ISSN 1306 - 696X

TURKISH JOURNAL of TRAUMA & EMERGENCY SURGERY

Ulusal Travma ve Acil Cerrahi Dergisi

Volume 32 | Number 6| June 2026

www.tjtes.org

TURKISH JOURNAL of TRAUMA & EMERGENCY SURGERY

Ulusal Travma ve Acil Cerrahi Dergisi

ISSUED BY THE TURKISH ASSOCIATION OF TRAUMA AND EMERGENCY SURGERY

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

Role of maslinic acid in ischemia-reperfusion-induced testicular injury in rats

Si-Ming Wei,[1,2] Yu-Min Huang[3]

[1]Shulan International Medical College, Zhejiang Shuren University, 310015 Hangzhou City, Zhejiang Province-*China*
[2]Faculty of Nursing, Zhejiang Chinese Medical University, 310053 Hangzhou City, Zhejiang Province-*China*
[3]Department of Sports Science, College of Education, Zhejiang University, 310058 Hangzhou City, Zhejiang Province-*China*

ABSTRACT

BACKGROUND: The pathophysiology of testicular ischemia-reperfusion is characterized by a marked increase in reactive oxygen species. Oxidative damage caused by reactive oxygen species to cellular components, including DNA, proteins and lipids, leads to injury of spermatogenic cells. Maslinic acid, a bioactive compound found in Olea europaea, hawthorn, and other medicinal plants, exhibits antioxidant properties. This study aimed to determine whether maslinic acid protects testicular sperm production following ischemia-reperfusion injury in a rat model.

METHODS: Male rats were randomly assigned to three groups: a control group (Group 1), an ischemia-reperfusion group (Group 2), and an ischemia-reperfusion + maslinic acid group (Group 3). Ischemia was induced in the left testis by two-hour torsion, followed by reperfusion via surgical detorsion. The treatment group received intraperitoneal administration of maslinic acid at the onset of detorsion procedure. Following detorsion, left orchiectomy was performed at either four hours or three months. To comprehensively assess testicular oxidative stress and function, we measured key indicators: malondialdehyde concentration (reflecting reactive oxygen species levels); activities of superoxide dismutase and catalase, representing components of the cellular antioxidant system; and overall spermatogenic efficiency. These parameters were evaluated using biochemical assays and histological analysis with hematoxylin-eosin staining.

RESULTS: Testicular ischemia-reperfusion significantly increased malondialdehyde levels while suppressing key antioxidant defenses (superoxide dismutase and catalase) and impairing spermatogenic function ($p<0.001$). Despite testicular damage induced by ischemia-reperfusion, maslinic acid treatment produced a partial restoration of these markers ($p<0.01$).

CONCLUSION: In summary, maslinic acid mitigates ischemia-reperfusion-induced testicular injury by enhancing superoxide dismutase and catalase activities while reducing reactive oxygen species.

Keywords: Maslinic acid; ischemia-reperfusion; testicular torsion.

INTRODUCTION

Testicular torsion, defined as the rotation of the spermatic cord, is one of the most urgent emergencies in urology. Its estimated prevalence is approximately 1 in 4,000 males by the age of 25.[1] Torsion compromises blood flow, depriving the testis of oxygen and resulting in ischemia. A critical period of approximately six hours is available for diagnosis and surgical detorsion,[2] during which restoration of blood flow can prevent irreversible testicular damage. Despite prompt intervention, testicular atrophy occurs in a substantial proportion of patients, with reported rates ranging from 25% to 60.2%.[3,4] The pathogenesis of testicular ischemia-reperfusion injury is complex and multifactorial, involving the initial ischemic

Cite this article as: Wei SM, Huang YM. Role of maslinic acid in ischemia-reperfusion-induced testicular injury in rats. Ulus Travma Acil Cerrahi Derg 2026;32:629-635.

Address for correspondence: Si-Ming Wei
Shulan International Medical College, Zhejiang Shuren University, 310015 Hangzhou City, Zhejiang Province, China
E-mail: wsm1971@hotmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(6):629-635 DOI: 10.14744/tjtes.2026.62296
Submitted: 17.10.2025 Revised: 27.01.2026 Accepted: 06.03.2026 Published: 03.06.2026

event, reperfusion-induced inflammation, oxidative stress, microvascular alterations, and multiple downstream mechanisms of injury. Among these, oxidative stress acts as a key driver of testicular damage.[5] This condition is characterized by a marked increase in reactive oxygen species, including hydrogen peroxide, hydroxyl radicals, and superoxide anions.[5] Reactive oxygen species attack cellular components, including DNA, proteins, and lipids, leading to damage of spermatogenic cells.[5]

Currently, no effective pharmacological treatments are available for testicular ischemia-reperfusion injury in clinical practice. Maslinic acid, a bioactive compound found in Olea europaea, hawthorn, and other medicinal plants, has attracted attention due to its diverse biological activities.[6-8] It has a molecular formula of C30H48O4 and a molecular weight of 472.7 g/mol.[7] Extensive pharmacological studies have demonstrated its potent antioxidant and anti-inflammatory effects.[8,9] Maslinic acid has been shown to protect various organs from ischemia-reperfusion injury, including the kidney, brain, and heart.[10-16] However, its potential protective role in testicular ischemia-reperfusion injury remains unexplored. In the present study, we employed a rat model of testicular ischemia-reperfusion to evaluate the therapeutic potential of maslinic acid by assessing oxidative stress markers and histopathological changes.

MATERIALS AND METHODS

Experimental Subjects and Ethical Considerations

Male Sprague–Dawley rats (250–300 g) were obtained from SLAC (Shanghai, China). Animals were housed under controlled conditions with a temperature of 20–22°C, relative humidity of 50–60%, and a 12-hour light/dark cycle. Standard laboratory chow and water were provided ad libitum. All experimental procedures were conducted in accordance with institutional ethical guidelines and were approved by the Ethics Committee at Zhejiang Shuren University (Date: August 16, 2024; Approval no: 20240816-01).

Experimental Design and Induction of Testicular Ischemia-Reperfusion

Rats were randomly assigned to three groups: control (Group 1, n=20), testicular ischemia-reperfusion (Group 2, n=20), and testicular ischemia-reperfusion plus maslinic acid treatment (Group 3, n=20). General anesthesia was induced with ketamine (50 mg/kg, intraperitoneally; Sigma-Aldrich, Saint Louis, MO, USA). Before surgery, the left ilioinguinal and scrotal regions were shaved and disinfected with 10% povidone-iodine solution. The left testis was exposed via a left ilioinguinal incision in all groups. In the control group, an 11/0 noninvasive suture was passed through the tunica albuginea, and the testis was returned to the scrotum without performing torsion-detorsion.[17] The incision was closed with 4/0 silk sutures. Testicular ischemia-reperfusion was induced by rotating the left testis 720° counterclockwise along the spermatic cord axis.[17] Ischemia was maintained for two hours by fixing the rotated testis to the scrotal wall using an 11/0 noninvasive suture to prevent spontaneous detorsion. Following the ischemic interval, testicular blood flow was restored by detorsion and repositioning of the testis. At the onset of reperfusion, the maslinic acid-treated group received maslinic acid (20 mg/kg, intraperitoneally; Sigma-Aldrich). The selected dose was based on previous studies demonstrating its efficacy against ischemia-reperfusion injury in multiple organs, particularly the kidney and heart.[10-14] To assess the acute-phase response, 10 rats from each group were sacrificed four hours after reperfusion. Left testicular tissues were promptly excised for the analysis of malondialdehyde levels and the activities of superoxide dismutase and catalase. The remaining animals (n=10 per group) were sacrificed at three months post-reperfusion. Left testicular tissues were collected to evaluate spermatogenic function.

Measurement of Malondialdehyde Levels in Testicular Tissue

Testicular tissue (100 mg) was rapidly homogenized in 1 mL of malondialdehyde lysis buffer at 4°C. The homogenate was centrifuged at 5,000 × g for 15 minutes at 4°C, and the supernatant was collected for analysis. Malondialdehyde levels were measured according to manufacturer's instructions using a kit from Jiancheng Bioengineering Institute (Nanjing, China).

Determination of Superoxide Dismutase and Catalase Activities

Testicular tissue was homogenized in normal saline at 4°C and centrifuged at 2,000 × g for 10 minutes at 4°C. The resulting supernatant was used to determine superoxide dismutase and catalase activities according to manufacturer's protocols (Jiancheng Bioengineering Institute, Nanjing, China).

Evaluation of Spermatogenic Function

Spermatogenic function was assessed based on seminiferous tubule diameter, Johnsen score, testicular weight, and seminiferous epithelium layer number.[18] After harvesting and weighing the rat testes, tissue samples were fixed in Bouin's solution for four hours for pathological evaluation. The testicular tissue was dehydrated using a series of progressively concentrated ethanol solutions. Xylene was then used to clear the specimens prior to paraffin embedding. Microtome sectioning of the paraffin-embedded blocks produced sections of 5 micrometers in thickness. The sections were dewaxed with xylene, hydrated through graded alcohols, and stained with hematoxylin and eosin (Sigma-Aldrich) for routine histopathological examination. For each section, a blinded pathologist randomly selected 20 seminiferous tubules, which were examined under a light microscope at 200× magnification. The diameter of the seminiferous tubules was measured using a microscope eyepiece fitted with a micrometer. Testicular spermatogenesis was evaluated using the 10-point Johnsen scoring system.[19] The lowest score (1) indicates seminiferous tubules lacking epithelial cells,[19] whereas the highest

score (10) represents complete and orderly spermatogenesis with abundant spermatozoa and a patent lumen.[19] The stratification of the seminiferous epithelium was determined by counting the number of cell layers from the basement membrane to the lumen.

Statistical Analysis

Statistical analysis of all biochemical and histopathological data was performed using GraphPad Prism 4 (San Diego, CA, USA). The Shapiro–Wilk test confirmed that the data were normally distributed. Data are presented as mean ± standard deviation. Comparisons among the three experimental groups were performed using one-way analysis of variance, followed by the Student–Newman–Keuls post hoc test. A p value <0.05 was considered statistically significant.

RESULTS

Maslinic Acid Reduced Malondialdehyde Levels in Testicular Tissue Following Ischemia-Reperfusion Injury

As shown in Figure 1, malondialdehyde levels were significantly higher ($p<0.001$) in the ischemia-reperfusion group compared with the control group. Treatment with maslinic acid significantly decreased malondialdehyde levels ($p<0.001$) compared with the untreated ischemia-reperfusion group.

Maslinic Acid Increased Superoxide Dismutase and Catalase Activities in Testicular Tissue Following Ischemia-Reperfusion Injury

As illustrated in Figure 2, the activities of the antioxidant enzymes superoxide dismutase and catalase were significantly lower ($p<0.001$) in the ischemia-reperfusion group than in the control group. Statistical analysis revealed that maslinic acid treatment significantly restored the activities of superoxide dismutase and catalase ($p<0.001$) in testicular tissue affected by ischemia-reperfusion injury.

Maslinic Acid Improved Spermatogenic Function Following Ischemia-Reperfusion Injury

Data revealed a pronounced impairment in spermatogenic function following testicular ischemia-reperfusion (Figs. 3, 4), characterized by significantly reduced ($p<0.001$) seminiferous tubule diameter, Johnsen score, testicular weight, and seminiferous epithelium layer number compared with the control group. Maslinic acid treatment demonstrated a significant ameliorating effect on testicular spermatogenic function (seminiferous tubule diameter: $p<0.01$; Johnsen score, testicular weight, and seminiferous epithelium layer number: $p<0.001$), partially counteracting the adverse effects of ischemia-reperfusion.

DISCUSSION

The primary concern in testicular torsion is the need for urgent treatment (detorsion) to restore testicular perfusion and prevent irreversible infarction. A strong negative correlation exists between time to detorsion and testicular survival rates. Clinically, these rates are approximately 90-100% and 50% for interventions performed within 4–8 hours and 12–24 hours, respectively.[20] Despite successful detorsion, postoperative testicular atrophy has been reported in 25% to 60.2% of cases.[3,4] The long-term consequences of two-hour testicular torsion, as demonstrated in our study, were evident three months after detorsion. Testicular impairment included significant reductions in seminiferous tubule diameter, Johnsen score, testicular weight, and seminiferous epithelium layer number (Figs. 3, 4).

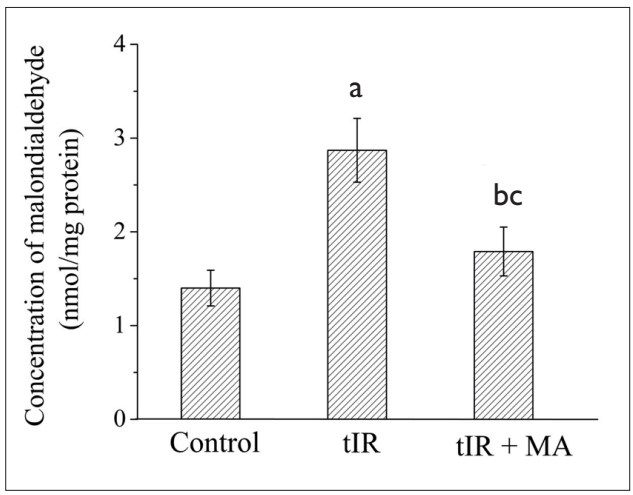

Figure 1. Maslinic acid (MA) administration reduced malondialdehyde levels in the testes. Malondialdehyde concentrations in testicular tissue were measured using a biochemical assay in control, testicular ischemia-reperfusion (tIR), and MA-treated groups. Data are presented as mean ± standard deviation (n=10). a: $p<0.001$ vs. control group; b: $p<0.01$ vs. control group; c: $p<0.001$ vs. tIR group.

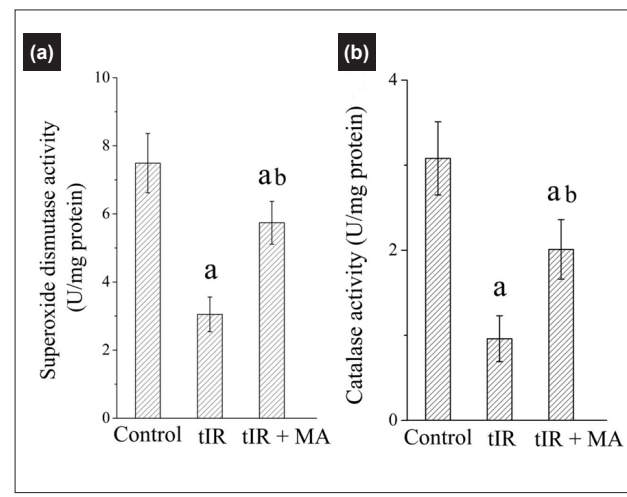

Figure 2. Maslinic acid (MA) administration increased the activities of **(a)** superoxide dismutase and **(b)** catalase in the testes. Enzyme activities were measured using biochemical assays in control, testicular ischemia-reperfusion (tIR), and MA-treated groups. Data are presented as mean ± standard deviation (n=10). a: $p<0.001$ vs. control group; b: $p<0.001$ vs. tIR group.

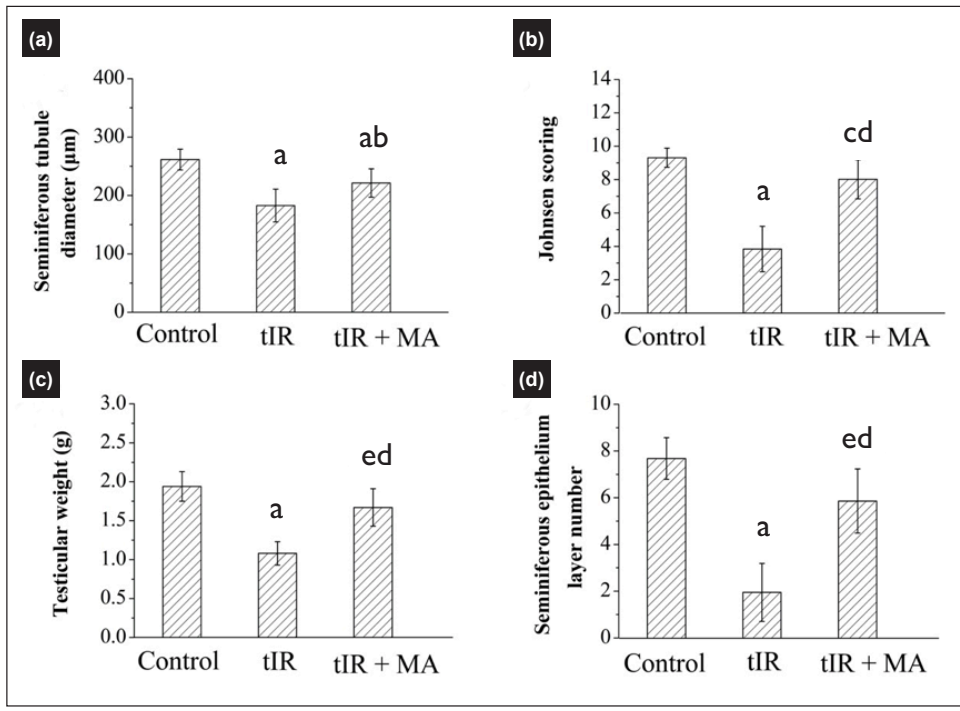

Figure 3. Maslinic acid (MA) administration improved spermatogenic function, as reflected by **(a)** seminiferous tubule diameter, **(b)** Johnsen score, **(c)** testicular weight, and **(d)** seminiferous epithelium layer number. These parameters were evaluated through histomorphological analysis in control, testicular ischemia-reperfusion (tIR), and MA-treated groups. Data are presented as mean ± standard deviation (n=10). a: p<0.001 vs. control group; b: p<0.01 vs. tIR group; c: p<0.05 vs. control group; d: p<0.001 vs. tIR group; e: p<0.01 vs. control group.

Reactive oxygen species (ROS) production increases following detorsion of a torsed testicle.[21] The oxidative modification of proteins, lipids, and DNA by reactive oxygen species represents a major mechanism of damage in spermatogenic cells.[5] Direct measurement of reactive oxygen species in testicular tissue is challenging due to their high reactivity and short lifespan.[17] Reactive oxygen species induce cellular membrane damage through lipid peroxidation.[22] Malondialdehyde, a byproduct of lipid peroxidation, is therefore widely used as a marker of reactive oxygen species.[23] In the present study, ischemia-reperfusion significantly increased malondialdehyde levels and was associated with impaired spermatogenesis (Figs. 1, 3, 4). These findings suggest that excessive reactive oxygen species generation during ischemia contributes to spermatogenic dysfunction. Maslinic acid administration significantly reduced testicular malondialdehyde levels and improved spermatogenic function compared with the ischemia-reperfusion group (Figs. 1, 3, 4). These results indicate that maslinic acid mitigates oxidative stress following testicular ischemia-reperfusion, thereby promoting recovery of spermatogenesis. Maslinic acid has been reported to be safe and beneficial in clinical settings, including in elderly women with knee osteoarthritis and in water polo athletes experiencing exercise-induced fatigue and muscle soreness.[24,25] Therefore, maslinic acid may represent a promising therapeutic candidate for testicular ischemia-reperfusion injury. However, the mechanism by which maslinic acid mitigates oxidative stress has yet to be determined.

For normal cell function to be maintained, a balance must exist between the production of reactive oxygen species and their elimination.[26] Superoxide dismutase and catalase are key components of the intracellular antioxidant defense system that protect cells from reactive oxygen species.[27] Superoxide dismutase catalyzes the dismutation of superoxide anions into hydrogen peroxide, which is subsequently decomposed into water and molecular oxygen by catalase.[28,29] In pathological conditions such as ischemia-reperfusion, increased reactive oxygen species production leads to oxidative damage that overwhelms endogenous antioxidant defenses, resulting in cellular injury and death.[30,31] In the present study, testicular ischemia-reperfusion disrupted this balance, as evidenced by increased malondialdehyde levels and decreased activities of superoxide dismutase and catalase, along with impaired spermatogenesis (Figs. 1-4). These findings support that excessive reactive oxygen species production during testicular ischemia-reperfusion depletes antioxidant defenses, thereby contributing to spermatogenic dysfunction. Data from Figures 1-4 indicate that maslinic acid treatment increased superoxide dismutase and catalase activities, reduced malondialdehyde levels, and improved spermatogenic func-

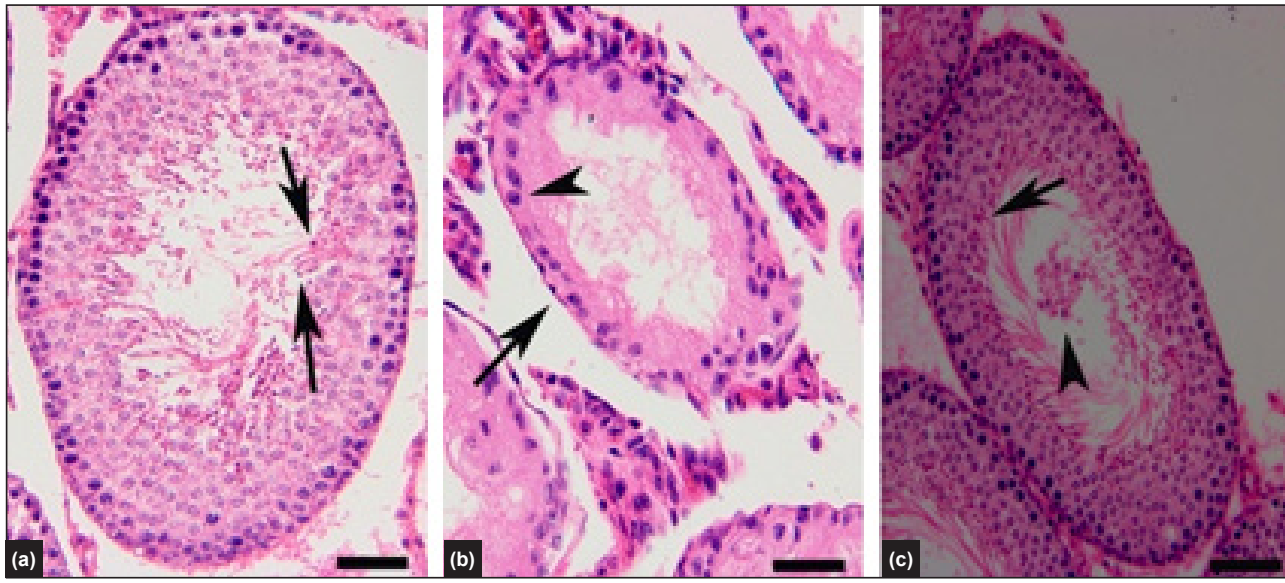

Figure 4. Representative hematoxylin and eosin-stained sections of testicular tissue. **(a)** Control group shows normal architecture, with well-organized epithelial layers containing numerous sperms (↑). The tubules exhibit clear, unobstructed lumina and normal diameter. **(b)** Following ischemia-reperfusion injury, the testes display substantial damage to the seminiferous tubules (↑), characterized by thinning of the epithelial lining (▲), absence of sperms, and a marked reduction in cross-sectional diameter. **(c)** Maslinic acid treatment restores the architecture and function of the seminiferous tubules to a state closely resembling that of the control group, as evidenced by complete spermatogenesis (presence of sperm, ↑), a comparable number of epithelial layers, and similar tubule diameter. However, exfoliated epithelial cells (▲) are observed within the tubular lumen, posing a potential risk of tubular blockage. Images were captured at 200× magnification. Scale bar = 40 micrometers.

tion in testicular tissue subjected to ischemia-reperfusion. These results suggest that maslinic acid alleviates oxidative stress by enhancing the activities of superoxide dismutase and catalase, thereby improving spermatogenic function.

Our study did not evaluate dose-dependent effects of maslinic acid in testicular ischemia-reperfusion injury. Therefore, the optimal therapeutic dose remains to be determined in future studies.

To evaluate spermatogenesis in the testes, hematoxylin and eosin-stained tissue sections were examined in this study. Histopathological evaluation was based on key parameters, including seminiferous tubule diameter, Johnsen score, and seminiferous epithelium layer number. These criteria are widely used in studies of testicular ischemia-reperfusion injury due to their effectiveness in reflecting tissue damage.[1,23] Additional markers, including germ cell apoptosis (assessed by methods such as the Terminal deoxynucleotidyl transferase dUTP nick end labeling (TUNEL) assay), integrity of the tubular basement membrane, interstitial edema, inflammatory cell infiltration, and ultrastructural alterations, also serve as valuable indicators of testicular injury. We plan to incorporate these markers into future studies.

Using an experimental model of testicular torsion-detorsion, Karlı et al.[32] evaluated the effects of medical ozone and hyperbaric oxygen treatment. Compared with the ischemia-reperfusion group, both treatments significantly reduced malondialdehyde levels, indicating decreased oxidative damage. Additionally, both groups showed significantly higher glutathione peroxidase activity, an antioxidant enzyme, compared with the ischemia-reperfusion group. Compared with both the ischemia-reperfusion and medical ozone groups, hyperbaric oxygen administration resulted in significantly increased superoxide dismutase activity. Consequently, hyperbaric oxygen demonstrated a stronger antioxidant effect than medical ozone, particularly with respect to superoxide dismutase activity. Histopathological assessment of the testicles was performed using the Cosentino scoring system. Although both medical ozone therapy and hyperbaric oxygen treatment were effective in reducing testicular ischemia-reperfusion injury, they demonstrated comparable results, with no significant difference between their effects. These findings suggest that both therapies may serve as antioxidant treatments for testicular torsion. Beyond malondialdehyde and superoxide dismutase, the study by Karlı et al.[32] differed from ours in terms of other evaluated parameters and pharmacological interventions. In future studies, we will incorporate measurements of glutathione peroxidase and the Cosentino score, and compare the efficacy of maslinic acid, medical ozone, and hyperbaric oxygen in the treatment of testicular ischemia-reperfusion injury to determine the most effective agent.

CONCLUSION

The role of maslinic acid in alleviating testicular ischemia-re-

perfusion injury has not been previously investigated, and this study aimed to address this gap. Our findings demonstrate that maslinic acid treatment improves spermatogenesis following ischemia-reperfusion injury. Its protective effects are mediated by antioxidant mechanisms, including increased superoxide dismutase and catalase activities and reduced reactive oxygen species levels. These findings suggest that maslinic acid may represent a promising therapeutic option for testicular damage caused by ischemia-reperfusion. However, further studies are required to confirm its tolerability and clinical efficacy before translation into clinical practice.

Ethics Committee Approval: This study was approved by the Ethics Committee at Zhejiang Shuren University (Date: 16.08.2024, Decision No: 20240816-01).

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

Informed Consent: Not applicable, as this study was conducted on experimental animals and did not involve human participants.

Conflict of Interest: None declared.

Financial Disclosure: This research was funded by the Zhejiang Provincial Natural Science Foundation of China (Grant Number: LY19H040001).

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DENEYSEL ÇALIŞMA - *ÖZ*

Sıçanlarda iskemi-reperfüzyonun neden olduğu testis hasarında maslinik asidin rolü

AMAÇ: Testis iskemi-reperfüzyonunun patofizyolojisi, reaktif oksijen türlerinde belirgin bir artışla karakterize edilir. Reaktif oksijen türlerinin DNA, proteinler ve lipitler dahil olmak üzere hücresel bileşenlere verdiği oksidatif hasar, spermatogenik hücrelerin hasar görmesine yol açar. Olea europaea, alıç ve diğer şifalı bitkilerde bulunan biyoaktif bir bileşik olan maslinik asit, antioksidan özellikler sergiler. Bu çalışma, maslinik asidin sıçan modelinde iskemi-reperfüzyon hasarı sonrası testis sperm üretimini koruyup korumadığını belirlemeyi amaçlamıştır.
GEREÇ VE YÖNTEM: Erkek sıçanlar rastgele üç gruba ayrılmıştır: Bir kontrol grubu (Grup 1), bir iskemi-reperfüzyon grubu (Grup 2) ve bir iskemi-reperfüzyon + maslinik asit grubu (Grup 3). İskemi, sol testiste iki saatlik torsiyonla indüklendi, ardından cerrahi detorsiyon yoluyla reperfüzyon sağlandı. Tedavi grubuna, detorsiyon prosedürünün başlangıcında intraperitoneal maslinik asit uygulandı. Detorsiyonun ardından, dört saat veya üç ay sonra sol orşiektomi gerçekleştirildi. Testislerdeki oksidatif stresi ve fonksiyonu kapsamlı bir şekilde değerlendirmek için, temel göstergeleri ölçtük: malondialdehit konsantrasyonu (reaktif oksijen türlerinin seviyelerini yansıtır); hücresel antioksidan sistemin bileşenlerini temsil eden süperoksit dismutaz ve katalaz aktiviteleri; ve genel spermatogenik verimlilik. Bu parametreler, biyokimyasal testler ve hematoksilen-eozin boyaması ile histolojik analiz kullanılarak değerlendirildi.
BULGULAR: Testis iskemi-reperfüzyonu, malondialdehit düzeylerini önemli ölçüde artırırken, temel antioksidan savunma mekanizmalarını (süperoksit dismutaz ve katalaz) baskıladı ve spermatogenez fonksiyonunu bozdu ($p<0.001$). İskemi-reperfüzyonun neden olduğu testis hasarına rağmen, maslinik asit tedavisi bu belirteçlerde kısmi bir düzelme sağladı ($p<0.01$).
SONUÇ: Özetle, maslinik asit, reaktif oksijen türlerini azaltırken süperoksit dismutaz ve katalaz aktivitelerini artırarak iskemi-reperfüzyonun neden olduğu testis hasarını hafifletmektedir.

Anahtar sözcükler: Maslinik asit; iskemi-reperfüzyon; testis torsiyonu.

Ulus Travma Acil Cerrahi Derg 2026;32(6):629-635 DOI: 10.14744/tjtes.2026.62296

ORIGINAL ARTICLE

Comparison of the effectiveness of RIPASA and modified Alvarado scores in identifying perforated appendicitis

Ahmet Kamburoğlu,[1] Şebnem Çimen,[2] Burak Uçaner,[3] Mehmet Zeki Buldanlı,[3] Oğuz Hançerlioğulları[3]

[1]Department of General Surgery, Çankırı State Hospital, Çankırı-*Türkiye*
[2]Department of General Surgery, Akyurt State Hospital, Ankara-*Türkiye*
[3]Department of General Surgery, Gülhane Training and Research Hospital, Ankara-*Türkiye*

ABSTRACT

BACKGROUND: Acute appendicitis is one of the most common emergency surgical conditions and may progress to perforation, sepsis, and mortality if not treated promptly. This study aimed to evaluate the effectiveness of the Raja Isteri Pengiran Anak Saleha Appendicitis (RIPASA) score and the Modified Alvarado Scoring System (MASS) in identifying perforated acute appendicitis.

METHODS: This study included 164 patients admitted to the General Surgery Department between June 2023 and December 2023 with a preliminary diagnosis of acute appendicitis. MASS and RIPASA scores, along with demographic data, were obtained from the Hospital Information Management System (HIMS) at the time of diagnosis.

RESULTS: A total of 153 patients were included in the final analysis. The mean age was 35.2±14.1 years (range: 18–82 years). Perforation was identified in 15.8% of cases evaluated by ultrasonography (USG) and 6.1% of those assessed by computed tomography (CT). A RIPASA score >7 demonstrated a sensitivity of 71.1% and a specificity of 54.7% for detecting perforation. Patients with perforation had significantly higher RIPASA and MASS scores (both $p<0.001$) and longer hospital stays ($p<0.001$).

CONCLUSION: Compared with the MASS scoring system, the RIPASA score demonstrates higher sensitivity and specificity and is associated with greater inflammation when elevated. Its incorporation into routine clinical practice may facilitate faster, more efficient, and cost-effective management in emergency and general surgical settings.

Keywords: Acute appendicitis; Modified Alvarado Scoring System; perforation; RIPASA.

INTRODUCTION

Acute appendicitis is one of the most common general surgical emergencies worldwide and often requires urgent surgical intervention. The lifetime risk is estimated at 8.6% in males and 6.7% in females.[1] If not treated promptly, acute appendicitis may progress to perforation, sepsis, and death, making early diagnosis and timely management essential. Surgical treatment is the standard of care, with both open and laparoscopic approaches widely used.

Clinically, acute appendicitis typically presents with pain migrating from the epigastric region to the right lower quadrant; however, presentations can vary considerably. Ultrasonography (USG) is the most commonly used imaging modality in the diagnosis of acute appendicitis, whereas computed tomography (CT) is considered the gold standard. In addition to imaging, various scoring systems have been developed to aid diagnosis and to differentiate appendicitis from other causes of acute abdomen. Among these, the Alvarado score (AS), introduced in 1986 and subsequently modified, is the most widely used. According to a 2023 meta-analysis, the sensitiv-

Cite this article as: Kamburoğlu A, Çimen Ş, Uçaner B, Buldanlı MZ, Hançerlioğulları O. Comparison of the effectiveness of RIPASA and modified Alvarado scores in identifying perforated appendicitis. Ulus Travma Acil Cerrahi Derg 2026;32:636-641.

Address for correspondence: Ahmet Kamburoğlu
Department of General Surgery, Çankırı State Hospital, Çankırı, Türkiye
E-mail: ahmetkamburoglu@yahoo.com

Ulus Travma Acil Cerrahi Derg 2026;32(6):636-641 DOI: 10.14744/tjtes.2026.30766
Submitted: 02.11.2025 Revised: 13.12.2025 Accepted: 15.01.2026 Published: 03.06.2026

ity of the Modified Alvarado Scoring System (MASS) ranges from 14% to 97%.[2] Although the Modified Alvarado Scoring System demonstrates good sensitivity and specificity, its development in Western populations may limit its generalizability. To address this limitation, the Raja Isteri Pengiran Anak Saleha Appendicitis (RIPASA) score was introduced in 2010 to improve the diagnosis of acute appendicitis in Eastern populations and has demonstrated higher sensitivity and specificity compared with MASS.[2] Although several studies have reported the superiority of RIPASA over MASS in diagnosing acute appendicitis,[2-5] no consensus exists regarding their relative effectiveness in the early and accurate identification of perforated acute appendicitis. Therefore, this study aimed to evaluate the effectiveness of RIPASA and MASS in diagnosing perforated acute appendicitis.

MATERIALS AND METHODS

This study included 164 patients admitted to the General Surgery Department of Gulhane Training and Research Hospital between June 2023 and December 2023 with a preliminary diagnosis of acute appendicitis. Eleven patients were excluded based on predefined exclusion criteria. The study was approved by the local ethics committee (decision no. 14/3, dated July 10, 2024) and was conducted in accordance with the ethical principles of the Declaration of Helsinki of the World Medical Association for research involving human subjects. All authors declare that the study complied with the Declaration of Helsinki and was prepared in accordance with the ethical standards of Türkiye. Patient data, including sex, age, MASS and RIPASA scores at admission, preoperative imaging findings, type of surgery performed, length of hospital stay, and postoperative pathology results, were retrospectively obtained from the Hospital Information Management System (HIMS). Patients under 18 years of age and those with pathology results indicating neoplasia were excluded. Cases with intraoperative perforation were identified based on surgical notes.

The RIPASA score includes more parameters than the MASS score. This system comprises a total of 18 parameters, with a maximum possible score of 17.5. One point is assigned for male sex, age under 40 years, anorexia, nausea and vomiting, symptom duration of less than 48 hours, right lower quadrant tenderness, rebound tenderness, elevated body temperature, increased white blood cell count, negative urine analysis, and foreign nationality. Half a point (0.5) is assigned for female sex, age over 40 years, right lower quadrant pain, migration of pain to the right lower quadrant, and symptom duration longer than 48 hours. Guarding in the right lower quadrant is assigned 2 points. The total score is calculated by summing these parameters.[5]

Statistical analyses were performed using SPSS version 22.0. Descriptive statistics were presented as numbers, percentages, means, standard deviations, and medians (interquartile range). The normality of variable distribution was assessed using visual methods (histograms and probability plots) and analytical tests (Kolmogorov–Smirnov and Shapiro–Wilk tests). Continuous variables were compared between the two groups using the Student's t-test. Nominal and categorical variables were analyzed using the chi-square test or Fisher's exact tests. The predictive value and diagnostic performance of the scoring systems for identifying perforation and negative appendectomy were evaluated using receiver operating characteristic (ROC) curve analysis. ROC results were expressed as the area under the curve (AUC) with 95% confidence intervals. The optimal cutoff value for diagnostic performance was determined using the Youden index. Diagnostic performance at the selected cutoff was reported in terms of sensitivity, specificity, positive likelihood ratio (+LR), negative likelihood ratio (–LR), positive predictive value (PPV), and negative predictive value (NPV). A p-value <0.05 was considered statistically significant for all analyses. Statistical analyses were performed using IBM SPSS Statistics, version 22.0 (IBM Corporation, Armonk, New York, United States).

RESULTS

The study included 153 patients with a mean age of 35.2±14.1 years (range: 18–82 years). Of these, 62.1% were male, corresponding to a male-to-female ratio of 1.6:1. CT was performed in 115 patients, while USG was used in 38 patients. Perforation was detected in 15.8% of patients in the USG group and 6.1% in the CT group. The mean RIPASA score was 7.3±1.5 (range: 4–11), and the mean MASS score was 5.8±1.8 (range: 1–10). Overall, perforation was observed in 24.8% of cases. A laparoscopic approach was used in most surgeries (74.5%), with conversion to open surgery required in 6.5% of patients. The negative appendectomy rate was 11.8%.

Descriptive characteristics were further analyzed according to the presence of perforation. Patients with perforation were significantly older (p=0.002). They also had significantly higher RIPASA (p<0.001) and MASS scores (p<0.001), as well as longer hospital stays (p<0.001). Among patients without perforation, USG suggested perforation in two cases; however, in all cases where CT indicated perforation, the diagnosis was confirmed.

