the table are statistical significance p-values. Post hoc pairwise analyses were conducted using the Mann–Whitney U test.

Table 6. *Post hoc* analysis of alkaline phosphatase levels among Frykman fracture types

Alkaline phosphatase levels	Frykman types I-II	Frykman types III-IV	Frykman types V-VI	Frykman types VII-VIII
Frykman types I-II	—	<0.001	0.001	0.006
Frykman types III-IV	<0.001	—	0.851	0.687
Frykman types V-VI	0.001	0.851	—	0.739
Frykman types VII-VIII	0.006	0.687	0.739	—

The values contained within the cells of the table are statistical significance p-values. Post hoc pairwise analyses were conducted using the Mann–Whitney U test.

Table 7. *Post hoc* analysis of calcium levels among Frykman fracture types

Calcium levels	Frykman types I-II	Frykman types III-IV	Frykman types V-VI	Frykman types VII-VIII
Frykman types I-II	—	<0.001	0.021	0.181
Frykman types III-IV	<0.001	—	0.386	0.008
Frykman types V-VI	0.021	0.386	—	0.169
Frykman types VII-VIII	0.181	0.008	0.169	—

The values contained within the cells of the table are statistical significance p-values. Post hoc pairwise analyses were conducted using the Mann–Whitney U test.

quently, fractures in this population most commonly occur as a result of high-energy trauma. Therefore, the occurrence of fractures following low-energy mechanisms in this age group may suggest the presence of underlying systemic or metabolic factors associated with impaired bone quality. The present study's main strength is its comprehensive evaluation of Vitamin D metabolism by assessing not only serum 25-(OH)D levels, but also its biologically active metabolite, 1,25-(OH)D. The principal finding of this study was that serum 1,25-(OH)D concentrations were significantly lower in patients with low-energy DRFs compared with age- and sex-comparable healthy controls, whereas total 25-(OH)D levels were similar between groups. This association remained significant after adjustment for age and sex in the multivariable analysis, supporting the robustness of the primary finding. These findings suggest an association between low-energy DRFs and altered Vitamin D metabolism, particularly involving the active Vitamin D metabolite, rather than demonstrating a causal relationship.

Vitamin D is essential for intestinal calcium absorption, bone mineralization, and skeletal remodeling, and Vitamin D deficiency has long been recognized as an important factor associated with fragility fractures. Previous studies have demonstrated that inadequate Vitamin D levels are associated with an increased risk of low-energy fractures, including DRFs.[9,10] Abe et al.[11] reported that reduced Vitamin D levels were associated with increased fracture severity in DRFs among peri- and postmenopausal women. Similarly, another study emphasized that patients presenting with DRFs often exhibit underlying metabolic bone abnormalities, including altered Vitamin D status and osteoporosis, suggesting that metabolic bone health is relevant in this patient population.[12] However, most previous studies evaluated only serum 25-(OH)D concentrations, which reflect Vitamin D stores rather than its

biological activity. In the present study, serum 25-(OH)D levels were similar between groups, whereas 1,25-(OH)D levels were lower in the fracture group. This discrepancy may indicate that evaluation of the active Vitamin D metabolite provides additional information beyond total Vitamin D status. However, because biochemical measurements were obtained after fracture occurrence, it cannot be determined whether lower 1,25-(OH)D levels preceded the fracture or reflected post-traumatic metabolic and inflammatory changes.

The conversion of 25-(OH)D to its active form, 1,25-(OH)D, is mediated primarily by 1α-hydroxylase (CYP27B1) in the kidney and in several extra-renal tissues, including bone-related cells. Therefore, differences between circulating 25-(OH)D and 1,25-(OH)D levels may reflect alterations in Vitamin D activation, degradation, or regulatory pathways. Inflammatory pathways may also influence Vitamin D metabolism. Vitamin D and its active metabolite exert immunomodulatory effects through the Vitamin D receptor, which is expressed in immune and bone cells. Experimental studies have demonstrated that proinflammatory cytokines can influence the expression of enzymes involved in Vitamin D metabolism, including CYP27B1 and CYP24A1, thereby altering the balance between activation and degradation of Vitamin D metabolites.[13] The age-stratified analysis showed that the difference in 1,25-(OH)D levels was not statistically significant in the youngest subgroup, whereas a significant difference was observed both in the overall analysis and in the older age categories. Although this finding may partly reflect the smaller sample size of the youngest subgroup, it also raises the possibility that age-related differences in Vitamin D metabolic regulation or inflammatory responses may influence the relationship between circulating 25-(OH)D and 1,25-(OH)D levels. Such age-related variation could potentially contribute to the stronger between-group difference observed in the older subgroups. Accordingly, the lower 1,25-(OH)D levels observed in the fracture group may be related either to pre-existing metabolic differences or to biological responses occurring after trauma. This uncertainty should be considered when interpreting the present findings.

Vitamin D also has well-recognized anti-inflammatory properties that are relevant to skeletal homeostasis and immune regulation.[14] Recent advances in bone imaging techniques have provided further insight into the relationship between Vitamin D metabolism and skeletal structure. High-resolution peripheral quantitative computed tomography studies have demonstrated that insufficient Vitamin D activity may be associated with thinner cortical bone, reduced trabecular connectivity, and increased cortical porosity, structural alterations that may compromise bone strength even in individuals with normal bone mineral density.[15] Vitamin D also regulates osteoblast and osteocyte function and influences calcium–phosphate homeostasis, all of which are important for maintaining bone microarchitecture and mechanical competence.[16] Although these mechanisms provide biological plausibility, the observational design of the present study does not allow direct mechanistic or causal conclusions.

From a clinical perspective, our findings suggest that assessing Vitamin D metabolism beyond serum 25-(OH)D levels may provide additional information in non-elderly adults presenting with low-energy DRFs. While serum 25-(OH)D levels were similar between the fracture and control groups, patients with fractures had significantly lower circulating 1,25-(OH)D levels, raising the possibility of altered Vitamin D activation or regulation. Importantly, this association remained significant after adjustment for age and sex, suggesting that the observed relationship was not explained by these variables. However, because mean serum 1,25-(OH)D levels remained within the laboratory reference range in both groups, the clinical significance of this difference remains uncertain. Nevertheless, these findings should be interpreted with caution, as they do not demonstrate a causal relationship between altered Vitamin D metabolism and fracture occurrence. Rather, they highlight a potential biological association that warrants further investigation. Prospective studies with pre-fracture or longitudinal measurements of Vitamin D metabolites are needed to determine whether these alterations precede fracture or develop as a consequence of the injury

Subgroup analysis according to the Frykman fracture classification revealed differences in metabolic parameters between fracture patterns. Patients with extra-articular fractures, corresponding to Frykman Types I-II, showed lower 25-(OH)D and calcium levels and higher ALP activity than some of the other fracture subgroups. This pattern may suggest differences in mineral metabolism or bone turnover among fracture subgroups. Similar metabolic patterns have been reported in studies linking Vitamin D insufficiency with impaired bone quality and increased fracture susceptibility.[17,18] Vitamin D deficiency has also been associated with reduced skeletal strength, particularly in cortical bone-dominant regions such as the distal radius.[17-19] In addition, Vitamin D and calcium metabolism are closely interconnected, and alterations in this endocrine axis may influence bone turnover and skeletal integrity. Recent studies have demonstrated that changes in Vitamin D status may be associated with bone turnover markers and mineral homeostasis, which are closely related to bone mineral density and fracture susceptibility.[20,21]

In addition to Vitamin D metabolism, biochemical markers involved in bone turnover provide important insight into skeletal physiology. Parameters such as Ca, P, PTH, and ALP play central roles in mineral homeostasis and bone remodeling.[22] In the present study, patients with extra-articular fractures demonstrated lower calcium levels accompanied by increased ALP activity, which may reflect differences in bone turnover among fracture patterns. However, total ALP is a non-specific biochemical marker and should not be interpreted as a specific indicator of osteoblastic activity, as its levels may also reflect ALP activity from non-osseous tissues.[22] Previous studies have also reported associations between ALP levels,

bone mineral density, and skeletal remodeling processes.[23,24] Furthermore, metabolic and inflammatory factors have been shown to be associated with low-energy fracture occurrence and healing responses. Chisalita et al.[25] reported that systemic metabolic factors, including inflammatory mediators and growth factor signaling, were related to low-energy DRFs and fracture healing. Nevertheless, the subgroup findings of the present study should be interpreted cautiously because the Frykman Types I-II subgroup included a relatively small number of patients and multiple post hoc comparisons were performed. These analyses were exploratory in nature and were not intended to provide confirmatory evidence for differences between individual Frykman subgroups. Given the potential for elevated Type I error probability associated with multiple comparisons, the observed associations should therefore be regarded as hypothesis-generating, rather than confirmatory.