Descriptive characteristics were also compared according to the presence of negative appendectomy. Patients who underwent negative appendectomy were significantly younger (p=0.002) and had significantly lower RIPASA (p=0.001) and MASS (p<0.001) scores. In one case evaluated by USG, findings were not consistent with acute appendicitis.

The predictive accuracy of the scoring systems for perforated acute appendicitis was assessed using ROC analysis. Both RIPASA (AUC=0.689, cutoff>7, p<0.001) and MASS (AUC=0.697, cutoff>6, p<0.001) were identified as signifi-

Table 1. Predictive value of the Raja Isteri Pengiran Anak Saleha Appendicitis (RIPASA) and Modified Alvarado Scoring System (MASS) scores for perforation and negative appendectomy

	AUC	95% CI	p value
Perforated appendicitis			
RIPASA	0.689	0.609-0.761	<0.001
MASS	0.697	0.618-0.769	<0.001
USG	0.753	0.587-0.878	0.014
CT	0.613	0.518-0.702	0.003
RIPASA >7 + USG	0.726	0.557-0.858	0.001
RIPASA >7 + CT	0.641	0.546-0.728	0.004
MASS >6 + USG	0.735	0.567-0.865	0.005
MASS >6 + CT	0.706	0.614-0.787	<0.001
Negative appendectomy			
RIPASA	0.754	0.678-0.820	<0.001
MASS	0.737	0.660-0.805	<0.001

Table 2. Diagnostic performance of the Raja Isteri Pengiran Anak Saleha Appendicitis (RIPASA) and Modified Alvarado Scoring System (MASS) scores for predicting perforation and negative appendectomy

	Cutoff	Sensitivity	Specificity	+LR	-LR	PPV	NPV
Perforated appendicitis							
RIPASA	>7	71.1	54.7	1.57	0.53	34.2	85.1
MASS	>6	63.1	68.7	2.02	0.54	40.0	84.9
USG	–	57.1	93.5	8.86	0.46	66.7	90.6
CT	–	22.5	100.0	–	0.77	100.0	77.8
RIPASA >7 + USG	–	100.0	45.1	1.82	–	29.2	100.0
RIPASA >7 + CT	–	70.9	57.1	1.66	0.51	37.9	84.2
MASS >6 + USG	–	85.7	61.2	2.21	0.23	33.3	95.0
MASS >6 + CT	–	70.9	70.2	2.38	0.41	46.8	86.8
Negative appendectomy							
RIPASA	<6.5	67.6	70.5	2.30	0.46	94.8	21.4
MASS	<4	83.8	58.8	2.04	0.28	94.2	31.3

cant predictors. USG demonstrated higher predictive accuracy for perforation (AUC=0.753, p=0.014) compared with CT (AUC=0.613, p=0.003). When imaging modalities were combined with scoring systems, the strongest predictors of perforation were MASS >6 + USG (AUC=0.735, p=0.005) and RIPASA >7 + USG (AUC=0.726, p=0.001) (Table 1).

A RIPASA score >7 yielded a sensitivity of 71.1% and a specificity of 54.7% for detecting perforation. When combined with USG, RIPASA >7 demonstrated 100% sensitivity and 45.1% specificity, while combination with CT resulted in 70.9% sensitivity and 57.1% specificity. A MASS score >6 demonstrated a sensitivity of 63.1% and a specificity of 68.7% for detecting perforation. In combination with USG, MASS >6 achieved 85.7% sensitivity and 61.2% specificity; when combined with CT, it showed 70.9% sensitivity and 70.2% specificity. For predicting negative appendectomy, a RIPASA score <6.5 demonstrated 67.6% sensitivity and 70.5% specificity, whereas a MASS score <4 showed 83.8% sensitivity and 58.8% specificity. The ROC curves of RIPASA and MASS for predicting perforation are presented in Figure 1, and detailed results are summarized in Table 2.

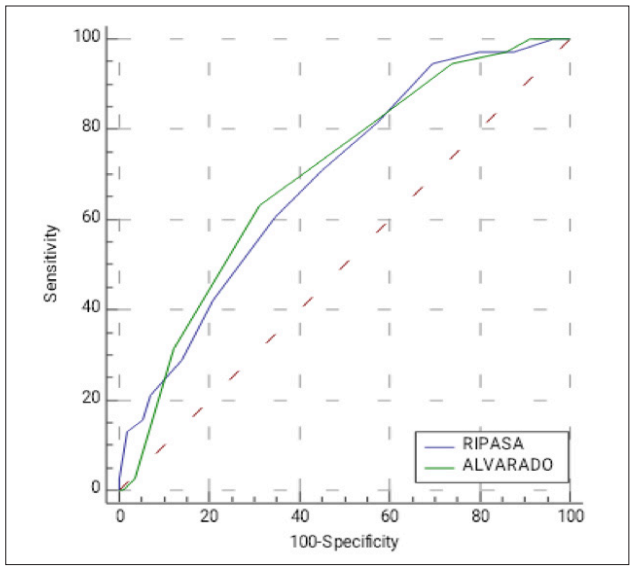

Figure 1. Receiver operating characteristic (ROC) curves of the Raja Isteri Pengiran Anak Saleha Appendicitis (RIPASA) and Modified Alvarado Scoring System (MASS) scores for predicting perforation.

DISCUSSION

The definitive diagnosis of acute appendicitis is established through histopathological examination. However, given that delays in diagnosis and treatment increase morbidity and mortality, rapid and accurate clinical diagnostic tools are essential. In current clinical practice, patients with suspected acute appendicitis are typically first evaluated using ultrasonography; if the findings are inconclusive, a CT is subsequently performed. Although these imaging modalities demonstrate high sensitivity and specificity, they are not always readily available in all healthcare settings. Additionally, factors such as retrocecal positioning of the appendix, perforation, and patient obesity may reduce the sensitivity and specificity of these imaging techniques.[6] Their use also contributes to increased healthcare costs. Furthermore, CT raises concerns regarding radiation exposure, leading to ongoing debate about its routine use.[7]

The most widely used scoring system worldwide, the MASS, has been debated in terms of its effectiveness in Eastern populations, as it was primarily developed based on Western cohorts. Consequently, the RIPASA scoring system, developed specifically for Eastern populations, has been reported to demonstrate higher specificity and sensitivity.[10] In a study by Memon et al.,[11] the sensitivity and specificity of MASS in Eastern populations were reported as 93.5% and 80.6%, respectively. The 2015 World Society of Emergency Surgery (WSES) Jerusalem guidelines stated that an Alvarado score <5 is sufficiently sensitive to exclude acute appendicitis but lacks specificity to confirm the diagnosis.[12]

In a study by Chong et al.,[13] the RIPASA score with a cutoff value of 7.5 demonstrated higher specificity and sensitivity than MASS. Similarly, studies by Radhoth et al.,[14] Nanjundaiah et al.,[15] and Erdem et al.[16] have shown that RIPASA outperforms MASS in both sensitivity and specificity. In the study conducted by Mumtaz et al.,[4] the RIPASA score demonstrated a sensitivity of 96% and a specificity of 82%. Compared with our findings, these values indicate substantially higher sensitivity and specificity. This discrepancy may be explained by the retrospective design of our study, which limited the inclusion of patient-reported symptoms in the scoring. However, some studies have reported no significant difference between RIPASA and MASS in diagnosing suspected appendicitis.[17] In one study including 72 patients, the sensitivity and specificity of RIPASA were 93.3% and 8.3%, respectively, whereas those of MASS were 75% and 41.6%, respectively. Notably, that study used a cutoff value of 8.5 for RIPASA and 6 for MASS.

To our knowledge, no previous studies have examined the correlation between imaging findings and RIPASA and MASS scores as investigated in our study. Among our patients, the mean RIPASA score was 8.1±1.4 in perforated cases and 7.0±1.4 in non-perforated cases. The mean MASS score was 6.7±1.3 in perforated cases and 5.5±1.8 in non-perforated cases. ROC curve analysis for perforated appendicitis identified cutoff values of 7 for RIPASA and 6 for MASS. A RIPASA score >7 demonstrated a sensitivity of 71.1% and a specificity of 54%, while a MASS score >6 showed a sensitivity of 63.1% and a specificity of 68.7%. These values are lower than those reported in similar studies.[13-15,19] This discrepancy may be attributed to the heterogeneity of our study population.

In a prospective study conducted by Koroth et al.,[20] appendicitis cases were stratified according to pathological stage using RIPASA-based risk groups (low, moderate, and high). No cases of perforated appendicitis were observed in the low-risk group, while a perforation rate of 0.9% was reported in the moderate-risk group. In contrast, the high-risk group (RIPASA score ≥12) demonstrated a perforation rate of 17.3%.

Perforated appendicitis is a major cause of mortality and morbidity, particularly in elderly patients. Delays in diagnosis and treatment are associated with prolonged hospital stays and increased healthcare costs. Therefore, in settings where imaging modalities are unavailable or a general surgeon is not present, the RIPASA scoring system can be used to assess patient risk and guide transfer decisions based on clinical urgency. Such an approach may also help reduce unnecessary workload in centers with high surgical or emergency department volume.

This study has several limitations. The retrospective design and incomplete data for some patients represent important constraints. Additional limitations include the relatively small sample size, the heterogeneity of the study population, and the lack of internal risk stratification within the scoring systems.

CONCLUSION

Compared with the MASS score, the RIPASA score demonstrates higher sensitivity and specificity and better reflects the severity of inflammation when elevated. Therefore, the RIPASA scoring system may be considered a valuable tool in routine clinical practice, facilitating faster, more efficient, and cost-effective decision-making in emergency departments and general surgery settings.

Ethics Committee Approval: This study was approved by the University of Health Sciences Gülhane Health Practice and Research Center Scientific Research Evaluation Board (Date: 10.07.2024, Decision No: 14/3).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: A.K., B.U.; Design: Ş.Ç., B.U.; Supervision: B.U., O.H.; Resource: A.K., B.U.; Materials: A.K., Ş.Ç.; Data collection and/or processing: A.K., Ş.Ç.; Analysis and/or interpretation: Ş.Ç., B.U.; Literature review: B.U., M.Z.B.; Writing: A.K., B.U.; Critical review: O.H., M.Z.B.

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*

RIPASA ve Modifiye Alvarado Skorlarının perfore apandisitleri tanımadaki etkinliğinin karşılaştırılması

AMAÇ: Akut apandisit dünya genelinde en sık karşılaşılan ve acil cerrahi müdahale gerektiren genel cerrahi acillerinden birisidir. Akut apandisit erken dönemde tedavi edilmediği takdirde perforasyon, sepsis ve mortalite ile seyredebilir; bu nedenle erken tanı ve tedavi önemlidir. Bu çalışmada, perfore akut apandisitlerin tanısında Raja Isteri Pengiran Anak Saleha Appendicitis (RIPASA) ve Modifiye Alvarado Skor Sistemi'nin (MASS) etkinliğini araştırmayı amaçladık.

GEREÇ VE YÖNTEM: Bu çalışmaya, genel cerrahi kliniğine Haziran 2023-Aralık 2023 tarihleri arasında akut apandisit ön tanısıyla yatırılan 164 hasta alındı. Hastaların cinsiyet, yaş, başvuru esnasındaki MASS ve RIPASA skorları, preoperatif görüntüleme bulguları, yapılan ameliyatın türü, hastaların yatış süresi ve postoperatif patoloji sonuçları retrospektif olarak Hastane Bilgi Yönetimi Sistemleri (HBYS) üzerinden toplandı.

BULGULAR: Çalışmaya alınan 153 hastanın yaş ortalaması 35.2±14.1 yıl idi (dağılım, 18-82 yaş). Ultrasonografi (USG) ile değerlendirilen olguların %15.8'inde, Bilgisayarlı Tomografi (BT) ile değerlendirilenlerin %6.1'inde perforasyon bildirildi. RIPASA skorunun 7'nin üzerinde olması perforasyon için %71.1 sensitivite, %54.7 spesifite göstermekteydi. Perforasyon izlenen olguların RIPASA ($p<0.001$) ve MASS ($p<0.001$) skorları daha yüksek, hospitalizasyon süresi daha uzundu ($p<0.001$).

SONUÇ: RIPASA skoru MASS skoruna göre daha yüksek sensitive ve spesifiteye sahiptir ve RIPASA skorunun daha yüksek değerlerde olması daha şiddetli inflamasyonun bir göstergesidir. Bu nedenle acil servislerde ve genel cerrahi pratiğinde daha hızlı, etkin ve düşük maliyetli işlemler yapabilmek için günlük pratiğe hızlıca alınmalıdır.

Anahtar sözcükler: Akut apandisit; Modifiye Alvarado skor sistemi; perforasyon; RIPASA.

Ulus Travma Acil Cerrahi Derg 2026;32(6):636-641 DOI:10.14744/tjtes.2026.30766

ORIGINAL ARTICLE

Can clinical scoring systems overcome the limitations of diagnostic methods for acute appendicitis in pregnancy?

Murat Özkara, Mehmet Mert Hıdıroğlu

Department of General Surgery, University of Health Sciences, Gülhane Training and Research Hospital, Ankara-*Türkiye*

ABSTRACT

BACKGROUND: Acute appendicitis during pregnancy is the most common indication for non-obstetric emergency surgery. However, physiological changes associated with pregnancy can reduce the sensitivity of its clinical signs and symptoms. This study aimed to compare the diagnostic performance of the Alvarado, Appendicitis Inflammatory Response (AIR), Raja Isteri Pengiran Anak Saleha Appendicitis (RIPASA), and Tzanakis scoring systems in pregnant patients, as well as to evaluate surgical outcomes.

METHODS: A total of 39 pregnant patients who underwent surgery for acute appendicitis between January 2017 and January 2025 were retrospectively analyzed. Demographic characteristics, gestational age, clinical presentation, laboratory parameters (white blood cell count [WBC], C-reactive protein [CRP]), ultrasonography findings, surgical approach (open vs. laparoscopic), histopathological results, and maternal and fetal outcomes were recorded. Alvarado, AIR, RIPASA, and Tzanakis scores were calculated for each patient. Patients were stratified into risk categories based on established cut-off values from the literature, and diagnostic performance was assessed against histopathological findings.

RESULTS: The mean age was 26.0±5.3 years, and the mean gestational age was 19.6±7.9 weeks; 53.8% of patients were in the second trimester. Open appendectomy was performed in 61.5% of cases, while 38.5% underwent laparoscopic appendectomy. High-risk classification rates were 66.7% for Alvarado, 69.2% for AIR, and 79.5% for both RIPASA and Tzanakis scores. Histopathology confirmed acute appendicitis in 66.7% of patients, perforated appendicitis in 15.4%, and a normal appendix in 17.9%. WBC and CRP levels were significantly higher in patients with confirmed appendicitis ($p<0.05$). The highest sensitivity and specificity were observed with the RIPASA (93.7% and 85.7%, respectively) and Tzanakis (90.6% and 71.4%) scoring systems. Laparoscopic surgery was associated with a shorter hospital stay compared to open surgery ($p<0.001$), with comparable maternal and fetal safety outcomes.

CONCLUSION: Clinical scoring systems are effective and reliable tools for diagnosing acute appendicitis in pregnant patients, with the RIPASA score demonstrating the highest diagnostic accuracy. Elevated CRP levels and leukocytosis may further support diagnosis. Laparoscopic appendectomy is a safe option associated with a shorter hospital stay compared with open surgery. These findings support the safe use of both clinical scoring systems and laparoscopic surgery in pregnant patients.

Keywords: Acute appendicitis; pregnancy; RIPASA.

INTRODUCTION

Abdominal pain accounts for approximately 10% of all emergency department admissions, and acute appendicitis is the most common diagnosis among patients hospitalized with this complaint. Acute appendicitis (AA) is one of the most frequent general surgical emergencies worldwide, with a lifetime risk of 7–8%.[1] Excluding obstetric and gynecological causes, acute appendicitis is the most common condition requiring emergency surgical intervention during pregnancy. Acute appendicitis most commonly occurs in the second and third decades of life, corresponding to the reproduc-

Cite this article as: Özkara M, Hıdıroğlu M. Can clinical scoring systems overcome the limitations of diagnostic methods for acute appendicitis in pregnancy? Ulus Travma Acil Cerrahi Derg 2026;32:642-651.

Address for correspondence: Mehmet Mert Hıdıroğlu

Department of General Surgery, University of Health Sciences, Gülhane Training and Research Hospital, Ankara, Türkiye

E-mail: merthidiroglu28@gmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(6):642-651 DOI: 10.14744/tjtes.2026.95036

Submitted: 31.10.2025 Revised: 15.12.2025 Accepted: 15.01.2026 Published: 03.06.2026

tive years, and is therefore frequently encountered during pregnancy. The incidence of AA in pregnancy has been reported to range from 1 in 500 to 1 in 2,000 pregnancies.[2] Physiological changes during pregnancy may alter the clinical presentation of acute appendicitis, with symptoms and physical examination findings varying according to gestational age. As the uterus enlarges, displacement of the appendix from McBurney's point toward a more superolateral position can further complicate diagnosis. Reported rates of fetal loss are approximately 1.5% in uncomplicated cases but may increase to as high as 36% in cases involving perforation, underscoring the critical importance of early diagnosis and timely treatment in pregnant women.[3]

The standard approach to the treatment of acute appendicitis in pregnancy is surgical intervention. However, several reports in the literature suggest that uncomplicated cases may be managed conservatively.[4,5] In one study in which 25% of pregnant women diagnosed with uncomplicated acute appendicitis were managed conservatively, the treatment failure rate was reported as 15%, and the rate of recurrence (re-diagnosis during the same gestational period) was 12%.[6] Although there is no clear consensus on the optimal surgical technique in pregnant patients, laparoscopic appendectomy has been increasingly recommended in recent years for the treatment of AA during pregnancy. This study aimed to evaluate the clinical findings, diagnostic methods, and scoring systems used in pregnant women with acute appendicitis at a single center, and to compare open and laparoscopic surgical techniques.

MATERIALS AND METHODS

A total of 39 pregnant patients who were admitted from the emergency department to our clinic and underwent surgery for acute appendicitis between January 2017 and January 2025 were retrospectively analyzed using the hospital information management system and patient records. All patients were evaluated by the obstetrics clinic prior to surgery to confirm pregnancy status, and fetal assessment was performed postoperatively. The following data were recorded: age, gestational week, presenting symptoms, laboratory parameters, radiological findings, surgical technique (open vs. laparoscopic appendectomy), histopathological results, and maternal and fetal complications. Additionally, the Alvarado score, Appendicitis Inflammatory Response (AIR) score, Raja Isteri Pengiran Anak Saleha Appendicitis (RIPASA) score, and Tzanakis score at admission were calculated for all patients. These scoring systems are summarized in Tables 1 and 2. Patients were stratified into risk groups based on literature-defined cutoff values: >7 for Alvarado, >9 for AIR, ≥7.5 for RIPASA, and ≥8 for Tzanakis scores, with values above these thresholds indicating high risk for AA.[7-9] All procedures were conducted in accordance with the ethical standards of the

Table 1. Alvarado and AIR scoring systems

	Alvarado score		AIR score	
	Migration of pain	1	Pain in right lower quad-rant	1
	Anorexia	1	Nausea	1
	Nausea	1		
	Right lower quadrant tenderness	2	Rebound	
			Light	1
Symptoms and find-ings (assigned score)	Rebound tenderness	1	Moderate	2
			Strong	3
	Elevated temperature	1	Elevated temperature	1
	WBC count	2	WBC count	1
	> 10,000 cells/mcL		10,000–14,900 cells/mcL	
			>15,000 cells/mcL	2
	PMN >75%	1	PMN: 70–84%	1
			PMN: >85%	2
			CRP: 10–49 g/dL	1
			CRP: >50 g/dL	2
Total possible score		10		12
Low risk		1–4		0–4
Moderate risk		5–6		5–8
High risk		7–10		9–12

Table 2. RIPASA and Tzanakis scoring systems

	RIPASA score		Tzanakis score	
Symptoms and findings (assigned score)	Right lower quadrant pain	0.5	Right lower quadrant tenderness	4
	Migration of pain	0.5	Nausea	1
	Anorexia	1		
	Nausea	1		
	Right lower quadrant			
	Rebound	3		
	Tenderness	1		
	Rebound	1		
	Guarding	2		
	Rovsing's sign	2		
	Elevated temperature	1		
	WBC count >10,000 cells/mcL	1	WBC count >12,000 cells/mcL	2
	Negative urinalysis	1		
	Male	1		
	Female	0.5		
	Age <40 years	1		
	Age >40 years	0.5	Positive ultrasound findings of appendi-citis	6
	Duration of symptoms			
	<48 hours	1		
	>48 hours	0.5		
	Foreign national	1		
Total possible score	16	15		
Low risk	<7.5	<8		
High risk	≥ 7.5	≥8		

RIPASA: Raja Isteri Pengiran Anak Saleha Appendicitis

institutional and national research committees, as well as the 1964 Declaration of Helsinki and its subsequent amendments. Ethical approval was obtained from the This study was approved by the Gülhane Training and Research Hospital Local Ethics Committee (Date: 31.08.2023, Decision no: 2023/192).

Statistical Analysis

Descriptive statistics were presented as numbers, percentages, mean ± standard deviation, and median (interquartile range). After assessing normality of distribution, continuous variables with normal distribution (age, gestational week, length of hospital stay, white blood cell count [WBC], and Alvarado, AIR, RIPASA, and Tzanakis scores) were compared between groups using the Student's t-test. Continuous variables with non-normal distribution (C-reactive protein [CRP]) were analyzed using the Mann-Whitney U test. Nominal data were compared using the chi-square test or Fisher's exact test. For diagnostic performance evaluation, conventional cutoff values reported in the literature were used. A 2×2 table was constructed based on histopathological confirmation of acute appendicitis. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy were calculated and expressed as percentages. Receiver operating characteristic (ROC) curve analysis was not performed due to the limited sample size. A p value <0.05 was considered statistically significant. All analyses were conducted using IBM SPSS Statistics® version 25 (IBM Corporation, 1 New Orchard Road, Armonk, New York, United States).

RESULTS

The mean age of the 39 patients included in the study was 26.0±5.3 years (range: 18–39 years). Regarding gestational age, 28.2% of patients were in the first trimester, 53.8% in the second trimester, and 17.9% in the third trimester. Open appendectomy was performed in 61.5% of patients, while 38.5% underwent laparoscopic appendectomy. The mean length of hospital stay was 2.8±1.2 days (range: 1–6 days).

Table 3. Descriptive characteristics of the patients

	n (%)
Age (years)	26.0±5.3
Gestational week	19.6±7.9
Trimester	
I	11 (28.2)
II	21 (53.8)
III	7 (17.9)
Positive ultrasound findings	19 (48.7)
Surgical technique	
Open appendectomy	24 (61.5)
Laparoscopic appendectomy	15 (38.5)
WBC (x109/L)	15.2±3.0
CRP (mg/dL)	42 (18-122)
Length of hospital stay (days)	2.8±1.2
Maternal complications	11 (28.2)
Surgical site infection	11 (100.0)
Preterm delivery	1 (2.6)
Alvarado score	6.9±1.4
Low	4 (10.3)
Moderate	9 (23.1)
High	26 (66.7)
AIR score	8.5±2.1
Low	2 (5.1)
Moderate	10 (25.6)
High	27 (69.2)
RIPASA score	10.0±2.7
Low	8 (20.5)
High	31 (79.5)
Tzanakis score	9.7±2.6
Low	8 (20.5)
High	31 (79.5)
Pathology	
Appendicitis	26 (66.7)
Perforated appendicitis	6 (15.4)
Normal appendix	7 (17.9)
Neoplasia	0

*Mean ± standard deviation (SD); **Median (min-max). WBC: White blood cell count; CRP: C-reactive protein; AIR: Appendicitis Inflammatory Response; RIPASA: Raja Isteri Pengiran Anak Saleha Appendicitis.

Maternal complications were observed in 11 patients, all of which were wound infections. Preterm labor occurred in one patient. According to clinical scoring systems, 66.7% of patients were classified as high risk for acute appendicitis based on the Alvarado score, 69.2% based on the AIR score, and 79.5% based on both the RIPASA and Tzanakis scores. Histopathological examination revealed a normal appendix in 17.9% of cases, acute appendicitis in 66.7%, and perforated appendicitis in 15.4% (Table 3).

According to histopathological findings, cases were categorized into two groups: histopathology-confirmed acute appendicitis (n=32) and normal appendix (n=7). WBC (p=0.032) and CRP (p=0.004) levels were higher in the acute appendicitis group. All maternal complications occurred in the acute appendicitis group; however, this difference did not reach statistical significance due to the small sample size. The Alvarado (p=0.033), AIR (p=0.001), RIPASA (p=0.004), and Tzanakis (p=0.003) scores were also higher in the acute appendicitis group. No significant differences were observed between groups with respect to other variables (Table 4).

The diagnostic performance of the scoring systems for histopathologically confirmed AA was evaluated. The Alvarado score demonstrated a sensitivity of 71.8% and specificity of 57.1%. The AIR score showed 81.2% sensitivity and 85.7% specificity, while the RIPASA score demonstrated 93.7% sensitivity and 85.7% specificity. The Tzanakis score yielded 90.6% sensitivity and 71.4% specificity. The highest accuracy rates were observed with the RIPASA (92.3%) and Tzanakis (87.1%) scores, whereas the Alvarado score had a lower accuracy (69.2%) (Table 5).

A comparison between patients who underwent open and laparoscopic appendectomy revealed that the length of hospital stay was significantly longer in the open appendectomy group (p<0.001), while AIR scores were lower in this group (p=0.038). Although the maternal complication rate was higher (37.5%) in the open appendectomy group compared to the laparoscopic group (13.3%), this difference was not statistically significant. No differences were found between the open and laparoscopic groups in terms of other clinical and demographic characteristics, Alvarado, RIPASA, and Tzanakis scores, or histopathological outcomes (Table 5 and 6).

DISCUSSION

Acute appendicitis is the most common non-obstetric surgical condition encountered during pregnancy. Although the diagnosis is primarily based on clinical findings, it can be challenging due to the physiological changes associated with pregnancy. Pregnant women with acute appendicitis are often initially admitted to obstetrics and gynecology clinics, where pregnancy-related conditions are primarily considered, potentially complicating the diagnosis.[10] Previous studies have reported that acute appendicitis is more common in pregnant women aged 20–30 years. In the present study, the mean age of patients diagnosed with acute appendicitis was 25.8 years (range: 18–39), consistent with the literature. Similarly, in line with reports indicating that appendicitis occurs most frequently during the second trimester, 53.1% of cases in our cohort were observed in this period.[11]

Baer et al.[12] demonstrated that, as the uterus enlarges in

Table 4. Comparison of patients according to histopathological findings

	Acute appendicitis (+) (n=32) n (%)	Normal appendix (-) (n=7) n (%)	p
Age	25.8±5.7	27.0±3.6	0.605[+]
Gestational week	19.6±8.2	19.2±7.4	0.906[+]
Trimester			0.566[++]
I	10 (31.2)	1 (14.3)	
II	17 (53.1)	4 (57.1)	
III	5 (15.6)	2 (28.6)	
Positive ultrasound findings	17 (53.1)	2 (28.6)	0.407[+++]
Surgical technique			0.216[+++]
Open appendectomy	18 (56.2)	6 (85.7)	
Laparoscopic appendectomy	14 (43.8)	1 (14.3)	
WBC (x10^9/L)	15.7±3.1	13.0±1.3	**0.032**[+]
CRP (mg/dL)	47.5 (18-122)	26 (18-41)	**0.004**[++++]
Length of hospital stay (days)	2.9±1.2	2.2±0.7	0.201[+]
Maternal complications	11 (34.4)	0	0.159[+++]
Preterm delivery	1 (3.1)	0	0.821[+++]
Alvarado score	7.1±1.3	5.8±1.5	**0.033**[+]
Low	2 (6.2)	2 (28.6)	
Moderate	7 (21.9)	2 (28.6)	
High	23 (71.9)	3 (42.9)	
AIR score	9.0±1.7	6.2±2.0	**0.001**[+]
Low	1 (3.1)	1 (14.3)	
Moderate	5 (15.6)	5 (71.4)	
High	26 (81.2)	1 (14.3)	
RIPASA score	10.6±2.4	7.5±2.2	**0.004**[+]
Low	2 (6.2)	6 (85.7)	
High score	30 (93.8)	1 (14.3)	
Tzanakis	10.3±2.5	7.1±0.6	**0.003**[+]
Low	3 (9.4)	5 (71.4)	
High	29 (90.6)	2 (28.6)	

*Mean ± standard deviation (SD); **Median (min-max). WBC: White blood cell count; CRP: C-reactive protein; AIR: Appendicitis Inflammatory Response; RIPASA: Raja Isteri Pengiran Anak Saleha Appendicitis. [+]Student's t-test; [++]Chi-square test; [+++]Fisher's exact test; [++++]Mann–Whitney U test.

Table 5. Diagnostic performance of scoring systems for acute appendicitis

	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Alvarado	71.8	57.1	88.4	30.7	69.2
AIR	81.2	85.7	96.3	50.0	82.0
RIPASA	93.7	85.7	96.7	75.0	92.3
Tzanakis	90.6	71.4	93.5	62.5	87.1

AIR: Appendicitis Inflammatory Response; RIPASA: Raja Isteri Pengiran Anak Saleha Appendicitis; PPV: Positive predictive value; NPV: Negative predictive value.

Table 6. Comparison of patients undergoing open and laparoscopic appendectomy

	Open (n=24) n (%)	Laparoscopic (n=15) n (%)	p
Age	26.2±4.9	25.7±6.2	0.793[+]
Gestational week	20.9±8.6	17.5±6.4	0.202[+]
Trimester			0.345[++]
I	6 (25.0)	5 (33.3)	
II	12 (50.0)	9 (60.0)	
III	6 (25.0)	1 (6.7)	
Positive ultrasound findings	10 (41.7)	9 (60.0)	0.265[++]
WBC (x109/L)	15.0±2.8	15.5±3.4	0.639[+]
CRP (mg/dL)	40.5 (18-116)	51 (18-122)	0.773[+++]
Length of hospital stay (days)	3.3±1.1	2.0±0.7	<0.001[+]
Maternal complications	9 (37.5)	2 (13.3)	0.150[++]
Preterm delivery	1 (4.2)	0	0.615[++]
Alvarado score	6.7±1.7	7.2±0.8	0.193[+]
Low	4 (16.7)	0	
Moderate	5 (20.8)	4 (26.7)	
High	15 (62.5)	11 (73.3)	
AIR score	8.1±2.5	9.3±0.8	0.038[+]
Low	2 (8.3)	0	
Moderate	9 (37.5)	1 (6.7)	
High	13 (54.2)	14 (93.3)	
RIPASA score	9.7±2.8	10.6±2.3	0.346[+]
Low	7 (29.2)	1 (6.7)	
High	17 (70.8)	14 (93.3)	
Tzanakis score	9.4±2.7	10.2±2.3	0.397[+]
Low	7 (29.2)	1 (6.7)	
High	17 (70.8)	14 (93.3)	
Pathology			0.294[++]
Appendicitis	14 (58.3)	12 (80.0)	
Perforated appendicitis	4 (16.7)	2 (13.3)	
Normal appendix	6 (25.0)	1 (6.7)	

*Mean ± standard deviation (SD); **Median (min-max). WBC: White blood cell count; CRP: C-reactive protein; AIR: Appendicitis Inflammatory Response; RIPASA: Raja Isteri Pengiran Anak Saleha Appendicitis. [+]Student's t-test; [++]Chi-square test; [+++]Mann–Whitney U test.

later stages of pregnancy, the appendix is displaced in a superolateral direction. This positional change may result in abdominal pain occurring outside the right lower quadrant, thereby complicating the clinical diagnosis of acute appendicitis. Additionally, the increased distance between the appendix and the anterior abdominal wall during pregnancy may reduce the prominence of rebound and guarding, further limiting the reliability of physical examination findings.[13] Despite changes in pain localization during pregnancy, Burcu et al.[14] reported that abdominal pain continues to be the predominant complaint among pregnant patients with acute appendicitis. Although ultrasonography is the most commonly used imaging modality for diagnosing AA in the general population, a meta-analysis including 1,593 patients reported sensitivity and specificity of 77.6% and 75.3%, respectively, in pregnant women. While the sensitivity of ultrasonography for diag-

nosing appendicitis in the non-pregnant population is 86%, it gradually decreases during pregnancy, reaching as low as 50% in the third trimester, highlighting the increased difficulty of diagnosing acute appendicitis in pregnant patients.[15] In our study, the sensitivity of ultrasonography for detecting acute appendicitis in pregnant patients was 53.1%. Considering that 71.3% of the patients were in the second and third trimesters, when ultrasonographic sensitivity is known to decline, these findings are consistent with the literature.

Studies have shown that leukocytosis during pregnancy results from an increase in the number of neutrophils in the bloodstream, particularly in the second trimester, when levels may reach approximately 15,000 cells/mm^3.[16] Since this physiological leukocytosis cannot be distinguished from that seen in acute appendicitis, the diagnosis becomes more challenging in the pregnant population. Although some studies report that leukocytosis is not a reliable marker during pregnancy, others suggest that it contributes to the diagnosis of appendicitis in pregnant women.[17] Peksoz et al.[18] reported that WBC is a sensitive laboratory marker for diagnosing acute appendicitis during pregnancy and for identifying complicated cases. While many studies have demonstrated the high sensitivity of WBC in diagnosing acute appendicitis during pregnancy, some recommend its combined use with neutrophil and lymphocyte levels rather than as a standalone marker due to its low specificity.[19] In our study, the mean leukocyte level in pregnant patients with histopathologically confirmed acute appendicitis (15,700 cells/mm^3) was significantly higher than in those without appendicitis (13,000 cells/mm^3). In our study, the significantly higher leukocyte levels observed in patients with appendicitis, together with the fact that 84.3% of patients were in the first and second trimesters, may explain the reduced sensitivity of leukocytosis, particularly in the later weeks of pregnancy.

C-reactive protein is another commonly used laboratory parameter in the evaluation of suspected acute appendicitis. However, as pregnancy is characterized by low-grade systemic inflammation and an associated immune response, the diagnostic value of acute-phase reactants may be limited during this period. Several studies have reported that CRP levels are higher in healthy pregnant women compared to the non-pregnant population.[20] Conversely, Sezİklİ et al.[21] reported that CRP levels were significantly higher in pregnant women diagnosed with AA compared to healthy pregnant women. In our study, the significantly elevated CRP levels in pregnant women with histopathologically confirmed AA support its potential contribution to diagnosis in this patient group.

The diagnostic process is further complicated by imaging limitations. Increased uterine volume during pregnancy reduces the sensitivity of ultrasonography, while computed tomography is generally avoided due to concerns regarding teratogenic effects. Lehnert et al.[22] evaluated 99 pregnant patients with suspected AA in the second and third trimesters and reported that the appendix could not be visualized by ultrasonography in 97% of cases, indicating limited diagnostic utility in this population. In pregnant patients in whom the appendix cannot be evaluated by ultrasonography, computed tomography and magnetic resonance imaging (MRI), which have similar sensitivity and specificity, are recommended; however, the rate of non-visualization of the appendix on MRI has been reported to increase to as high as 43% due to anatomical changes in the later stages of pregnancy.[23] In our study, the appendix could not be visualized on ultrasonography in 51.3% of pregnant patients with suspected acute appendicitis, and only 53.1% of patients with pathologically confirmed appendicitis demonstrated positive ultrasonographic findings. Although the diagnostic contribution of ultrasonography in our study was higher than that reported in some previous studies in the literature, the inability to detect appendicitis in 46.9% of patients with a condition requiring emergency surgery suggests that ultrasonography alone is insufficient as a diagnostic modality. These factors make the diagnosis of acute appendicitis in pregnant women more complex and difficult compared to the non-pregnant population. In this context, clinical scoring systems may serve as useful adjuncts in the diagnostic process.

Various scoring systems have been developed for the diagnosis of acute appendicitis. Kularatna et al.[24] compared these systems and reported that the AIR score had the highest diagnostic performance, with 92% sensitivity and 63% specificity. The Alvarado score, the most well-known scoring system, demonstrated high sensitivity (99%) but relatively low specificity. Therefore, it has been suggested that it may help shorten waiting times in the emergency department and reduce unnecessary computed tomography use in patients with suspected acute appendicitis.[25] Several studies comparing the AIR and Alvarado scores have reported that the AIR score performs better than the Alvarado score.[26] In a meta-analysis including 12 studies and 2,161 patients, the RIPASA score showed higher sensitivity than the Alvarado score.[27] Similarly, a prospective study of 300 patients found the RIPASA score to be superior to the Alvarado score in terms of accuracy, sensitivity, and specificity for the diagnosis of acute appendicitis.[28] Another meta-analysis including 14 studies and 2,235 patients reported that the Tzanakis scoring system demonstrated higher sensitivity than the Alvarado score.[29] Although several studies in the literature have compared the diagnostic performance of these scoring systems or evaluated them in specific populations, such as pediatric patients, data on their use in pregnant populations are limited. In the present study, commonly used clinical scoring systems were compared to assess their contribution to diagnosis in pregnant patients, a group in which conventional diagnostic methods have notable limitations.

In our study, the Alvarado, AIR, RIPASA, and Tzanakis scores were significantly higher in pregnant patients with pathologically confirmed appendicitis compared to those without appendicitis. In a study by Mantoglu et al.[9] comparing nine

scoring systems, the RIPASA score demonstrated the best performance in pregnant women, followed by the AIR and Tzanakis scores. Similarly, in our study, the RIPASA score showed the highest diagnostic performance, while the Tzanakis and AIR scores ranked second and third, respectively. Consistent with the findings of Bardakçi et al.,[30] our results showed that the AIR score performed better than the Alvarado score in pregnant patients with acute appendicitis, with the Alvarado score demonstrating the lowest diagnostic performance. This observation is also supported by Çomçalı et al.,[31] who reported the superiority of the Tzanakis score over the Alvarado score in diagnosing acute appendicitis in this population. Although some studies have reported higher sensitivity and specificity of the Alvarado score in pregnant patients with acute appendicitis, its diagnostic accuracy appears to be higher in the first trimester and decreases in later trimesters; this variation may be related to differences in gestational age among study populations.[32] In another study comparing diagnostic imaging with the AIR score in pregnant patients, the sensitivity of imaging methods was reported as 47%, whereas the AIR score demonstrated a sensitivity of 97%.[33] In another study evaluating the clinical scores of 180 pregnant patients who underwent MRI for suspected AA, the sensitivity of MRI was found to be higher than that of the Alvarado, Tzanakis, RIPASA, and AIR scoring systems. In that study, scoring systems yielded false-negative results in up to 84% of pregnant women diagnosed with acute appendicitis. However, considering that these patients had inconclusive clinical findings, could not be diagnosed by ultrasonography, and subsequently underwent MRI, the relatively low diagnostic performance of the scoring systems in this group is expected.[34]

Although some studies recommend conservative management in selected cases of acute appendicitis during pregnancy, the standard approach remains surgical treatment.[5] While laparoscopic surgery has become the standard approach in the general population, its use during pregnancy is controversial. Although some studies have associated laparoscopic surgery with an increased risk of fetal loss, many others have reported no significant difference between laparoscopic and open surgery in pregnant women in terms of surgical complications and obstetric outcomes.[35] In our study, no fetal loss was observed, and no significant difference was found between laparoscopic and open appendectomy in terms of preterm labor. However, the length of hospital stay was significantly shorter in patients who underwent laparoscopic appendectomy compared to those who underwent open surgery. This finding is consistent with a meta-analysis including 22 studies and 4,694 cases of appendicitis in pregnancy, which reported that laparoscopic surgery was associated with shorter hospital stay and lower rates of wound infection compared to open surgery.[36] In our study, no significant difference was found between the laparoscopic and open surgery groups in terms of maternal complications, including wound infection. Despite ongoing debate, current evidence from the literature, together with our findings, suggests that laparoscopic surgery maintains its advantages in both the general and pregnant population and can be used safely. This should be taken into consideration by clinicians when selecting surgical techniques in pregnant patients.

Our study has several limitations, including a small sample size and a retrospective design.

CONCLUSION

The findings of our study indicate that clinical scoring systems are effective tools in the diagnosis of acute appendicitis in pregnant women, with the RIPASA score demonstrating higher sensitivity and specificity compared to other scoring systems. Additionally, elevated CRP levels and leukocytosis may contribute to the diagnostic process in this population. While laparoscopic appendectomy is associated with a shorter hospital stay compared to open surgery, it demonstrates a similar safety profile in terms of obstetric and surgical complications. These results support the safe and appropriate use of both clinical scoring systems and laparoscopic surgery in pregnant patients with suspected appendicitis. Further large-scale, prospective, and more homogeneous studies are needed to clarify remaining uncertainties and guide clinical decision-making.

Ethics Committee Approval: This study was approved by the Gülhane Training and Research Hospital Ethics Committee (Date: 31.08.2023, Decision No: 2023/192).

Peer-review: Externally peer-reviewed.

Informed Consent: Retrospective study.

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

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*

Gebelikte akut apandisit tanı yöntemlerinin kısıtlılıkları klinik skorlama sistemleri ile aşılabilir mi?

AMAÇ: Gebelikte akut apandisit, obstetrik patolojiler dışında en sık acil cerrahi nedenidir. Gebelikteki fizyolojik değişimler akut apandisit semptom ve bulgularının duyarlılığını azaltmaktadır. Bu çalışmanın amacı, gebe hastalarda Alvarado, Appendicitis Inflammatory Response (AIR), Raja Isteri Pengiran Anak Saleha Appendicitis (RIPASA) ve Tzanakis skorlama sistemlerinin etkinliğini karşılaştırmak ve cerrahi tekniklerin sonuçlarını değerlendirmektir.

GEREÇ VE YÖNTEM: Ocak 2017-Ocak 2025 tarihleri arasında, akut apandisit tanısı ile ameliyat edilen 39 gebe hasta retrospektif olarak incelendi. Hastaların demografik verileri, gestasyonel haftaları, semptom ve bulguları, laboratuvar parametreleri (WBC, CRP), ultrasonografi bulguları, uygulanan cerrahi teknikler (açık/laparoskopik), histopatolojik sonuçlar, maternal ve fetal komplikasyonlar kaydedildi. Alvarado, AIR, RIPASA ve Tzanakis skorları hesaplanarak hastalar literatürde belirlenen kestirim değerlerine göre risk gruplarına ayrıldı ve histopatolojik tanı ile karşılaştırıldı.

BULGULAR: Hastaların yaş ortalaması 26.0±5.3 yıl, gestasyonel haftaları 19.6±7.9 idi; %53.8'i II. trimesterdeydi. Hastaların %61.5'ine açık apendektomi, %38.5'ine laparoskopik apendektomi yapıldı. Hastaların Alvarado skoruna göre %66.7'si, AIR skoruna göre %69.2'si, RIPASA ve Tzanakis skorlarına göre %79.5'i yüksek risk grubundaydı. Histopatolojik olarak olguların %66.7'si akut apandisit, %15.4'ü perfore apandisit, %17.9'u normal apendiks olarak değerlendirildi. Akut apandisit tanılı hastalarda WBC ve CRP düzeyleri anlamlı şekilde yüksek bulundu ($p<0.05$). Skorlama sistemlerinin duyarlılık ve özgüllük oranları RIPASA (%93.7 ve %85.7) ve Tzanakis (%90.6 ve %71.4) skorlarında en yüksek olarak izlendi. Laparoskopik cerrahi, açık cerrahiye kıyasla daha kısa hastanede kalış süresi sağladı ($p<0.001$) ve maternal/fetal komplikasyonlar açısından benzer güvenlik profiline sahipti.

SONUÇ: Gebelerde akut apandisit tanısında klinik skorlama sistemleri etkin ve güvenilir bir araçtır; RIPASA skoru en yüksek tanısal performansı göstermektedir. CRP yüksekliği ve lökositoz, tanıya katkı sağlayabilir. Laparoskopik apendektomi, açık cerrahiye kıyasla kısa hastanede kalış süresi ile güvenli bir seçenektir. Bu bulgular, gebe hastalarda hem klinik skorlama sistemlerinin hem de laparoskopik cerrahinin güvenle kullanılabileceğini desteklemektedir.

Anahtar sözcükler: Akut apandisit; gebelik; RIPASA.

Ulus Travma Acil Cerrahi Derg 2026;32(6):642-651 DOI: 10.14744/tjtes.2026.95036

ORIGINAL ARTICLE

Evaluating the effectiveness of trauma scores in predicting morbidity and mortality in patients with concomitant thoracic trauma

Suzan Temiz Bekce,[1] Dincer Göksülük[2]

[1]Department of Thoracic Surgery, Kayseri City Hospital, Kayseri-*Türkiye*
[2]Department of Biostatistics, Erciyes University Faculty of Medicine, Kayseri-*Türkiye*

ABSTRACT

BACKGROUND: Trauma is a major global health concern due to its potential to affect multiple organ systems and its association with high rates of morbidity and mortality. This study aimed to comparatively evaluate the accuracy of various trauma scoring systems in predicting morbidity and mortality among patients with blunt thoracic trauma across different age groups.

METHODS: A retrospective analysis was conducted on 210 patients treated for thoracic trauma at the Department of Thoracic Surgery, Kayseri City Hospital, between October 2022 and January 2024. Patients were categorized into three age groups: 18–44 years, 45–64 years, and ≥65 years. Data collected included demographic characteristics, comorbidities, anticoagulant use, mechanism of injury, thoracic and extrathoracic injuries, and histories of intensive care unit (ICU) admission and intubation. The predictive performance of the Glasgow Coma Scale (GCS), Revised Trauma Score (RTS), Chest Trauma Score (CTS), Injury Severity Score (ISS), and Trauma and Injury Severity Score (TRISS) for mortality, intubation, and ICU admission was assessed using receiver operating characteristic (ROC) analysis.

RESULTS: The mean age of the patients was 53.43 years, with a predominance of males. Traffic accidents were the most common cause of trauma. The prevalence of comorbidities and anticoagulant use increased with age. The ICU admission rate was 32.38%, and the overall mortality rate was 4.28%. ROC analysis demonstrated that ISS and TRISS had strong predictive performance for mortality, need for intubation, and ICU admission across all age groups.

CONCLUSION: Thoracic trauma is a severe form of injury associated with high rates of morbidity and mortality. The findings suggest that ISS and TRISS are reliable predictors of trauma severity regardless of age. Incorporating these scoring systems into hospital triage and clinical decision-making may facilitate early diagnosis and support timely, effective management.

Keywords: Morbidity; mortality; thoracic trauma; trauma scoring systems.

INTRODUCTION

Thoracic trauma represents a significant category of injuries, ranging from minor conditions to life-threatening situations. Depending on the patient's clinical status, it remains a major contributor to morbidity and mortality worldwide.[1-3]

Patients with thoracic trauma may present with a variety of clinical conditions at the time of injury, including rib fractures, hemopneumothorax, and pulmonary contusion. Additionally, secondary complications that develop during follow-up may further worsen the clinical course.

A thorough evaluation of thoracic injuries is essential for guiding management and determining appropriate follow-up strategies.[4] Among the factors influencing prognosis and

Cite this article as: Temiz Bekce S, Göksülük D. Evaluating the effectiveness of trauma scores in predicting morbidity and mortality in patients with concomitant thoracic trauma. Ulus Travma Acil Cerrahi Derg 2026;32:652-660.

Address for correspondence: Suzan Temiz Bekce
Department of Thoracic Surgery, Kayseri City Hospital, Kayseri, Türkiye
E-mail: suzantemiz@erciyes.edu.tr

Ulus Travma Acil Cerrahi Derg 2026;32(6):652-660 DOI: 10.14744/tjtes.2025.43780
Submitted: 09.10.2025 Revised: 20.10.2025 Accepted: 08.01.2026 Published: 03.06.2026

mortality, the severity of trauma remains one of the most critical determinants.[5]

Treatment algorithms based on trauma scoring systems have been shown to improve patient outcomes and reduce the duration of hospitalization.[6,7] Moreover, standardized trauma assessment models are recommended to ensure accurate prediction of clinical outcomes and to identify potential risk factors in patients with thoracic trauma.[8]

Reducing mortality and achieving effective triage remain the primary goals of trauma management.[9] In addition, variables such as patient age and sex have been reported to influence both injury pattern and clinical outcomes following trauma.[10]

The mechanisms of trauma and the prevalence of comorbidities vary across different age groups. In this study, patients with thoracic trauma were stratified into three age categories: 18–44 years, 45–64 years, and ≥65 years. The primary aim was to evaluate the predictive value of several trauma scoring systems for morbidity and in-hospital mortality across these age groups. Additionally, the study sought to determine whether integrating these scoring systems into triage protocols could facilitate the rapid and effective implementation of treatment strategies.

Given the challenges associated with accurately assessing the severity of thoracic injuries in the early post-traumatic period, this study also evaluated the predictive performance of various trauma scoring systems in estimating the need for mechanical ventilation and intensive care across different age groups.

MATERIALS AND METHODS

This retrospective descriptive study was approved by the Ethics Committee for Clinical Research of Kayseri City Hospital (Date: 06.12.2023; Decision No: 970) and conducted in accordance with the principles of the Declaration of Helsinki. Patients who were referred to the Department of Thoracic Surgery for thoracic trauma between October 2022 and January 2024 were included in the study. Cases were categorized into three age groups: 18–44 years (Group 1), 45–64 years (Group 2), and ≥65 years (Group 3). The study population included a broad spectrum of cases, ranging from simple injuries to complex multiple traumas.

During data collection, the following variables were evaluated: demographic characteristics, comorbidities, anticoagulant use, vital signs, mechanisms of injury, rib fractures, associated bone and organ injuries, anatomical location of thoracic trauma, tube thoracostomy procedures, history of intubation, complications during follow-up, laboratory findings, and mortality outcomes. All patients included in the study underwent thoracic computed tomography imaging.

To assess the severity of thoracic injuries, several trauma scoring systems were utilized, including the Glasgow Coma Scale (GCS), Revised Trauma Score (RTS),[11] Chest Trauma Score (CTS),[12] Injury Severity Score (ISS),[13] and Trauma and Injury Severity Score (TRISS).[14] Although TRISS is calculated differently for penetrating and blunt trauma, only blunt trauma cases were included in this study.

Blunt thoracic trauma typically results from increased intrathoracic pressure.[15] Compared with penetrating trauma, blunt thoracic injuries may present with less apparent and more difficult-to-detect findings on physical examination.[16]

To ensure consistency in clinical evaluation, patients with penetrating injuries were excluded. Individuals younger than 18 years were also excluded. In addition, patients with missing laboratory data or inadequate imaging findings (n=154) were excluded from the analysis. Post-discharge mortality was not considered; only in-hospital mortality during the follow-up period was evaluated. After applying these criteria, a total of 210 patients were included in the study.

Statistical Analysis

Statistical analyses were performed using IBM SPSS (version 26.0; IBM Corp., Armonk, NY, USA), TURCOSA (version 1.0; Turcosa Ltd., Kayseri, Türkiye; available at www.turcosa.com.tr), and the R programming language (version 4.3.0; R Foundation for Statistical Computing, Vienna, Austria; available at www.r-project.org). The choice of software depended on the type of analysis and specific requirements. Numerical variables were summarized as mean ± standard deviation or median (interquartile range), depending on the distribution. Categorical variables were expressed as frequencies and percentages. The normality of numerical variables was assessed using both graphical methods (e.g., histograms, box plots, and Q-Q plots) and analytical tests, including the Shapiro–Wilk test. Parametric and non-parametric hypothesis tests were applied for group comparisons based on data distribution. For normally distributed variables, intergroup comparisons were performed using Student's t-test and one-way analysis of variance (ANOVA). When the assumption of normality was not met, the Mann–Whitney U test and Kruskal–Wallis test were used. Categorical variables were analyzed using chi-square tests, including Pearson's chi-square and Fisher's exact test, as appropriate.

Correlation analyses were conducted to evaluate relationships between variables, using Pearson correlation coefficients for normally distributed data and Spearman correlation coefficients for non-normally distributed data. Survival analyses were performed to identify risk factors influencing morbidity, mortality, and survival outcomes. Kaplan–Meier analysis was used to compare survival times between groups.

To assess the discriminatory ability of each scoring system in predicting mortality, receiver operating characteristic (ROC) curves were generated, and the area under the curve (AUROC) was calculated. A p-value <0.05 was considered statistically significant for all analyses.

RESULTS

Statistical analysis was completed for patients who met the inclusion criteria and presented with thoracic trauma. Of the 210 patients, 149 (70.95%) were male and 61 (29.04%) were female, with a mean age of 53.43 years (range: 18–92 years). The mechanisms of trauma differed across age groups: traffic accidents were most common in the younger group (Group 1), falls from height or stairs predominated in the middle-aged group (Group 2), and same-level falls were most frequent in the older group (Group 3) (p<0.001) (Table 1).

A significant increase in the prevalence of chronic comorbidities was observed with advancing age (p<0.001). Similarly, anticoagulant use was significantly higher in Groups 2 and 3 compared with Group 1 (p<0.001) (Table 1).

Regarding pulmonary contusion, bilateral minimal contusion was the most common finding across all groups (p<0.001). However, no significant differences were observed between groups in terms of bilateral rib fractures (p=0.623), multiple fractures of the same rib (p=0.802), or the presence of flail chest (p=0.775). Tube thoracostomy was performed in 45 patients (21.42%), with no significant differences between groups (p=0.775) (Table 2).

There were also no statistically significant differences between groups in terms of complications (atelectasis: p=0.279; pneumonia: p=0.446; others: p=0.372) or history of intubation (p=0.524). A total of nine patients (4.28%) died; however, mortality rates did not differ significantly between groups (p=0.091) (Table 2).

Analysis of trauma score means revealed no significant differences between groups for GCS (p=0.469), RTS (p=0.256), or TRISS (p=0.57) (Table 3). CTS values increased with age and differed significantly among the groups (Group 1: 3.6; Group 2: 4.9; Group 3: 5.72; p<0.001). ISS was significantly higher in Group 1 compared with the other groups (p<0.001), while no difference was observed between Groups 2 and 3 (Table 3). Among patients admitted to the intensive care unit, both CTS (p<0.001) and TRISS (p=0.003) were significantly associated with ICU admission across all groups (Table 4).

In subgroup analyses of intubated patients, GCS, RTS, and TRISS demonstrated the highest predictive performance in Group 1 (AUROC=1, p<0.001). In Group 2, TRISS (AUROC=0.99), ISS (AUROC=0.98), CTS (AUROC=0.96), and GCS (AUROC=0.90) were strong predictors (all p<0.001). In Group 3, ISS (AUROC=0.98) and TRISS (AUROC=0.96) demonstrated the best predictive performance (all p<0.001) (Table 5).

For predicting ICU length of stay, TRISS (AUROC=0.83, p<0.001) and ISS (AUROC=0.82, p<0.001) were significant predictors in Group 1. In Group 2, ISS (AUROC=0.86, p<0.001) and TRISS (AUROC=0.85, p<0.001) showed the highest predictive accuracy. In Group 3, TRISS (AUROC=0.76, p<0.001) and ISS (AUROC=0.75, p<0.001) also demonstrated significant predictive value (Table 5).

In the analysis of mortality, ISS (AUROC=0.98, p<0.001), TRISS (AUROC=0.97, p<0.001), and GCS (AUROC=0.97, p<0.001) were significant predictors in Group 1. In Group

Table 1. Descriptive statistics of demographic characteristics, mechanisms of trauma, comorbidities, and anticoagulant use

	All patients (n=210)	Group 1 (18–45 years) (n=70) (%)	Group 2 (46–64 years) (n=70) (%)	Group 3 (≥65 years) (n=70) (%)	p value
Sex					
Female	61	15 (24.59)	23 (37.70)	23 (37.70)	0.228
Male	149	55 (36.91)	47 (31.54)	47 (31.54)	
Age	53.43±19.40	30.47±8.22	55.41±5.48	74.42±7.51	<0.001
Cause of trauma					<0.001
Traffic accident	105	53 (50.47)	31 (29.52)	21 (20)	
Fall from height	36	9 (25)	17 (47.22)	10 (27.77)	
Fall from ladder	11	2 (18.18)	5 (45.45)	4 (36.36)	
Same-level fall	44	1 (2.27)	13 (29.54)	30 (68.18)	
Other causes (bicycle accidents, animal bites, lifting-related injuries, carrying-related injuries, massage-related injuries, sports injuries)	14	5 (35.71)	4 (28.57)	50.44 (35.71)	
Presence of comorbidities	100	12 (12)	27 (27)	61 (61)	<0.001
Anticoagulant use	36	2 (5.55)[a]	12 (33.33)[b]	22 (61.11)[b]	<0.001

*Values are presented as mean ± standard deviation or number (percentage), as appropriate. In multiple comparisons, groups sharing the same letter do not differ significantly, whereas different letters indicate a statistically significant difference.

Table 2. Clinical findings, trauma characteristics, hospitalization data, complications, and mortality across age groups

	All patients (n=210)	Group 1 (18–45 years) (n=70) (%)	Group 2 (46–64 years) (n=70) (%)	Group 3 (≥65 years) (n=70) (%)	p value
Rib fracture (any)	179	44 (24.58)[a]	65 (36.3)[b]	70 (39.10)[b]	<0.001
Bilateral rib fractures	16	5 (31.25)	7 (43.75)	4 (25)	0.623
Flail chest	4	1 (25)	1 (25)	2 (50)	0.775
Sternum fracture	16	7 (43.75)	6 (37.5)	3 (18.75)	0.415
Contusion					<0.001
Minimal (right lung parenchyma)	21	9 (42.85)	9 (42.85)	3 (14.28)	
Extensive (right lung parenchyma)	6	3 (50)	1 (16.66)	2 (33.33)	
Minimal (left lung parenchyma)	16	9 (56.25)	5 (31.25)	2 (12.5)	
Extensive (right lung parenchyma)	4	0	1 (25)	3 (75)	
Minimal (bilateral lung parenchyma)	61	19 (31.14)	27 (44.26)	15 (24.59)	
Extensive (bilateral lung parenchyma)	5	5 (100)	0	0	
All patients with contusions	113	45 (39.82)	43 (38.05)	25 (22.11)	
Parenchymal injury (pulmonary hematoma, pulmonary laceration, pneumatocele)	31	15 (48.38)	9 (29.03)	7 (22.58)	0.140
Hemothorax	53	16 (30.18)	18 (33.96)	19 (35.84)	0.838
Pneumothorax	58	25 (43.1)	20 (34.48)	13 (22.41)	0.075
Hemopneumothorax	32	10 (31.25)	10 (31.25)	12 (37.5)	0.863
Pneumomediastinum	10	4 (40)	5 (50)	1 (40)	0.255
Subcutaneous emphysema	28	8 (28.57)	12 (42.85)	8 (28.57)	0.517
Chest tube placement	45	16 (35.55)	16 (35.55)	13 (28.88)	0.775
Extrathoracic injuries					
Head and neck	52	19 (36.53)	19 (36.53)	14 (26.92)	0.528
Lower extremity	32	20 (62.5)[a]	7 (21.8)[b]	5 (15.62)[b]	<0.001
Upper extremity	36	17 (47.22)[a]	14 (38.88)[a]	5 (13.88)[b]	0.020
Pelvis	28	14 (50)	9 (32.14)	5 (17.85)	0.081
Abdomen	50	24 (48)[a]	15 (30)[ab]	11 (22)[b]	0.030
Surgery after trauma	39	23 (58.97)[a]	11 (28.20)[b]	5 (12.82)[b]	<0.001
Hospitalization	151	58 (38.41)[a]	51 (33.77)[ab]	42 (27.81)[b]	0.011
Hospital stay (days)	6.49	9.08 (1-120)	6.11 (1-40)	4.28 (1-50)	0.055
Complications					
Atelectasis	18	7 (38.88)	8 (44.44)	3 (16.66)	0.279
Pneumonia	13	5 (38.46)	6 (46.15)	2 (15.38)	0.446
Other complications (prolonged air leak, acute kidney injury, empyema, hemothorax, pneumothorax, pneumomediastinum, pleural effusion, etc.)	24	7 (29.16)	11 (45.83)	6 (25)	0.372
Intubation	15	6 (40)	6 (40)	3 (20)	0.524
ICU admission	68 (32.38%)	31 (45.58%)[a]	23 (33.82%)[ab]	14 (20.58%)[b]	0.009
ICU stay (days)	9.02±19.77	11.83±21.93	8.21±9.70	5.85±3.97	0.470
Mortality	9 (4.28%)	2 (22.22%)	3 (33.33%)	4 (44.44%)	0.911

In multiple comparisons, groups sharing the same letter do not differ significantly, whereas different letters indicate statistically significant differences.

Table 3. Comparison of trauma scoring system values across age groups

Scoring system	Overall (n=210)	Group 1 (n=70)	Group 2 (n=70)	Group 3 (n=70)	p value
HGCS	14.12	13.8	14.22	14.35	0.469
RTS	7.48	7.31	7.55	7.59	0.259
CTS	4.74	3.6[a]	4.9[b]	5.72[c]	<0.001
ISS	11.73	15.11[a]	11.48[ab]	8.59[b]	<0.001
TRISS	7.80	7.2	9.65	6.54	0.57

In multiple comparisons, groups sharing the same letter do not differ significantly, whereas different letters indicate statistically significant differences.

Table 4. The average scores and p-values of patients admitted to the intensive care unit

Scoring system	Group 1 (n=31)	Group 2 (n=23)	Group 3 (n=17)	p value
GCS	15 [11, 15]	15 [14, 15]	15 [10, 15]	0.899
RTS	7.8 [6.9, 7.8]	7.8 [7.5, 7.8]	7.8 [6.66, 7.8]	0.578
CTS	4 [3, 6]	6 [5, 8]	7 [5, 8.25]	<0.001
ISS	18 [13, 29]	17 [12, 27]	14.5 [4.75, 20.5]	0.145
TRISS	1.3 [0.9, 6.7]	6.1 [3.5, 21.3]	5.1 [2.27, 17.05]	0.003

*Values are presented as mean ± standard deviation or median [first quartile, third quartile] depending on data distribution.

Table 5. Receiver operating characteristic (ROC) analysis of trauma scoring systems for predicting intubation, intensive care unit admission, and mortality

	Group 1	p value	Group 2	p value	Group 3	p value
History of intubation						
GCS	1 (0.95-1)	<0.001	0.90 (0.81-0.96)	<0.001	0.79 (0.68-0.88)	0.088
RTS	1 (0.95-1)	<0.001	0.82 (0.71-0.90)	0.003	0.64 (0.52-0.75)	0.429
CTS	0.73 (0.61-0.83)	0.064	0.96 (0.89-0.99)	<0.001	0.69 (0.57-0.79)	0.141
ISS	0.95 (0.88-0.99)	<0.001	0.98 (0.91-0.99)	<0.001	0.98 (0.91-0.99)	<0.001
TRISS	1 (0.94-1)	<0.001	0.99 (0.93-1)	<0.001	0.96 (0.88-0.99)	<0.001
ICU admission						
GCS	0.67 (0.55-0.78)	<0.001	0.66 (0.53-0.76)	0.002	0.69 (0.56-0.79)	0.006
RTS	0.69 (0.57-0.79)	<0.001	0.63 (0.50-0.74)	0.005	0.62 (0.50-0.73)	0.051
CTS	0.70 (0.58-0.80)	0.001	0.81 (0.71-0.89)	<0.001	0.71 (0.59-0.82)	0.003
ISS	0.82 (0.71-0.90)	<0.001	0.86 (0.76-0.93)	<0.001	0.75 (0.63-0.85)	<0.001
TRISS	0.83 (0.72-0.91)	<0.001	0.85 (0.75-0.92)	<0.001	0.76 (0.64-0.85)	<0.001
Mortality						
GCS	0.97 (089-0.99)	<0.001	0.97 (0.89-0.99)	<0.001	0.84 (0.74-0.92)	0.007
RTS	0.95 (0.87-0.98)	<0.001	0.80 (0.69-0.88)	0.071	0.73 (0.61-0.83)	0.125
CTS	0.88 (0.78-0.94)	<0.001	0.97 (0.90-0.99)	<0.001	0.76 (0.64-0.85)	0.020
ISS	0.98 (0.91-0.99)	<0.001	0.98 (0.92-0.99)	<0.001	0.99 (0.94-1)	<0.001
TRISS	0.97 (0.91-0.99)	<0.001	0.98 (0.92-0.99)	<0.001	0.97 (0.90-0.99)	<0.001

*Values are presented as AUC (95% confidence interval). AUC: Area under the receiver operating characteristic (ROC) curve.

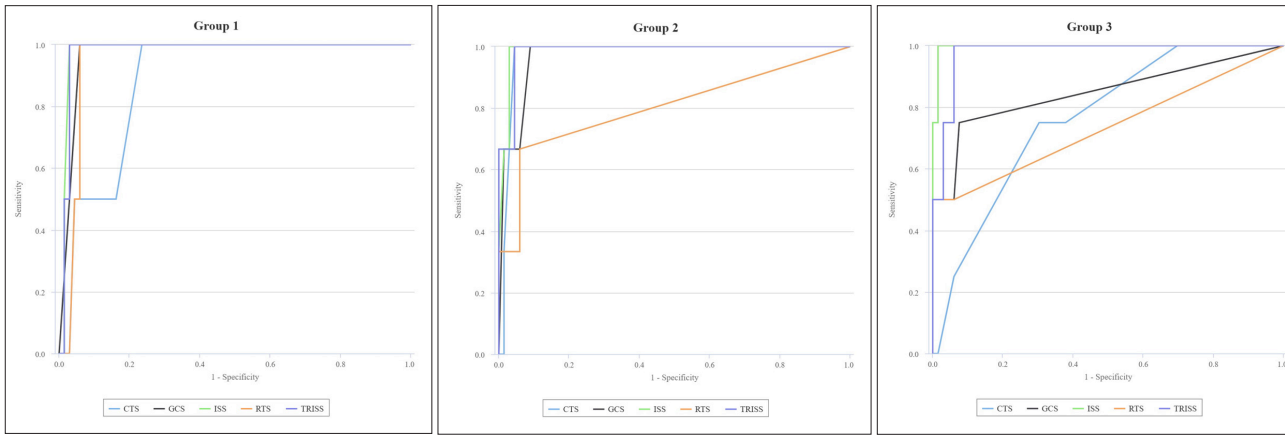

Figure 1-3. Receiver operating characteristic (ROC) illustrating the predictive performance of trauma scoring systems for mortality in each age group (Group 1, Group 2, and Group 3, respectively). The figures display the following scoring systems with their corresponding colors: Glasgow Coma Scale (GCS, black), Revised Trauma Score (RTS, orange), Chest Trauma Score (CTS, blue), Injury Severity Score (ISS, green), and Trauma and Injury Severity Score (TRISS, dark blue).

2, TRISS (AUROC=0.98, p<0.001), ISS (AUROC=0.98, p<0.001), and GCS (AUROC=0.97, p<0.001) were the most influential parameters. In Group 3, ISS (AUROC=0.99, p<0.001) and TRISS (AUROC=0.97, p<0.001) demonstrated strong predictive performance (Table 5). Mortality-related AUROC curves are presented as Figures 1, 2, and 3 for the respective age groups.

DISCUSSION

In this retrospective study, we aimed to compare the performance of various trauma scoring systems in predicting mortality, morbidity, and injury severity across different age groups. Additionally, we evaluated whether age-stratified trauma scores provide optimal predictive value for in-hospital triage.

Previous studies on blunt thoracic trauma have reported mean ages of 48.9±19.3 years in Korea,[17] 44.7 years in China,[18] and 46.1 years in the German Trauma Registry (Trauma Register DGU®).[19] In the present study, the mean age of the patient population was 53.4±19.4 years.

A predominance of male patients has been consistently reported in previous studies. Similarly, in the present study, 70.9% of the patients were male, with no statistically significant differences among age groups (p=0.228).[20-22]

Khursheed et al. (2019) reported that 56.17% of thoracic injuries were related to traffic accidents.[20] Likewise, Asim et al.[21] (2020) found that 52.2% of blunt thoracic trauma cases were caused by road traffic accidents. A 2021 study from China also reported that 54% of blunt trauma cases resulted from traffic accidents.[18] Simple falls have also been identified as an important cause of trauma, particularly among elderly patients.[23,24,25] In our study, traffic accidents were identified as the primary cause of trauma in 105 patients (50%). Subgroup analyses showed that traffic accidents were more frequent in Group 1, falls from height or stairs predominated in Group 2, and same-level falls were most common in Group 3 (p<0.001).

In a Norwegian study of patients aged over 18 years with thoracic trauma, anticoagulant use was reported in 18% of cases.[26] In our study, anticoagulant use was higher in Groups 2 and 3 compared with Group 1. Similarly, the prevalence of comorbidities was highest in Group 3. However, despite this, no increase in mortality was observed in Group 3, and mortality rates did not differ significantly between the groups.

Most studies report that extrathoracic injuries are present in the majority of chest trauma cases.[27-29] Kavurmacı et al.[25] found that head trauma was significantly more common in patients aged 65 years and older.

In our study, extrathoracic injuries were observed in 107 patients (50.95%), with the head and neck region being the most frequently affected area (24.76%). Lower extremity injuries were significantly more common in Group 1 compared with Groups 2 and 3 (p<0.001), while no significant difference was observed between Groups 2 and 3. Upper extremity injuries were more frequent in Groups 1 and 2 than in Group 3 (p=0.020). Similarly, abdominal injuries were significantly more common in Groups 1 and 2 compared with Group 3 (p<0.001), with no significant difference between Groups 1 and 2.

The literature indicates that the majority of thoracic injuries can be effectively managed with tube thoracostomy.[21,30-32] In our study, tube thoracostomy was performed in 21.42% of cases, with no statistically significant difference among the three age groups.

Rib fractures are the most commonly reported injury in tho-

racic trauma.[20,21,33] Consistent with the literature, rib fractures were the most frequent injury in our cohort, although they were significantly less common in the younger age group.

A 2021 study from China reported an ICU admission rate of 68.1% among patients with blunt thoracic trauma, while a Norwegian study found that 41% of patients required ICU monitoring.[18,26] A retrospective analysis based on the Trauma Register DGU® reported a mean ICU stay of 11.7 days and a mean hospital stay of 25 days in patients with multiple injuries and blunt thoracic trauma.[19] Novakov et al. reported a mean hospital length of stay of 8.7 days, whereas Khursheed et al. reported 9.88 days.[20,34]

In our study, the ICU admission rate was 32.38%, with no statistically significant differences between groups. The mean hospital length of stay was 6.49 days, and no significant intergroup differences were observed.

Mortality rates in thoracic trauma vary widely in the literature. Khursheed et al.[20] reported a mortality rate of 13.7% in patients with blunt thoracic trauma, whereas Asım et al.[21] reported a rate of 2.6%. Kavurmacı et al.[25] found a mortality rate of 1.5% among patients aged 65 years and older. Another study conducted in China in 2021 reported a mortality rate of 11.8% in patients with blunt trauma.[18] In our study, the in-hospital mortality rate was 4.28%, with no significant differences observed between age groups.

Harde et al.[35] stratified patients into two groups based on the CTS (low CTS <5 and high CTS ≥5) and reported that a CTS greater than 5 was significantly associated with higher rates of pneumonia, increased need for mechanical ventilation, and mortality in thoracic trauma. Similarly, a 2024 study reported that patients with severe thoracic trauma had a mean CTS of ≥6.[36]

In our study, the mean CTS was 4.74, with values of 3.66 in Group 1, 4.9 in Group 2, and 5.72 in Group 3. The age-related increase in CTS and the differences between groups, particularly among patients admitted to the intensive care unit, were statistically significant. The AUROC for the association between CTS and mortality was 0.877 ($p<0.001$).

In a 2022 study comparing Mechanism, Glasgow Coma Scale, Age, and Arterial Pressure (MGAP) score, ISS, New Injury Severity Score (NISS), and TRISS scores, TRISS (AUROC=0.920) and MGAP (AUROC=0.900) demonstrated the highest accuracy in predicting mortality.[37] Another study published in 2008 reported AUROC values of 0.934 for TRISS and 0.907 for ISS.[38] Taslak Şengül et al.[39] reported an AUROC of 0.888 for ISS, while Lancey and Poole demonstrated significant correlations between mortality and ISS, RTS, and TRISS.[40,41] Our study also showed that TRISS, ISS, and GCS had high statistically significant predictive accuracy for in-hospital mortality.

In a 2021 study from China, the mean ISS was 21.14, with higher values observed in patients admitted to the intensive care unit.[18] In contrast, a 2012 study including 278 patients reported a mean ISS of 28.7 but found limited predictive performance for acute respiratory distress syndrome (ARDS) and mortality (AUROC for ARDS: 0.56, $p=0.537$; AUROC for mortality: 0.61, $p=0.776$).[42] A Korean study comparing TRISS (AUROC=0.942), ISS (AUROC=0.866), and RTS (AUROC=0.894) concluded that TRISS had the highest predictive value.[17] Ünlü et al.[43] also reported significant correlations between the duration of mechanical ventilation and GCS, RTS, and TRISS scores.

In our study, the predictive performance of trauma scoring systems for morbidity varied across age groups. Among intubated patients, GCS, RTS, TRISS, and ISS demonstrated the highest predictive accuracy in Group 1; TRISS, ISS, CTS, and GCS in Group 2; and ISS and TRISS in Group 3. For predicting intensive care unit length of stay, ISS and TRISS were the most reliable scoring systems across all age groups. In terms of mortality prediction, ISS, TRISS, GCS, and RTS showed the best performance in Group 1, whereas ISS and TRISS were the most effective predictors in Groups 2 and 3.

CONCLUSION

In this study, we evaluated patients with blunt thoracic trauma to determine the predictive performance of various trauma scoring systems for mortality and morbidity. A statistically significant association was identified between intensive care unit admission and mortality. ROC analysis demonstrated that TRISS, ISS, and GCS had strong predictive performance for mortality. For predicting the need for intubation, ISS and TRISS showed high accuracy across all age groups. Similarly, ISS and TRISS were the most effective predictors for intensive care unit admission regardless of age.

Although GCS and RTS are the most commonly used trauma scoring systems in our country, our findings indicate that ISS and TRISS provide reliable estimates of trauma severity across all age groups. Furthermore, the use of ISS and TRISS may offer valuable support for in-hospital triage and clinical decision-making.

Ethics Committee Approval: This study was approved by the Ethics Committee for Clinical Research of Kayseri City Hospital (Date: 06.12.2023, Decision No: 970).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: S.T.B.; Design: S.T.B.; Supervision: S.T.B.; Resource: S.T.B.; Materials: S.T.B.; Data Collection and/or Processing: S.T.B.; Analysis and/or Interpretation: S.T.B., D.G.; Literature Search: S.T.B.; Writing: S.T.B., D.G.; Critical Reviews: S.T.B., D.G.