This study has several strengths and limitations. One of its key strengths is the comprehensive evaluation of Vitamin D metabolism by measuring both total 25-(OH)D and its biologically active form, 1,25-(OH)D. This approach provided a broader understanding of the metabolic changes associated with low-energy DRFs than assessment of 25-(OH)D alone. In addition, all biochemical analyses were performed using standardized laboratory procedures, increasing the reliability of the measurements. Another strength is the inclusion of an age- and sex-comparable control group drawn from the same non-elderly adult population, which helped minimize age-related confounding. However, the relatively broad age range of 18–60 years may still reflect considerable biological variability in factors such as hormonal status, physical activity, bone metabolism, and lifestyle. Future studies focusing on more homogeneous age groups, particularly adults over 40 or 45 years of age, may help clarify these associations more precisely.

Several limitations should be considered. First, all biochemical measurements in the fracture group were obtained after the fracture had occurred. Therefore, it is not possible to determine whether the observed reduction in serum 1,25-(OH)D levels preceded the fracture or resulted from post-traumatic metabolic, inflammatory, or bone turnover-related changes. Consequently, the present findings demonstrate an association rather than causation. Second, several potential confounding variables known to influence Vitamin D metabolism and fracture risk were not systematically recorded or fully controlled, including body mass index, renal function parameters, smoking status, alcohol consumption, physical activity level, dietary Vitamin D intake, sunlight exposure, and seasonal variation. The absence of these variables limited the ability to perform comprehensive multivariable adjustment, although age and sex were accounted for in the multivariable analysis. Third, bone mineral density measurements or microarchitectural imaging assessments were not available, preventing direct correlation between biochemical findings and structural bone characteristics. In addition, osteoporosis was excluded based on documented medical history and prior clinical diagnosis rather than systematic bone mineral density assessment. Therefore, previously undiagnosed low bone mineral density or osteoporosis cannot be completely excluded. Finally, the relatively small and unequal sample sizes of some Frykman subgroups, particularly the Frykman Types I-II subgroup, should be considered when interpreting the subgroup findings. The pairwise comparisons were exploratory and were not adjusted for multiple testing. Given the relatively small subgroup sizes, the application of highly conservative multiple-comparison corrections could have increased the risk of Type II error and potentially obscured clinically relevant exploratory findings. Therefore, these subgroup findings should be considered hypothesis-generating rather than confirmatory, and interpreted with caution given the potential for an increased risk of Type I error.

CONCLUSION

In conclusion, non-elderly adults with low-energy DRFs had lower serum 1,25-(OH)D levels than age- and sex-comparable healthy controls, whereas serum 25-(OH)D levels did not differ between the groups. The association between lower serum 1,25-(OH)D levels and low-energy DRFs remained significant after adjustment for age and sex. These findings suggest that changes in Vitamin D metabolism may be associated with low-energy DRFs in this population. However, because biochemical measurements were obtained after the fracture and residual confounding cannot be excluded, no causal relationship can be inferred. Further prospective studies with serial measurements of Vitamin D metabolites before and after fracture are needed to better understand the temporal relationship between Vitamin D metabolism and the risk of low-energy fractures.

Ethics Committee Approval: The study protocol was approved by the Marmara University Faculty of Medicine Non-Interventional Clinical Research Ethics Committee (Date: 01.06.2025, Decision No: 09.2025.25-0481).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: B.K., B.G., D.G.; Design: B.K., B.G., D.G.; Supervision: B.G., D.G.; Resource: U.A., B.K., İ.Ö., S.N.Ç.; Materials: B.K., U.A., İ.Ö., S.N.Ç.; Data collection and/or processing: U.A., S.N.Ç., İ.Ö.; Analysis and/or interpretation: B.G., B.K.; Literature review: B.K., S.N.Ç.; Writing: B.K.; Critical review: B.G., U.A., İ.Ö.

Informed Consent: Written informed consent was obtained.

Conflict of Interest: None declared.

Financial Disclosure: The author declared that this study has received no financial support.

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ORİJİNAL ÇALIŞMA - *ÖZ*

D vitamini metabolitleri ile yaşlı olmayan erişkinlerde düşük enerjili distal radius kırıkları arasındaki ilişki

AMAÇ: Düşük enerjili distal radius kırığı gelişen 18–60 yaş arası erişkinlerde D vitamini metabolizmasının değerlendirilmesi amaçlandı. Bu kapsamda serum 25-hidroksivitamin D [25-(OH)D] ve aktif D vitamini formu olan 1,25-dihidroksivitamin D [1,25-(OH)D] düzeyleri, yaş ve cinsiyet açısından benzer sağlıklı kontrollerle karşılaştırıldı. Ayrıca D vitamini metabolitleri, alkalen fosfataz, kalsiyum, fosfat ve parathormon düzeylerinin kırığın eklem tutulumu ile ilişkisi incelendi.

GEREÇ VE YÖNTEM: Bu gözlemsel olgu-kontrol çalışmasına, düşük enerjili distal radius kırığı olan 18–60 yaş arası 102 hasta ve aynı yaş aralığında 138 sağlıklı kontrol dahil edildi. Düşük enerjili travma, 1,5 metreden daha düşük seviyeden düşme gibi mekanizmalar olarak tanımlandı. Yüksek enerjili travma, metabolik kemik hastalığı, kronik böbrek veya karaciğer hastalığı, malignite, glukokortikoid kullanımı ve son altı ay içinde D vitamini desteği kullanımı dışlama kriterleri olarak belirlendi. Kırıklar Frykman sınıflamasına göre değerlendirildi. Serum 25-(OH)D ve 1,25-(OH)D düzeyleri ELISA yöntemiyle ölçüldü; alkalen fosfataz, kalsiyum, fosfat ve parathormon düzeyleri kaydedildi.

BULGULAR: Toplam 240 katılımcı analiz edildi. Hasta ve kontrol grupları arasında yaş ve cinsiyet dağılımı açısından anlamlı fark saptanmadı (sırasıyla p=0.285 ve p=0.855). Serum 25-(OH)D düzeyleri gruplar arasında benzerdi (p=0.557). Buna karşın serum 1,25-(OH)D düzeyleri düşük enerjili distal radius kırığı grubunda kontrol grubuna göre anlamlı olarak daha düşüktü (p<0.001). Frykman sınıflamasına göre yapılan alt grup analizinde 25-(OH)D, alkalen fosfataz ve kalsiyum düzeyleri açısından anlamlı farklılık saptandı (sırasıyla p=0.009, p=0.001 ve p=0.002). Ekstraartiküler kırıklarda 25-(OH)D düzeyleri daha düşük, alkalen fosfataz düzeyleri ise daha yüksek bulundu. Kalsiyum düzeyleri de bazı intraartiküler kırık alt gruplarına göre daha düşük seyretti.

SONUÇ: Düşük enerjili distal radius kırığı olan 18–60 yaş arası erişkinlerde, serum 25-(OH)D düzeyleri sağlıklı kontrollerle benzer olmasına rağmen serum 1,25-(OH)D düzeyleri daha düşük bulundu. Bu bulgular, aktif D vitamini metabolizmasındaki değişikliklerin düşük enerjili distal radius kırıkları ile ilişkili olabileceğini düşündürmektedir. Serum 25-(OH)D düzeyleri benzer olsa bile aktif D vitamini metabolitlerinin değerlendirilmesi, bu hasta grubunda metabolik durumun daha kapsamlı anlaşılmasına katkı sağlayabilir.

Anahtar sözcükler: 1, 25-dihidroksivitamin D; D vitamini metabolizması; distal radius kırığı; düşük enerjili kırık; Frykman sınıflaması.