Informed Consent: Written informed consents were obtained from patients who participated in this 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*

Toraks travmasının eşlik ettiği hasta gruplarında travma skorlarının nihai sonuçlarının morbidite ve mortaliteyi öngörmedeki başarısının incelenmesi

AMAÇ: Travma, çoklu organ sistemlerini etkileyebilmesi ve yüksek morbidite ile mortalite oranlarına yol açması nedeniyle hem ülkemizde hem de küresel düzeyde önemli bir sağlık sorunudur. Künt toraks travmalı hastalarda farklı travma skorlama sistemlerinin yaş gruplarına göre morbidite ve mortaliteyi öngörmedeki başarılarının karşılaştırmalı olarak değerlendirilmesi amaçlanmıştır.
GEREÇ VE YÖNTEM: Ekim 2022-Ocak 2024 tarihleri arasında Kayseri Şehir Hastanesi Göğüs Cerrahisi Kliniğinde toraks travması tanısıyla izlenen 210 hasta retrospektif olarak incelendi. Olgular, yaş değişkenine göre üç grupta sınıflandırıldı: Birinci grup (18-44 yaş), ikinci grup (45-64 yaş) ve üçüncü grup (65 yaş ve üzeri). Hastaların demografik özellikleri, komorbid hastalıkları, antikoagülan kullanımı, travma mekanizması, torasik ve ekstratorasik yaralanmaları, yoğun bakım ve entübasyon öyküleri değerlendirildi. GKS (Glasgow Koma Skoru), RTS (Revize Travma Skoru), CTS (Göğüs Travma Skoru), ISS (Yaralanma Şiddet Skoru) ve TRISS (Travma ve Yaralanma Şiddet Skoru) sistemlerinin mortalite, entübasyon ve yoğun bakım gereksinimini öngörmedeki performansları ROC analizi ile karşılaştırıldı.
BULGULAR: Hastaların yaş ortalaması 53.43 yıl olup, çoğunluğu erkekti. En sık travma nedeni trafik kazasıydı. Yaş ilerledikçe komorbiditeler ve antikoagülan kullanımı oranlarının artış gösterdiği gözlendi. Yoğun bakım yatış oranı %32.38, mortalite oranı %4.28 olarak belirlendi. ROC analizine göre ISS ve TRISS skorları tüm yaş gruplarında mortalite, entübasyon gerekliliği ve yoğun bakım gereksinimini öngörmede iyi performansı sergiledi.
SONUÇ: Toraks travmaları, yüksek morbidite ve mortalite oranlarıyla seyreden ciddi yaralanmalardır. Bulgular, ISS ve TRISS skorlarının yaş farkı gözetmeksizin travma şiddetini belirlemede güvenilir göstergeler olduğunu ortaya koymaktadır. Bu skorların hastane içi triyaj ve klinik karar verme süreçlerinde kullanılması, erken tanı ve etkili tedaviye önemli ölçüde katkı sağlayabilir.

Anahtar sözcükler: Morbidite; mortalite; toraks tavması; travma skor sistemleri.

Ulus Travma Acil Cerrahi Derg 2026;32(6):652-660 DOI: 10.14744/tjtes.2025.43780

ORIGINAL ARTICLE

Danger in the kitchen: pressure cooker burns

Abidin Tüzün, İlhan Taş

Department of General Surgery Clinic, Health Sciences University Diyarbakır Gazi Yaşargil Health Practice and Research Hospital, Diyarbakır-*Türkiye*

ABSTRACT

BACKGROUND: Burns resulting from pressure cooker explosions are preventable domestic injuries that occur during routine kitchen use; however, they are underrepresented in the medical literature despite their potential severity. This study aimed to evaluate the clinical and demographic characteristics, treatment approaches, and outcomes of patients with pressure cooker-related burns.

METHODS: In this retrospective study, medical records of patients who presented to a tertiary burn center with pressure cooker-related burns between 2016 and 2024 were reviewed. Collected data included demographic characteristics, burn location and depth, total body surface area (TBSA), time to hospital admission, treatment modalities, and clinical outcomes.

RESULTS: A total of 41 patients were included in the study. The vast majority were female (97.6%), with a mean age of 36.2±13.5 years. Most injuries were second-degree burns (92.7%). The most commonly affected anatomical regions were the head and neck (65.9%) and the anterior chest (61%). Escharotomy was performed in 29.3% of patients, and 2.4% required skin grafting. Delayed hospital presentation was significantly associated with an increased need for surgical intervention (p=0.001).

CONCLUSION: Pressure cooker-related burns predominantly affect women and frequently involve cosmetically and functionally important anatomical regions. Although the total burn surface area is often limited, the depth and location of these injuries may lead to significant complications. These findings highlight the importance of increasing public awareness regarding the safe use of pressure cookers and emphasize the need for prompt medical evaluation to reduce morbidity. Overall, the results underscore the seriousness of domestic burn injuries and the importance of preventive public health measures.

Keywords: Burn injury; domestic accident; scalds; escharotomy; pressure cooker.

INTRODUCTION

Burn injuries represent a major global health problem with substantial medical, psychological, and economic consequences. With the advancement of industry and technology, both the incidence and diversity of burn injuries have increased.[1] In recent years, pressure cookers have become increasingly popular in domestic kitchens because they are widely promoted as a faster, healthier, and more efficient method of cooking. However, the growing use of pressure cookers has also been associated with an increase in reports of scald injuries resulting from sudden release of hot contents.[2] Although pressure cooker use is primarily associated with burn injuries,[3] rare traumatic injuries such as mandibular fractures[4] and ocular perforations[5] have also been reported.

In the United States, pressure cookers are used as a household cooking appliance in approximately 20% of homes.[6] These devices utilize steam pressure to cook food rapidly. The operating principle of pressure cookers is based on the relationship between pressure and the boiling point of water. Equipped with a valve calibrated to a specific pressure threshold, these cookers function under elevated pressure conditions. The valve, which can be adjusted according to the desired cooking intensity, releases steam once a critical pressure threshold is reached, thereby functioning as a safety

Cite this article as: Tüzün A, Taş İ. Danger in the kitchen: pressure cooker burns. Ulus Travma Acil Cerrahi Derg 2026;32:661-666.
Address for correspondence: Abidin Tüzün
Department of General Surgery Clinic, Health Sciences University Diyarbakır Gazi Yaşargil Health Practice and Research Hospital, Diyarbakır, Türkiye
E-mail: atuzun_1@hotmail.com
Ulus Travma Acil Cerrahi Derg 2026;32(6):661-666 DOI: 10.14744/tjtes.2025.28799
Submitted: 04.08.2025 Revised: 29.09.2025 Accepted: 25.12.2025 Published: 03.06.2026

mechanism to prevent explosions.[7] These airtight vessels are designed to raise the boiling temperature of water from 100°C to approximately 121–125°C at a standard pressure of about 15 pounds per square inch. Despite their widespread use, severe burn injuries associated with pressure cookers are rarely reported in the literature.[6,7]

This study aims to investigate burn injuries associated with pressure cookers, which are widely used in household kitchens, and to contribute to the limited literature on this topic. To the best of our knowledge, this study presents the largest case series to date specifically addressing burns resulting from pressure cooker incidents.

MATERIALS AND METHODS

Study Design and Setting

This retrospective chart review was conducted at a tertiary-level burn center. Between January 2016 and December 2024, a total of 3,410 patients were hospitalized for burn treatment at our institution, of whom 41 patients (1.2%) were included in the study due to burns caused by pressure cooker incidents.

Patient Selection and Inclusion Criteria

Patients were identified through electronic medical records using diagnosis codes related to pressure cooker burns. The inclusion criteria were defined prior to data collection and included all patients presenting with burn injuries resulting from pressure cooker accidents. No exclusion criteria were applied based on age or sex.

Data Collection

Demographic data (age, sex, and date of admission) and clinical burn characteristics (burn location, burn depth, and total body surface area [TBSA] involved) were collected. Information on major complications and treatment outcomes (complete recovery, treatment abandonment, or death) were also recorded using a standardized data collection form.

Data Extraction and Quality Control

Two independent researchers, blinded to the study objectives, extracted the data. Any discrepancies between reviewers were resolved through discussion. Inter-rater reliability was assessed using a randomly selected sample of patient charts, and discrepancies identified during the process were reviewed and corrected accordingly.

Ethical Approval

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Ethical approval was obtained from the Health Sciences University Diyarbakır Gazi Yaşargil Health Practice and Research Hospital Local Ethics Committee (Decision No. 435, April 25, 2025). Patient confidentiality was maintained throughout the study, and all data were anonymized prior to analysis. Written informed consent was obtained from the patient featured in the image (Fig. 1) for the scientific publication of the photograph.

Statistical Analysis

Continuous variables were presented as mean±standard deviation (range: minimum–maximum), while categorical variables were expressed as numbers and percentages (%). For comparisons between groups (patients who underwent escharotomy versus those who did not), the Mann-Whitney U test was used to analyze continuous variables with non-parametric distributions. A p-value of <0.05 was considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics for Windows, version 22.0 (Armonk, NY, USA).

RESULTS

A total of 41 patients were included in the study. Most patients were female (n=40; 97.6%). The mean age of the patients was 36.2±13.5 years (range: 10–69 years). Based on burn depth, 92.7% (n=38) of the cases were classified as second-degree burns. The most frequently affected body regions were the head and neck (65.9%), anterior chest (61%), left upper extremity (61%), and right upper extremity (56.1%). Figure 1 shows a patient with extensive burns involving the head and neck, anterior chest, and both upper extremities caused by a pressure cooker injury.

Wound cultures were positive in three patients (7.3%), all of whom had Staphylococcus epidermidis. Regarding treatment, 28 patients (68.3%) received dressing care, 12 patients (29.3%) underwent escharotomy, and one patient (2.4%) required grafting following escharotomy.

The mean time to hospital admission was 26.9±57.7 hours (range: 1–240 hours), the mean length of hospital stay was 4.2±3.6 days (range: 0–15 days), and the mean follow-up period was 19.4±18.0 days (range: 1–94 days). The average total body surface area affected was 8.2±3.7% (range: 1–15%). Analysis of seasonal distribution indicated that cases most commonly occurred in fall (41.5%) and spring (31.7%) (Table 1). When patients were grouped according to whether escharotomy was performed, the time to hospital admission was

Figure 1. Extensive pressure cooker burn involving the head and neck, anterior chest, and bilateral upper extremities.

Table 1. Demographic, clinical, and treatment characteristics of patients with pressure cooker burns

Characteristic	Mean±SD (Min-Max), n (%)
Age	36.2±13.5 (10-69)
Sex	
Male	1 (2.4%)
Female	40 (97.6%)
Wound culture result	
Negative	38 (92.7%)
Positive	3 (7.3%)
Burn depth	
Second-degree	38 (92.7%)
Third-degree	3 (7.3%)
Treatment modality	
Escharotomy	12 (29.3%)
Escharotomy + grafting	1 (2.4%)
Dressing	28 (68.3%)
Affected body region	
Head and neck	27 (65.9%)
Eye	4 (9.8%)
Chest	25 (61%)
Back	2 (4.9%)
Left upper extremity	25 (61%)
Right upper extremity	23 (56.1%)
Left lower extremity	2 (4.9%)
Right lower extremity	4 (9.8%)
Burn percentage	8.2±3.7 (1-15)
Time to hospital admission (hours)	26.9±57.7 (1-240)
Length of hospital stay (days)	4.2±3.6 (0-15)
Follow-up duration (days)	19.4±18.0 (1-94)
Season of injury	
Fall	17 (41.5%)
Spring	13 (31.7%)
Winter	8 (19.5)
Summer	3 (7.3%)

significantly shorter in the non-escharotomy group (p=0.001) (Table 2).

DISCUSSION

In this retrospective study, we found that pressure cooker-related burns predominantly occurred in middle-aged women. The injuries were mainly concentrated in the upper body, particularly the face and upper extremities. Additionally, deeper burns and a greater need for escharotomy were significantly associated with delayed hospital presentation.

Previous studies have reported that burns caused by pressure cooker explosions account for approximately 1.8–2.75% of all burn injuries.[1,8-10] In our series, this rate was 1.2%. The mean age of patients in our study fell within the middle-aged group, and women constituted the vast majority of cases. These findings are consistent with reports in the literature indicating that pressure cooker injuries most commonly affect housewives involved in meal preparation. In the case series by Meriç et al.,[7] which included 32 patients, more than 90% were women, with a mean age of 42.3 years. Similarly, in a study by Perera et al.,[11] five of the seven patients were female. We believe that the cultural tendency for women to spend more time in the kitchen and assume primary cooking responsibilities is the main reason for this gender disparity. In contrast, our series included very few pediatric cases, likely because pressure cookers are typically operated by adults. Nevertheless, children may still be indirectly exposed to these injuries. One study reported that nearly all steam burns in infants were associated with pressure cooker accidents, although most injuries were superficial in nature.[12] Therefore, while children are less commonly affected, they remain vulnerable to significant burn injuries when exposed to such incidents. Domestic cooking-related burns represent an important cause of morbidity and mortality among women and children worldwide.[13] Pressure cooker accidents constitute a specific subset of these injuries and particularly affect housewives. Recent epidemiological data emphasize that domestic cooking burns remain a major public health concern, accounting for up to 25% of all household injuries, many of which are preventable through improved safety awareness, user education, and safer appliance design.[14]

In our study, the most frequently affected anatomical regions were the head, neck, and upper torso with facial involvement being particularly common. This finding is consistent with previous case reports and small case series.[2,7] Perera et al.[11] reported superficial facial burns in all seven patients in their cases. Similarly, facial burns were observed in most patients

Table 2. Comparison of admission time between patients with and without escharotomy

Group	n	Mean rank	Sum of ranks	p value
Escharotomy	13	29.73	386.5	0.001
Non-escharotomy	28	16.95	474.5	

Mann-Whitney U Test.

in our cohort. This pattern likely reflects the close proximity of the individual to the device at the time of the explosion, often while attempting to open the lid. Burns involving the face and upper extremities not only result in significant aesthetic disfigurement but may also lead to long-term functional impairment and psychological distress, highlighting the importance of multidisciplinary management.[15] Another typical injury pattern involves scald burns to the upper extremities. During an explosion, individuals may instinctively attempt to grasp or push away the pressure cooker, resulting in direct exposure to hot liquids and steam. For example, in the case report by Kulahcı et al.,[16] a 44-year-old male sustained deep second- and third-degree burns to the arms, shoulders, neck, and face after boiling food was forcefully discharged during lid removal. Similarly, in our study, many patients presented with scald burns affecting the arms and anterior chest. In another report, a patient sustained a mandibular fracture caused by the pressure wave generated during a pressure cooker explosion,[4] demonstrating that these incidents may produce not only thermal injuries but also blunt trauma and fractures from flying metallic fragments. Atreya et al.[3] further suggested that the mechanism of pressure cooker explosions may resemble that of a "homemade explosive," with pressure waves and shrapnel potentially causing penetrating trauma. Although no orthopedic or penetrating injuries were identified in our series, these reports highlight the potential for multisystem trauma in such accidents. Therefore, the clinical evaluation of patients injured in pressure cooker incidents should not be limited to burn wounds; clinicians should also consider possible ocular injuries, fractures, and internal organ damage.

An important characteristic of pressure cooker-related burns is that the total body surface area involved is often limited. In our study, most patients had burns affecting less than 10% TBSA, typically presenting as localized scald injuries. This observation is consistent with previous reports. Perera et al.[11] documented TBSA involvement ranging from 1% to 4% in all cases in their series. In a case reported by Schukow and Nordyke, a pressure cooker explosion caused approximately 10% TBSA second-degree burns requiring multidisciplinary management.[6] In one of the largest case series on this topic, Meriç et al.[7] reported that only one patient required grafting for deep burns, while most patients were treated conservatively due to the predominance of superficial injuries.[7] Similarly, in our study, only one patient required surgical excision and grafting for a third-degree burn. However, even when the affected surface area is limited, burns involving critical anatomical regions (such as the face or eyes) or deeper burn injuries may still require intensive management and surgical intervention.[17] Several studies have demonstrated that burns involving less than 10% TBSA, particularly when located in functionally important areas, are associated with prolonged hospital stays and higher complication rates.[18] Most pressure cooker burns present as superficial to deep dermal injuries; early fluid resuscitation, adherence to appropriate wound care protocols, and timely surgical intervention when indicated can significantly improve clinical outcomes.[7]

Our findings also indicated a seasonal variation in the incidence of pressure cooker-related burns. Presentations were more frequent during the fall and spring months, whereas a relative decline was observed during the summer. Although data on seasonal distribution are limited, Çıkman et al.[19] reported that over a four-year period the highest frequency of burn injuries occurred in spring (31%), with a notable peak in March, while the lowest number of cases was observed during the summer. Conversely, some studies have reported higher burn incidence during the summer months.[20,21] In another study conducted at our center that included all burn cases, we also observed higher frequencies during spring and fall.[22] The present series demonstrated a similar pattern, with most cases occurring in October and November. We believe that the decreased number of cases during the summer may be related to the preference for lighter meals and the reduced use of pressure cookers during this period. Additionally, sociocultural factors, including seasonal dietary patterns and variations in household activity levels, may influence the temporal distribution of domestic burn injuries.[23]

One of the most significant findings of our study was the relationship between time to hospital admission and treatment requirements. Time to burn center admission emerged as a critical determinant of treatment modality in pressure cooker-related injuries. Patients who presented shortly after injury were typically managed conservatively, whereas those with delayed presentation had a significantly greater need for surgical escharotomy. This observation is consistent with the established literature on burn care, which indicates that delayed hospital admission is associated with poorer wound outcomes. Ozbek et al.[24] demonstrated significantly higher rates of wound contamination and infection among patients with delayed hospital admission following burn injuries. The prolonged presence of necrotic tissue increases the risk of infection and predisposes patients to septic complications, underscoring the importance of early surgical excision for deep burns. Previous studies have also shown that delays in escharotomy may increase both morbidity and mortality.[25] Although no mortality was observed in our study, some patients with delayed presentation developed wound infections and experienced prolonged hospital stays. The most effective strategy to reduce the need for surgical interventions such as escharotomy is prompt and appropriate burn management. Early specialized burn care within the first 24 hours has been associated with a 35–50% reduction in surgical intervention rates and significantly improved functional outcomes.[26]

CONCLUSION

Burn injuries caused by pressure cooker explosions, similar to other thermal injuries, are largely preventable forms of trauma. Although these injuries typically present as scald burns involving a limited total body surface area, they frequently

affect anatomically and functionally critical regions such as the face and hands, potentially resulting in significant functional impairment and aesthetic complications. Early medical evaluation and timely intervention improve treatment effectiveness and substantially reduce the risk of complications. We believe that increasing public awareness regarding the safe use of pressure cookers and promoting proper handling practices are essential for preventing these injuries, thereby enhancing individual safety and reducing the burden on healthcare systems.

Ethics Committee Approval: This study was approved by the Health Sciences University Diyarbakır Gazi Yaşargil Health Practice and Research Hospital Ethics Committee (Date: 25.04.2025, Decision No: 435).

Peer-review: Externally peer-reviewed.

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

Mutfaktaki tehlike: Düdüklü tencere yanıkları

AMAÇ: Düdüklü tencere patlamalarına bağlı yanıklar, ev içi kullanım sırasında meydana gelen, önlenebilir nitelikte fakat tıbbi literatürde yeterince yer almayan ciddi yaralanmalardır. Bu çalışma, bu tür yaralanmaların klinik ve demografik özelliklerini, tedavi süreçlerini ve sonuçlarını incelemeyi amaçlamaktadır.

GEREÇ VE YÖNTEM: Bu retrospektif çalışmada, 2016 ile 2024 yılları arasında üçüncü basamak bir yanık merkezine düdüklü tencere kaynaklı yanık nedeniyle başvuran hastaların tıbbi kayıtları incelendi. Veriler arasında demografik özellikler, yanık yeri ve derinliği, toplam vücut yüzey alanı (TBSA), hastaneye başvuru süresi, tedavi yöntemleri ve klinik sonuçlar yer aldı.

BULGULAR: Çalışmaya toplam 41 hasta dahil edildi. Hastaların büyük çoğunluğu kadındı (%97.6) ve yaş ortalaması 36.2±13.5 yıldı. Yanıkların çoğu ikinci dereceydi (%92.7). En sık etkilenen bölgeler baş-boyun (%65.9) ve ön göğüs bölgesiydi (%61). Hastaların %29,3'üne eskarektomi uygulandı, %2.4'üne deri grefti yapıldı. Gecikmeli başvuru, cerrahi müdahale gereksiniminde anlamlı artışla ilişkiliydi (p=0.001).

SONUÇ: Düdüklü tencere yanıkları ağırlıklı olarak kadınları etkilemekte ve çoğunlukla kozmetik ve fonksiyonel açıdan önemli anatomik bölgelerde meydana gelmektedir. Yanıkların yüzey alanı genellikle sınırlı olsa da, derinlikleri ve yerleşimleri ciddi sonuçlara neden olabilmektedir. Bu durum, halkın düdüklü tencere kullanımı konusunda bilinçlendirilmesi gerektiğini ve olası komplikasyonları azaltmak adına erken medikal müdahalenin önemini ortaya koymaktadır. Bu bulgular, ev içi kazaların ciddiyetine dikkat çekmekte ve koruyucu halk sağlığı önlemlerinin gerekliliğini vurgulamaktadır.

Anahtar sözcükler: Düdüklü tencere; eskarektomi; ev kazası, haşlanma; yanık yaralanması.

Ulus Travma Acil Cerrahi Derg 2026;32(6):661-666 DOI: 10.14744/tjtes.2025.28799

ORIGINAL ARTICLE

Evaluation of morphological findings in fire-related deaths: a retrospective study

Büşra Baydemir Kılınç,[1] Abdulkadir Sancı,[2] Ahmet Nezih Kök[3]

[1]Balıkesir Forensic Medicine Branch Office, Balıkesir-*Türkiye*

[2]Kars Forensic Medicine Branch Office, Kars-*Türkiye*

[3]Department of Forensic Medicine Atatürk University Faculty of Medicine, Erzurum-*Türkiye*

ABSTRACT

BACKGROUND: Fire-related deaths are a significant global public health concern. Although most cases are accidental, some may involve suicide or homicide, making forensic autopsy essential for determining the cause of death. Variations in mortality rates between countries, along with the presence of soot residues and heat-related artifacts, can complicate postmortem interpretation. The classic cherry-pink skin discoloration is not consistently observed; therefore, detection of soot in the upper respiratory tract provides important evidence. This study aimed to evaluate the demographic, forensic, and pathological characteristics of fire-related deaths.

METHODS: This retrospective study analyzed fire-related deaths subjected to autopsy at the Morgue Specialization Department of the Erzurum Group Presidency of the Forensic Medicine Institution between 2018 and 2024. Parameters assessed included age, sex, origin of the incident, seasonal distribution, location of the event, degree of burns, and indicators of vitality.

RESULTS: The majority of fire-related deaths were accidental and occurred predominantly in adult males. Most incidents took place in residential settings, with a higher frequency observed during the fall and winter seasons. Autopsy findings commonly revealed third- and fourth-degree burns, as well as soot deposition in the respiratory tract and associated pulmonary pathologies. In cases involving prolonged hospitalization, complications emerged as a major contributing factor to mortality.

CONCLUSION: Fire-related mortality is influenced not only by the extent and severity of burns but also by associated complications and characteristics of vulnerable populations. From a forensic medicine perspective, there is a need to develop fire safety policies and comprehensive strategies to reduce fire-related deaths.

Keywords: Fire; autopsy; forensic medicine.

INTRODUCTION

Fire-related deaths are recognized as a significant global public health problem. The rate of deaths per 100 fires has been reported as 0.3 in the United States, 1.9 in Russia, and 0.9 in South Korea. In 2020, thousands of fire-related deaths were reported in countries such as the United States, China, Japan, and Germany.[1] As approximately 10% of fires are believed to be intentionally set, all fire-related deaths are considered potentially suspicious, and the cause of the fire must be thoroughly investigated. The manner of death in individuals recovered from fire scenes may be classified as accidental, suicidal, or homicidal.[2] Previous studies indicate that most fire-related deaths are accidental, with suicide being the second most common cause. Arson following homicide, or arson used as a method of homicide, is relatively rare.[3]

A forensic medical evaluation of burned or charred bodies must be conducted with great care, as death may result from a variety of causes. It is essential to determine whether the

Cite this article as: Baydemir Kılınç B, Sancı A, Kök AN. Evaluation of morphological findings in fire-related deaths: A retrospective study. Ulus Travma Acil Cerrahi Derg 2026;32:667-674.

Address for correspondence: Büşra Baydemir Kılınç

Balıkesir Forensic Medicine Branch Office, Balıkesir, Türkiye

E-mail: busrabaydemirk@gmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(6):667-674 DOI: 10.14744/tjtes.2025.71067

Submitted: 14.09.2025 Revised: 16.09.2025 Accepted: 18.12.2025 Published: 03.06.2026

victim was alive at the time of exposure to fire. Thermal effects can obscure or even prevent accurate determination of the cause and manner of death.[4] In cases of homicide, the perpetrator's primary aim is often to conceal evidence of the crime; therefore, establishing whether the victim died before or after the fire is of critical importance. During postmortem examination, the presence of soot in the respiratory and digestive tracts, as well as elevated levels of carboxyhemoglobin (HbCO) in the blood, are considered key indicators of vitality.[5] Furthermore, heat-related artifacts, such as thermal fractures and heat hematomas, may complicate the interpretation of findings and hinder accurate determination of the cause and manner of death in cases recovered from fire scenes. A cherry-red discoloration, a classic sign of carbon monoxide exposure, may be observed; however, this finding is not consistently present in cases involving severe burns.[6] The upper respiratory tract should be carefully examined for evidence of smoke inhalation. Soot-stained mucus lining the trachea and main bronchi, as well as soot deposits in the nostrils and oropharynx, are important indicators of antemortem exposure.[7]

Data on fire-related deaths in our country are limited. This study aims to contribute to the literature by evaluating the macroscopic morphological findings in cases recovered from fire scenes and subjected to autopsy at the Erzurum Forensic Medicine Group Directorate.

MATERIALS AND METHODS

In this study, data from 2,722 autopsies performed at the Erzurum Forensic Medicine Group Directorate of the Ministry of Justice between January 1, 2018 and December 31, 2024, were retrospectively reviewed. Thirty-one cases recovered from fire scenes, in which the cause of death was determined to be burns or burn-related complications, were included in the study. Cases in which death was solely due to carbon monoxide intoxication without evidence of burns were excluded. Information on the cases included in the study was obtained from institutional archive records, forensic investigation files, information provided by relatives, and the National Judiciary Network Project (UYAP) system. For each case, detailed data were collected on autopsy findings, sociodemographic characteristics, age group (0–18 years: pediatric; 18–64 years: adult; ≥65 years: geriatric), season and year of the incident, comorbid diseases, sex, place of residence (urban/rural), location of the incident (home, workplace, outdoor areas including home extensions), and origin of the event. All data were recorded in a Microsoft Excel database (Microsoft, USA).

Statistical Analysis

Statistical analysis was performed using IBM SPSS version 29 (IBM Corp., Armonk, NY, USA). Categorical variables were expressed as frequencies and percentages, while continuous variables were presented as mean ± standard deviation. Complementary statistics were presented as numbers (n) and percentages (%), and the Pearson chi-square test was used to assess associations between variables. A p value of <0.05 was considered statistically significant. Ethics committee approval for the study was obtained from the Education and Scientific Research Commission of the Forensic Medicine Institution on July 8, 2025 (Date: 08.07.2025, Decision no: 21589509/2025/508). The study was conducted in accordance with the principles of the Declaration of Helsinki.

RESULTS

A total of 31 autopsy cases were evaluated between January 1, 2018 and December 31, 2024, at the Erzurum Forensic Medicine Group Directorate of the Forensic Medicine Institution. Autopsies were most frequently performed in 2019 (29%). Cases occurred most commonly during the fall (38.8%) and winter (29%) seasons, predominantly in residential settings (77.3%) and rural areas (87.1%). Two cases were determined to be suicide-related. Of the cases, 58.1% (n=18) were male, and 45.2% (n=14) were in the adult age group, with a mean age of 47.06±28.42 years (range: 1–92) (Table 1).

It was determined that 51.6% of the cases (n=16) were hospitalized following the incident. The mean duration of treatment was 13.81±21.86 days (range: 1–90). Death was attributed to burns and related complications in 71% of cases (n=22), carbonization-level burns in 22.6 (n=7), burns combined with carbon monoxide (CO) intoxication in 3.2% (n=1), and burns with myocardial infarction in 3.2% (n=1).

Second-degree burns were observed in 12.9% of cases (n=4), 75% of which occurred in individuals over 65 years of age. Third-degree burns were present in 58% of cases (n=18), with 55.6% (n=10) in the adult age group. Fourth-degree burns were identified in 29% of cases (n=9), with 44% (n=4) occurring in individuals under 18 years of age. No statistically significant association was found between age groups and burn degree (p=0.146). Analysis of burn degree by sex showed that 75% of second-degree burns occurred in males, while 67% (n=6) of fourth-degree burns were observed in males. No statistically significant relationship was identified between sex and burn degree (p=0.542) (Table 2).

A pugilistic posture was observed in 16% of cases (n=5), most frequently in those with fourth-degree burns (80%). A statistically significant association was found between burn degree and the presence of a pugilistic posture (p=0.022). Soot deposition in the respiratory tract was observed in 25% of cases (n=1) with second-degree burns and in 89% of cases (n=8) with fourth-degree burns. A statistically significant relationship was identified between soot deposition in the respiratory tract and burn severity (p=0.003). Bone pathologies, including fractures and amputations, were observed exclusively in cases with fourth-degree burns (p=0.017) (Table 3).

Burn extent was evaluated based on total body surface area using Wallace's Rule of Nines. Burns involving 0–20% of the

Table 1. Age, sex, location, time of death, and origin of cases

	n	%
Age group		
0–18	7	22.5
19–64	14	45.2
≥65	10	32.3
Sex		
Female	13	41.9
Male	18	58.1
Year		
2018	3	9.7
2019	9	29
2020	7	22.6
2021	5	16.1
2022	2	6.5
2023	2	6.5
2024	3	9.7
Season		
Spring	3	9.7
Summer	7	22.6
Fall	12	38.8
Winter	9	29
Location of incident		
Home	26	77.3
Workplace	2	6.5
Inside vehicle	2	6.5
Home extensions/open areas	3	9.7
Origin		
Accidental	29	93.6
Suicide	2	6.4
Place of residence		
Urban	4	12.9
Rural	27	87.1

body surface area were present in 19% of cases (n=6), 21–49% in 9.6% (n=3), and ≥50% in 71.5% of cases (n=22). In all pediatric cases, burns involved more than 50% of the body surface area. No statistically significant association was found between age and burn extent (p=0.258). Regarding sex distribution, 67% of cases with burns covering 21–49% of the body surface area were male, while 59% of cases with burns ≥50% were male. No statistically significant association was observed between sex and burn extent (p=0.878) (Table 4).

In 14 cases (45.1%), burn-related internal organ pathology and complications were identified. Among these, six cases developed pulmonary complications, including pneumonia and acute respiratory distress syndrome (ARDS), while the remaining cases exhibited pathologies such as cerebral hemorrhage, rectal prolapse, gastric ulcer, and acute renal failure. Compartment syndrome developed in two cases. All cases with accompanying pulmonary pathology died during hospitalization. The distribution of pathological findings is presented in Figure 1.

In the pediatric age group, all cases occurred at home in the presence of family members. In the adult age group, 14.2% of cases lived alone, and 64.2% (n=9) required hospitalization following the incident. In the geriatric age group, 60% (n=6) of individuals lived alone, and 60% were hospitalized. Overall, 77.3% of fire incidents occurred in residential settings, 9.7% in home extensions or open areas, and the remaining cases resulted from fires associated with traffic accidents or occupational explosions.

Review of medical histories revealed that 19.3% of cases (n=6) had conditions affecting cognitive or motor function, including gonarthrosis, intellectual disability, hemiplegia, epilepsy, Alzheimer's disease, and Parkinson's disease. One case involved a pregnant individual.

Examination of scene investigation reports indicated that two deaths in an industrial setting, classified as occupational accidents, were caused by fires resulting from sodium chlorate ($NaClO_3$) explosions.

Table 2. Distribution of burn degree according to sex and age group

Burn degree	Sex	n (%)	p	n (%)	n (%)	n (%)	
2nd de-gree	Male	3 (9.7)		0	1 (3.3)	2 (6.4)	
	Female	1 (3.3)		0	0	1 (3.3)	
3rd de-gree	Male	9 (29)	**0.542**	2 (6.4)	5 (16.1)	2 (6.4)	**0.146**
	Female	9 (29)		1 (3.3)	5 (16.1)	3 (9.7)	
4th degree	Male	6 (19.3)		2 (6.4)	3 (9.7)	1 (3.3)	
	Female	3 (9.7)		2 (6.4)	0	1 (3.3)	

Table 3. Evaluation of pugilistic posture, bone pathology, and soot deposition in the lower respiratory tract according to burn degree

Burn degree	Pugilistic posture n (%)		p	Bone pathology n (%)		p	Soot deposition (lower respiratory tract) n (%)		p
	Yes	No		Yes	No		Yes	No	
2nd degree	0	4 (12.9)	**0.022**	0	4 (12.9)	**0.017**	1 (3.2)	3 (9.6)	**0.003**
3rd degree	1 (3.2)	17 (54.8)		0	18 (58.1)		4 (12.9)	14 (45.3)	
4th degree	4 (12.9)	5 (16.2)		3 (9.6)	6 (19.4)		8 (25.8)	1(3.2)	

Table 4. Distribution of burn extent according to sex and age group

Burn extent (%)	Sex n (%)	n (%)	p	0–18 years n (%)	19–64 years n (%)	≥65 years n (%)	p
0–20	Male	3 (9.7)		0	1 (3.3)	2 (6.4)	
	Female	3 (9.7)		0	2 (6.4)	1 (3.3)	
21–49	Male	2 (6.4)	**0.878**	0	1 (3.3)	1 (3.3)	**0.258**
	Female	1 (3.3)		0	0	1 (3.3)	
>50	Male	13 (41.9)		4 (12.9)	7 (22.5)	2 (6.4)	
	Female	9 (29)		3(9.7)	3 (9.7)	3 (9.7)	

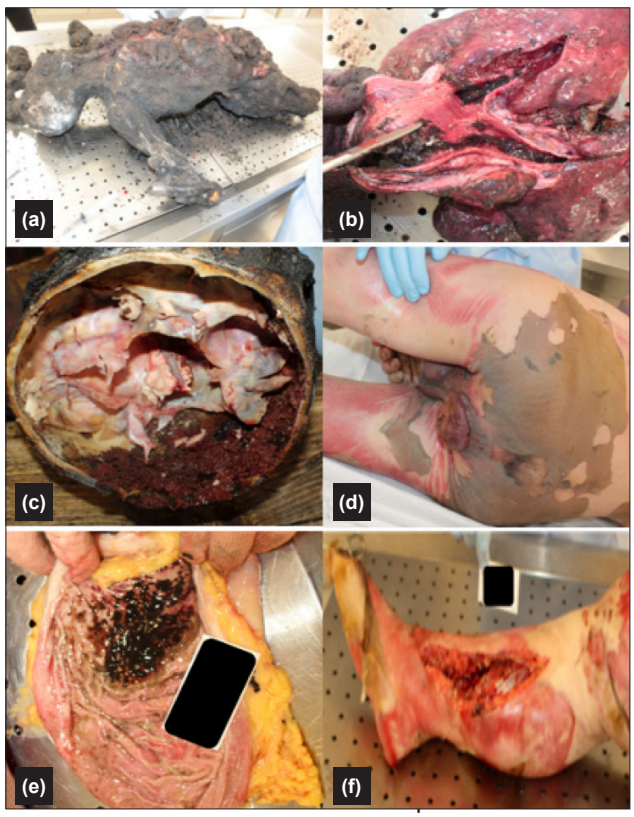

Figure 1. Findings from different cases: **(a)** Upper and lower limb amputations due to burns with varying degrees of carbonization; **(b)** Soot deposition in the trachea and lower respiratory tract; **(c)** Heat hematoma; **(d)** Rectal prolapse; **(e)** Curling ulcer in the stomach; **(f)** Compartment syndrome.

(58.1%) and in the adult age group (45.2%). Previous studies conducted in Istanbul, Ankara, Muğla, and Trabzon, Türkiye, have reported male predominance ranging from 63.3% to 75.4%, with mean ages between 41 and 60 years.[2,5,6,10] Men may be at higher risk due to factors such as lower compliance with fire safety measures, increased risk-taking behavior, and greater exposure to hazardous environments. Similarly, studies conducted in Israel and Germany have reported male predominance, while the mean age of fire-related deaths varies across countries, for example, 26.8 years in India and 52.9 years in the United Kingdom. In the United States, the male-to-female ratio has been reported as 2.2.[11-15] These findings suggest that males constitute a higher-risk group for fire-related mortality, while age distribution may vary depending on the sociocultural characteristics of different regions. Factors such as the proportion of men working outdoors or in more hazardous occupations, individual behavioral characteristics, and gender roles can be considered among the factors explaining gender differences in fire-related deaths. Therefore, placing emphasis on awareness messages targeting the male population in fire prevention and education programs indicates the need to focus on these at-risk segments of the population in fire safety policies.

Considering seasonal distribution, incidents were found to occur most frequently in fall (38.8%) and winter (29%). Similar studies conducted in Türkiye show that fire-related deaths frequently occur in winter, ranging from 26.7% to 52%.[2,5,6,10] These deaths have been reported to occur particularly in win-

ter and spring in the United Kingdom and in winter in Iran.[16,17] Due to the climate of the region where the study was conducted, the need for heating may begin in fall, prior to the winter season, unlike in other regions. Therefore, the misuse or inadequate maintenance of devices such as stoves, boilers, and electric heaters during these seasons may increase the risk of fire. Furthermore, low humidity (dry air) in the region encourages fires to spread rapidly, while neglecting fire safety precautions can further exacerbate the situation.

Our study shows that 83.8% of fires occur in the home environment. According to 2023 American Burn Association (ABA) data, 61% of burn cases occurred in private homes. A study conducted in South Australia found that 48.4% of fire-related deaths occurred in enclosed spaces,[18,19] and a review by Kumar et al.[20] reported that 73.9% of burn cases occurred in the home environment. The high rate of burns occurring in the home environment can be attributed to several factors, including the large proportion of time individuals spend at home, the prevalence of indoor risk factors (e.g., stoves, electrical appliances, and kitchen-related accidents), and inadequate safety measures. Furthermore, the widespread use of tandoors in the region is another important factor that increases the risk of fire. To reduce fire risks, it is essential to strengthen safety measures in homes and minimize potential hazards that could lead to accidents.

In our study, 51.6% of cases (n=16) were rescued alive from the fire scene but died after receiving treatment in the hospital. In the literature, a study conducted in Ankara reported this rate as 38.7%, while another study evaluating 61 cases in Muğla reported that two cases died after hospitalization. Additionally, a study conducted in Israel reported that burns accounted for approximately 3% of all trauma cases requiring hospitalization.[6,10,15] Third-degree burns were the most common (58%), followed by fourth-degree burns (29%). In other studies conducted in our country, the incidence of fourth-degree burns ranged from 36% to 83.6%, followed by third-degree burns.[5,6,10,15] Due to the severe tissue damage caused by third- and fourth-degree burns, these burn types play a critical role in mortality risk and the development of complications. The high incidence of these severe burn types among cases rescued from fire environments further emphasizes the importance of early intervention and effective burn treatment.

In our study, a small proportion of cases in the adult age group lived alone, whereas more than half of the cases in the geriatric age group lived alone. This finding suggests that social isolation increases with advancing age and that family and social support mechanisms weaken over time. Delays in emergency response among elderly individuals living alone significantly increase the risk of mortality and morbidity in life-threatening events such as fires. Similarly, the literature indicates that older adults who live alone are more vulnerable to disasters and accidents, with particularly poor prognoses in burn cases.[5,6] Furthermore, conducting similar epidemiological studies in different regions of Türkiye will contribute to the development of fire and burn prevention strategies by improving the understanding of regional differences and associated risk factors. However, regardless of the quality of healthcare services, complications, infections, and organ failure secondary to burns can substantially reduce survival rates.

The evidence in this study was categorized based on legal investigation files, crime scene examinations, and witness statements. It was determined that the majority of deaths (93.6%) were accidental in origin, while two individuals died in the workplace due to a $NaClO_3$ explosion. Studies conducted both in India and nationally similarly report that most deaths are accident-related.[2,6,12] This is often due to the failure to take basic precautions or the neglect of fire safety procedures, highlighting the need for more effective, continuous, and comprehensive training programs to improve individuals' ability to respond appropriately during fires. Therefore, increasing fire safety awareness and educating individuals on how to act in emergencies is essential. Ensuring workplace safety is also critical. Sodium chlorate is used in industry as a herbicide to control weeds by inhibiting water absorption, in the paper and pulp industry for bleaching processes, and in the production of explosives due to its oxidizing properties.[21] The deaths resulting from a sodium chlorate explosion in this study highlight that, despite its industrial benefits, sodium chlorate poses serious safety risks. As a powerful oxidizing agent, it must be handled with caution, and occupational health and safety measures should be strengthened accordingly.

The effect of heat on the body during a fire, in which the hands are found raised in front of the face (pugilistic posture), may create the impression that the individual was involved in a struggle prior to death.[22] In our study, the pugilistic posture (16%) was observed more frequently in cases with fourth-degree burns and less commonly in those with third-degree burns. This rate has been reported as 37.8% in Italy and 20.8% in a study conducted in our country, with a higher frequency noted in fourth-degree burns.[3,10] Although these findings are important for understanding the severity and effects of injuries, they are not considered definitive criteria for distinguishing between ante-mortem and post-mortem events.[23]

It is well established in the literature that soot formed during a fire can passively deposit around the mouth and nose in the absence of inhalation; however, such passive accumulation does not extend beyond the level of the vocal cords.[24] The presence of soot in the esophagus and stomach, beyond the respiratory tract, the existence of a hyperemic line at the junction between burned and intact skin, and elevated levels of carboxyhemoglobin in the blood are considered vital signs and indicators of exposure to fire prior to death.[10] Our study found that the likelihood of soot deposition in the lower respiratory tract increases with burn severity.

A study using an animal (sheep) model to examine mucus migration in the upper respiratory tract following burns demonstrated that, within the first 4–24 hours, obstruction was limited to the bronchial airways. In the subsequent period (24–72 hours), the degree of bronchial obstruction increased and extended distally to the small airways and parenchyma.[25] These findings suggest that as burn severity increases, soot deposition, mucus accumulation, and airway obstruction may progressively worsen over time, leading to more severe respiratory complications.

In our study, bone pathologies such as fractures and amputations were identified in 9% of cases and were exclusively associated with deaths due to fourth-degree burns, occurring in one-third of these cases. Similarly, a study conducted in Muğla reported heat fractures and heat hematomas in partially or completely charred bodies.[6] Bone fractures resulting from burns represent postmortem heat-related lesions and should not be confused with ante-mortem injuries. Exposure to extreme heat causes the burning of muscles, tendons, and soft tissues, leaving the underlying bones directly exposed, which may result in heat-induced fractures. These fractures typically have irregular edges, and skull fractures may cross suture lines, whereas ante-mortem fractures generally terminate at suture lines. Furthermore, such fractures may be partial in thickness and may expose the spongy layer.[26] However, depending on the severity of the burn, distinguishing between ante-mortem and postmortem fractures may not always be possible. Therefore, during autopsy, suspicious areas should be thoroughly documented photographically, assessed for signs of vitality, and sampled for histopathological examination when necessary.

In 14 cases (45.1%), macroscopic internal organ pathologies and burn-related complications were identified. According to the literature, internal organ pathologies following burns may include brain microabscesses due to Staphylococcus pyogenes septicemia, myocardial hemorrhage, and pyelonephritis in the kidneys. It has also been reported that gastrointestinal ulcerations may develop, particularly in cases involving 40–70% total body surface area burns; that Pseudomonas sepsis may occur during prolonged hospitalization; and that pulmonary edema, mucus plugging, congestion, and atelectasis are common findings.[27] Similarly, in our study, pathological findings were most frequently observed in the lungs and kidneys. Lung pathology was present in all cases requiring hospitalization. In one case, a Curling's ulcer developed in the stomach, likely due to ischemia and cell necrosis of the gastric mucosa associated with reduced plasma volume. In another case involving severe burns, rectal prolapse was observed. Severe burns may contribute to rectal prolapse by reducing blood flow to surrounding tissues and impairing the function of muscles, connective tissue, and neural structures, ultimately leading to decreased tone. Early diagnosis and management of such complications in hospitalized patients are essential for improving quality of life and reducing mortality rates.

In 19.3% of cases (n=6), conditions affecting memory and motor function were identified. A similar study reported 21 cases with conditions such as paralysis, psychosis, depression, bipolar disorder, and hearing loss.[5] In our study, the identified conditions included gonarthrosis, intellectual disability, hemiplegia, epilepsy, Alzheimer's disease, and Parkinson's disease. These physical and mental health disorders may be associated with an increased risk of burn trauma, particularly among elderly individuals. Furthermore, uncontrolled epilepsy is known to pose a significant risk due to seizure-related injuries.[28,29] Therefore, understanding the relationship between physical and mental health conditions and burn trauma is important for strengthening treatment and rehabilitation processes in these patients.

A nine-year study conducted in Iran examined the etiology and outcomes of burns in 51 pregnant women and found that burn surface areas exceeding 40% and the presence of inhalation injuries were strongly associated with maternal and fetal mortality.[30] In our study, one case involving a woman in the seventh to eighth month of pregnancy presented with third-degree burns covering 60% of the total body surface area. It is well established that deep burns affecting a large body surface area in pregnant patients adversely affect both maternal and fetal outcomes. When considered alongside the increased oxygen demand, circulatory load, and altered immune response during pregnancy, the systemic stress caused by burns can have severe consequences for both the mother and the fetus. Additionally, the cardiovascular and respiratory adaptations of pregnancy may exacerbate the severity of inhalation injury and further increase the risk of mortality.

CONCLUSION

Fire is one of the leading causes of preventable deaths at both individual and societal levels. Reducing fire-related deaths is not only a medical and legal priority but also a critical public health responsibility. In this study, fire-related deaths were most common among adult males and occurred predominantly during the fall and winter seasons, primarily in residential settings. With the exception of two cases, the deaths were accidental in origin. Findings such as pugilistic posture, bone fractures, and soot deposition in the lower respiratory tract were more frequent with increasing burn severity. Additionally, complications including burn-related cerebral hemorrhage, rectal prolapse, gastric ulcer, acute renal failure, and compartment syndrome were observed. These findings not only contribute to forensic medical practice but also highlight the need to develop fire safety policies and more comprehensive strategies to reduce fire-related deaths.

Ethics Committee Approval: This study was approved by the Forensic Medicine Institute Presidency (Date: 08.07.2025, Decision No: 21589509/2025/508).

Peer-review: Externally peer-reviewed.

Informed Consent: Retrospective study.

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

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*

Yangına bağlı ölümlerde morfolojik bulguların değerlendirilmesi: Retrospektif çalışma

AMAÇ: Yangınla ilişkili ölümler dünya çapında önemli bir sağlık sorunudur. Ölümlerin çoğu kaza orijinli olmakla birlikte bazı vakalar intihar veya cinayet ile ilişkili olabileceğinden ölüm nedenini belirlemek için otopsi yapılır. Ülkeler arasında ölümlerin oranları değişkenlik göstermekle birlikte, yangın kaynaklı ölümlerde is kalıntıları ve ısıya bağlı artefaktlar yorumlamada zorluklar yaratabilir. Ciltte kiraz pembesi değişimi her zaman belirgin olmayabilir, üst solunum yollarındaki is incelemeleri ise önemli kanıtlar sunar. Bu çalışmada, yangına bağlı ölümlerin demografik, adli ve patolojik özelliklerinin incelenmesi amaçlanmıştır.

GEREÇ VE YÖNTEM: Çalışma kapsamında, Adli Tıp Kurumu Erzurum Grup Başkanlığı Morg İhtisas Dairesi'nde 2018-2024 yılları arasında gerçekleştirilen otopsilerde yangına bağlı ölümler; yaş, cinsiyet, olayın orijini, mevsimsel dağılım, olay yeri, yanık dereceleri ve vitalite bulguları açısından retrospektif olarak değerlendirilmiştir.

BULGULAR: Çalışmada yangına bağlı ölümlerin çoğunlukla kaza orijinli olduğu, erkek cinsiyet ve erişkin yaş grubunda daha sık görüldüğü belirlenmiştir. Olguların önemli bir kısmında olayların ev ortamında ve özellikle sonbahar-kış mevsimlerinde meydana geldiği saptanmıştır. Otopsi bulgularında sıklıkla 3. ve 4. derece yanıklar ile birlikte solunum yollarında is birikimi ve akciğer patolojileri tespit edilmiştir. Ayrıca uzun süreli hastane yatışı gerektiren olgularda komplikasyonların mortalite üzerinde belirleyici olduğu görülmüştür.

SONUÇ: Yangın ölümleri yalnızca yanık yüzey alanı ve derecesiyle değil, eşlik eden komplikasyonlar ve risk gruplarının özellikleriyle de ilişkilidir. Adli tıp uygulamalarının ışığında yangın güvenliği politikalarının geliştirilmesi ve yangın kaynaklı ölümleri azaltmaya yönelik kapsamlı stratejilerin oluşturulması gerekmektedir.

Anahtar sözcükler: Adli tıp; otopsi; yangın.

Ulus Travma Acil Cerrahi Derg 2026;32(6):667-674 DOI: 10.14744/tjtes.2025.71067

ORIGINAL ARTICLE

Clinical outcomes of middle meningeal artery embolization in trauma-related chronic subdural hematoma

Ahmet Eren Seçen,[1] Halis Emre Çiftci,[1] Musa Onur Özbakır,[1] Afşin Emre Akpınar,[1] Bige Sayın,[2] Ergun Daglioglu[3]

[1]Department of Neurosurgery, Ankara Bilkent City Hospital, Ankara-*Türkiye*
[2]Department of Radiology, Ankara Bilkent City Hospital, Ankara-*Türkiye*
[3]Department of Neurosurgery, University of Health Sciences, Ankara Bilkent City Hospital-*Türkiye*

ABSTRACT

BACKGROUND: Middle meningeal artery (MMA) embolization has emerged as a promising therapeutic option in the management of chronic subdural hematoma (cSDH). However, data specifically focusing on trauma-related cSDH remain limited. This study aimed to evaluate the safety and clinical outcomes of MMA embolization in patients with trauma-related cSDH and to investigate radiological predictors of treatment success.

METHODS: This retrospective study included patients with trauma-related cSDH who underwent MMA embolization at our institution between 2024 and 2025. Demographic, clinical, and radiological data—including midline shift (MLS) and hematoma thickness—were systematically collected. Functional outcomes were assessed using the modified Rankin Scale (mRS). Recurrence, need for surgical intervention, procedural complications, and mortality were recorded. Receiver operating characteristic (ROC) analysis was performed to evaluate the predictive value of midline shift for treatment failure.

RESULTS: A total of 52 patients with a documented history of trauma were included. Embolization alone was performed in 43 patients (82.7%), whereas nine patients (17.3%) underwent combined embolization and surgical treatment. Preprocedural MLS was significantly greater in the embolization-plus-surgery group than in the embolization-only group (7.6±3.9 mm vs. 4.5±3.8 mm, p=0.03). No significant between-group differences were observed in residual hematoma thickness or MLS at 6 weeks (p>0.05). Functional outcomes improved at 90 days compared with baseline. An MLS threshold of 4.5 mm demonstrated the highest predictive accuracy for treatment failure, with a sensitivity of 78% and a specificity of 56%.

CONCLUSION: MMA embolization appears to be a safe and clinically feasible treatment option for trauma-related cSDH. In carefully selected patients, it may serve as both an adjunct and an alternative to surgery. MLS may represent a practical and readily accessible parameter for risk stratification and patient selection. Prospective controlled studies are warranted to further validate these findings.

Keywords: Chronic subdural hematoma; middle meningeal artery embolization; trauma.

INTRODUCTION

Chronic subdural hematoma (cSDH) is one of the most common neurosurgical conditions, particularly among the elderly population.[1] The reported incidence in the general population ranges from 1.7 to 20.6 cases per 100,000 person-years and increases to 58.1 per 100,000 among older individuals.[2] Owing to population aging, surgical treatment of chronic and subacute subdural hematoma is projected to become the most commonly performed neurosurgical procedure by

Cite this article as: Seçen AE, Çiftçi HE, Özbakır MO, Akpınar AE, Sayın B, Dağlıoğlu E. Clinical outcomes of middle meningeal artery embolization in trauma-related chronic subdural hematoma. Ulus Travma Acil Cerrahi Derg 2026;32:675-682.

Address for correspondence: Ahmet Eren Seçen
Department of Neurosurgery, Ankara Bilkent City Hospital, Ankara, Türkiye
E-mail: ahmet.eren.secen@gmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(6):675-682 DOI: 10.14744/tjtes.2026.29709
Submitted: 23.02.2026 Revised: 05.03.2026 Accepted: 20.05.2026 Published: 03.06.2026

2030.[3] Despite advances in surgical management, recurrence rates remain between 8% and 20%, whereas complication rates range from 3% to 28%.[4]

In elderly patients, cSDH is associated with prolonged hospitalization, increased morbidity and mortality, and substantial healthcare costs.[4] These challenges have encouraged the development of minimally invasive alternatives, such as middle meningeal artery (MMA) embolization.[5] The rationale for MMA embolization is to reduce blood flow to the vascularized inflammatory membranes responsible for hematoma persistence and recurrence.[3] Several recent studies have suggested that MMA embolization may reduce recurrence rates and serve as either an adjunct or an alternative to surgery in selected patients.[6]

Trauma is commonly associated with the development of chronic subdural hematoma, particularly in elderly individuals with cerebral atrophy and increased vulnerability of bridging veins.[7] Following one or more traumatic events, an asymptomatic latency period typically occurs.[8] During this interval, biological mediators—including type I and III procollagen, fibrin, angiopoietin-2, vascular endothelial growth factor (VEGF), and various cytokines and chemokines—promote membrane formation and progressive hematoma enlargement.[9-12] These mechanisms are believed to account for the delayed clinical presentation, with symptoms typically developing approximately 4–7 weeks after the initial traumatic event.[7]

Middle meningeal artery embolization can be performed using various embolic agents, including n-butyl cyanoacrylate (nBCA), ethylene-vinyl alcohol copolymer (Onyx), polyvinyl alcohol (PVA) particles, and coils.[13] Although generally considered safe, selection of embolic material may influence procedural risk and complication profiles.[5] Initially introduced as an adjunct to surgical evacuation, MMA embolization has increasingly evolved into a potential primary treatment strategy with advances in endovascular techniques and imaging technology. Despite its growing acceptance, not all patients can be successfully managed with embolization alone. Radiological parameters, particularly the degree of mass effect, may influence the likelihood of requiring subsequent surgical intervention. Identifying these factors is essential for optimizing patient selection and guiding clinical decision-making in trauma-related cSDH.

Therefore, the aim of this study was to evaluate the clinical and radiological outcomes of patients with trauma-related chronic subdural hematoma treated with MMA embolization and to investigate radiological factors associated with the need for subsequent surgical intervention.

MATERIALS AND METHODS

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki (1964) and its subsequent amendments. Ethical approval was obtained from the Ankara Bilkent City Hospital Clinical Research Ethics Committee (Date: 04.02.2026, Decision no: TABED 2-26-1988). Written informed consent was obtained from all patients prior to treatment. The study was reported in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.[14]

Patient Population

This retrospective, single-center study included consecutive patients who underwent MMA embolization for cSDH between January 2024 and January 2025. During the study period, 81 patients underwent treatment, of whom 55 had a documented history of cranial trauma. Three patients were excluded because of unavailable follow-up data, resulting in a final study cohort of 52 patients. Inclusion criteria were age ≥18 years, documented head trauma, and treatment with MMA embolization. Patients without documented trauma or with incomplete clinical or radiological data were excluded. Baseline data included demographics, comorbidities, use of antiplatelet or anticoagulant medications, neurological status at admission, and radiological findings. Patients were categorized into two groups: those managed with embolization alone and those requiring subsequent surgical evacuation. Surgical intervention was considered in patients who developed new or progressive neurological deficits or demonstrated no radiological improvement in hematoma thickness or midline shift. The decision to perform burr-hole evacuation or mini-craniotomy was based on membrane characteristics.

Endovascular Technique

All procedures were performed under general anesthesia. Selective MMA angiography was obtained before embolization. Embolization was performed using liquid embolic agents and/or coils. The choice of embolic material was individualized according to anatomical considerations, including MMA caliber, vessel tortuosity, and the presence of hazardous anastomoses, as well as technical availability. In cases involving potentially dangerous anastomoses (e.g., ophthalmic artery connections), the microcatheter was advanced distally beyond the bifurcation of the frontal and parietal branches before embolization. Patients with bilateral cSDH underwent bilateral embolization during the same session. All procedures were performed via transfemoral access using a three-axis distal access system (Fig. 1).

Follow-up and Radiological Assessment

Clinical and radiological data were collected retrospectively from hospital records. All patients underwent non-contrast computed tomography (nCCT) before embolization, and early inpatient computed tomography (CT) scans were obtained within 48 hours after the procedure to assess for complications or procedure-related hemorrhage. Follow-up imaging was performed at approximately 6 weeks, and functional outcomes were evaluated at 90 days using the modified Rankin Scale (mRS) based on available records. A favorable clinical

outcome was defined as an improvement of at least one point in mRS compared with baseline. Radiological analyses were primarily based on six-week follow-up imaging. All images were retrospectively reviewed for hematoma laterality, maximum hematoma thickness, midline shift (MLS), presence of internal membranes, postoperative hemorrhage, newly developed ischemic lesions, and other intracranial findings potentially related to the intervention. Hematoma thickness and MLS were measured on coronal nCCT images. MLS was defined as the perpendicular distance from the anatomical midline—determined by a line connecting the crista frontalis and the posterior falx cerebri—to the septum pellucidum (Fig. 2).

Statistical Analysis

Statistical analyses were performed using SPSS software (version 21.0; IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD), whereas categorical variables were presented as frequencies and percentages. Comparisons between the embolization-only and embolization-plus-surgery groups were performed using the independent samples t-test for continuous variables and the chi-square test for categorical variables. Receiver operating characteristic (ROC) curve analysis was performed to evaluate the predictive performance of preprocedural midline shift for the need for subsequent surgical intervention. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 52 patients with a documented history of cranial trauma who underwent middle meningeal artery embolization for chronic subdural hematoma were included in the final analysis. The mean patient age was 66.5±15.7 years (range, 25–89 years), and 43 patients (82.7%) were male. Comorbidi-

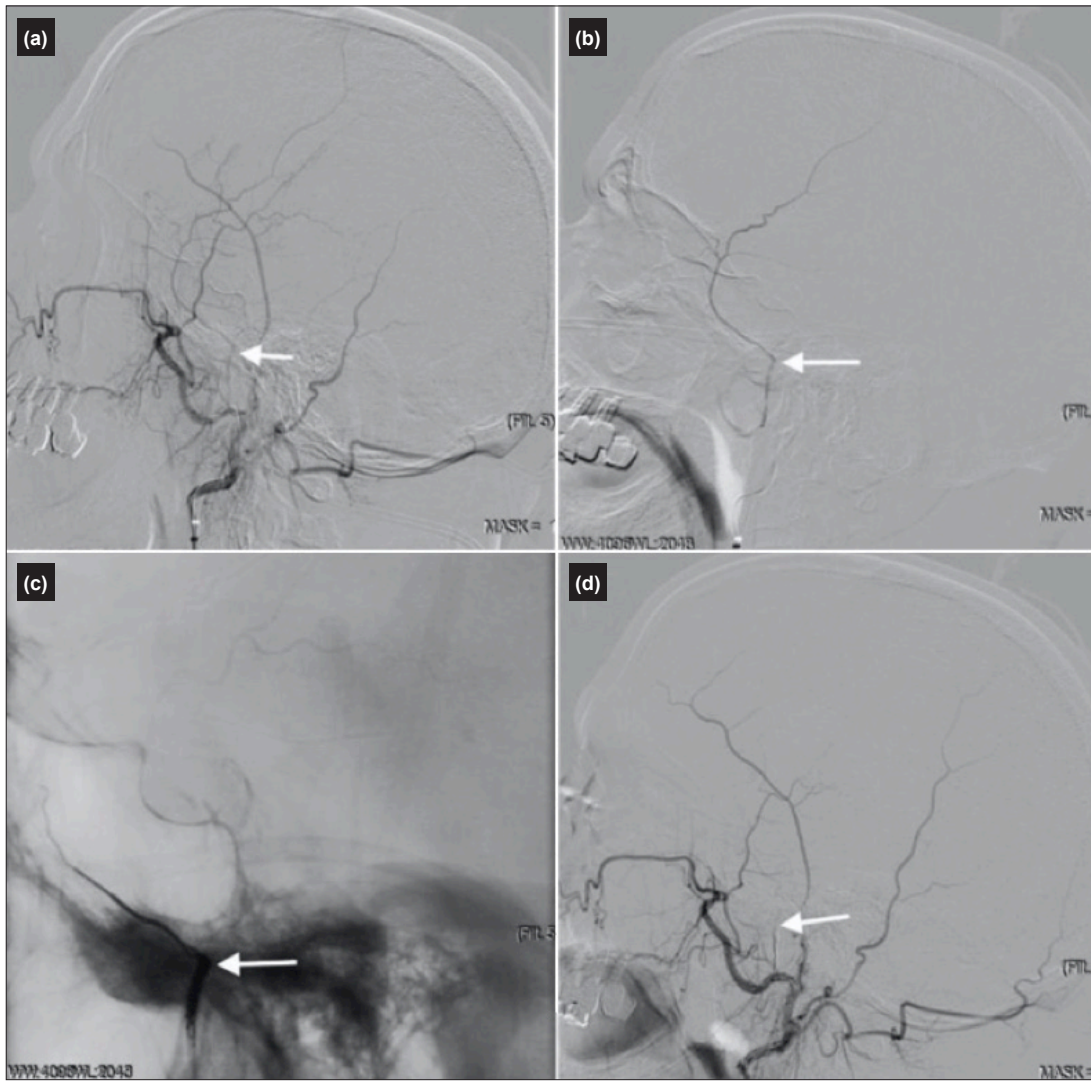

Figure 1. (a) Preoperative digital subtraction angiography (DSA) demonstrating the middle meningeal artery (MMA). **(b)** Selective angiography of the MMA. (**c**) Deployment of coil embolization material within the MMA. **(d)** Post-embolization control angiography demonstrating successful occlusion.

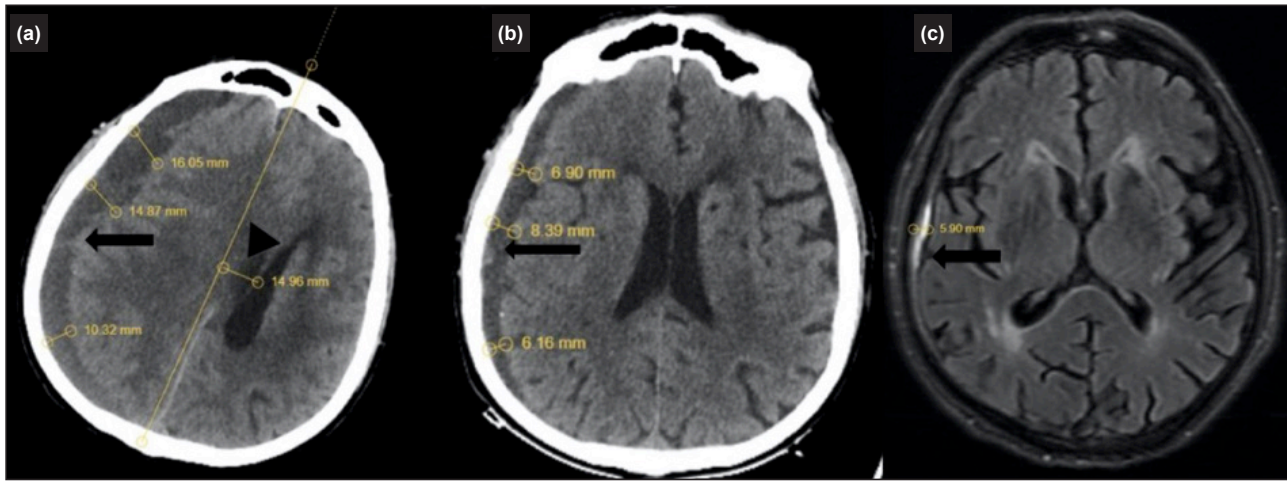

Figure 2. (a) Preoperative computed tomography (CT) image demonstrating measurements of hematoma thickness and midline shift (MLS). **(b)** Sixth-week follow-up CT image after embolization alone. **(c)** Third-month follow-up magnetic resonance imaging (MRI) demonstrating radiological resolution. ↑: hematoma thickness; ▲: midline shift (MLS).

ties were present in 28 patients (53.8%), including hypertension, diabetes mellitus, coronary artery disease, and atrial fibrillation. Regarding antithrombotic therapy, 19.2% of patients were receiving acetylsalicylic acid, 7.7% were receiving prasugrel, 7.7% were receiving warfarin, and one patient was receiving multiple antiplatelet agents. Among the study population, 43 patients (82.7%) were treated with embolization alone, whereas nine patients (17.3%) required subsequent surgical evacuation following embolization. No statistically significant differences were observed between the embolization-only and embolization-plus-surgery groups regarding demographic characteristics or comorbidities (p>0.05) (Table 1).

Hematomas were located on the right side in 20 patients (38.5%), on the left side in 23 patients (44.2%), and bilaterally in nine patients (17.3%). The mean preprocedural hematoma thickness was 20.7±7.9 mm, and the mean MLS was 5.1±4.0 mm. Among patients who required surgical intervention, mini-craniotomy was performed in eight patients (88.9%), whereas burr-hole evacuation was performed in one patient (11.1%). Procedure-related complications following embolization occurred in two patients, including one case of transient facial paralysis and one case of palpebral edema. When treatment groups were compared, the mean preprocedural MLS was 4.5±3.8 mm in the embolization-only group and 7.6±3.9 mm in the embolization-plus-surgery group. This difference was statistically significant (p=0.03). However, no statistically significant between-group differences were observed in baseline hematoma thickness or other baseline radiological parameters (p>0.05). At the six-week follow-up, no significant differences were observed between groups regarding residual hematoma thickness or midline shift (p>0.05) (Table 1).

Table 1. Comparison of demographic characteristics, comorbidities, and radiological outcomes between treatment groups

Variable	Embolization only (n=43)	Embolization + surgery (n=9)	p
Age (years)	67.4±15.9	62.2±14.9	0.36*
Sex (Male/Female)	35 (67.3%)/8 (15.4%)	8 (15.4%)/1 (1.9%)	0.59≠
Comorbidities (Yes/No)	25 (48.1%)/18 (34.6%)	2 (3.8%)/7 (13.5%)	0.06≠
Preprocedural MLS (mm)	4.5±3.8	7.6±3.9	0.03*
Postprocedural MLS (mm, 6 weeks)	0.6±1.6	1.8±2.7	0.08*
Preprocedural SDHT (mm)	20.9±7.9	20.0±8.2	0.77*
Postprocedural SDHT (mm, 6 weeks)	8.1±6.7	9.2±10.6	0.06*

*Continuous variables are presented as mean ± standard deviation (min-max) and were compared using the independent samples t-test. ≠Categorical variables are presented as number (%) and were compared using the chi-square test. A p-value <0.05 was considered statistically significant. MLS: Midline shift; SDHT: Subdural hematoma thickness.

Table 2. Distribution of modified Rankin Scale scores at admission, post-intervention, and 90-day follow-up

mRS score	Admission n (%)	Post-intervention n (%)	90-day follow-up n (%)
0	-	-	20 (38.5%)
1	-	2 (3.8%)	14 (26.9%)
2	7 (13.5%)	4 (7.7%)	8 (15.4%)
3	37 (71.2%)	38 (73.1%)	5 (9.6%)
4	6 (11.5%)	6 (11.5%)	3 (5.8%)
5	2 (3.8%)	0	0
6 (death)	0	0	2 (3.8%)

mRS: Modified Rankin Scale.

ROC curve analysis demonstrated that preprocedural MLS was significantly associated with the need for subsequent surgical intervention following embolization, with an area under the curve (AUC) of 0.73, indicating acceptable discriminatory performance. An MLS threshold of 4.5 mm provided the optimal balance between sensitivity and specificity, yielding a sensitivity of 78% and specificity of 56% (Fig. 3).

Clinical outcomes were assessed using the mRS. The distribution of mRS scores at admission and at the 90-day follow-up is presented in Table 2. Overall, functional status improved at 90 days compared with baseline. Two patients (3.8%) died during follow-up due to pulmonary complications unrelated to the embolization procedure.

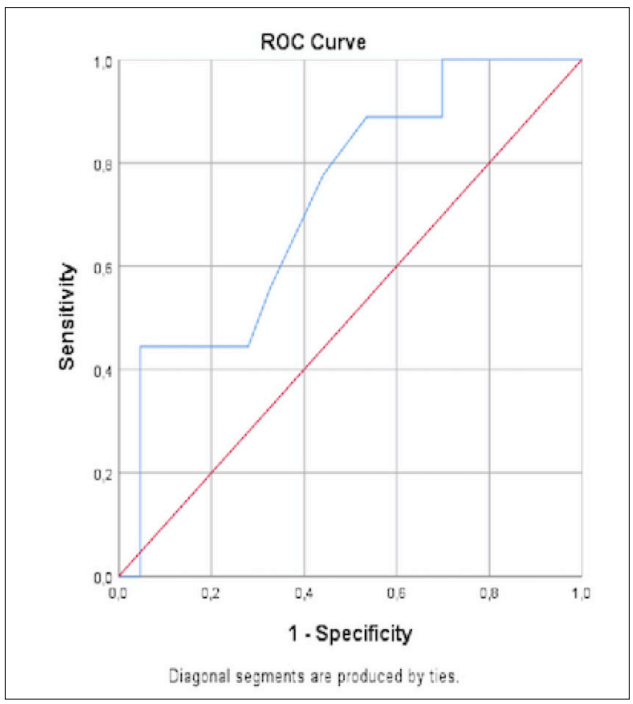

Figure 3. Receiver operating characteristic (ROC) curve analysis of preprocedural midline shift (MLS) for predicting the need for subsequent surgical intervention. Area under the curve (AUC)=0.73; optimal cut-off value 4.5 mm (sensitivity 78%, specificity 56%).

DISCUSSION

In this retrospective study, we evaluated the clinical and radiological outcomes of different treatment strategies in patients with cSDH and a documented history of cranial trauma. Our findings suggest that MMA embolization is associated with favorable radiological evolution and acceptable clinical outcomes, particularly in carefully selected patients.

Over the past decade, MMA embolization has emerged as a promising minimally invasive endovascular treatment strategy for cSDH.[5,6] The rationale for this approach is based on the pathophysiology of cSDH, in which fragile neomembranes supplied predominantly by distal branches of the MMA contribute to persistent inflammation, recurrent microhemorrhage, and progressive hematoma expansion.[3,7] By targeting this vascular supply, embolization aims to interrupt the cycle of rebleeding and membrane-driven exudation, thereby promoting hematoma stabilization and gradual resorption.[3,6]

Despite growing evidence supporting its efficacy, integration of MMA embolization into routine clinical practice remains cautious. Concerns regarding its relatively recent adoption, procedural cost, variability in embolic materials and techniques, and the absence of universally accepted selection criteria continue to influence treatment decisions. Additionally, heterogeneity among published studies contributes to ongoing debate regarding optimal indications and patient selection.

Early observational studies reported encouraging technical and clinical outcomes, demonstrating high procedural success rates and meaningful radiological resolution.[15-18] Campos et al.[15] reported a technical success rate of 100% in a cohort of 132 patients, with complete radiological resolution observed in nearly half of cases. More recently, higher-level evidence has emerged. In a large multicenter randomized trial includ-

ing 310 patients, Fiorella et al.,[16] demonstrated that MMA embolization significantly reduced recurrence and treatment failure rates compared with standard management alone. These findings are further supported by contemporary meta-analyses. A systematic review by Chen et al.[17] concluded that both standalone embolization and combined embolization with surgical evacuation are effective approaches, with treatment selection largely influenced by baseline hematoma characteristics. Similarly, the meta-analysis of randomized controlled trials by Papageorgiou et al.[18] demonstrated a significant reduction in recurrence rates with MMA embolization. Collectively, accumulating evidence—from observational studies to randomized trials and meta-analyses—supports MMA embolization as a safe and effective therapeutic option, particularly in carefully selected patients. Importantly, most large randomized trials have included heterogeneous cSDH populations, whereas the present study specifically focused on trauma-related cases, providing a more etiologically homogeneous cohort.

While several recent meta-analyses have consistently shown reduced recurrence and progression rates after MMA embolization, improvements in functional outcomes have not been uniformly demonstrated. For example, the systematic review by Kabir et al.[19] reported lower recurrence rates without significant improvement in functional outcomes. Similarly, pooled analyses of randomized trials, including MAGIC-MT (Managing Non-acute Subdural Hematoma Using Liquid Materials: A Chinese Randomized Trial of Middle Meningeal Artery Treatment), STEM (SQUID Trial for the Embolization of the Middle Meningeal Artery for the Treatment of Chronic Subdural Hematoma), and EMBOLISE (Embolization of the Middle Meningeal Artery to Prevent Recurrence of Chronic Subdural Hematoma), demonstrated reduced hematoma progression but no clear superiority in functional recovery.[3,16,20,21] In contrast, we observed significant improvement in mRS scores at 90 days compared with baseline. Two patients died during follow-up; however, neither death was attributable to the embolization procedure. Nevertheless, this finding should be interpreted cautiously because the present study did not include a non-embolization control group, and observed functional improvement may partially reflect the natural clinical course of cSDH rather than the isolated effect of embolization.

In our cohort, embolization was performed either as a primary treatment or in combination with surgical evacuation during the same session. Importantly, patients treated with embolization alone demonstrated significantly lower baseline midline shift values than those who subsequently required surgery, suggesting that treatment allocation was influenced by initial disease severity. These findings further emphasize the importance of individualized treatment selection in patients with trauma-related cSDH. Although radiological improvement was observed in both treatment groups, baseline midline shift differed significantly between patients managed with embolization alone and those requiring additional surgical evacuation, indicating that initial disease severity played a central role in therapeutic decision-making. Rather than reflecting differences in intrinsic treatment efficacy, the observed outcomes appear to be closely associated with appropriate patient stratification. Therefore, careful assessment of radiological findings and clinical status remains essential when determining the optimal treatment strategy.

ROC curve analysis demonstrated that preprocedural MLS was associated with the need for subsequent surgical intervention, with an AUC of 0.73, indicating acceptable discriminatory performance. An MLS threshold of 4.5 mm provided the optimal balance between sensitivity (78%) and specificity (56%). Although specificity was moderate, this threshold may serve as a practical reference value for treatment planning and patient counseling. Given its simplicity and broad availability, MLS represents a pragmatic radiological parameter for risk stratification.

This study has several limitations. First, its retrospective, non-randomized design limits causal inference and introduces the potential for selection bias. Second, the relatively small sample size reduced statistical power and precluded multivariable adjustment. Furthermore, treatment decisions were based on institutional practice patterns rather than predefined standardized criteria. These limitations should be considered when interpreting the present findings.