Ulus Travma Acil Cerrahi Derg 2026;32(11):1425-1434 DOI: 10.14744/tjtes.2026.06812

CASE SERIES

Emergency management of obturator hernıa in elderly patients: A case series and surgical strategy

Ender Bademkıran,[1] Doğuş Coşkun,[2] Ekin Ulusoy,[1] Halil Uğur Savaş[3]

[1]Department of General Surgery, Akhisar Mustafa Kirazoğlu State Hospital, Manisa-*Türkiye*
[2]Department of Radiology, Akhisar Mustafa Kirazoğlu State Hospital, Manisa-*Türkiye*
[3]Department of Emergency, Akhisar Mustafa Kirazoğlu State Hospital, Manisa-*Türkiye*

ABSTRACT

Obturator hernia (OH) is a rare but potentially life-threatening cause of intestinal obstruction, accounting for approximately 0.07–1% of all abdominal wall hernias. It occurs predominantly in very elderly, multiparous, and underweight women and is commonly referred to as the "little old lady's hernia." Due to its deep anatomical location and the absence of specific clinical findings, OH remains a significant diagnostic challenge even for experienced surgeons. Diagnostic delay is common and contributes to the high reported mortality rates, ranging between 13% and 40%. Therefore, early recognition supported by a high index of clinical suspicion is essential for improving outcomes. Computed tomography (CT) has become the most reliable imaging modality for preoperative diagnosis, enabling accurate identification of the herniated bowel loop as well as evaluation of bowel viability and associated complications. In this study, we present three elderly, cachectic female patients admitted with signs and symptoms of mechanical intestinal obstruction who were diagnosed with OH using CT imaging and underwent emergency surgical treatment. Surgical management included both laparoscopic transabdominal preperitoneal repair and open midline laparotomy depending on intraoperative findings and patient condition. In all cases, primary suture repair of the obturator defect was preferred instead of polypropylene mesh reinforcement. This strategy was guided by the presence of enteric contamination, bowel perforation, suspected ischemia, or advanced patient frailty associated with increased risk of delayed complications related to polypropylene mesh material. This case series demonstrates that successful management depends primarily on early CT-based diagnosis, sustained clinical suspicion, and individualized surgical decision-making.

Keywords: Clinical suspicion; emergency surgery; hernia repair; intestinal obstruction; laparoscopy; obturator hernia.

INTRODUCTION

Obturator hernia (OH) is a rare and clinically challenging type of abdominal wall hernia, with a reported incidence ranging between 0.07% and 1% of all cases.[1,2] It is characterized by the protrusion of bowel segments through the obturator canal along the lateral pelvic wall. Colloquially known as the "little old lady's hernia," it occurs most frequently in very elderly, underweight, and multiparous women.[3] The primary predisposing factors include a widened pelvic anatomy, generalized connective tissue laxity, and a significant reduction in preperitoneal fat volume, which normally acts as a protective cushion for the obturator canal.[4]

The obturator canal typically measures 2–3 cm in length and approximately 1 cm in width, transmitting the obturator nerve and vessels.[5] Due to the narrow and rigid nature of this anatomical space, incarceration and strangulation of herniated bowel segments are frequent occurrences. Clinically, approximately 90% of patients present with acute intestinal obstruction.[6] Although the Howship–Romberg sign – pain radiating along the medial aspect of the thigh due to compression of the obturator nerve – is considered highly pathognomonic, its clinical presence is inconsistent, occurring in only 15–50% of cases.[7]

Cite this article as: Bademkıran E, Coşkun D, Ulusoy E, Savaş HU. Emergency management of obturator hernia in elderly patients: A case series and surgical strategy. Ulus Travma Acil Cerrahi Derg 2026;32:1435-1440.

Address for correspondence: Ender Bademkıran
Department of General Surgery, Akhisar Mustafa Kirazoğlu State Hospital, Manisa, Türkiye
E-mail: drebademkiran@gmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(11):1435-1440 DOI: 10.14744/tjtes.2026.63754
Submitted: 24.12.2025 Revised: 01.03.2026 Accepted: 13.04.2026 Published: 05.11.2026

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At present, computed tomography (CT) imaging is the gold standard for diagnosis, boasting an accuracy rate of nearly 90%.[8,9] and playing a critical role in reducing morbidity by preventing further diagnostic delays. While surgical intervention represents the definitive treatment, the optimal operative strategy remains controversial. Midline laparotomy continues to be the traditional approach in emergency presentations, particularly in patients with suspected bowel compromise or delayed diagnosis.[10] However, minimally invasive surgery has increasingly gained acceptance, with laparoscopic techniques offering both diagnostic exploration and therapeutic repair. Among these, the transabdominal preperitoneal (TAPP) approach provides excellent visualization of the obturator canal and allows simultaneous assessment of bowel viability and contralateral defects.[11,12]

CASE PRESENTATION

Case 1

Presentation and Clinical Evaluation: An 85-year-old cachectic, multiparous woman presented to a tertiary emergency department with a 3-day history of abdominal pain, nausea, vomiting, and obstipation. After 28 h of observation without a definitive diagnosis at another facility, she was transferred to our department. On physical examination, the abdomen was not significantly distended, but mild lower abdominal discomfort was noted. No inguinal hernia was palpable. Notably, the patient reported pain radiating to the medial aspect of the thigh, consistent with a positive Howship–Romberg sign. Initial laboratory evaluations were unremarkable.

Diagnostic imaging

Plain abdominal radiography revealed multiple air–fluid levels. While the initial CT interpretation at the previous center described a general ileus without identifying a specific site of herniation, a second expert radiological consultation was requested due to high clinical suspicion. This focused review clearly identified a bowel loop herniating between the obturator internus and externus muscles (Fig. 1).

Surgical technique

The patient was placed in the supine position with a 15–20° Trendelenburg tilt. A laparoscopic TAPP approach was utilized. A 10-mm umbilical camera port and two 5-mm lateral working ports were inserted. The peritoneum was incised from the medial aspect of the anterior superior ıliac spine to the medial umbilical ligament. Retzius space was dissected between the symphysis pubis and Cooper's ligament. The incarcerated loop was reduced using atraumatic graspers with coordinated traction and counter-traction after widening the peritoneal dissection (Fig. 2). Direct forceful pulling, use of energy devices near the hernia neck, and blind dissection were strictly avoided. Although the bowel was viable with active peristalsis, focal hyperemia was noted. Due to the patient's extreme frailty and the risk of delayed perforation in these ischemic areas, polypropylene mesh was avoided, and the defect was closed primarily with 2/0 Vicryl sutures.

Outcome

By post-operative day 5, the patient had tolerated oral intake and resumed gas passage. However, she subsequently developed acute respiratory distress and was transferred to the ıntensive care unit. Despite intensive management, she required mechanical ventilation on day 14 and succumbed to cardiac arrest on post-operative day 52.

Case 2

Presentation and clinical evaluation

A 94-year-old multiparous, cachectic woman presented with a 2-day history of abdominal pain, nausea, and obstipation.



Figure 1. Computed tomography image demonstrating herniation of a small bowel loop through the obturator canal between the pectineus and obturator externus muscles.

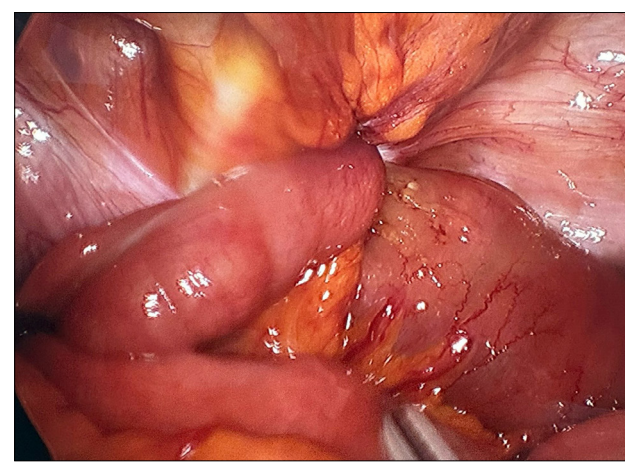


Figure 2. Laparoscopic view of the incarcerated small bowel segment herniated through the obturator canal after reduction.

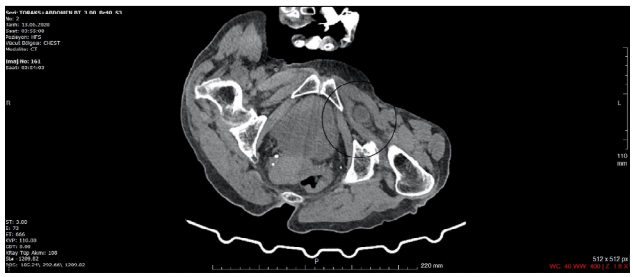


Figure 3. Computed tomography image showing a right-sided obturator hernia with small bowel herniation through the obturator canal.