CONCLUSION

In this cohort of patients with trauma-related cSDH, MMA embolization was associated with hematoma regression and functional stabilization or improvement in functional outcomes in appropriately selected cases. Patients managed with embolization alone demonstrated lower baseline midline shift values, reflecting real-world selection of patients with less severe disease.

Preprocedural midline shift showed moderate predictive value for subsequent surgical intervention, and a threshold of 4.5 mm may aid treatment stratification. MMA embolization appears to be a safe and clinically feasible therapeutic option, serving not only as an adjunct to surgery but also as a viable alternative in carefully selected patients. Prospective randomized studies with larger cohorts are warranted to better define treatment indications and optimize patient selection.

Ethics Committee Approval: This study was approved by the Ankara Bilkent City Hospital Clinical Research Ethics Committee (Date: 04.02.2026, Decision No: TABED 2-26-1988).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: A.E.S., H.E.Ç.; Design: A.E.S., H.E.Ç.; Supervision: E.D., B.S.; Resource: E.D., A.E.S., B.S.; Materials: H.E.Ç., A.E.S., M.O.Ö., A.E.A.; Data collection and/or processing: A.E.S., M.O.Ö., H.E.Ç.; Analysis and/or interpretation: A.E.S., H.E.Ç., A.E.A.; Literature re-

view: A.E.S., H.E.Ç., M.O.Ö.; Writing: A.E.S., H.E.Ç., A.E.A.; Critical review: A.E.S., E.D., B.S.

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*

Travmaya bağlı kronik subdural hematomda middle meningeal arter embolizasyonunun klinik sonuçları

AMAÇ: Middle meningeal arter (MMA) embolizasyonu, kronik subdural hematom (kSDH) tedavisinde umut verici bir terapötik seçenek olarak öne çıkmıştır. Ancak özellikle travmaya bağlı kSDH olgularına odaklanan veriler sınırlıdır. Bu çalışmada, travmaya bağlı kSDH hastalarında MMA embolizasyonunun güvenliğinin ve klinik sonuçlarının değerlendirilmesi ve tedavi başarısının radyolojik belirleyicilerinin araştırılması amaçlanmıştır.
GEREÇ VE YÖNTEM: Bu retrospektif çalışmaya, 2024–2025 yılları arasında kurumumuzda travmaya bağlı kSDH nedeniyle MMA embolizasyonu uygulanan hastalar dahil edilmiştir. Demografik, klinik ve radyolojik veriler - orta hat kayması (MLS) ve hematom kalınlığı - sistematik olarak toplanmıştır. Fonksiyonel sonuçlar, modifiye Rankin Skalası (mRS) kullanılarak değerlendirilmiştir. Nüks, cerrahi gereksinimi, işleme bağlı komplikasyonlar ve mortalite kaydedilmiştir. MLS'nin tedavi başarısızlığını öngörmedeki değerini değerlendirmek amacıyla ROC analizi yapılmıştır.
BULGULAR: Travma öyküsü bilinen toplam 52 hasta çalışmaya dahil edilmiştir. Kırk üç hastada (%82.7) yalnızca embolizasyon uygulanırken 9 hastada (%17.3) embolizasyon ve cerrahi kombine edilmiştir. İşlem öncesi MLS değeri, yalnızca embolizasyon uygulanan gruba kıyasla embolizasyon + cerrahi grubunda anlamlı olarak daha yüksek bulunmuştur (7.6±3.9 mm'ye karşı 4.5±3.8 mm; p=0.03). Altıncı haftada rezidüel hematom kalınlığı veya MLS açısından gruplar arasında anlamlı fark saptanmamıştır (p>0.05). Doksanıncı günde fonksiyonel durumun başlangıca göre iyileştiği gözlenmiştir. 4.5 mm'lik MLS eşik değeri, tedavi başarısızlığını öngörmede en yüksek prediktif doğruluğu göstermiş olup %78 duyarlılık ve %56 özgüllük sağlamıştır.
SONUÇ: MMA embolizasyonu, travmaya bağlı kSDH tedavisinde güvenli ve klinik olarak uygulanabilir bir seçenek gibi görünmektedir. Uygun hasta seçimi yapıldığında cerrahiye hem tamamlayıcı hem de alternatif bir yaklaşım olarak değerlendirilebilir. MLS, risk sınıflandırması ve hasta seçimi açısından pratik ve erişilebilir bir parametre olabilir. Bu bulguların doğrulanması için prospektif kontrollü çalışmalara ihtiyaç vardır.

Anahtar sözcükler: Kronik subdural hematom; middle meningeal arter embolizasyonu; travma.

Ulus Travma Acil Cerrahi Derg 2026;32(6):675-682 DOI: 10.14744/tjtes.2026.29709

ORIGINAL ARTICLE

Prognostic value of the shock index in Fournier's gangrene: a retrospective cohort study comparing established mortality scoring systems

Yusuf Emre Aytin,[1] Mustafa Ozan Ataçer,[2] Oğuzhan Alp Öztürk,[3] Sezer Berkay Gorça,[1] Caner Özer,[4] Muhammed Şamil Yekeler,[1] Gökhan Çevik,[4] Ahmet Tolgay Akıncı,[5] İrfan Coşkun[1]

[1]Department of General Surgery, Trakya University Faculty of Medicine, Edirne-*Türkiye*
[2]Department of Urology, Esme State Hospital, Usak-*Türkiye*
[3]Department of General Surgery, Sultan I. Murat State Hospital, Edirne-*Türkiye*
[4]Department of Urology, Trakya University Faculty of Medicine, Edirne-*Türkiye*
[5]Department of Neurosurgery, Trakya University Faculty of Medicine, Edirne-*Türkiye*

ABSTRACT

BACKGROUND: Fournier's gangrene is a rapidly progressive, life-threatening necrotizing infection of the perineal and genital regions, associated with persistently high mortality despite advances in surgical and intensive care. Early and reliable prognostic assessment is essential for improving patient outcomes. This study aimed to evaluate the prognostic performance of the Shock Index (SI) in predicting mortality in patients with Fournier's gangrene and to compare its discriminatory ability with established scoring systems.

METHODS: This retrospective cohort study included adult patients diagnosed with Fournier's gangrene who presented to the emergency department of a tertiary university hospital and underwent surgical debridement between January 2015 and December 2024. Demographic, clinical, and laboratory data were extracted from institutional and national electronic health records. Survivors and non-survivors were compared using appropriate statistical tests. Variables associated with mortality were assessed using logistic regression analysis. Receiver operating characteristic (ROC) analysis was performed to evaluate the predictive performance of SI and conventional scoring systems, and the optimal SI cut-off for mortality prediction was determined using Youden's index.

RESULTS: A total of 158 patients (mean age 62.3±13.4 years; 86.1% male) were included, with an overall mortality rate of 17.1%. Non-survivors were significantly older ($p<0.001$), and comorbidities including coronary artery disease, chronic heart failure, and chronic renal failure were significantly associated with mortality. At admission, non-survivors had higher heart and respiratory rates and lower systolic blood pressure. ROC analysis demonstrated that the Shock Index had the highest discriminatory performance for mortality prediction (area under the curve=0.952; 95% confidence interval 0.918–0.986; $p<0.001$), outperforming the Fournier Gangrene Severity Index, Uludağ Fournier Gangrene Severity Index, Laboratory Risk Indicator for Necrotizing Fasciitis, and quick Sequential Organ Failure Assessment. An optimal SI threshold of 0.866 yielded 92.6% sensitivity and 83.2% specificity.

CONCLUSION: The Shock Index demonstrated superior prognostic accuracy compared with conventional scoring systems in patients with Fournier's gangrene. Given its simplicity and reliance on two readily available hemodynamic parameters, SI represents a practical tool for early risk stratification. Prospective, multicenter studies are needed to further validate its clinical utility.

Keywords: Fournier's gangrene; mortality; prognosis; Shock index.

Cite this article as: Aytin YE, Ataçer MO, Gorça SB, Özer C, Yekeler MŞ, Çevik G, et al. Prognostic value of the shock index in Fournier's gangrene: A retrospective cohort study comparing established mortality scoring systems. Ulus Travma Acil Cerrahi Derg 2026;32:683-693.

Address for correspondence: Yusuf Emre Aytin
Department of General Surgery, Trakya University Faculty of Medicine, Edirne, Türkiye
E-mail: aytinyusuf@gmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(6):683-693 DOI: 10.14744/tjtes.2026.58823
Submitted: 24.11.2025 Revised: 09.02.2026 Accepted: 19.03.2026 Published: 03.06.2026

INTRODUCTION

Fournier's gangrene (FG) is a rapidly progressive and potentially fatal condition. It represents a form of necrotizing fasciitis that develops as a result of blood clots in the skin, caused by infections leading to pus accumulation in the anorectal, perineal, or genitourinary regions.[1] Despite the availability of broad-spectrum antibiotics and advances in intensive care and resuscitation, FG remains one of the most severe surgical infections, with a high mortality rate among acute conditions. As reported in the literature, mortality rates range between 10% and 30%.[2-4] The rapidly progressive nature of the disease necessitates early diagnosis and aggressive surgical intervention. In this context, the identification of objective parameters capable of predicting mortality risk at an early stage is of critical clinical importance.

Several studies and meta-analyses have evaluated the prognostic performance of established scoring systems, including the Fournier's Gangrene Severity Index (FGSI), Uludağ Fournier's Gangrene Severity Index (UFGSI), Laboratory Risk Indicator for Necrotizing Fasciitis (LRINEC), and quick Sequential Organ Failure Assessment (qSOFA). Although these scoring systems are significantly associated with mortality, they have been criticized for their complexity, reliance on laboratory parameters, and limited applicability in emergency clinical settings.[5,6] These limitations highlight the need for simpler, faster, and more readily accessible prognostic indicators.

In recent years, increasing attention has been directed toward novel and objective biomarkers for predicting mortality in FG. Among laboratory-based indicators of systemic inflammatory response, the neutrophil-to-lymphocyte ratio (NLR) and the C-reactive protein-to-albumin ratio (CAR) have been shown to correlate with mortality in various sepsis-related conditions. These ratios have also been shown to possess prognostic significance in patients with FG.[7,8] Their availability through routine laboratory testing makes them attractive tools for early risk stratification in clinical practice.

Similarly, the Shock Index (SI), defined as the ratio of heart rate to systolic blood pressure, has been recognized as an early indicator of hemodynamic instability. Owing to its simplicity, the SI requires minimal laboratory data. It has demonstrated high accuracy in predicting mortality in patients with sepsis, trauma, and cardiovascular emergencies.[9-11] However, data regarding the prognostic value of SI in Fournier's gangrene are limited, and direct comparative studies with existing scoring systems are scarce.

The present study comprehensively analyzed the clinical, laboratory, and surgical factors associated with mortality in patients treated for Fournier's gangrene. In addition, it evaluated the prognostic performance of SI in comparison with widely accepted scoring systems reported in the literature, including FGSI, UFGSI, LRINEC, and qSOFA. The aim was to determine an optimal threshold value for SI, calculated solely from vital signs, to predict mortality. This approach was intended to facilitate early identification of high-risk cases and thereby improve treatment management in patients with Fournier's gangrene.

MATERIALS AND METHODS

Study Design and Ethical Approval

The study was designed as a single-center retrospective cohort study. Ethical committee approval was granted by the Trakya University Faculty of Medicine Non-Interventional Clinical Research Ethics Committee (Decision No: 2025/491, Date: 03/11/2025). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki, as revised in 2013. Due to the retrospective design, patient confidentiality was strictly maintained, all data were anonymized, and informed consent was waived.

Participants

Patients who presented to the emergency department between January 1, 2015 and December 31, 2024 and were diagnosed with Fournier's gangrene based on clinical, laboratory, and radiological findings were included. All patients underwent surgical debridement at the Departments of General Surgery and Urology, Trakya University Faculty of Medicine. Data for eligible cases were obtained through retrospective review of the hospital information management system and clinical archives.

Inclusion Criteria

- Adult patients aged ≥18 years
- Non-pregnant patients
- Availability of complete clinical, laboratory, and treatment records
- Patients who underwent surgical debridement.

Exclusion Criteria

- Patients younger than 18 years
- Pregnant patients
- Missing essential clinical and laboratory data
- Patients with clinically diagnosed Fournier's gangrene who died before surgical evaluation and debridement.

Clarification

Three patients with clinically confirmed Fournier's gangrene experienced cardiac arrest during transfer or shortly after admission to the emergency department and required advanced resuscitation, including intubation and continuous vasoactive/inotropic support. Under these conditions, heart rate and systolic blood pressure do not reliably reflect intrinsic hemodynamic status. Therefore, the corresponding Shock Index values were considered pharmacologically influenced and unsuitable for prognostic analysis. These cases were included in the screening population but excluded from the final analytical cohort.

Between January 1, 2015 and December 31, 2024, a total of 168 patients were clinically diagnosed with Fournier's gangrene. The patient selection process and exclusions are illustrated in the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) flow diagram (Fig. 1).

Data Collection and Variables

Data for this study were collected retrospectively from the hospital information management system and clinical records. Missing or incomplete data were verified and supplemented, when available, using the national electronic health record platform "e-Nabız."[12] The primary outcome was in-hospital all-cause mortality, defined as death occurring during the index hospitalization from emergency department admission to discharge or death, as determined from institutional and national electronic health records. Variables were categorized into demographic characteristics, clinical findings, laboratory parameters, treatment modalities, and mortality outcomes. Demographic data included age, sex, and the presence of comorbidities. The comorbid conditions evaluated included diabetes mellitus, hypertension, coronary artery disease, cerebrovascular disease, chronic heart failure, and chronic renal failure.

Clinical data included the patients' general condition and vital signs at admission to the emergency department. The following parameters were recorded: body temperature (T, °C), heart rate (HR, beats/minute), systolic blood pressure (SBP, mmHg), and respiratory rate (RR, breaths/minute). Level of consciousness was assessed using the Glasgow Coma Scale (GCS), and systemic response was evaluated using the qSOFA score. Additionally, the Shock Index was calculated as the ratio of heart rate to systolic blood pressure at presentation.

Laboratory data were obtained from routine biochemical and hematological tests performed at emergency admission. To assess the metabolic and inflammatory burden of the disease, blood glucose, urea, creatinine, sodium (Na), potassium (K), bicarbonate (HCO3), albumin, C-reactive protein (CRP), and hemoglobin A1c (HbA1c) levels were analyzed. Hematological parameters included hemoglobin (Hb), hematocrit (Hct), white blood cell count (WBC), neutrophils (NEU), lymphocytes (LYM), monocytes (MONO), and platelet count (PLT). Additionally, derived inflammatory markers, including the NLR and CAR, were calculated.

Treatment-related variables included the surgical and medical approaches applied to patients. Surgical variables comprised the number of debridements, additional surgical procedures performed in conjunction with debridement (e.g., diversion procedures), and the wound care method (wet dressing or negative-pressure wound therapy [vacuum-assisted closure, VAC]).

Time-dependent clinical variables included the interval between emergency department presentation and surgical intervention (minutes), length of hospital stay (days), and length of intensive care unit stay (days).

The dataset was structured to include all key parameters incorporated in validated prognostic models for FG. These variables were analyzed to identify factors associated with mortality. Established scoring systems were calculated for each patient to enable direct comparison with the Shock Index.

Scoring Systems

This study evaluated prognostic scoring systems widely accepted in the literature for predicting mortality in FG. For each patient, the FGSI, UFGSI, LRINEC, and qSOFA scores were calculated.

The FGSI is based on nine physiological and laboratory parameters: body temperature, heart rate, respiratory rate, serum sodium, potassium, creatinine, bicarbonate, hematocrit, and leukocyte count. Each parameter is scored from 0 to 4, with a total score ≥9 indicating a high risk of mortality.

The UFGSI incorporates all FGSI parameters with the addition of two variables: patient age and the anatomical extent of infection.

The LRINEC score was developed for the early diagnosis and severity assessment of necrotizing soft tissue infections and is based on C-reactive protein, leukocyte count, hemoglobin, sodium, creatinine, and glucose levels.

The qSOFA score is derived from three parameters: respiratory rate, systolic blood pressure, and mental status (Glasgow Coma Scale ≤13). Each parameter is assigned 1 point, yield-

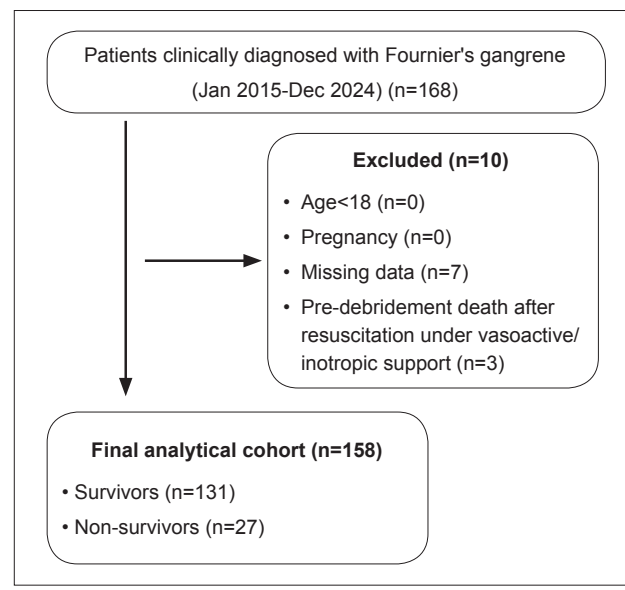

Figure 1. STROBE-compliant flow diagram illustrating patient screening, application of inclusion and exclusion criteria, and final cohort composition. *Three patients with clinically confirmed Fournier's gangrene died before surgical debridement after resuscitation under vasoactive/inotropic support and were excluded from the analytical cohort, as their hemodynamic measurements were considered non-representative.*

ing a total score ranging from 0 to 3; a score ≥2 indicates an increased risk of mortality.

The Shock Index is defined as the ratio of heart rate to systolic blood pressure. In this study, in addition to established scoring systems used in Fournier's gangrene, SI was also calculated as a prognostic parameter.

Statistical Analysis

Statistical analyses were performed using Jamovi (version 2.5.5; The Jamovi Project, Sydney, Australia). An a priori power analysis was conducted using G*Power (version 3.1) with α=0.05, power (1−β)=0.80, an effect size of 0.8 (large), and an allocation ratio (N_1/N_2) of 0.20, based on an estimated mortality rate of approximately 20% in patients with FG. The required sample size was calculated as 96. The distribution of continuous variables were assessed using the Shapiro–Wilk test. Normally distributed variables are presented as mean ± standard deviation, whereas non-normally distributed variables are expressed as median (interquartile range).

Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate. Continuous variables were compared between two groups using the Student's t-test or the Mann–Whitney U test, depending on data distribution.

Variables that showed a statistically significant association with mortality in univariate analyses, along with clinically relevant confounders (including age and major comorbidities), were entered into a multivariable binomial logistic regression model to identify independent predictors of mortality. Adjusted odds ratios (OR) with 95% confidence intervals (CI) were calculated to assess the independent prognostic value of the Shock Index. Receiver operating characteristic (ROC) curve analysis was performed to compare the performance of prognostic scoring systems (FGSI, UFGSI, LRINEC, qSOFA, and SI) in predicting mortality. Area under the curve (AUC) values, along with sensitivity and specificity for each scoring system, were calculated.

Furthermore, the optimal cut-off value for the SI for predicting mortality was determined using the Youden index. A p value <0.05 was considered statistically significant in all analyses.

RESULTS

A total of 158 patients who met the inclusion criteria were included in the study. The mean age was 62.3±13.4 years and was significantly higher in patients with fatal outcomes (p<0.001). The male-to-female ratio was 86.1% to 13.9%; however, mortality was significantly higher among female patients (p=0.004).

Table 1. Demographic characteristics and comorbidities of patients with Fournier's gangrene according to survival status

	All patients (n=158)	Survivors (n=131)	Non-survivors (n=27)	p-value
Age (years)	62.3±13.4	60.2±13.0	72.6±10.1	<0.001[q]
Sex				
Female	22 (13.9%)	13 (9.9%)	9 (33.3%)	
Male	136 (86.1%)	118 (90.1%)	18 (66.7%)	0.004[y]
Comorbidities				
Diabetes mellitus (+)	89 (56.3%)	72 (55%)	17 (63%)	
Diabetes mellitus (-)	69 (43.7%)	59 (45%)	10 (37%)	0.445[z]
Hypertension (+)	56 (35.4%)	42 (32%)	14 (51.9%)	
Hypertension (-)	102 (64.6%)	89 (68%)	13 (48.1%)	0.050[z]
Cerebrovascular disease (+)	12 (7.6%)	8 (6.1%)	4 (14.8%)	
Cerebrovascular disease (-)	146 (92.4%)	123 (93.9%)	23 (85.2%)	0.120[z]
Coronary artery disease (+)	29 (18.4%)	19 (14.5%)	10 (37%)	
Coronary artery disease (-)	129 (81.6%)	112 (85.5%)	17 (63%)	0.012[y]
Chronic heart failure (+)	23 (14.6%)	15 (11.5%)	8 (29.6%)	
Chronic heart failure (-)	135 (85.4%)	116 (88.5%)	19 (70.4%)	0.031[y]
Chronic renal failure (+)	17 (10.8%)	11 (8.4%)	6 (22.2%)	
Chronic renal failure (-)	141 (89.2%)	120 (91.6%)	21 (77.8%)	<0.001[y]

Continuous variables are presented as mean ± standard deviation; categorical variables are presented as number (percentage). [y]Fisher's exact test; [z]Pearson's chi-square test; [q]Student's t-test.

Table 2. Vital parameters of patients with Fournier's gangrene at admission according to survival status

	All patients	Survivors (n=131)	Non-survivors (n=27)	p-value
Body tem-perature (°C)	36.7 (0.547)	36.6 (0.5)	37.1 (0.95)	0.003
Heart rate (/min)	90 (21.8)	88 (16)	113 (15.5)	<0.001
Respiratory rate (/min)	18 (7)	18 (7)	20 (10)	0.001
Systolic blood pres-sure (mmHg)	120 (20)	120 (18)	108 (15)	<0.001

Data are presented as median (interquartile range). Comparisons between survivors and non-survivors were performed using the Mann–Whitney U test.

Table 3. Laboratory findings and derived ratios of patients with Fournier's gangrene according to survival status

	All patients	Survivors (n=131)	Non-survivors (n=27)	p-value
Glucose (mg/dL)	148 (125)	143 (127)	166 (83.5)	0.074[x]
HbA1c	6.8 (2.8)	6.7 (2.9)	7.2 (2.1)	0.259[x]
Urea (mg/dL)	47 (45)	41 (36.5)	115 (108)	<0.001[x]
Creatinine (mg/dL)	0.97 (0.645)	0.9 (0.485)	2.5 (2.43)	<0.001[x]
Sodium (mmol/L)	135±4.05	135±4.09	134±3.73	0.150[q]
Potassium (mmol/L)	4.4 (1)	4.3 (1)	5.2 (1.35)	<0.001[x]
Bicarbonate (HCO_3) (mEq/L)	22 (7.75)	23 (7)	18 (6.5)	0.030[x]
Albumin (g/dL)	2.74±0.568	2.78±0.571	2.51±0.503	0.021[q]
CRP (mg/L)	51.9 (224)	39.1 (146)	311 (198)	<0.001[x]
CAR	24 (81.3)	13.2 (60.7)	121 (88.7)	<0.001[x]
Hemoglobin (g/dL)	12±2.32	12.1±2.40	11.1±1.65	0.027[q]
Hematocrit (%)	35±5.74	35.5±5.79	32.7±4.91	0.020[q]
Platelet ($10\times10^3/\mu L$)	304 (177)	315 (173)	261 (148)	0.30[x]
Neutrophils ($10\times10^3/\mu L$)	14.1 (9.29)	14.1 (9.86)	14.2 (6.64)	0.363[x]
Lymphocytes ($10\times10^3/\mu L$)	1.21 (1.02)	1.30 (1.16)	0.80 (0.630)	0.001[x]
Monocytes ($10\times10^3/\mu L$)	1.09 (0.68)	1.10 (0.725)	0.77 (0.725)	0.005[x]
White blood cells ($10\times10^3/\mu L$)	17.9 (8.82)	17.9 (9.4)	17.8 (7.2)	0.365[x]
NLR	11.5 (15)	9.86 (14)	16.5 (28)	0.008[x]

Continuous variables are presented as mean ± standard deviation or median (interquartile range). CAR: C-reactive protein-to-albumin ratio; CRP: C-reactive protein; NLR: Neutrophil-to-lymphocyte ratio. [x]Mann–Whitney U test; [q]Student's t-test.

The most common comorbidities were diabetes mellitus (56.3%) and hypertension (35.4%). Coronary artery disease, chronic heart failure, and chronic renal failure were significantly associated with mortality (p=0.012, p=0.031, and p<0.001, respectively). The distribution of demographic characteristics and comorbidities is presented in Table 1.

As shown in Table 2, all vital parameters measured at admission were significantly associated with mortality. In patients with fatal outcomes, body temperature (37.1°C, interquartile range [IQR]: 0.95), heart rate (113/min, IQR: 15.5), and respiratory rate (20/min, IQR: 10) were significantly higher, whereas systolic blood pressure (108 mmHg, IQR: 15) was lower.

Laboratory findings were evaluated using the first blood samples obtained at emergency admission. Data distribution was assessed using the Shapiro–Wilk test. The Student's t-test was applied to normally distributed variables, while the Mann–Whitney U test was used for non-normally distributed variables. Biochemical analysis demonstrated that urea (p<0.001), creatinine (p<0.001), and CRP (p<0.001) levels were significantly higher in patients with mortality, whereas albumin (p<0.021) levels were significantly lower. Hematolog-

Table 4. Time-dependent and treatment-related variables of patients with Fournier's gangrene according to survival status

	All patients	Survivors (n=131)	Non-survivors (n=27)	p-value
Time from admission to surgery (min)	232 (231)	216 (240)	240 (214)	0.616[x]
Length of hospital stay (days)	16 (18)	17 (15.5)	12 (33.5)	0.850[x]
ICU stay (days)	0 (2)	0 (0)	9 (33.5)	<0.001[x]
Number of debridements	2 (3)	2 (3)	3 (3)	0.323[x]
Wound management				
Wet dressing	133 (84.2%)	113 (86.3%)	19 (70.4%)	
Vacuum-assisted closure	25 (15.8%)	18 (13.7%)	8 (29.6%)	0.042[y]
Diversion				
Yes	30 (18.9%)	19 (14.5%)	11 (40.7%)	
No	128 (91.1%)	112 (85.5%)	16 (59.3%)	0.002[z]

Continuous variables are presented as median (interquartile range); categorical variables are presented as number (percentage). [x]Mann–Whitney U test; [y]Fisher's exact test; [z]Pearson's chi-square test. ICU: Intensive care unit.

Table 5. Multivariable logistic regression analysis identifying independent predictors of in-hospital mortality

	Adjusted OR	95% CI	p-value
Shock Index (continuous)	4.77×10^{6}	5637.20–4.03×10^{9}	<0.001
Age (years)	1.05	0.998–1.11	0.093
Coronary artery dis-ease	1.10	0.09–13.60	0.940
Chronic heart failure	3.32	0.34–32.64	0.304
Chronic renal failure	2.79	0.40–19.63	0.302

OR: Odds ratio; CI: Confidence interval. All variables were entered simultaneously into the multivariable model. The odds ratio for the Shock Index represents the effect per one-unit increase in the continuous SI value.

ical analysis revealed that hemoglobin (p=0.027), hematocrit (p=0.027), and lymphocyte counts (p<0.001) were significantly lower in patients who died.

The CAR and NLR, both indicators of systemic inflammatory response, were significantly higher in patients with fatal outcomes (121, IQR: 88.7; and 16.5, IQR: 28, respectively). Both parameters showed a strong association with mortality (p<0.001 and p=0.008, respectively) (Table 3).

Analysis of time- and treatment-related variables (Table 4) revealed significant associations between mortality and intensive care unit length of stay (p<0.001), diversion procedures (p=0.002), and wound care method (p=0.042). Patients with fatal outcomes had longer ICU stays (9 days, IQR: 33.5) and higher rates of diversion procedures (40.7%). Additionally, the relationship between wound care method and debridement frequency was evaluated. The median number of debridements was higher in patients treated with (4, IQR: 2) compared to those treated with wet dressings (2, IQR: 2), and this difference was statistically significant (p<0.001).

In multivariable logistic regression analysis adjusted for age and major comorbidities (Table 5), the Shock Index remained an independent predictor of in-hospital mortality (adjusted OR=4.77×10^{6}, 95% CI: 5637.20–4.03×10^{9}, p<0.001). Age and comorbid conditions, including coronary artery disease, chronic heart failure, and chronic renal failure, were not independently associated with mortality after adjustment.

To further evaluate the prognostic value of the Shock Index in FG, an initial binomial logistic regression analysis demonstrated a significant association between SI and mortality (p<0.001). ROC analysis was subsequently performed to assess its discriminatory performance and to compare it with established scoring systems (FGSI, UFGSI, LRINEC, and qSOFA). The results showed that SI had the highest discriminatory power among the evaluated parameters (AUC=0.952, 95% CI: 0.918–0.986, p<0.001). SI demonstrated superior discriminatory performance for predicting mortality com-

Table 6. Cut-off values of Shock Index for predicting mortality based on Youden's Index

Cut-off	Sensitivity (%)	Specificity (%)	Youden's Index
0.802	100.0	71.0	0.710
0.835	96.3	79.4	0.757
0.866*	92.6	83.2	0.758
0.891	88.9	86.3	0.751
0.898	85.2	88.5	0.737
0.939	81.5	91.6	0.731
0.975	77.8	94.7	0.724
0.987	74.1	96.2	0.703
1.024	63.0	97.7	0.607
1.043	55.6	98.5	0.540
1.092	40.7	99.2	0.400
1.178	25.9	100.0	0.259

OR: Odds ratio; CI: Confidence interval. All variables were entered simultaneously into the multivariable model. The odds ratio for the Shock Index represents the effect per one-unit increase in the continuous SI value.

pared with FGSI (AUC: 0.882), UFGSI (AUC: 0.862), qSOFA (AUC: 0.826), and LRINEC (AUC: 0.769). Although all scoring systems showed significant predictive value, SI achieved the best combination of sensitivity and specificity, indicating high overall diagnostic accuracy (Fig. 2).

Following ROC analysis, the optimal cut-off value of the SI for predicting mortality was determined using Youden's index. An SI value of 0.866 was identified as the optimal threshold, yielding a sensitivity of 92.6% and a specificity of 83.2% (Youden index=0.758) (Table 6). These findings highlight the potential utility of SI as a prognostic tool in the assessment of Fournier's gangrene.

DISCUSSION

Fournier's gangrene is a severe infection that requires a multidisciplinary approach and is associated with high mortality rates despite advances in modern treatment.[13] Although prompt surgical debridement and broad-spectrum antibiotic therapy are the cornerstones of management, mortality rates remain substantial, suggesting that the determinants of prognosis are not yet fully understood. Early identification of patients at high risk of mortality is therefore critical for effective clinical management. To achieve this, a range of prognostic scoring systems are used, including FGSI, UFGSI, LRINEC, and qSOFA.[14-16] However, the computational complexity and reliance on laboratory parameters limit their practical applicability, particularly in emergency settings. This has led to a growing demand for more practical, rapid, and easily applicable prognostic indicators.

The mortality rate of 17.1% observed in this study is consistent with rates reported in the literature.[2-4] Previous studies have shown that advanced age is associated with poorer prognosis in FG. The etiology of this phenomenon has been attributed to several factors. Firstly, there is a weakening of the immune response, which is characteristic of advanced age. Secondly, there is an increased burden of comorbidities, i.e., the presence of more than one disease or condition in an individual. Thirdly, there are decreased systemic reserves, i.e., the body's ability to respond to stress and maintain bodily functions.[2,17] The findings of this study are consistent with the literature, as the mean age of patients who died was significantly higher than that of survivors.

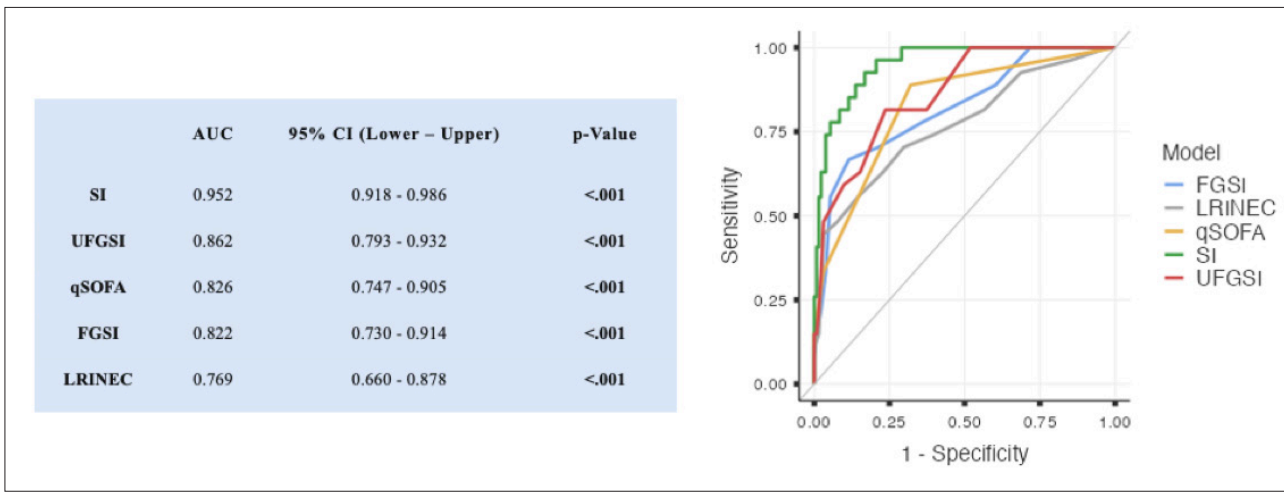

Figure 2. Comparison of receiver operating characteristic curves and corresponding area under the curve values demonstrating the diagnostic performance of mortality prediction models, including the Shock Index, in patients with Fournier's gangrene. *AUC: Area under the curve; CI: Confidence interval; FGSI: Fournier Gangrene Severity Index; LRINEC: Laboratory Risk Indicator for Necrotizing Fasciitis; qSOFA: Quick Sequential Organ Failure Assessment; SI: Shock Index; UFGSI: Uludağ Fournier Gangrene Severity Index.*

When comorbidities were examined, diabetes mellitus (DM) was the most prevalent, accounting for 56.3% of cases. However, no statistically significant association was found between DM and mortality. Similarly, Yanar et al.[18] reported that, although DM was the most common comorbid condition, it was not significantly associated with mortality. These findings suggest that DM may predispose individuals to the development of FG through impaired tissue perfusion and suppression of the immune response, but it appears to play a secondary role in determining disease prognosis. Previous studies have documented that cardiac and renal dysfunction complicate the maintenance of hemodynamic stability in FG and significantly impact mortality.[19,20] In line with these findings, the present study demonstrated that coronary artery disease, chronic heart failure, and chronic renal failure were significantly associated with mortality.

All vital parameters measured at emergency admission showed a statistically significant correlation with mortality. Specifically, systolic blood pressure was significantly lower and heart rate significantly higher in fatal cases. Consistent with these results, the literature indicates that low systolic blood pressure and tachycardia are markers of poor prognosis in FG. In a meta-analysis, Eke N. reported that systemic hypotension independently increased mortality,[21] while Sorensen et al.[22] identified tachycardia and hypotension as early indicators of shock in fatal cases. In a similar vein, Ouanes et al.[23] reported that mortality was significantly higher in patients with a heart rate ≥89/min, and approximately doubled in those with an SBP ≤115 mmHg. When considered alongside the existing literature, these findings suggest that early hemodynamic assessment in FG may serve as an important prognostic indicator of mortality.

Laboratory findings indicated that an increased systemic inflammatory response had a statistically significant impact on mortality. In particular, the CAR showed a significant association with mortality. Özgül and Uzmay[24] reported an AUC value of 0.907, demonstrating the high accuracy of CAR in predicting mortality in Fournier's gangrene. Several studies have also shown that the neutrophil-to-lymphocyte ratio, another marker of systemic inflammation, is an independent prognostic indicator of mortality.[25,26] Consistent with these findings, NLR was also statistically significant in mortality cases in the present study. However, there is some controversy regarding its predictive value. In a study of 109 FG patients, Raizhanda et al.[27] reported that NLR alone is not a reliable predictor. These findings suggest that laboratory markers should be used as complementary tools within the clinical context rather than as standalone predictors of mortality.

The analysis further demonstrated that mortality rates were higher in patients requiring prolonged intensive care unit stays and in those who underwent diversion. Both variables showed a statistically significant association with mortality. These findings indicate that more aggressive surgical interventions and prolonged critical care are markers of advanced disease and higher-risk cases. The findings of the present study are consistent with those of previous research, which indicate that the duration of intensive care unit stay is significantly longer in cases with a fatal outcome in FG.[28,29] Ozturk et al.[30] reported that diversion is more frequently preferred in the presence of anal sphincter involvement and perineal contamination, and that this approach may be associated with higher mortality rates. In their study, Korkut et al.[31] hypothesized that diversion in FG patients may be associated with mortality. However, this association is not causal; rather, it is considered an indicator reflecting the advanced stage of the disease.

The findings of the present study indicate that the number of repeated debridements is not directly correlated with mortality, suggesting that surgical success depends not only on the frequency of intervention but also on the timing and extent of the procedure. Consistent with these results, Özlülerden et al.[32] in a study aimed at predicting poor prognosis in FG, reported no statistically significant association between the number of debridements and mortality. Moreover, the literature emphasizes that early, extensive, and radical debridement may reduce mortality by limiting the progression of necrotic tissue.[33,34] No significant difference in mortality was observed between wound care methods (wet dressing versus negative pressure wound therapy [VAC]). Similarly, Yanaral et al.[35] highlighted that, in FG, prognosis is more strongly influenced by regular wound care and sustained infection control than by the specific wound care techniques itself.