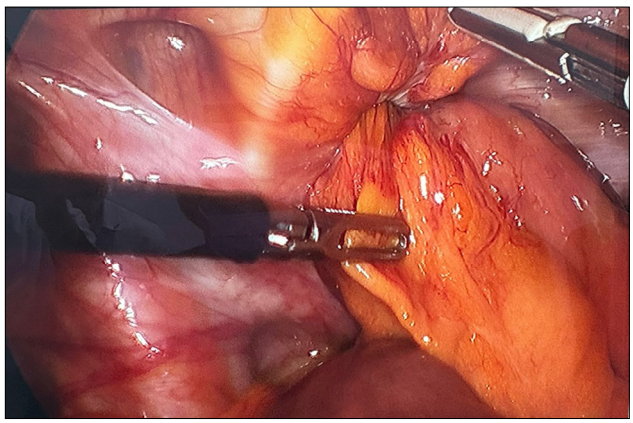


Figure 4. Laparoscopic view of the incarcerated bowel loop and mesentery within the obturator canal.

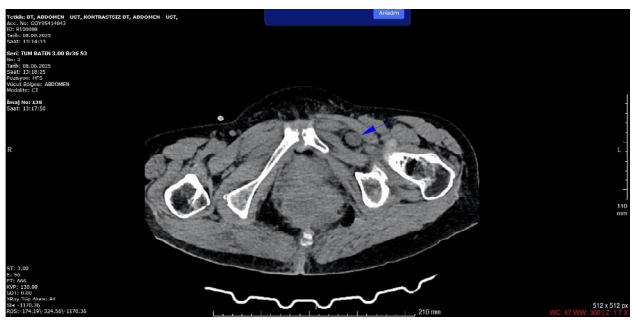


Figure 5. Computed tomography image demonstrating a left-sided obturator hernia with herniation of the small bowel through the obturator canal.

Physical examination revealed mild abdominal distension and localized tenderness in the lower quadrants; the Howship–Romberg sign was negative.

Diagnostic imaging

Initial plain radiography demonstrated small bowel obstruction. The preliminary CT scan identified air–fluid levels but failed to identify the hernia. Given the high-grade obstruction, a second radiological review was requested, which successfully identified a bowel loop herniating between the pectineus and obturator externus muscles, confirming a right-sided OH (Fig. 3).

Surgical technique

A laparoscopic approach was initiated as described in Case 1 (Fig. 4). During the reduction of the tightly incarcerated loop, two perforations occurred, leading to enteric contamination. The procedure was converted to open surgery via a midline incision. Due to gross contamination of the surgical field, the use of polypropylene mesh was contraindicated. The bowel was repaired primarily, and the obturator defect was closed using 2/0 non-absorbable sutures.

Outcome

The patient's post-operative course was uneventful, and she was discharged on day 5. During the 6-month follow-up period, no recurrence, hematoma, seroma, or chronic pain was identified.

Case 3

Presentation and Clinical Evaluation: A 76-year-old multiparous, cachectic woman presented with a 4-day history of escalating abdominal pain and vomiting. Physical examination revealed significant abdominal distension and diffuse tenderness. The Howship–Romberg sign was negative.

Diagnostic imaging

The initial CT imaging promptly demonstrated a bowel loop herniating between the pectineus and obturator externus muscles. Furthermore, the CT scan revealed an associated intra-abdominal abscess collection adjacent to the hernia site. Based on these findings, an open surgical approach was primarily selected to ensure adequate drainage and contamination control (Fig. 5).

Surgical technique

An infra-umbilical and supra-umbilical midline laparotomy was performed. Intraoperative exploration confirmed that the incarcerated bowel loop was necrotic and had perforated, resulting in a localized abscess. A segmental small bowel resection was performed, followed by a primary end-to-end anastomosis. Due to the bacterial contamination and the presence of an abscess, polypropylene mesh use was strictly avoided. The obturator defect was closed primarily using 2/0 Vicryl sutures.

The patient recovered unremarkable and was discharged on day 7. The 6-month follow-up evaluation showed no evidence of recurrence, hematoma, seroma formation, or chronic pelvic pain.

Surgical Strategy and Technical Considerations

In all cases, reduction of the incarcerated bowel was performed using gentle traction–countertraction techniques following adequate preperitoneal dissection. Direct forceful pulling and energy device use near the obturator canal were avoided to prevent vascular or nerve injury. The rigid anatomical structure of the obturator canal necessitates controlled enlargement of the peritoneal incision to facilitate safe reduction.

The decision between mesh reinforcement and primary suture repair was individualized. Although mesh repair has been increasingly reported, several factors influenced our preference for primary closure: Suspected bowel ischemia, intraoperative contamination, advanced patient frailty, and the risk of delayed perforation. In elderly cachectic patients, avoiding prosthetic material was considered a safer strategy to minimize infectious complications.

DISCUSSION

OH represents a rare but life-threatening cause of intestinal obstruction requiring rapid diagnosis and individualized emergency surgical management. Despite its rarity, it carries disproportionately high morbidity and mortality rates, largely attributable to delayed diagnosis and the advanced age and frailty of affected patients. Previous retrospective series have reported mortality rates ranging between 13% and 40%, emphasizing the importance of early recognition and timely surgical intervention.[13,14]

Diagnostic Challenges and Role of CT

The clinical diagnosis of OH remains difficult due to its deep pelvic location and absence of visible external swelling. Most patients present with nonspecific symptoms of mechanical small bowel obstruction, frequently resulting in diagnostic delay. Although the Howship–Romberg sign is traditionally described as pathognomonic, its sensitivity is variable and insufficient for reliable clinical diagnosis.[15] CT has therefore become the diagnostic gold standard, allowing direct visualization of herniated bowel loops, assessment of bowel viability, and identification of associated complications such as strangulation or abscess formation.[16] In our series, two patients required secondary radiologic review for definitive diagnosis, highlighting that imaging interpretation must be guided by strong clinical suspicion and close surgeon–radiologist collaboration.

Laparoscopic Versus Open Repair

Emergency midline laparotomy has historically been considered the standard approach because it enables rapid exploration and bowel resection when necessary. However, increasing experience with minimally invasive surgery has shifted contemporary management toward laparoscopic repair. Laparoscopy provides superior visualization of deep pelvic anatomy, reduced post-operative pain, earlier mobilization, and shorter hospital stay compared with open surgery.[17] Furthermore, laparoscopic exploration allows inspection of the contralateral obturator canal, where occult or bilateral OHs may coexist in a small but clinically relevant proportion of patients.[18] In our experience, laparoscopy served both diagnostic and therapeutic purposes; nevertheless, prompt conversion to open surgery remained mandatory in the presence of perforation or contamination.

TAPP Versus Extraperitoneal Techniques

Both TAPP and totally extraperitoneal (TEP) approaches have been described for OH repair. While TEP avoids peritoneal entry, it limits intra-abdominal assessment and evaluation of bowel viability. In emergency settings where strangulation is suspected, TAPP offers a decisive advantage by permitting complete abdominal exploration and immediate management of ischemic bowel segments.[19] Adequate Trendelenburg positioning, wide peritoneal dissection, and controlled traction–countertraction maneuvers are essential to minimize iatrogenic injury within the rigid obturator canal.

Primary Repair Versus Mesh Reinforcement

The optimal method of obturator defect closure remains controversial. Mesh reinforcement has been increasingly reported due to tension-free repair principles and potentially lower recurrence rates.[20] Nevertheless, OHs differ from other groin hernias in that the defect is typically small and surrounded by rigid pelvic structures, allowing secure primary closure in selected patients. In the present series, primary suture repair was intentionally preferred. This decision reflected patient-specific risk stratification rather than technical limitation. Advanced age, cachexia, possible bowel ischemia, and the risk of delayed perforation favored the avoidance of polypropylene mesh material. Our short-term follow-up without recurrence supports the feasibility of primary repair in emergency and high-risk scenarios.

Management in Contaminated Fields

Contamination remains a decisive determinant of operative strategy. Emergency hernia surgery principles generally discourage permanent mesh implantation in contaminated environments due to increased risks of surgical site infection and mesh-related complications.[20] Two patients in our series presented with perforation or abscess formation requiring bowel repair or resection. Under these circumstances, primary tissue repair represents the safest and most pragmatic approach. In frail elderly patients, even borderline bowel viability may predispose to delayed ischemic perforation, further supporting cautious avoidance of foreign material.

Proposed Surgical Decision Algorithm

Management of OH should integrate patient physiology, contamination status, and bowel viability rather than relying on a single standardized operative technique. Laparoscopy should be considered the initial approach in hemodynamically stable patients due to its diagnostic superiority and therapeutic flexibility. However, surgeons must maintain a low threshold for conversion when ischemia, perforation, or severe contamination is encountered. Individualized intraoperative decision-making remains central to successful outcomes.

Proposed Surgical Strategy

Based on our experience and available literature, the following practical strategy may assist emergency surgeons:

- Hemodynamically stable patients without perforation → laparoscopic TAPP preferred
- Suspicion of ischemia or abscess → primary open approach

• Contaminated field or frail elderly patient → primary suture repair

• Clean field with viable bowel → mesh repair may be considered.

In summary, OH management should not follow a rigid technical paradigm but rather a patient-tailored strategy balancing minimally invasive benefits with surgical safety. Early CT diagnosis, flexible operative planning, and individualized repair selection represent the key determinants of improved outcomes in this rare but potentially fatal emergency condition.

The present study contributes practical decision-making guidance rather than technical novelty. Our experience emphasizes that emergency OH surgery should be guided by contamination status, bowel viability, and patient frailty. The proposed strategy integrates laparoscopic advantages with safe conversion principles and supports selective primary repair in contaminated or high-risk elderly patients.

CONCLUSION

OH should be considered in elderly, thin, and multiparous women presenting with intestinal obstruction. Although laparoscopic TAPP provides significant diagnostic and therapeutic advantages, the operative strategy must be individualized according to patient physiology, bowel viability, and contamination status. Early diagnosis supported by CT imaging and timely surgical intervention remains the most important determinants of survival.

Our experience suggests that in frail elderly patients, particularly in the presence of borderline bowel viability or enteric contamination, primary suture repair represents a safe and pragmatic alternative to prosthetic reinforcement. Ultimately, successful management depends on maintaining a high index of clinical suspicion and adopting a flexible, patient-tailored surgical strategy rather than a single standardized operative approach.

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: E.B.; Design: E.U.; Supervision: E.B.; Resource: E.B.; Materials: E.B.; Data collection and/or processing: D.C.; Analysis and/or interpretation: D.C.; Literature review: E.U.; Writing: E.B.; Critical review: H.U.S.

Informed Consent: Written informed consent was obtained from the patients (or their legal guardians) who participated in this study for the publication of their clinical details and any accompanying images.

Conflict of Interest: None declared.

Financial Disclosure: The author declared that this study has received no financial support.

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OLGU SERİSİ - *ÖZ*

Yaşlı hastalarda obtürator hernisinin acil yönetimi: Bir olgu serisi ve cerrahi strateji

Obturator hernisi (OH), tüm abdominal duvar fıtıkları arasında yaklaşık %0.07–1 oranında görülen, nadir ancak potansiyel olarak yaşamı tehdit eden bir intestinal obstrüksiyon nedenidir. En sık ileri yaşta, multipar ve düşük vücut kitle indeksine sahip kadınlarda görülmekte olup literatürde sıklıkla "küçük yaşlı kadın fıtığı" olarak tanımlanmaktadır. Derin anatomik yerleşimi ve özgül klinik bulguların çoğu zaman bulunmaması nedeniyle obturator hernisi, deneyimli cerrahlar için dahi önemli bir tanısal güçlük oluşturmaktadır. Tanıda yaşanan gecikmeler, bildirilen %13–40 arasındaki yüksek mortalite oranlarının başlıca nedenidir. Bu nedenle yüksek klinik şüphe düzeyi ile desteklenen erken tanı, hasta sonuçlarının iyileştirilmesinde kritik öneme sahiptir. Bilgisayarlı tomografi (BT), herniye bağırsak segmentinin doğru şekilde gösterilmesine, barsak canlılığının değerlendirilmesine ve eşlik eden komplikasyonların saptanmasına olanak sağlaması nedeniyle günümüzde preoperatif tanıda en güvenilir görüntüleme yöntemi haline gelmiştir. Bu çalışmada, mekanik intestinal obstrüksiyon bulguları ile başvuran, BT ile obturator hernisi tanısı konulan ve acil cerrahi tedavi uygulanan üç yaşlı, kaşektik kadın hasta sunulmuştur. Cerrahi tedavi, intraoperatif bulgular ve hastanın klinik durumuna göre laparoskopik transabdominal preperitoneal (TAPP) yaklaşım veya açık orta hat laparotomi şeklinde gerçekleştirilmiştir. Tüm olgularda obturator defektin onarımında prostetik mesh yerine primer sütür onarımı tercih edilmiştir. Bu yaklaşım; enterik kontaminasyon varlığı, barsak perforasyonu, şüpheli iskemi bulguları ve ileri derecede frail hastalarda prostetik materyale bağlı gecikmiş komplikasyon riskinin yüksek olması temelinde belirlenmiştir. Bu olgu serisi, obturator hernisinin başarılı yönetiminin esas olarak erken BT temelli tanı, sürdürülen klinik şüphe ve hastaya özgü bireyselleştirilmiş cerrahi karar verme sürecine bağlı olduğunu göstermektedir.

Anahtar sözcükler: Acil cerrahi; fıtık onarımı; intestinal obstrüksiyon; klinik şüphecilik; laparoskopi; obturator hernisi.

Ulus Travma Acil Cerrahi Derg 2026;32(11):1435-1440 DOI: 10.14744/tjtes.2026.63754

CASE REPORT

A rare injury combination: Hawkins type I talar neck fracture, Jones fracture, and calcaneal avulsion fracture accompanying a bimalleolar ankle fracture

Mustafa Kara,[1] Bedri Karaismailoğlu[2]

[1]Department of Orthopedics and Traumatology, Selahaddin Eyyübi State Hospital, Diyarbakır-*Türkiye*
[2]Department of Orthopaedics and Traumatology, Cerrahpaşa University, İstanbul-*Türkiye*

ABSTRACT

Bimalleolar ankle fractures are common traumatic injuries and can usually be identified using standard radiographic examinations. However, associated fractures – particularly non-displaced fractures of the talus and calcaneus – may be overlooked on plain radiographs. Accurate identification of accompanying injuries in complex ankle trauma is of great importance for appropriate treatment planning. In this report, we present a rare case of a bimalleolar ankle fracture accompanied by a Hawkins type I talar neck fracture, a Jones fracture, and a calcaneal avulsion fracture. While the bimalleolar ankle fracture and Jones fracture were detected on initial plain radiographs, the talar neck fracture and calcaneal avulsion fracture were identified only by computed tomography (CT). The bimalleolar ankle fracture, talar neck fracture, and Jones fracture were treated surgically, whereas the calcaneal avulsion fracture was managed conservatively. In ankle trauma, particularly in cases involving multiple fractures, plain radiographs may be insufficient and associated injuries can be overlooked. Talar neck fractures and calcaneal avulsion fractures may not be detected on standard radiographs when they are non-displaced. This case highlights the critical role of advanced imaging modalities, particularly CT, in identifying associated fractures in complex ankle injuries. The use of CT in complex ankle trauma increases diagnostic accuracy and contributes to appropriate treatment planning.

Keywords: Bimalleolar ankle fracture; calcaneal fracture; jones fracture; talar neck fracture.

INTRODUCTION

Bimalleolar ankle fractures are among the most common lower extremity injuries encountered in orthopedic practice, and they constitute a significant proportion of these injuries.[1] In most cases, these fractures can be adequately evaluated using standard radiographic examinations. However, associated fractures involving the talus and hindfoot region may not be detected on plain radiographs, particularly in non-displaced cases or when they are obscured by prominent malleolar fractures.

Talus neck fractures have particular clinical importance due to the unique anatomy of the talus, the extensive articular surface coverage, and its limited vascularity.[2] Delayed diagnosis of these fractures may lead to serious complications such as avascular necrosis.[3] The coexistence of talus neck fractures with bimalleolar ankle fractures is rare and may pose diagnostic challenges, particularly in non-displaced cases.[4] In this case report, we present a rare fracture combination emphasizing the diagnostic value of computed tomography (CT) in ankle trauma.

CASE REPORT

A 59-year-old patient presented with complaints of pain and swelling in the ankle following a pedestrian traffic accident.

Cite this article as: Kara M, Karaismailoğlu B. A rare injury combination: Hawkins type I talar neck fracture, Jones fracture, and calcaneal avulsion fracture accompanying a bimalleolar ankle fracture. Ulus Travma Acil Cerrahi Derg 2026;32:1441-1445.