A comparison of established prognostic scoring systems for Fournier's gangrene (FGSI, UFGSI, LRINEC, and qSOFA) with the Shock Index demonstrated that SI had superior prognostic performance, with a greater ability to discriminate between survivors and non-survivors. These findings suggest that SI is a practical and effective tool for early mortality risk assessment, particularly during the initial clinical evaluation. The identified optimal SI cut-off value represents a critical threshold above which the risk of mortality increases substantially in patients with Fournier's gangrene. In multivariable logistic regression analysis adjusted for age and major comorbidities, the Shock Index remained an independent predictor of in-hospital mortality. Laboratory and treatment-related variables were excluded from the multivariable model due to the limited number of mortality events and the risk of multicollinearity. Moreover, individual vital signs were intentionally excluded, as the Shock Index is directly derived from heart rate and systolic blood pressure.

The high discriminatory performance of the Shock Index observed in our cohort may be attributable to the relatively homogeneous disease severity among surgically treated patients, as well as the exclusion of cases with pharmacologically altered hemodynamic measurements prior to definitive evaluation. In addition, the Shock Index directly reflects early hemodynamic compromise, a key determinant of mortality in necrotizing infections.

The calculation of SI is straightforward, requiring only systolic blood pressure and heart rate. This simplicity enables early risk stratification without the need for laboratory data or complex calculations, making it a practical tool for clinical decision-making in emergency departments and intensive care settings. Consistent with the literature, İnal et al.[36] and Kumar et al.[37] reported a strong association between SI and mortality in critically ill patients with multiple trauma, sepsis, and shock. In the context of Fournier's gangrene, previous studies have suggested a potential association between SI and adverse outcomes; however, direct comparisons with established prognostic scoring systems remain limited.[9,38]

The findings of this study should be interpreted in light of several limitations. The retrospective, single-center design may limit generalizability and introduce selection bias. Although all consecutive patients who underwent surgical debridement were included, those who died prior to surgical evaluation were excluded, as their recorded vital signs were obtained under active resuscitation and vasoactive or inotropic support. Consequently, SI measurements in these cases were considered non-representative of the underlying disease physiology. However, this exclusion may have introduced survivorship bias and contributed to an overestimation of the predictive performance of the Shock Index.

The relatively small number of mortality events may increase the risk of overly optimistic discrimination estimates in ROC analyses and limit the number of variables that could be reliably included in the multivariable model. Furthermore, the Shock Index was calculated using single time-point vital signs recorded at emergency department admission, and dynamic hemodynamic changes during the clinical course were not assessed. External validation in independent cohorts was not performed; therefore, the identified cut-off value may not be directly generalizable to other populations or settings. Although multivariable adjustment was conducted for major confounders such as age and comorbidities, residual confounding cannot be entirely excluded. Prospective, multicenter studies with larger sample sizes are warranted to validate these findings and to further clarify the clinical utility of the Shock Index in Fournier's gangrene.

CONCLUSION

This study addresses an important gap in the literature by directly comparing the prognostic value of the Shock Index with that of widely used scoring systems in Fournier's gangrene. In emergency settings, where laboratory results may be delayed or access to comprehensive clinical data is limited, SI may serve as a rapid and practical tool for early risk stratification. However, further validation through prospective, multicenter studies across diverse patient populations is necessary to confirm its clinical reliability and generalizability.

Ethics Committee Approval: This study was approved by the Trakya University Faculty of Medicine Non-Interventional Clinical Research Ethics Committee (Date: 03.11.2025, Decision No: 2025/491).

Peer-review: Externally peer-reviewed.

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

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*

Fournier gangreninde şok indeksinin prognostik değeri: Yerleşik mortalite puanlama sistemleriyle karşılaştırmalı retrospektif kohort çalışması

AMAÇ: Fournier gangreni, perineal ve genital bölgeleri tutan, hızlı ilerleyici ve yaşamı tehdit eden bir nekrotizan enfeksiyon olup, cerrahi ve yoğun bakım alanındaki gelişmelere rağmen mortalitesi yüksek seyretmektedir. Bu hastalarda erken ve güvenilir prognostik değerlendirme, klinik sonuçların iyileştirilmesi açısından kritik öneme sahiptir. Bu çalışmanın amacı, Şok İndeksi'nin (SI) Fournier gangreninde mortaliteyi öngörme performansını değerlendirmek ve ayırt ediciliğini mevcut skorlama sistemleri ile karşılaştırmaktır.

GEREÇ VE YÖNTEM: Bu retrospektif kohort çalışmasına, Ocak 2015–Aralık 2024 tarihleri arasında bir üçüncü basamak üniversite hastanesinin acil servisine başvuran ve cerrahi debridman uygulanan Fournier gangreni tanılı erişkin hastalar dahil edilmiştir. Demografik, klinik ve laboratuvar verileri kurumsal ve ulusal elektronik sağlık kayıtlarından elde edilmiştir. Sağ kalanlar ile kaybedilen hastalar uygun istatistiksel yöntemlerle karşılaştırılmış; mortalite ile ilişkili değişkenler lojistik regresyon analizine tabi tutulmuştur. Şok İndeksi ve diğer geleneksel skorlama sistemlerinin (FGSI, UFGSI, LRINEC, qSOFA) mortaliteyi öngörme performansı ROC analizi ile değerlendirilmiş; SI için optimal eşik değer Youden indeksi kullanılarak belirlenmiştir.

BULGULAR: Çalışmaya dahil edilen 158 hastanın (ortalama yaş 62.3±13.4 yıl; %86,1 erkek) genel mortalite oranı %17.1 idi. Kaybedilen hastalar anlamlı ölçüde daha ileri yaştaydı ($p<0.001$) ve koroner arter hastalığı, kronik kalp yetmezliği ile kronik böbrek yetmezliği mortalite ile ilişkili bulundu. Başvuru anında kaybedilen hastalarda kalp ve solunum hızı daha yüksek, sistolik kan basıncı ise daha düşüktü. ROC analizine göre Şok İndeksi mortaliteyi öngörmede en yüksek ayırt edici güce sahipti (AUC=0.952; %95 GA 0.918–0.986; $p<0.001$) ve FGSI, UFGSI, LRINEC ve qSOFA skorlarını geride bıraktı. SI için belirlenen optimal eşik değerin (0.866) mortalite öngörümünde %92.6 duyarlılık ve %83,2 özgüllük sağladığı görüldü.

SONUÇ: Fournier gangreninde Şok İndeksi, geleneksel skorlama sistemlerine kıyasla üstün prognostik doğruluk göstermiştir. Yalnızca iki kolay erişilebilir hemodinamik parametreye dayanması nedeniyle erken risk sınıflandırmasında pratik ve uygulanabilir bir araç olarak öne çıkmaktadır. Bulguların doğrulanması için ileriye dönük çok merkezli çalışmalara ihtiyaç vardır.

Anahtar sözcükler: Fournier gangreni; mortalite; prognoz; şok indeksi.

Ulus Travma Acil Cerrahi Derg 2026;32(6):683-693 DOI: 10.14744/tjtes.2026.58823

ORIGINAL ARTICLE

Anesthetic management and early outcomes in patients with earthquake-induced crush and compartment syndrome: A single-center retrospective analysis

Tuğba Nur Taygurt,[1] Gökhan Erdem,[2] Süleyman Taygurt,[1] Muhammed Nezih Koç[3]

[1]Department of Anesthesiology and Reanimation, Ministry of Health, Kırşehir Training and Research Hospital, Kırşehir-*Türkiye*
[2]Department of Anesthesiology and Reanimation, Health Sciences University, Ankara Bilkent City Hospital, Ankara-*Türkiye*
[3]Department of Anesthesiology and Reanimation, Yunak State Hospital, Ministry of Health, Konya-*Türkiye*

ABSTRACT

BACKGROUND: This retrospective study aimed to evaluate anesthesia management, intraoperative support strategies, and 60-day clinical outcomes in patients requiring surgical intervention, including fasciotomy and/or amputation, due to crush and compartment syndrome following the February 6, 2023, Kahramanmaraş earthquakes. The study also sought to identify predictors of mortality and contribute to the field of disaster medicine.

METHODS: This single-center study reviewed the data of 64 patients who underwent emergency surgery between February 6 and April 6, 2023. Retrospectively collected and analyzed data included patient demographics, ASA (American Society of Anesthesiologists) physical status classification, anesthesia techniques used, intraoperative support provided, and 60-day follow-up clinical outcomes, including mortality, renal function, and muscle necrosis markers.

RESULTS: Most patients (93.8%) underwent surgery under general anesthesia due to systemic instability. This finding highlights the critical role of the systemic effects of traumatic injuries and crush syndrome in the choice of anesthesia. The 60-day mortality rate was 11.1%. Significant decreases in muscle necrosis markers, such as CK, AST, and ALT, were observed after fasciotomy. This finding suggests that even delayed fasciotomy may be effective in reducing the systemic toxic load. A key finding was that the preoperative albumin/lactate ratio was identified as a strong and independent predictor of mortality. This ratio may serve as a practical biomarker for patient risk stratification and prognosis.

CONCLUSION: In cases of crush and compartment syndrome following an earthquake, general anesthesia was widely preferred over regional techniques because of patients' severe systemic instability. The data show that surgical interventions, such as fasciotomy, can successfully reduce the systemic toxic load and improve patient outcomes. Furthermore, a simple biomarker, such as the preoperative albumin/lactate ratio, could be a critical tool for predicting patient risk and mortality, especially in resource-limited settings following a disaster. This study provides important information for planning anesthesia and surgical management strategies in similar disaster situations.

Keywords: Anesthesia; crush syndrome; earthquakes; fasciotomy; mortality.

INTRODUCTION

On February 6, 2023, two major earthquakes struck Türkiye, with epicenters in Pazarcık (Kahramanmaraş) (Mw 7.7) and Elbistan (Kahramanmaraş) (Mw 7.6).[1] These catastrophic events affected a wide geographic region encompassing 11 provinces, impacting approximately 14 million people and resulting in more than 50,000 deaths according to official reports.

Cite this article as: Taygurt TN, Erdem G, Taygurt S, Koc MN. Anesthetic management and early outcomes in patients with earthquake-induced crush and compartment syndrome: a single-center retrospective analysis. Ulus Travma Acil Cerrahi Derg 2026;32:694-701.

Address for correspondence: Muhammed Nezih Koç
Department of Anesthesiology and Reanimation, Yunak State Hospital, Ministry of Health, Konya, Türkiye
E-mail: mnezihkoc@gmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(6):694-701 DOI: 10.14744/tjtes.2025.88870
Submitted: 15.09.2025 Revised: 04.11.2025 Accepted: 05.11.2025 Published: 03.06.2026

The most frequently encountered injuries in the post-earthquake period were extremity trauma and crush syndrome.[2] In cases when compartment syndrome develops, early fasciotomy is the gold standard of treatment. However, under disaster conditions, surgical intervention may be delayed. While some patients can be managed conservatively, others may require delayed fasciotomy or even amputation.[3,4] Furthermore, metabolites released following crush injuries can lead to acute kidney injury, which may be life-threatening.[5]

Our hospital, located approximately 595 km from the earthquake-affected region, did not experience shortages of anesthesia equipment or personnel for general anesthesia. On the first day following the disaster, most surgical patients received general anesthesia. This approach was influenced by the high incidence of crush syndrome, the unstable clinical condition of many patients, and the psychological stress associated with the disaster. Due to the overwhelming patient volume, it was not feasible to provide peripheral nerve blocks for all patients. Consequently, pain management during the initial phase relied on a multimodal approach combining systemic nonsteroidal anti-inflammatory drugs (NSAIDs) and opioids.

Following the 2023 Kahramanmaraş earthquakes, many injured individuals were transferred to city hospitals outside the disaster zone to receive surgical and intensive care. This study aims to evaluate anesthesia management strategies, including the techniques used and intraoperative supportive interventions, in patients who underwent surgery after the earthquake. Additionally, we analyzed clinical outcomes within the first 60 days post-disaster, identified risk factors associated with mortality, and assessed changes in laboratory parameters, with the goal of presenting the experience gained during this disaster response.

The two devastating earthquakes centered in Kahramanmaraş on February 6, 2023, resulted in widespread casualties and a high incidence of extremity injuries among survivors. In the setting of disaster surgery, crush and compartment syndromes are common; however, data on the anesthetic management of earthquake victims are limited. Therefore, this study aimed to describe anesthesia practices, intraoperative support strategies, and 60-day outcomes in earthquake victims requiring surgery, as well as to evaluate biomarkers associated with mortality.

MATERIALS AND METHODS

Study Design

This single center, descriptive retrospective study evaluates anesthesia management, intraoperative support strategies, and early outcomes in adult patients with earthquake induced crush and/or compartment syndrome who required emergency surgery following the February 6, 2023 Kahramanmaraş earthquakes.

Study Population and Sample

The study population consisted of earthquake victims who underwent emergency trauma surgery in the Neurology–Orthopedics operating room between February 6, 2023 and April 6, 2023. A total of 64 patients who underwent emergency fasciotomy and/or amputation during this period were included in the analysis.

Data Collection

Data were obtained from anesthesia records and the hospital information management system. Collected variables included demographic characteristics (age, sex, and body weight), types of trauma, number of affected extremities, and clinical parameters such as duration of intubation and length of hospital stay. Perioperative data included American Society of Anesthesiologists (ASA) physical status classification, type of anesthesia, surgical procedures performed, blood transfusion requirements, and use of intraoperative inotropic support. Laboratory parameters measured before and after anesthesia, such as urea, creatinine, albumin, aspartate aminotransferase (AST), alanine aminotransferase (ALT), creatine kinase (CK), and lactate, were also recorded. Outcome data, including mortality, were collected comprehensively.

Data Analysis

Data were analyzed using descriptive statistical methods and presented as line graphs, funnel plots, box plots, and tables. The Wilcoxon signed-rank test and paired t-test were used to compare laboratory values before and after fasciotomy. Correlation analysis and logistic regression were performed to assess the association between mortality and selected biomarkers.

Ethics

Ethical approval was obtained from the Scientific and Ethical Review Board for Medical Research (TABED) of Ankara Bilkent City Hospital (January 15, 2025; TABED 1-25-903). The study was conducted in accordance with the Declaration of Helsinki.

RESULTS

Demographic and Baseline Clinical Characteristics

A total of 64 patients (n=64) were included in the study. The mean age was 31.76±14.31 years, with a median of 28 years (range: 6–75). Females comprised 54.7% (n=35) of the cohort, while males accounted for 45.3% (n=29).

Regarding ASA physical status, 38.1% (n=24) of patients were classified as ASA IIE, 44.4% (n=28) as ASA IIIE, 14.3% (n=9) as ASA IVE, and 3.2% (n=2) as ASA VE (percentages calculated based on 63 patients with available ASA data). The most frequently performed procedure was fasciotomy (64.1%, n=41), followed by amputation (31.3%, n=20) and debridement (6.3%, n=4). General anesthesia (GA) was administered in 93.8% (n=60) of cases. At admission, 82.8% (n=53) of patients were breathing spontaneously, 7.8% (n=5) required oxygen support, and 9.4% (n=6) were intubated.

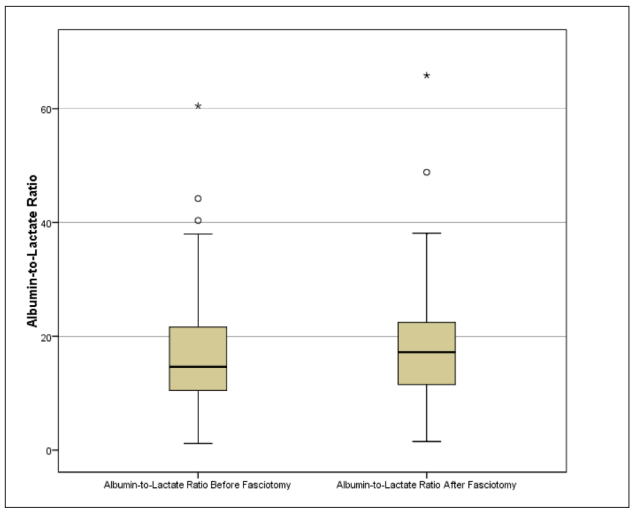

Figure 1. Boxplot of the albumin-to-lactate ratio before and after fasciotomy.

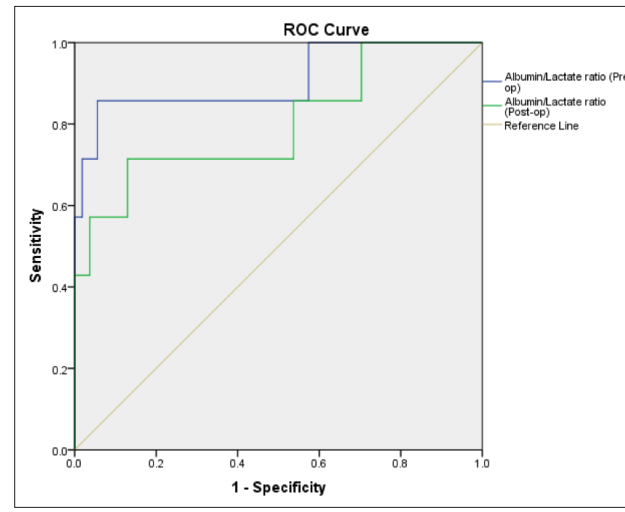

Figure 2. Receiver operating characteristic (ROC) curve of the albumin-to-lactate ratio before and after fasciotomy.

Perioperative Management and Clinical Outcomes

Sodium chloride solution (0.9% NaCl) was used intraoperatively in 93.8% of cases. Among patients requiring inotropic support, noradrenaline was the most commonly used agent (15.6%, n=10). Postoperative analgesia most frequently included tramadol (48.4%) and paracetamol (28.1%).

The mean operative time was 107.58±48.28 minutes. The mean intensive care unit (ICU) stay was 22.85±26.80 days, and the mean total hospital stay was 69.25±55.27 days. Hemodialysis was required in 45.9% (n=28) of patients, while continuous renal replacement therapy (CRRT) was used in 3.3% (n=2). The overall mortality rate was 11.1% (n=7).

Effect of Fasciotomy on Laboratory Parameters

Following fasciotomy, significant decreases were observed in CK, AST, ALT, and lactate levels (all p≤0.009). Hemoglobin and albumin levels also decreased significantly (p=0.010 and p=0.001, respectively).

Biomarkers Predicting Mortality

Correlation analysis showed that pre-fasciotomy base excess was inversely correlated with mortality (r=−0.413, p=0.001). The neutrophil-to-lymphocyte ratio (NLR) demonstrated a positive correlation with mortality both before and after fasciotomy (r=0.289, p=0.012; r=0.221, p=0.043, respectively). Platelet-to-lymphocyte ratio (PLR) was negatively correlated with mortality in both the pre- and post-fasciotomy periods (r=−0.246, p=0.028; r=−0.259, p=0.022). The albumin-to-lactate ratio (ALR) showed a negative correlation with mortality both preoperatively and postoperatively (Spearman's ρ=−0.450, p<0.001; ρ=−0.330, p=0.009).

Multivariable logistic regression analysis, including preoperative platelet-to-lymphocyte ratio (PLR), NLR, ALR, and C-reactive protein-to-lactate ratio (CRP-to-lactate ratio), identified preoperative ALR as an independent predictor of mortality (B=−0.364; Wald=8.579; p=0.003; odds ratio [OR]=0.695).

Graphical analyses further supported the prognostic value of ALR. The box plot illustrating ALR distribution before and after fasciotomy (Fig. 1) demonstrated a notable change in postoperative values. Receiver operating characteristic (ROC) analysis showed that both preoperative and postoperative ALR had strong predictive performance for mortality (Fig. 2). The area under the curve (AUC) for preoperative ALR was 0.907, indicating that it predicted mortality with 85.7% sensitivity and 85.2% specificity. The postoperative AUC for ALR was 0.799 (Table 7). These findings support the use of ALR as an early, noninvasive, and practical biomarker for predicting mortality.

DISCUSSION

Our cohort was characterized by a young median age (28 years), a high burden of systemic injury (61.9% classified as ASA IIIE or higher; 39 of 63 patients with available ASA data), crush syndrome secondary to prolonged entrapment, and a high rate of acute kidney injury (dialysis requirement: 45.9%). Key findings included the predominant use of GA (93.8%), a high rate of fasciotomy (64.1%), and an in-hospital mortality rate of 11.1%.[1,6] The most notable and original finding of this study is that preoperative ALR independently predicted mortality (OR: 0.695; p=0.003), indicating its potential as a clinically useful tool for early risk stratification.[6] Graphical analyses further supported the prognostic value of ALR. The postoperative increase in ALR observed in Figure 1 is consistent with clinical improvement and a reduction in metabolic burden. Additionally, ROC analysis (Fig. 2) and the corresponding area under the curve values (Table 7) demonstrated that preoperative ALR predicts mortality with high accuracy. From a clinical perspective, mortality risk was significantly higher in patients with ALR values below the cutoff of 9.05.

Table 1. Demographic and baseline clinical characteristics of the patients

Age (years)	
Median (interquartile range)	28 (23-41)
n (%)	
Sex	
Male	29 (45.3%)
Female	35 (54.7%)
ASA Score	
ASA IIE	24 (38.1%)
ASA IIIE	28 (44.4%)
ASA IVE	9 (14.3%)
ASA VE	2 (3.2%)
Type of surgery	
Fasciotomy	41 (64.1%)
Amputation	20 (31.3%)
Debridement	4 (6.3%)
Other	2 (3.1%)
Type of anesthesia	
General anesthesia	60 (93.8%)
Spinal anesthesia	3 (4.7%)
Epidural anesthesia	1 (1.6%)
Respiratory status on admission	
Spontaneous breathing	53 (82.8%)
Oxygen support	5 (7.8%)
Intubated	6 (9.4%)

ASA classification was unavailable for one patient; percentages are calculated based on 63 patients with available data.

These findings suggest that ALR may be integrated into disaster surgery settings for early triage and prioritization of intensive care, alongside existing scoring systems.

The high rate of general anesthesia in our cohort is consistent with reports from other centers following the same disaster. Kılınçarslan et al.[1] reported a GA rate of 93.9% in 375 cases, while Erkilic et al.[6] reported its use in 577 of 650 procedures. Although regional anesthesia (RA) is theoretically recommended in mass casualty settings due to its potential for resource conservation and reduced opioid requirements,[7] the pathophysiological features of severe crush injury, such as hemodynamic instability, metabolic acidosis, and possible coagulopathy, often limit its applicability. In particular, neuraxial techniques may carry a risk of collapse due to sympathectomy, while altered consciousness and psychological trauma can further impair patient cooperation.[8-11] Nevertheless, when feasible, RA can provide effective anesthesia and analgesia, reduce opioid-related adverse effects, and potentially decrease intensive care utilization.[10,12-14]

Most fasciotomies in our cohort were performed "late" relative to the traditionally recommended 6–12-hour window.[15-19] Therefore, indications for fasciotomy should be individualized, taking into account factors such as sustained pressure >30 mmHg for more than 8 hours, as well as overall patient condition.[16,20,21] The significant postoperative reductions in CK, AST, ALT, and lactate suggest effective source control and attenuation of systemic toxicity. These findings support the notion that even delayed fasciotomy may be beneficial in selected patients with adequately resuscitated and viable limbs. The concurrent increase in CRP reflects a subsequent systemic inflammatory response, underscoring the need for

Table 2. Perioperative management and clinical outcomes

Continuous variables	**Mean±SD/Median (interquartile range)**
Duration of surgery (min)	107.58±48.28/90 (75-128)
Duration of intubation (days)	3.80±11.69/0 (0-0)
ICU length of stay (days)	22.85±26.80/10 (4-36)
Hospital length of stay (days)	69.25±55.27/59 (32-102)
Glasgow Coma Scale (GCS)	13.95±2.63/15 (15-15)
Categorical variables, n (%)	
Intraoperative fluid management	
0.9% NaCl	60 (93.8%)
Balanced crystalloid solution	6 (9.4%)
Colloid (Voluven)	4 (6.3%)
Other (buffered, dextrose, polydex)	16 (25.0%)
Inotropic support	
Noradrenaline	10 (15.6%)
Dopamine	2 (3.1%)
Adrenaline	1 (1.6%)
Blood product usage	
Red blood cell suspension	18 (28.1%)
Fresh frozen plasma	8 (12.5%)
Platelet suspension	2 (3.1%)
Fibrinogen	1 (1.6%)
Dialysis requirement	
Hemodialysis	28 (45.9%)
CRRT	2 (3.3%)
Mortality	
Yes	7 (11.1%)
No	56 (88.9%)

SD: Standard deviation; ICU: Intensive care unit; CRRT: Continuous renal replacement therapy. Some patients received more than one type of fluid or analgesic; therefore, percentages may exceed 100%. 60-day outcome data were unavailable for one patient; percentages are calculated based on 63 patients with available data. Dialysis status data were unavailable for three patients; percentages are calculated based on 61 patients with available data.

Table 3. Comparison of selected laboratory parameters before and after fasciotomy

	Before fasciotomy (Mean±SD)	Before Fasciotomy Median (Min–Max)	After fasciotomy (Mean±SD)	After fasciotomy Median (Min–Max)	p-value
Lactate (mmol/L)	2.36±2.42	1.81 (0.50-14.36)	1.82±1.70	1.32 (0.41-11.51)	0.009*
Albumin (g/L)	24.48±7.29	24.00 (8.03-49.00)	22.79±6.08	21.00 (11.00-49.00)	0.001*
Uric acid (mg/dL)	5.12±3.12	4.75 (0.90-14.10)	4.58±2.82	4.05 (0.90-11.40)	0.001*
GFR (mL/min/1.73 m²)	88.78±58.67	102.50 (0.00-206.00)	94.02±62.44	106.00 (0.00-243.00)	0.110*
AST (U/L)	852.36±1352.53	274.00 (22.00-6345.00)	741.74±1313.86	225.00 (19.00-7626.00)	<0.001*
ALT (U/L)	355.05±627.52	136.00 (23.00-3412.00)	346.67±735.12	129.00 (23.00-5036.00)	0.001*
Hemoglobin (g/dL)	9.42±1.80	9.10 (5.70-14.60)	8.85±1.72	8.50 (5.40-14.70)	0.010†
CRP (mg/L)	123.30±77.15	108.00 (0.49-344.40)	133.72±80.67	116.20 (4.00-346.50)	0.027*
Creatine kinase (U/L)	30605.20±53098.47	8478.00 (125.00-257067.00)	24271.62±41329.81	6093.00 (64.00-193733.00)	<0.001*
Potassium (mmol/L)	4.38±1.15	4.10 (2.50-7.80)	4.27±1.05	4.10 (2.60-7.20)	0.120†
Chloride (mmol/L)	105.23±5.79	105.00 (89.00-117.00)	105.89±5.12	106.00 (95.00-118.00)	0.238†
Base excess (BE) (mmol/L)	−2.88±6.66	-2.10 (-22.20-13.40)	−1.90±5.53	-2.15 (-19.30-14.20)	0.457*
Neutrophil-to-lymphocyte ratio (NLR)	11.81±8.03	9.49 (1.27-40.96)	12.33±7.63	10.72 (2.47-42.37)	0.395*
Platelet-to-lymphocyte ratio (PLR)	253.61±178.42	194.08 (41.18-724.32)	272.25±201.89	217.27 (41.82-1012.50)	0.391*
Albumin-to-lactate ratio	17.7±11.03	14.63 (1.18-60.49)	18.39±11.06	17.21 (1.52-65.85)	0.680*

*SD: Standard deviation; Min: Minimum; Max: Maximum; GFR: Glomerular filtration rate; AST: Aspartate aminotransferase; ALT: Alanine aminotransferase; CRP: C-reactive protein; PLT: Platelet; LYM: Lymphocyte. Wilcoxon signed-rank test; †Paired t-test.

Table 4. Correlation analysis between mortality and biomarker ratios

	Correlation coefficient (r/ρ)	p-value
Pre-fasciotomy base excess (BE) (mmol/L)	-0.413*	0.001
Post-fasciotomy base excess (mmol/L)	-0.182*	0.085
Pre-fasciotomy neutrophil-to-lymphocyte ratio (NLR)	0.289*	0.012
Post-fasciotomy neutrophil-to-lymphocyte ratio (NLR)	0.221*	0.043
Pre-fasciotomy platelet-to-lymphocyte ratio (PLR)	-0.246*	0.028
Post-fasciotomy platelet-to-lymphocyte ratio (PLR)	-0.259*	0.022
Pre-fasciotomy albumin-to-lactate ratio (ALR)	-0.450†	<0.001
Post-fasciotomy albumin-to-lactate ratio (ALR)	-0.330†	0.009

*PLT: Platelet; LYM: Lymphocyte. Point-biserial correlation; †Spearman correlation.

Table 5. Logistic regression analysis results for mortality

Variable	B	SE	Wald	p value	OR (95% CI)
Preoperative albumin-to-lactate ratio (ALR)	-0.364	0.124	8.579	0.003	0.695 (0.545-0.886)

B: Regression coefficient; SE: Standard error; OR: Odds ratio; CI: Confidence interval.

aggressive ICU management to prevent complications such as late sepsis and acute respiratory distress syndrome (ARDS).[22]

The prognostic value of the ALR observed in this study is consistent with findings reported in sepsis, septic shock, polytrauma, traumatic brain injury (TBI), and other critical illnesses.[23-26] However, some studies have reported higher lactate-to-albumin ratios in non-survivors without demonstrating independent predictive value in multivariable analy-

Table 6. Key prognostic biomarkers for mortality

Biomarker/Ratio (preoperative)	Correlation with mortality (ρ/r)	p-value	Logistic regression result (OR)
Albumin-to-lactate ratio (ALR)	ρ=-0.450	<0.001	**0.695 (p=0.003)**
Base deficit	r=-0.413	0.001	Not independently pre-dictive
Neutrophil-to-lymphocyte ratio (NLR)	r=0.289	0.012	Not independently pre-dictive
Platelet-to-leukocyte ratio (PLR)	r=-0.246	0.028	Not independently pre-dictive

Table 7. Analysis of preoperative and postoperative albumin-to-lactate ratios

Parameter	AUC	Std. Error	p-value	95% CI (Lower–Upper)	Cut-off	Sensitivity (%)	Specificity (%)
Albumin-to-lactate ratio (preoperative)	0.907	0.076	<0.001	0.758–1.000	9.05	85.7	85.2
Albumin-to-lactate ratio (postoperative)	0.799	0.106	0.011	0.591–1.000	13.4	71.4	72.2

ses, or without superiority over established scoring systems.[27,28] Mechanistically, ALR reflects the interplay between perfusion and metabolic stress (lactate) and the patient's inflammatory and nutritional status (albumin),[29,30] thereby serving as a marker of "physiologic exhaustion." In the context of disaster medicine, ALR may offer a practical tool for early triage and resource allocation.

Previous earthquake series have documented a high incidence of crush injuries and compartment syndrome.[16,31-34] Similarly, our cohort demonstrated a high burden of severe extremity trauma, with fasciotomy performed in 64.1% of patients and amputation in 31.3%. Fluid resuscitation predominantly involved isotonic saline. While early aggressive fluid therapy is critical for preventing renal injury, further studies are needed to clarify the impact of fluid type and volume on clinical outcomes.

This study has several limitations, including its retrospective, single-center design and relatively small sample size (n=64). Prospective, multicenter studies are needed to validate the prognostic utility of ALR in disaster settings. Further research should also address optimal decision-making in late-presenting compartment syndrome (fasciotomy versus amputation), potentially incorporating advanced imaging modalities and novel biomarkers. Additionally, long-term outcomes, including functional status, psychological impact, and quality of life, should be further investigated.

CONCLUSION

In this cohort of 64 surgically managed earthquake victims, GA predominated due to instability and limited patient cooperation. Significant postoperative reductions in CK, AST, ALT, and lactate levels indicate effective attenuation of systemic toxic burden, even in cases of delayed surgical intervention, whereas persistent inflammatory responses highlight the ongoing need for intensive care. Preoperative ALR independently predicted mortality, suggesting its potential as a practical tool for early triage in mass disaster settings.[6,23-26,29,30] Future studies should prospectively validate the prognostic value of ALR, refine evidence-based management strategies for late-presenting compartment syndrome, and assess long-term outcomes.

Ethics Committee Approval: Ethical approval was obtained from the Scientific and Ethical Review Board for Medical Research (TABED) of Ankara Bilkent City Hospital (Date: 15.01.2025, Decision No: TABED 1-25-903).

Acknowledgments: We thank the Departments of Anesthesiology and Reanimation, and Orthopedics and Traumatology at Ankara Bilkent City Hospital for their contributions.

Peer-review: Externally peer-reviewed.

Informed Consent: Informed consent was not required due to the retrospective design of the study; this was approved by the Ethics Committee.

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

Deprem kaynaklı crush/kompartman sendromu hastalarında anestezi yönetimi ve erken dönem sonuçlar: Tek merkezli retrospektif analiz

AMAÇ: Bu retrospektif çalışma, 6 Şubat 2023 Kahramanmaraş depremleri sonrası crush ve kompartman sendromu nedeniyle cerrahi müdahale (fasyotomi ve/veya ampütasyon) gerektiren hastalarda anestezi yönetimini, intraoperatif destek stratejilerini ve 60 günlük klinik sonuçları değerlendirmeyi amaçlamıştır. Çalışma, mortaliteyi öngören belirteçleri belirleyerek afet tıbbı alanına katkı sağlamayı hedeflemektedir.

GEREÇ VE YÖNTEM: Tek merkezli olarak yürütülen bu çalışma kapsamında, 6 Şubat–6 Nisan 2023 tarihleri arasında acil cerrahi uygulanan 64 hastanın verileri incelenmiştir. Demografik bilgiler, hastaların ASA (Amerikan Anesteziyoloji Derneği) fiziksel durum sınıflandırması, uygulanan anestezi teknikleri, operasyon sırasında verilen destek tedavileri ve 60 günlük takip süresince elde edilen klinik sonuçlar (mortalite, böbrek fonksiyonları, kas nekrozu belirteçleri) retrospektif olarak toplanmış ve analiz edilmiştir.

BULGULAR: Hastaların büyük çoğunluğu (%93.8) sistemik instabilite nedeniyle genel anestezi altında ameliyat edilmiştir. Bu durum, travmatik yaralanmaların ve crush sendromunun sistemik etkilerinin anestezi seçimindeki belirleyici rolünü göstermektedir. 60 günlük takip sürecinde mortalite oranı %11.1 olarak belirlenmiştir. Fasyotomi sonrası kas nekrozu belirteçleri olan CK, AST ve ALT seviyelerinde anlamlı düşüşler gözlenmiştir. Bu bulgu, geç uygulanan fasyotominin dahi sistemik toksik yükü azaltmada etkili olabileceğini ortaya koymaktadır. En önemli bulgulardan biri, preoperatif albümin/laktat oranının mortalite için güçlü ve bağımsız bir öngörücü olarak saptanmasıdır. Bu oran, hastaların risk sınıflandırması ve prognoz tahmini için pratik bir biyobelirteç olarak öne çıkmaktadır.

SONUÇ: Deprem sonrası crush ve kompartman sendromu gibi durumlarda hastaların şiddetli sistemik instabilitesi nedeniyle genel anestezi, bölgesel tekniklere kıyasla daha yaygın olarak tercih edilmiştir. Elde edilen veriler, fasyotomi gibi cerrahi müdahalelerin sistemik toksik yükü başarılı bir şekilde düşürdüğünü ve hasta sonuçlarını iyileştirebileceğini göstermektedir. Ayrıca, preoperatif albümin/laktat oranı gibi basit bir biyobelirtecin, özellikle kısıtlı kaynakların olduğu afet bölgelerinde, hasta riskini ve mortaliteyi öngörmede kritik bir araç olabileceği sonucuna varılmıştır. Bu çalışma, benzer afet durumlarında anestezi ve cerrahi yönetim stratejilerinin planlanması için önemli bilgiler sunmaktadır.

Anahtar sözcükler: Anestezi; deprem; crush sendromu; fasyotomi; mortalite.

Ulus Travma Acil Cerrahi Derg 2026;32(6):694-701 DOI: 10.14744/tjtes.2025.88870

ORIGINAL ARTICLE

Conservative treatment versus percutaneous intramedullary pinning for acute tendinous mallet finger: Does pin configuration matter?

Oğuz Kaya, Fuat Malkoc, Mustafa Ümit Gürbüz, Muhammed Kazez

Department of Orthopedics and Traumatology, Elazığ Fethi Sekin City Hospital, Elazığ-*Türkiye*

ABSTRACT

BACKGROUND: Acute tendinous mallet finger (Doyle type I) is commonly treated with continuous immobilization of the distal interphalangeal (DIP) joint; however, treatment success largely depends on patient compliance. Percutaneous intramedullary (IM) Kirschner wire DIP joint transfixation represents a minimally invasive surgical alternative, although the clinical relevance of different pin configurations remains unclear. This study compared conservative and surgical treatment methods and evaluated the impact of different pin configurations on clinical outcomes.

METHODS: This retrospective cohort study included 93 adult patients with acute tendinous mallet finger who presented within 7 days of injury and were followed for at least 12 months. Patients were allocated into three groups: conservative treatment with a tape-reinforced Stack splint (n=33), percutaneous IM Kirschner wire DIP joint transfixation with the pin left exposed (n=30), and IM transfixation with the pin buried within the fingertip pulp (n=30). The primary outcome was residual DIP joint extension lag at final follow-up. Secondary outcomes included functional results according to the Crawford criteria and treatment-related complications.