Address for correspondence: Mustafa Kara
Department of Orthopedics and Traumatology, Selahaddin Eyyübi State Hospital, Diyarbakır, Türkiye
E-mail: drmustafakara44@gmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(11):1441-1445 DOI: 10.14744/tjtes.2026.17060
Submitted: 15.02.2026 Revised: 09.04.2026 Accepted: 11.04.2026 Published: 05.11.2026
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Figure 1. Anteroposterior ankle radiograph demonstrating a bimalleolar fracture.



Figure 2. Lateral ankle radiograph demonstrating a Jones fracture. The talus and calcaneal fractures are not clearly distinguishable on plain radiography.



Figure 3. Anteroposterior foot radiograph demonstrating the Jones fracture.

Physical examination revealed diffuse tenderness around the ankle as well as swelling and tenderness along the lateral border of the foot. Neurovascular examination was normal, and no open wound was identified.

Initial ankle radiographs demonstrated a bimalleolar ankle fracture and a Jones fracture at the base of the fifth metatarsal (Figs. 1-3). CT was performed to further evaluate the fracture pattern in detail and to assess joint congruency. CT imaging revealed a non-displaced Hawkins type I talar neck fracture and a calcaneal avulsion fracture, which were not clearly visible on the initial radiographs (Figs. 4 and 5).



Figure 4. Sagittal computed tomography image demonstrating the talar fracture.

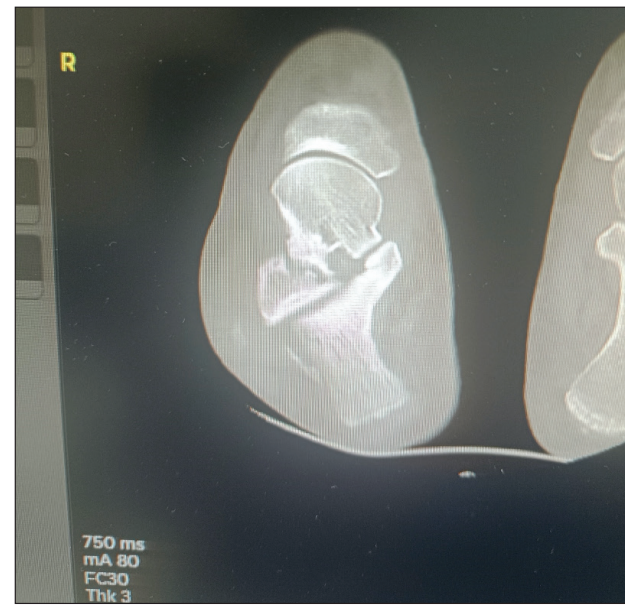


Figure 5. Axial computed tomography image demonstrating fractures of the talus and calcaneus.



Figure 6. Early post-operative anteroposterior ankle radiograph demonstrating plate-and-screw fixation of the lateral malleolus, cannulated screw fixation of the medial malleolus and Jones fracture, and headless cannulated screw fixation of the talar fracture.



Figure 7. Lateral ankle radiograph obtained at 6 months postoperatively.

Surgical treatment was planned, and the patient was operated on in the supine position under tourniquet control. Fixation of the lateral malleolus fracture was achieved using a plate and screws, whereas the medial malleolus fracture was fixed with two cannulated screws. Stability of the talar neck fracture was provided using two headless cannulated screws. The Jones fracture was fixed with a single cannulated screw. The calcaneal avulsion fracture was managed conservatively due to minimal displacement and small fragment size.

Postoperatively, the extremity was immobilized, and the patient was advised to remain non-weight-bearing. Range of motion exercises were initiated after wound healing. Gradual weight-bearing was started at the 2nd post-operative month.

During follow-up, no complications were observed except for a transient superficial skin infection around the lateral malleolus. At the final follow-up visit at 6 months, radiographic evaluation demonstrated union of all fractures. No clinical or radiological findings suggestive of avascular necrosis of the talus were detected (Figs. 6 and 7). The patient regained ankle range of motion and returned to daily activities without any limitations.

DISCUSSION

Bimalleolar fractures are common injuries in ankle trauma and are generally easily recognized on plain radiographs. However, concomitant fractures of the talus and calcaneus may be overlooked on standard radiographic evaluation, particularly in non-displaced cases. Due to the complex anatomy of the talus, its relationship with multiple articular surfaces, and its limited vascularity, early recognition and appropriate management of fractures involving this region are of great importance.[5,6]

In the present case, although the bimalleolar ankle fracture and the Jones fracture were clearly identified on plain radiographs, the talar neck fracture and the calcaneal avulsion fracture could only be detected through CT. This finding highlights the importance of advanced imaging modalities in ankle trauma when there is a discrepancy between clinical findings and radiographic evaluation. In particular, non-displaced talar neck fractures such as Hawkins type I may pose diagnostic challenges when assessed solely with plain radiographs.

In the literature, talar neck fractures have most commonly been reported in association with high-energy trauma, open fractures, or fracture-dislocations, and in rare cases, concomitant medial malleolar fractures or bimalleolar ankle fractures have been described.[7,8] However, to the best of our knowledge, there are no reported cases in the literature describing the coexistence of a bimalleolar ankle fracture with

a Hawkins type I talar neck fracture, a Jones fracture, and a calcaneal avulsion fracture. Therefore, the present case represents an unusual fracture combination that falls outside the typical injury patterns previously described in the literature.

The treatment approach for talar neck fractures is determined by considering the degree of displacement, congruency of the articular surfaces, and ankle stability.[9] Although conservative treatment options have frequently been reported for Hawkins type I fractures, the presence of concomitant ankle instability and multiple associated fractures may influence the decision toward surgical stabilization.[10] In the present case, fixation of the talar neck fracture with headless cannulated screws contributed to restoration of ankle stability together with the bimalleolar fracture fixation, and anatomical alignment was achieved in the early post-operative period.

Calcaneal avulsion fractures are often encountered as small bony fragments, and treatment planning is mainly determined by fragment size and location, degree of displacement, and the condition of the surrounding soft tissues.[11] In the present case, the calcaneal avulsion fracture was managed conservatively since it did not require surgical intervention, and no complications related to this fracture were observed during follow-up.

Furthermore, the literature has demonstrated that CT is significantly more sensitive than plain radiographs in detecting associated talar and hindfoot fractures in ankle trauma.[12] In particular, non-displaced talar neck fractures and small calcaneal avulsion fractures may be easily overlooked on standard radiographs. It has also been reported that the presence of multiple fractures around the ankle directly influences treatment decisions and surgical planning. Therefore, routine incorporation of CT into the evaluation process is recommended in complex ankle trauma to identify occult fractures.

Finally, this case underscores the importance of careful evaluation for associated injuries in patients presenting with bimalleolar ankle fractures. Although standard radiographs are typically sufficient for initial assessment, concomitant fractures – particularly of the talus and hindfoot – may be easily overlooked. Routine use of CT for all such cases may not be justified; however, advanced imaging should be strongly considered in the presence of high-energy trauma, persistent or disproportionate pain, or when clinical findings are not fully explained by radiographic results. Maintaining a high index of suspicion is essential to avoid missed injuries and to ensure appropriate management.

CONCLUSION

This case demonstrates that focusing solely on apparent malleolar fractures in ankle trauma may be insufficient, as concomitant occult fractures can directly influence the treatment strategy. CT plays a critical role in clarifying the diagnosis and guiding appropriate treatment planning, particularly in complex ankle injuries with suspected multiple fractures.

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: M.K., B.K.; Design: M.K., B.K.; Supervision: M.K., B:K.; Resource: M.K.; Materials: M.K.; Data collection and/or processing: M.K.; Analysis and/or interpretation: M.K., B.K.; Literature review: M.K., B:K.; Writing: M.K., B.K.; Critical review: M.K., B.K.

Informed Consent: Written informed consent was obtained from the patient for the publication of this case report and the accompanying images.

Conflict of Interest: None declared.

Financial Disclosure: The author declared that this study has received no financial support.

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OLGU SUNUMU - *ÖZ*

Bimalleoler ayak bileği kırığı ile birlikte görülen Hawkins tip I talus boyun kırığı, Jones kırığı ve kalkaneus avülsiyon kırığı: Nadir bir yaralanma kombinasyonu

Bimalleoler ayak bileği kırıkları sık karşılaşılan travmalar olup çoğu zaman tanı klinik muayene ve standart radyografiler ile kolaylıkla konulabilmektedir. Ancak bu kırıklara eşlik eden, özellikle non-deplase talus ve kalkaneus kırıkları, direkt grafilerde kolaylıkla gözden kaçabilmektedir. Kompleks ayak bileği travmalarında eşlik eden yaralanmaların tespit edilmesi, uygun tedavi planlaması açısından büyük önem taşımaktadır. Bu yazıda, bimalleoler ayak bileği kırığına Hawkins Tip I talus boyun kırığı, Jones kırığı ve kalkaneus avülsiyon kırığının eşlik ettiği nadir bir olgu sunulmaktadır. Başlangıçta yapılan direkt radyografilerde bimalleoler ayak bileği kırığı ve Jones kırığı saptanırken, talus boyun kırığı ile kalkaneus avülsiyon kırığı ancak bilgisayarlı tomografi incelemesi ile tespit edilebilmiştir. Bimalleoler ayak bileği kırığı, talus boyun kırığı ve Jones kırığı uygun yöntemler ile cerrahi olarak tespit edilmiş, kalkaneus avülsiyon kırığı ise konservatif yöntemlerle takip edilmiştir. Ayak bileği travmalarında, özellikle çoklu kırık birlikteliklerinde, direkt grafiler yetersiz kalabilmekte ve ek yaralanmalar gözden kaçabilmektedir. Talus boyun kırıkları ve kalkaneus avülsiyon kırıkları, non-deplase olmaları durumunda standart radyografilerde saptanamayabilir. Bu olgu, kompleks ayak bileği travmalarında ileri görüntüleme yöntemlerinin, özellikle bilgisayarlı tomografinin, eşlik eden kırıkların tanınmasındaki kritik rolünü ortaya koymaktadır. Kompleks ayak bileği travmalarında bilgisayarlı tomografi kullanımı, tanısal doğruluğu artırarak uygun tedavi stratejisinin belirlenmesine katkı sağlamaktadır.

Anahtar sözcükler: Bimalleoler kırık, Jones kırığı, kalkaneus kırığı, Talus boyun kırığı.

Ulus Travma Acil Cerrahi Derg 2026;32(11):1441-1445 DOI: 10.14744/tjtes.2026.17060

CASE REPORT

Severe acute gastric volvulus: A case report with perforation and extra-gastric ischemic findings

Samet Paydaş,[1] **Mehmet Aykut Yıldırım**[2]

[1]Department of General Surgery, Konya City Hospital, Konya-*Türkiye*
[2]Department of General Surgery, Necmettin Erbakan University Faculty of Medicine, Konya-*Türkiye*

ABSTRACT

Acute gastric volvulus is a rare but life-threatening surgical emergency associated with high morbidity and mortality. Its non-specific clinical presentation can lead to delays in diagnosis, resulting in devastating complications. A 36-year-old male patient presented to the emergency department with sudden-onset abdominal distension and respiratory distress. He had severe hemodynamic instability and signs of an acute abdomen on admission. Imaging revealed intraperitoneal free air. Emergency laparotomy demonstrated a 270° gastric volvulus complicated by ischemia and perforation. In addition, pneumatosis intestinalis of the small bowel and Meckel's diverticulum perforation were observed, likely. Acute gastric volvulus should be kept in mind in patients presenting to the emergency department with sudden abdominal distension and rapid clinical deterioration. Although early diagnosis and emergency surgical intervention are of vital importance, mortality remains high in unstable patients.

Keywords: Acute gastric distension; gastric perforation in gastric volvulus; gastric volvulus; pneumatosis intestinalis.

INTRODUCTION

Acute gastric volvulus is characterized by abnormal rotation of the stomach exceeding 180°, leading to obstruction and potential vascular compromise.[1,2] Despite its rarity, it is considered a true surgical emergency due to the risk of ischemia, necrosis, and perforation.[3,4] Mortality rates are particularly high in delayed or complicated cases.[3-5]

Clinical presentation can vary across a wide spectrum, ranging from nonspecific symptoms to sudden hemodynamic collapse. Although Borchardt's triad – characterized by epigastric pain, retching without vomiting, and inability to pass a nasogastric tube – has been classically described, it is not present in every patient.[1-3,6] This variability contributes to diagnostic delays.

Gastric volvulus can be classified as primary or secondary. Secondary forms are more common and are generally associated with diaphragmatic anomalies such as paraesophageal hernia.[3,7] However, cases developing without predisposing factors have also been reported.

In this report, we present a case of gastric volvulus triggered by acute gastric distension, with rapid progression and fatal outcome, emphasizing the importance of early diagnosis and emergency surgical management.

CASE REPORT

A 36-year-old male patient with no known comorbidities presented with sudden-onset abdominal distension and severe abdominal pain that had begun approximately 2 h prior. He had no history of previous surgery, chronic illness, or substance use.

On admission, the patient's general condition was poor, with an altered level of consciousness, shallow breathing, and a markedly distended and rigid abdomen consistent with an acute abdomen. Vital signs indicated severe hemodynamic

Cite this article as: Paydaş S, Yıldırım MA. Severe acute gastric volvulus: A case report with perforation and extra-gastric ischemic findings. Ulus Travma Acil Cerrahi Derg 2026;32:1446-1449.

Address for correspondence: Samet Paydaş
Department of General Surgery, Konya City Hospital, Konya, Türkiye
E-mail: sametpaydas@gmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(11):1446-1449 DOI: 10.14744/tjtes.2026.54015
Submitted: 10.01.2026 Revised: 04.05.2026 Accepted: 06.05.2026 Published: 05.11.2026

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instability: Heart rate 156 beats/min, blood pressure 61/38 mmHg, and oxygen saturation 82%. Arterial blood gas analysis revealed severe respiratory acidosis. Plain radiography showed intraperitoneal free air. The combination of acute abdomen findings, hemodynamic instability, and free intraperitoneal air on plain radiography constituted a strong indication for emergency surgical intervention. The pre-operative differential diagnosis included sigmoid colon volvulus or perforation secondary to gastric volvulus.

In the present case, the surgical decision-making process was shaped by the patient's clinical status at the time of presentation. Marked hemodynamic instability, signs of an acute abdomen, and intraperitoneal free air on plain radiography were evaluated as strong findings in favor of gastrointestinal perforation. Therefore, it was anticipated that advanced imaging would delay surgical intervention, and emergency laparotomy was decided on. In this setting, further imaging was considered unlikely to provide additional diagnostic benefit and could have delayed definitive management; therefore, no additional imaging was performed before surgery. Additional imaging was therefore deemed unlikely to alter management and was avoided to prevent delay. Furthermore, nasogastric decompression was not attempted preoperatively due to the patient's clinical instability and the risk of possible perforation.

Exploratory laparotomy revealed an approximately 270° organoaxial gastric volvulus complicated by ischemia and perforation at the site of torsion (Figs. 1 and 2). The stomach was markedly distended, with perforation located on the posterior wall secondary to ischemia. No diaphragmatic defect or hiatal hernia was identified. Further exploration showed pneumatosis intestinalis and areas of segmental ischemia in the small bowel (Figs. 3 and 4). In addition, a Meckel's diverticulum located in the terminal ileum with a distal perforation was identified.

Gastric perforation was repaired using a linear stapler (Fig. 5). The Meckel's diverticulum was resected (Fig. 6), and the abdominal cavity was irrigated. Drains were placed in the subhepatic, perisplenic, and pelvic regions.

In the post-operative period, the patient was transferred to the intensive care unit under mechanical ventilation and high-dose vasopressor support. Despite all aggressive resuscitation measures, refractory shock persisted, and the patient died 3 h postoperatively.



Figure 1. Intraoperative view demonstrating a 270° gastric volvulus with marked gastric distension and torsion of the stomach (arrow).



Figure 2. Intraoperative view showing gastric perforation at the site of ischemia secondary to gastric volvulus (arrow).

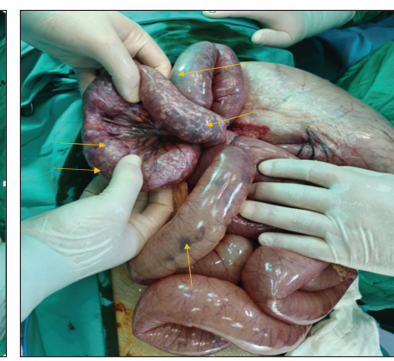


Figure 3. Intraoperative view demonstrating segmental intestinal ischemia associated with increased intra-abdominal pressure (arrows).

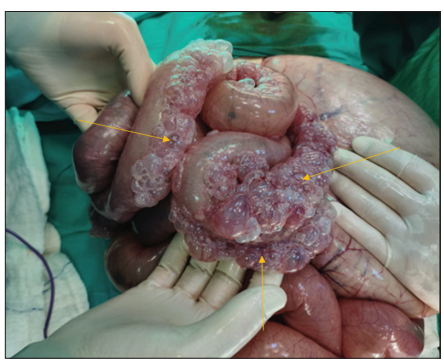


Figure 4. Intraoperative view demonstrating pneumatosis intestinalis involving small bowel loops (arrows).

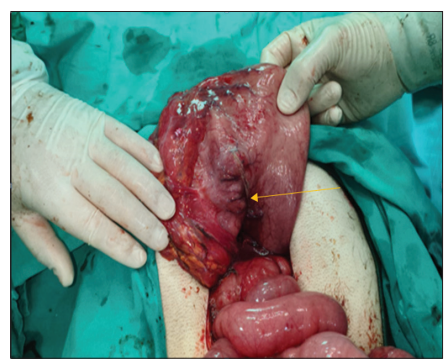


Figure 5. Intraoperative view demonstrating primary repair of the gastric perforation using a linear stapler (arrow).



Figure 6. Intraoperative view after closure of the perforated Meckel's diverticulum using a linear stapler (arrow).

DISCUSSION

Gastric volvulus is a rare but potentially fatal condition, and early diagnosis is challenging due to its non-specific clinical presentation.[3,4,8] Although it is more commonly seen in elderly patients with underlying anatomical predispositions, this case demonstrates that it can also occur in young individuals without known risk factors.

The management of gastric volvulus has evolved considerably in recent years; in stable patients with early diagnosis, nasogastric tube placement for gastric decompression and supportive measures are recommended.[1,2,9] However, the literature emphasizes that conservative approaches are insufficient in cases complicated by strangulation, ischemia, or perforation, and that delay significantly increases mortality in such patients. Therefore, emergency surgical intervention is accepted as the standard treatment approach in acute gastric volvulus cases accompanied by signs of complications.[3,4,9] In our case as well, the patient was taken to emergency surgery without delay due to the presence of ischemia and perforation secondary to strangulation at the gastric level, which is consistent with the approach recommended in the literature.

The majority of gastric volvulus cases reported in the literature occur in elderly patients and are frequently associated with anatomical anomalies such as paraesophageal hernia.[3,4,7,8] In contrast, no predisposing factor was identified in the presented case, and its occurrence in a young patient distinguishes it from the typical patient profile described in the literature.

The clinical presentation of gastric volvulus is highly variable and can range from nonspecific symptoms to sudden hemodynamic collapse. Although Borchardt's triad is considered characteristic, it may not be present in all patients, as observed in this case.[1-3,6] The absence of vomiting despite severe retching, along with rapid respiratory deterioration and hemodynamic instability, illustrates the deceptive and fulminant course of the disease.

One of the notable features of this case is that acute gastric distension is thought to have played a role as a triggering factor. Sudden-onset distension can rapidly lead to torsion, vascular compromise, and subsequent perforation. While gastric volvulus is most commonly associated with structural anomalies, cases triggered by acute gastric distension are rarely reported in the literature.[3,4] In this patient, the excessive increase in gastric volume is thought to have elevated intra-abdominal pressure, adversely affecting not only the stomach but also the perfusion of the small bowel.

A significant proportion of cases in the literature have been shown to develop strangulation, indicating a high risk of ischemic complications in acute gastric volvulus. In our case, strangulation developed at the gastric level, with secondary ischemia and perforation. These findings support the notion that acute gastric volvulus is a clinical condition that can progress rapidly and lead to life-threatening complications in a short period.[3-5]

Pneumatosis intestinalis is generally associated with mesenteric ischemia and may be indicative of serious underlying pathology.[10] Meckel's diverticulum perforation is extremely rare and, particularly in the setting of elevated intra-abdominal pressure, may be associated with underlying ischemic processes or impaired bowel perfusion.[11] The extra-gastric findings observed in this case may be better interpreted as a rare and possible association rather than a clearly established pathophysiological consequence. The pneumatosis intestinalis and Meckel's diverticulum perforation may be associated with the severe intra-abdominal process accompanying gastric volvulus; however, a definitive causal relationship cannot be established and remains speculative.

In particular, the classic series by Carter et al.[5] emphasized

Table 1. Comparison of the present case with representative cases from the literature

Study	Age	Predisposing factor	Type of volvulus	Complications	Associated intestinal findings	Outcome
Wu et al.[1]	>60	Diaphragmatic hernia	Organoaxial	Rare ischemia	None	Favorable with treatment
Chau and Dufel[2]	Variable	Anatomical defects	Mixed	Rare perforation	None	Good with early management
Rashid et al.[3]	50–70	Paraesophageal hernia	Organoaxial	Ischemia/ perforation	None	Increased mortality if delayed
Carter et al.[5]	Wide range	Diaphragmatic defects	Organoaxial	Perforation	None	High mortality
Teague et al.[12]	Middle-aged	Hernia/ligament laxity	Mixed	Ischemia	None	Good with surgery
Present case	36	None identified	270° Organoaxial volvulus	Ischemia+ perforation	Pneumatosis intestinalis+ Meckel's diverticulum perforation	Fatal

that mortality is higher in cases complicated by delayed diagnosis. Similarly, recent studies indicate that delay in diagnosis is the most important determinant of prognosis (Table 1).[1,2] In our case, the severe hemodynamic instability and advanced intra-abdominal pathological burden present at admission resulted in a fatal outcome despite early surgical intervention.

The treatment approach depends on the patient's clinical stability. Decompression may be attempted in stable patients; however, emergency surgical intervention is mandatory in the presence of ischemia, perforation, or shock.[9,12] Despite timely surgical intervention, mortality remains high in complicated cases;[4,5,12] this is supported by the fatal clinical course observed in the presented case.

CONCLUSION

This case represents a gastric volvulus occurring in a young patient without predisposing factors, with advanced complications and rare associated intestinal findings, thereby distinguishing it from existing knowledge in the literature. This demonstrates that gastric volvulus should be kept in mind not only in classic risk groups but also in atypical patients, and that prognosis can deteriorate dramatically, particularly in the presence of complex intra-abdominal findings.

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: S.P., M.A.Y.; Design: S.P., M.A.Y.; Supervision: S.P., M.A.Y.; Resource: S.P., M.A.Y.; Materials: S.P., M.A.Y.; Data collection and/or processing: S.P., M.A.Y.; Analysis and/or interpretation: S.P., M.A.Y.; Literature review: S.P., M.A.Y.; Writing: S.P., M.A.Y.; Critical review: S.P., M.A.Y.

Conflict of Interest: The authors declare that they have no conflicts of interest. Written informed consent was obtained from the patient's legal representatives for the publication of the clinical data related to this case..

Financial Disclosure: The author declared that this study has received no financial support.

Use of AI for Writing Assistance: The authors declared that artificial intelligence was not used in the study.

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OLGU SUNUMU - *ÖZ*

Şiddetli akut gastrik volvulus: Perforasyon ve ekstra-gastrik iskemik bulgularla seyreden bir olgu sunumu

Akut gastrik volvulus, yüksek morbidite ve mortalite ile ilişkili, nadir ancak yaşamı tehdit eden bir cerrahi acildir. Nonspesifik klinik prezentasyonu tanıda gecikmeye yol açarak yıkıcı komplikasyonlara neden olabilir. Otuz altı yaşında erkek hasta, ani başlayan karın distansiyonu ve solunum sıkıntısı ile acil servise başvurdu. Başvuru sırasında ciddi hemodinamik instabilite ve akut batın bulguları mevcuttu. Görüntülemede intraperitoneal serbest hava saptandı. Acil laparotomide iskemi ve perforasyon ile komplike olmuş 270° gastrik volvulus tespit edildi. Ayrıca, muhtemelen artmış intraabdominal basınca sekonder olarak ince barsakta pnömatozis intestinalis ve Meckel divertikül perforasyonu izlendi. Erken cerrahi müdahaleye rağmen hasta refrakter şok gelişimi sonrası erken postoperatif dönemde kaybedildi. Acil serviste ani karın distansiyonu ve hızlı klinik kötüleşme ile başvuran hastalarda akut gastrik volvulus akılda tutulmalıdır. Erken tanı ve acil cerrahi müdahale hayati önem taşımakla birlikte, instabil hastalarda mortalite yüksek seyretmektedir.

Anahtar sözcükler: Acil cerrahi; akut batın; gastrik perforasyon; gastrik volvulus; pnömatozis intestinalis.

Ulus Travma Acil Cerrahi Derg 2026;32(11):1446-1449 DOI: 10.14744/tjtes.2026.54015