RESULTS: Baseline DIP extension lag did not differ significantly among the groups (p=0.801). At final follow-up, residual extension lag was significantly greater in the conservative group (median 4°) compared with the surgical groups (0.5° and 1°, respectively; p<0.001). Multicategorical analysis of Crawford grades showed no significant intergroup difference (p=0.095); however, dichotomous analysis (excellent + good outcomes) demonstrated significantly higher success rates in the surgically treated groups compared with the conservative group (p=0.014). Skin maceration was more frequent in the conservative group (p<0.001), whereas pin-site irritation was significantly more common in the exposed pin group (p=0.006). No significant differences were observed among the groups regarding superficial infection.

CONCLUSION: In patients with acute tendinous mallet finger, percutaneous IM Kirschner wire DIP joint transfixation provides superior extension control and higher functional success rates compared with conservative treatment. Although pin configuration does not significantly influence functional outcomes, it affects patient comfort and the complication profile. Treatment decisions should therefore be individualized based on patient compliance and functional expectations.

Keywords: Acute tendinous mallet finger; distal interphalangeal joint; intramedullary Kirschner wire; distal interphalangeal (DIP) joint transfixation; conservative treatment; percutaneous pinning.

INTRODUCTION

Mallet finger (MF) is a common hand injury characterized by loss of active extension at the distal interphalangeal (DIP) joint, resulting from either rupture of the terminal extensor tendon or an avulsion fracture at the dorsal base of the distal phalanx (Fig. 1).[1] Although MF injuries are frequently encountered in patients presenting to emergency depart-

Cite this article as: Kaya O, Malkoç F, Ümit M, Kazez M. Conservative treatment versus percutaneous intramedullary pinning for acute tendinous mallet finger: does pin configuration matter? Ulus Travma Acil Cerrahi Derg 2026;32:702-714.

Address for correspondence: Muhammed Kazez

Department of Orthopedics and Traumatology, Elazığ Fethi Sekin City Hospital, Elazığ, Türkiye

E-mail: mkzz23@hotmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(6):702-714 DOI: 10.14744/tjtes.2026.18598

Submitted: 24.01.2026 Revised: 10.03.2026 Accepted: 16.03.2026 Published: 03.06.2026

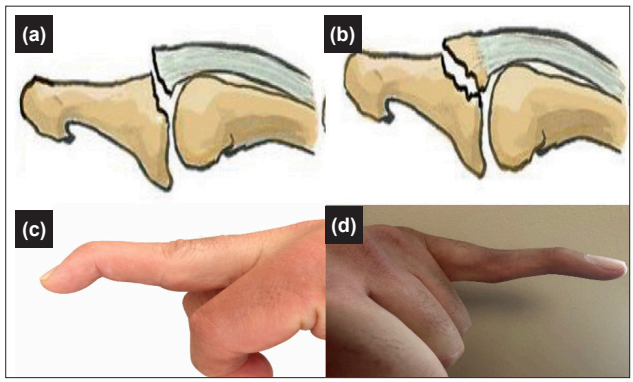

Figure 1. Spectrum of mallet finger pathology. **(a)** Schematic illustration of tendinous mallet finger caused by rupture of the terminal extensor tendon. **(b)** Bony mallet finger resulting from a dorsal avulsion fracture of the distal phalanx. **(c)** Clinical appearance of acute mallet finger demonstrating loss of active extension at the distal interphalangeal joint. **(d)** Swan-neck deformity developing as a late complication of untreated or inadequately treated mallet finger.

ments with acute hand trauma, they may be underestimated as minor injuries or overlooked in the absence of appropriate radiographic evaluation.[2] Failure to establish an early diagnosis and initiate appropriate treatment may lead to persistent extension lag, cosmetic deformity, and late complications such as swan-neck deformity (Fig. 1), potentially necessitating more complex surgical interventions for an otherwise manageable condition.[1,2]

Mallet finger injuries encompass a broad clinical spectrum according to the Doyle classification, ranging from isolated soft-tissue injuries to complex lesions involving large bony fragments with DIP joint subluxation.[3] Tendinous MF (Doyle type I), which involves isolated injury to the terminal extensor tendon without an associated fracture, is the most commonly encountered form in clinical practice.[3] The mechanism of injury is typically related to low-energy trauma and most often results from sudden passive hyperflexion or hyperextension of the extended fingertip following axial loading during daily activities.[4] Although sports-related injuries are more common in younger individuals, population-based studies indicate that household activities account for a substantial proportion of cases, particularly among middle-aged and elderly patients.[4,5]

The primary goal in the management of tendinous MF is accurate recognition in the acute phase and prompt initiation of appropriate treatment. The fundamental principle of treatment is continuous immobilization of the DIP joint in full extension to facilitate optimal healing of the terminal extensor mechanism.[6] Accordingly, conservative treatment is generally considered the first-line approach for acute Doyle type I injuries, and various extension splints are widely used.[6] However, the success of conservative treatment is highly dependent on patient compliance and the ability of the splint to maintain uninterrupted DIP joint extension.[6,7] Even brief episodes of DIP joint flexion during treatment may disrupt tendon healing and lead to treatment failure or the need for surgical intervention.[6,7] Furthermore, the requirement for prolonged immobilization, typically lasting 6–8 weeks, may reduce patient tolerance and negatively affect treatment adherence in routine clinical practice.[6]

In clinical practice, aluminum splints, classic Stack splints, and tape-reinforced Stack splints designed to enhance stability (Fig. 2) are commonly used; however, there is no clear consensus regarding the superiority of any specific splint type in terms of functional outcomes.[8,9] Current evidence suggests that patient compliance, rather than splint type, is the primary determinant of successful conservative treatment.[6]

In cases where conservative treatment cannot be maintained, or in patients with high functional demands, surgical treatment options may be considered. Fixation of the DIP joint in full extension using a Kirschner wire (K-wire) is a minimally invasive surgical technique that provides stable immobilization independent of patient compliance.[10] Compared with

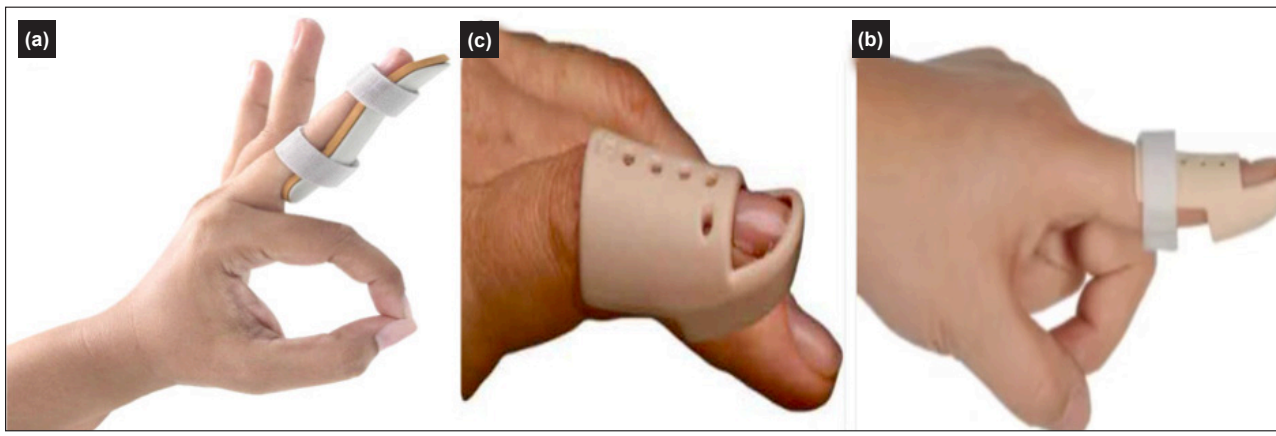

Figure 2. Splinting methods used in conservative treatment. **(a)** Aluminum finger splint used for immobilization of the distal interphalangeal (DIP) joint in full extension. **(b)** Classic Stack splint applied to maintain continuous DIP joint extension. **(c)** Tape-reinforced Stack splint designed to enhance stability and improve patient compliance during conservative treatment.

open tendon repair techniques, percutaneous intramedullary (IM) pinning offers the advantages of minimal soft tissue disruption and relatively low surgical morbidity.[11] However, evidence directly comparing different percutaneous pin configurations, particularly exposed versus buried IM pinning, in patients with acute tendinous MF remains limited.[11]

The aim of this study was to compare conservative and surgical treatment methods in patients with acute Doyle type I tendinous MF and to evaluate the impact of different pin configurations used during percutaneous IM pinning on clinical outcomes. We hypothesized that surgical treatment would provide superior functional outcomes compared with conservative management and that pin configuration may influence patient comfort and complication profiles.

MATERIALS AND METHODS

Study Design and Ethical Approval

This retrospective observational cohort study was conducted at a tertiary-level trauma center. The study protocol was approved by the local institutional ethics committee (session date: October 16, 2025; approval number: 2025/17-07). All procedures were performed in accordance with the ethical principles of the Declaration of Helsinki.

Patient Selection

Patients presenting to the emergency department or orthopedic outpatient clinic with hand trauma between January 2022 and January 2025 and diagnosed with acute tendinous MF were retrospectively reviewed. The diagnosis was established based on clinical examination and standard anteroposterior and lateral radiographs of the hand to exclude associated osseous pathology. To ensure a homogeneous acute-phase cohort, only patients presenting within 7 days of injury were included.

Inclusion Criteria

Patients meeting all of the following criteria were included:

- Age ≥18 years
- Diagnosis of acute tendinous MF
- Presentation within 7 days of injury
- Absence of bony avulsion or articular surface–involving fracture of the distal phalanx
- Completion of treatment according to the initially selected treatment modality
- Availability of clinical follow-up data for at least 12 months.

Exclusion Criteria

Patients were excluded if any of the following criteria were present:

- Open injuries
- Bony avulsion involving the articular surface of the distal phalanx or other associated fractures
- Concomitant tendon or bone injuries involving the same finger
- Previous trauma or surgery affecting the same finger with residual functional impairment
- Noncompliance with conservative treatment requiring a change in treatment modality
- Incomplete clinical follow-up data.

Treatment Decision Process and Group Allocation

The treatment modality was determined after all patients received standardized information regarding both conservative and surgical options. During the decision-making process, injury characteristics, the patient's clinical status, functional expectations, motivation, and occupational requirements were taken into account. All patients were evaluated using a standardized clinical decision-making algorithm.

Surgical treatment was primarily considered for patients in whom adherence to prolonged splint use was expected to be poor, those requiring early functional recovery, or individuals for whom uninterrupted immobilization was impractical due to occupational demands. Importantly, treatment selection was not based solely on patient preference; surgical intervention was performed only when deemed clinically appropriate and was confirmed by the responsible orthopedic and traumatology specialist.

After treatment initiation, patients were categorized into three groups according to the modality applied:

Group 1: Conservative treatment with a tape-reinforced Stack splint

Group 2: Percutaneous IM K-wire DIP transfixation with the pin left exposed

Group 3: IM K-wire transfixation with the pin buried within the fingertip pulp.

In a subset of patients initially managed conservatively, protocol deviations occurred during follow-up. These included delayed presentation beyond the acute phase, noncompliance with splint use (e.g., intermittent use, premature discontinuation, or unintended finger flexion during splint care), inadequate stabilization resulting from the use of splint types other than the tape-reinforced Stack splint, or conversion to surgical treatment for clinical indications.

To preserve treatment homogeneity in intergroup comparisons, these patients were excluded from the primary comparative analysis and classified as a separate subgroup representing conservative treatment failure (Group 4). Data from this subgroup were analyzed descriptively only.

Radiographic Evaluation

At baseline, all patients underwent radiographic evaluation to exclude osseous pathology and associated avulsion fractures. Standard anteroposterior (AP) and true lateral radiographs (isolated lateral view of the affected finger) were obtained for

the involved digit (Fig. 3). To avoid misinterpretation due to superposition, all images were assessed with specific focus on the target finger.

As only tendinous MF cases were included in the study and intraoperative fluoroscopic confirmation was performed during percutaneous IM K-wire transfixation in the surgical groups, routine postoperative radiographic follow-up was not conducted. Instead, patients were evaluated clinically during follow-up, with emphasis on functional outcomes, wound status, pin-related complications, and maintenance of DIP joint extension.

Preoperative Extension Lag Assessment

Active DIP joint extension lag was assessed clinically using a standard goniometer placed over the dorsal aspect of the joint, while the proximal interphalangeal (PIP) joint was maintained in a neutral position. All measurements were performed according to a standardized protocol by experienced orthopedic surgeons (Fig. 3).

Clinical Evaluation and Outcome Measures

All patients were followed through routine clinical visits during the follow-up period, and outcome measures were assessed at the final follow-up using a standardized clinical examination protocol. Only patients with a minimum follow-up duration of 12 months were included in the analysis. This time point was selected as it represents a reliable stage at which tendinous healing is complete, residual extension lag has stabilized, and functional outcomes can be consistently evaluated.

Primary Outcome Measure

• Active DIP joint extension lag, measured in degrees at the final follow-up visit.

Secondary Outcome Measures

• Functional outcomes at final follow-up assessed according to the Crawford classification criteria

• Treatment-related complications, including:

o Skin maceration

o Nail deformity

o Pin-site irritation

o Superficial or deep infection

o Permanent extension lag

o Swan-neck deformity.

All clinical evaluations were performed by orthopedic and traumatology specialists experienced in hand surgery, using a standardized measurement protocol to ensure consistency across assessments.

Conservative Treatment Protocol

Conservative treatment was applied to patients with acute tendinous MF who were either not considered suitable candidates for surgery or preferred nonoperative management (Group 1). The primary goal of conservative management was continuous immobilization of the DIP joint in full extension to facilitate healing of the terminal extensor tendon at an appropriate length and tension.

A tape-reinforced Stack splint was used in all conservatively treated patients (Fig. 4). The splint was applied to maintain the DIP joint in full extension while allowing free motion of the PIP joint. The tape-reinforced Stack splint was preferred over conventional Stack or aluminum splints due to its improved stability and lower risk of displacement during daily activities.

Patients were instructed to wear the splint continuously for at least 8 weeks, 24 hours per day. Emphasis was placed on the importance of uninterrupted immobilization, as even brief removal of the splint or unintended DIP joint flexion could

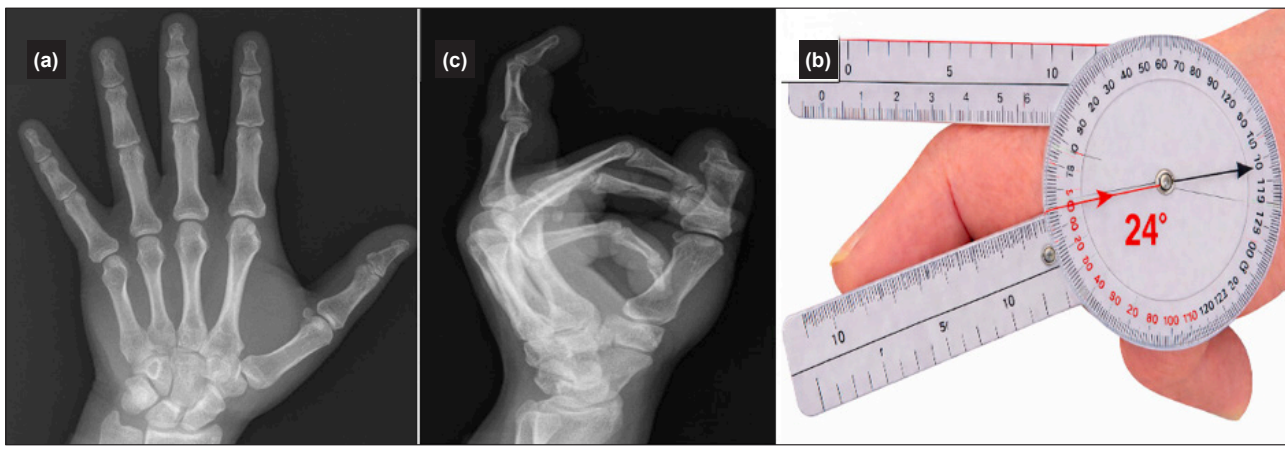

Figure 3. Baseline radiographic and clinical assessment of acute tendinous mallet finger. **(a)** Standard anteroposterior radiograph of the affected digit obtained at initial presentation to exclude bony injury and avulsion fractures. **(b)** True lateral radiograph confirming the absence of osseous pathology and isolated tendinous involvement. ©Standardized clinical measurement of active distal interphalangeal (DIP) joint extension lag using a goniometer from the dorsal aspect, with the proximal interphalangeal (PIP) joint maintained in neutral position.

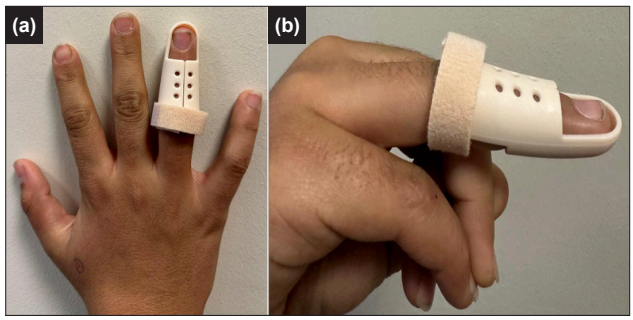

Figure 4. Conservative treatment using a tape-reinforced Stack splint. **(a,b)** Clinical views of Group 1 patients treated with a tape-reinforced Stack splint for continuous immobilization of the distal interphalangeal (DIP) joint in full extension.

compromise tendon healing. Patients were educated on techniques to prevent DIP flexion during necessary splint removal and received detailed instructions regarding splint care, skin hygiene, and early recognition of skin-related complications.

During the conservative treatment period, patients attended regular outpatient follow-up visits. At each visit, splint positioning, skin integrity, the presence of maceration or irritation, and patient compliance were systematically assessed. Skin maceration and splint-related irritation were recognized as common limitations of conservative treatment.

Surgical Techniques

Surgical treatment was performed in patients with acute tendinous MF who were not considered suitable candidates for conservative management or who preferred surgical intervention. Percutaneous IM K-wire DIP joint transfixation was used as the surgical technique in all cases.

All procedures were performed in the operating room without the use of a tourniquet and under digital block anesthesia using 2 mL of prilocaine hydrochloride. A single prophylactic intravenous dose of 1 g cefazolin was administered preoperatively, and no routine postoperative antibiotic therapy was prescribed.

The primary objective of surgery was to achieve stable fixation of the DIP joint in full extension and to facilitate optimal healing of the terminal extensor mechanism. A 1.0-mm IM K-wire was used in all surgically treated cases. Hyperextension was intentionally avoided to reduce the risk of dorsal skin compromise and related complications.

IM K-Wire DIP Transfixation Technique

With the patient in the supine position, the affected finger was prepared and draped in a sterile fashion. The DIP joint was manually positioned in full extension and maintained throughout the procedure. A 1.0-mm K-wire was inserted from the distal tip of the distal phalanx, approximately 2 mm distal to the nail plate, and advanced proximally through the IM canal of the distal phalanx into the middle phalanx, thereby stabilizing the DIP joint in extension. Proper wire placement and joint alignment were confirmed intraoperatively using fluoroscopy.

Pin Configuration and Surgical Subgroups

Surgically treated patients were further divided into two subgroups based on the configuration of the distal end of the IM K-wire used for DIP joint transfixation.

Group 2: IM K-Wire DIP Transfixation with the Pin Left Exposed

In this group, the distal end of the K-wire was left external to the skin. The exposed portion of the wire was bent to maintain stability and protected with a sterile dressing (Fig. 5). Postoperatively, patients received standardized instructions regarding pin-site care and dressing changes.

The main advantage of this technique is the ease of pin removal under outpatient clinic conditions without the need for an additional surgical procedure. However, leaving the pin exposed may be associated with disadvantages such as pin-site irritation or superficial infection, the need for regular dressing changes, and discomfort due to snagging during daily activities. Therefore, all patients received detailed education regarding pin-site care and hygiene.

Group 3: IM K-Wire DIP Transfixation with the Pin Buried within the Fingertip Pulp

In this group, the distal end of the IM K-wire was bent and embedded within the fingertip pulp of the distal phalanx. The K-wire length ensured adequate retention for possible subsequent removal. After trimming to the appropriate length, the wire was inserted subcutaneously through a minimal skin incision (Fig. 5), thereby eliminating contact between the pin and the external environment. Suturing was not required due to the small size of the incision.

This technique was employed to reduce pin-site irritation, eliminate the need for routine dressing changes, prevent discomfort from snagging during daily activities, and facilitate an earlier return to daily and occupational functions.

Postoperative Care and Rehabilitation

In both surgical groups, no additional external splint was applied postoperatively, as the DIP joint was stably fixed using IM K-wire for DIP transfixation. Patients were advised to avoid active DIP joint motion during the early postoperative period; however, early free motion of the PIP and metacarpophalangeal joints was permitted. During follow-up visits, pin stability, wound condition, and potential complications were assessed using a standardized clinical examination protocol.

In the group with the pin left exposed, patients received standardized instructions regarding pin-site care and dressing changes. In contrast, patients with pins embedded within the fingertip pulp were followed clinically without the need for routine dressing changes, as the minimal incision typically healed rapidly.

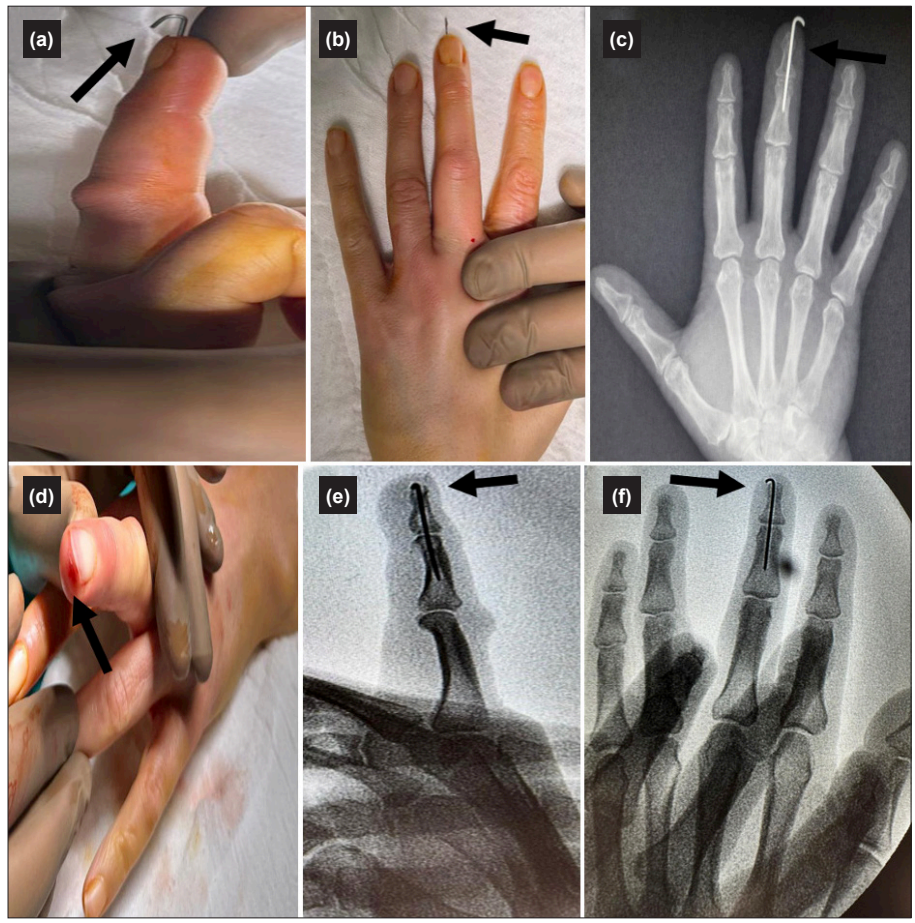

Figure 5. Percutaneous intramedullary (IM) pinning techniques and pin configurations. **(a)** Lateral clinical view after percutaneous pinning with the K-wire left exposed (Group 2). **(b)** Anteroposterior clinical view with arrows indicating the exposed distal end of the K-wire. **(c)** Anteroposterior radiograph demonstrating IM fixation with an exposed pin configuration. **(d)** Clinical photograph showing a minimal pulp incision in a patient treated with a buried pin configuration (Group 3). **(e)** Lateral radiograph demonstrating IM pinning with the distal end buried within the pulp. **(f)** Anteroposterior radiograph showing stable IM fixation with a buried pin configuration.

IM K-wires were routinely removed under outpatient conditions at approximately 6 weeks postoperatively, based on clinical healing and functional recovery. Following pin removal, no additional immobilization was applied, and patients were encouraged to gradually resume daily activities within pain tolerance.

However, activities placing excessive stress on the DIP joint, including forceful gripping, heavy lifting, repetitive flexion, and trauma-prone activities, were restricted for approximately 2 weeks after pin removal. Hand exercises, as well as return to occupational and sporting activities, were gradually permitted according to clinical recovery and functional status, with supervised rehabilitation provided when necessary.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows (IBM Corp., Armonk, NY, USA). The distribution of continuous variables was assessed using the Shapiro–Wilk test and visual inspection methods, including histograms and Q–Q plots. Continuous variables that were not normally distributed are presented as median and interquartile range (IQR), whereas categorical variables are expressed as counts and percentages (%).

Comparisons among the three treatment groups (conservative treatment with a tape-reinforced MF splint, IM K-wire DIP transfixation with the pin left exposed, and IM K-wire DIP transfixation with the pin buried within the fingertip pulp) were performed using the Kruskal–Wallis test for continuous variables. When a statistically significant difference was detected, pairwise comparisons were conducted using Dunn–Bonferroni corrected post hoc analyses.

Functional outcomes were evaluated according to the Crawford criteria using both multicategorical (excellent/good/fair/poor) and dichotomous classifications to enhance clinical interpretability (successful: excellent + good; unsuccessful: fair

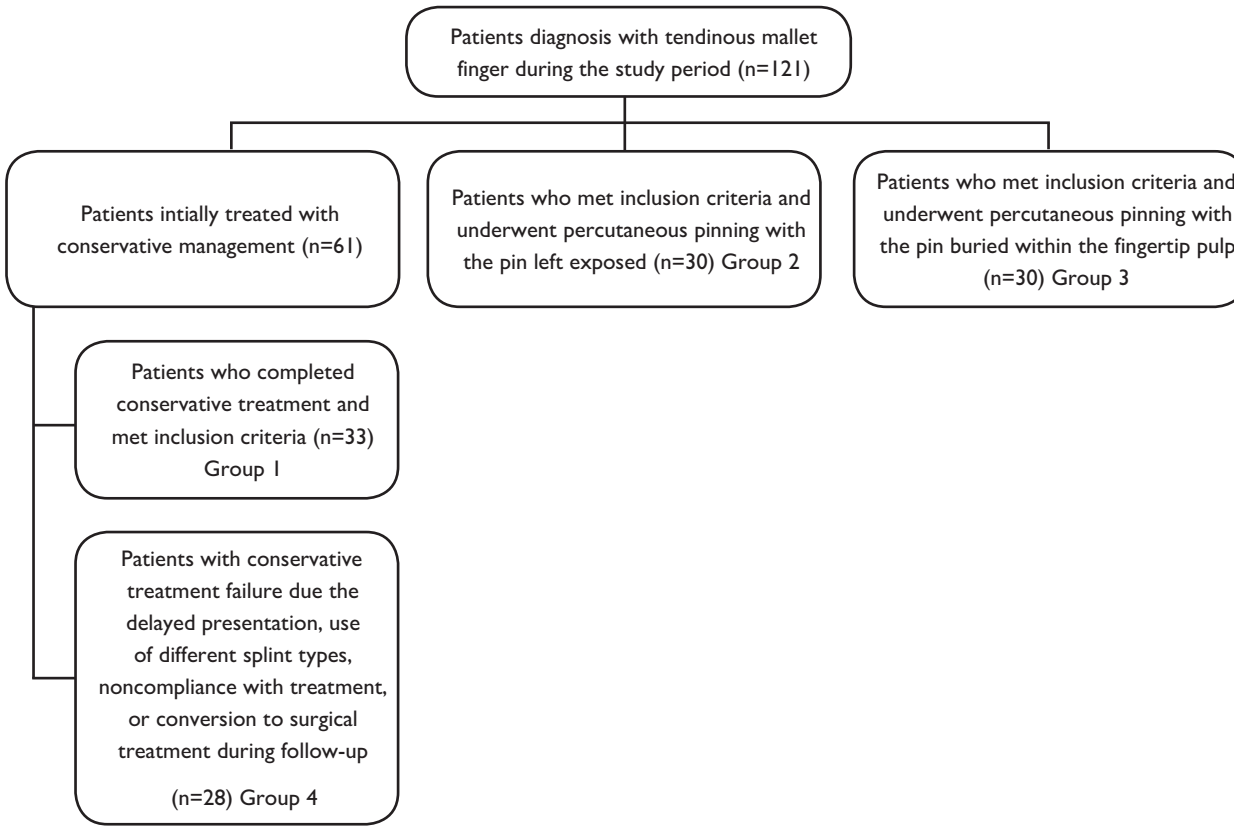

Figure 6. Study flow diagram. Flowchart illustrating patient selection, application of inclusion and exclusion criteria, and allocation into treatment groups. Of 121 patients diagnosed with tendinous mallet finger, 93 met the inclusion criteria and were included in the comparative analysis. Patients with failed conservative treatment were excluded from intergroup comparison and are reported as a separate descriptive subgroup (Group 4).

+ poor). Due to low expected cell counts in some categories, categorical variables were compared between groups using the Fisher–Freeman–Halton exact test, and exact p values were reported.

Residual DIP joint extension lag was compared among groups and further analyzed in relation to Crawford functional outcomes using Spearman's correlation analysis.

For all statistical tests, a p value <0.05 was considered statistically significant.

RESULTS

Patient Flow and Study Population

During the study period, a total of 121 patients who presented to the emergency department or orthopedic outpatient clinic with acute hand trauma and were diagnosed with tendinous MF were retrospectively evaluated. After applying the inclusion and exclusion criteria, 93 patients constituted the final study population and were allocated into three groups according to the treatment modality:

• **Group 1:** Conservative treatment with a tape-reinforced Stack splint (n=33)

• **Group 2:** IM K-wire DIP transfixation with the pin left exposed (n=30)

• **Group 3:** IM K-wire DIP transfixation with the pin buried within the fingertip pulp (n=30).

A post hoc power analysis indicated that a sample size of 93 patients provided 85% statistical power to detect differences in the primary outcome (Kruskal–Wallis test; α=0.05, effect size f=0.35).

Of the 61 patients initially assigned to conservative treatment, 28 (45.9%) experienced conservative treatment failure due to protocol deviations or noncompliance. To preserve intergroup homogeneity, these patients were excluded from the comparative analyses and evaluated separately as a descriptive subgroup (Group 4).

The patient selection process, application of inclusion and exclusion criteria, and distribution of patients across treatment groups are illustrated in Figure 6.

Demographic and Clinical Characteristics

The median age of the 93 patients included in the study was 44 years (IQR: 36–52). Thirteen patients (14.0%) were male and 80 (86.0%) were female. The fourth finger was the most

Table 1. Demographic and baseline clinical characteristics of the treatment groups

Characteristic	Group 1 (n=33)	Group 2 (n=30)	Group 3 (n=30)	p value
Age (years), mean±SD	43.6±10.9	44.2±11.5	44.1±11.2	p=0.91
Female sex, n (%)	28 (84.8)	26 (86.7)	25 (83.3)	p=0.88
Male sex, n (%)	5 (15.2)	4 (13.3)	5 (16.7)	
Affected finger n (%)				
Fourth finger	16 (48.5)	14 (46.7)	15 (50.0)	
Third finger	9 (27.3)	8 (26.7)	10 (33.3)	p=0.74
Second finger	5 (15.2)	5 (16.7)	4 (13.3)	
Fifth finger	3 (9.0)	3 (10.0)	1 (3.3)	
Dominant hand in-volvement, n (%)	23 (69.7)	21 (70.0)	22 (73.3)	p=0.80
Injury mechanism, n (%)				
Daily activities	26 (78.8)	22 (73.3)	21 (70.0)	p=0.57
Sports-related injury	7 (21.2)	8 (26.7)	9 (30.0)	
Time to presentation (days), mean±SD	3.1±1.5	2.9±1.3	3.0±1.4	p=0.83

frequently affected digit, followed by the third, second, and fifth fingers. Injuries involved the dominant hand in approximately two-thirds of cases. The fourth finger was the most commonly affected digit across all groups, with no significant intergroup difference (p=0.74).

Most injuries resulted from low-energy trauma during daily activities, whereas sports-related injuries were more common in younger patients. The median time from injury to presentation was 3 days (IQR: 2–4).

No statistically significant differences were observed among the treatment groups with respect to age, sex, affected finger distribution, dominant hand involvement, injury mechanism, or time to presentation (all p>0.05) (Table 1).

Pre- and Post-Treatment Clinical Findings

At baseline, active DIP joint extension lag ranged from 20° to 35°, with a median of 30° for the entire cohort. No statistically significant difference was observed among the treatment groups in terms of pre-treatment extension lag (p=0.801).

At final follow-up, residual DIP joint extension lag ranged from 0° to 19°. The median residual extension lag was 4° in Group 1, 0.5° in Group 2, and 1° in Group 3.

Intergroup comparison demonstrated a statistically significant difference in residual extension lag at final follow-up (Kruskal–Wallis test, p<0.001). Post hoc analysis revealed that patients treated conservatively had significantly greater residual extension lag compared with both surgical groups (Bonferroni-adjusted p<0.05). No statistically significant difference was observed between the two surgical groups (p>0.05).

These findings indicate that surgical stabilization provides superior correction of extension lag compared with conservative treatment in patients presenting in the acute phase (Table 2).

Functional Outcomes – Crawford Evaluation

Functional outcomes were assessed at final follow-up using the Crawford criteria. Excellent results were observed

Table 2. Comparison of clinical outcomes among treatment groups

Parameter	Group 1 (n=33)	Group 2 (n=30)	Group 3 (n=30)	p value (between groups)	Statistical test
Pre-treatment					
DIP extension lag (°), median (IQR)	30 (20–35)	30 (22–35)	30 (23–35)	p=0.801	Kruskal-Wallis
Final follow-up DIP extension lag (°), median (IQR)	10 (5–15)	5 (0–10)	4 (0–8)	<0.001	Kruskal-Wallis
Pre- to post-treatment change (°), median	20	25	26	<0.001	Wilcoxon signed-rank
Final DIP joint flexion (°), mean±SD	50±5	45±6	45±5	p=0.28	Kruskal-Wallis

Table 3. Functional outcomes according to Crawford criteria and residual extension lag

Variable	Group 1 (n=33)	Group 2 (n=30)	Group 3 (n=30)	p value
Crawford grade†				0.095*
Excellent	3 (9.1)	8 (26.7)	8 (26.7)	
Good	20 (60.6)	20 (66.7)	20 (66.7)	
Fair	10 (30.3)	2 (6.6)	2 (6.6)	
Poor	0 (0.0)	0 (0.0)	0 (0.0)	
Successful outcome (excellent + good)†	23 (69.7)	28 (93.4)	28 (93.4)	0.012*
Unsuccessful outcome (fair + poor)†	10 (30.3)	2 (6.6)	2 (6.6)	
Post-treatment DIP extension lag (°)‡	10.0 (5.0–15.0)	5.0 (0.0–10.0)	4.0 (0.0–8.0)	<0.001**

Data are presented as n (%) or median (interquartile range). †Fisher–Freeman–Halton exact test; ‡Kruskal–Wallis test; *Exact p value; **Highly statistically significant at p<0.001.

in 19 patients (20.4%), good results in 60 patients (64.5%), and fair results in 14 patients (15.1%); no patients had poor outcomes. Overall, the rate of excellent and good outcomes was 84.9%.

When functional outcomes were compared among treatment groups, the surgical groups (Groups 2 and 3) demonstrated higher rates of excellent and good outcomes compared with the conservative group, whereas fair outcomes were more common in the conservative group. However, analysis using the Fisher–Freeman–Halton exact test, accounting for the multicategorical structure of the Crawford classification, revealed no statistically significant difference in the distribution of Crawford grades among groups (p=0.095).

To improve clinical interpretability, Crawford outcomes were further analyzed using a dichotomous classification (successful outcome: excellent + good; unsuccessful outcome: fair + poor). Based on this analysis, the rate of successful outcomes was significantly higher in the surgically treated groups compared with the conservative group (Fisher's exact test, p=0.014).

Functional outcomes according to the Crawford criteria were consistent with residual extension lag measured at final follow-up, with better functional results associated with lower residual extension lag values (Table 3).

Complications and Treatment-Related Adverse Events

Complications and treatment-related adverse events were analyzed separately for each group. No major complications, including deep infection, permanent flexion contracture (>25°), nail bed deformity, or the need for secondary surgical intervention, were observed in any patient.

In the conservative treatment group, minor adverse events related to prolonged splint use were more frequent. Skin maceration or local irritation was observed in eight patients (24.2%), which was significantly higher than in the surgical groups (p<0.001). In addition, 6 patients (18.2%) reported treatment dissatisfaction related to splint care requirements, limitations in daily activities, and delayed return to work.

In the surgical group with exposed K-wires, minor complications associated with external pin contact were predominant. Four patients (13.3%) experienced pin-site irritation and discomfort due to pin snagging during daily activities, which was significantly more frequent compared with the buried pin group (p=0.006). Superficial pin-site infection occurred in two patients (6.7%), all of whom were successfully managed with local wound care and a short course of oral antibiotics. No statistically significant difference was observed between groups (p=0.13). Overall, four patients in this group reported treatment dissatisfaction related to pin-associated discomfort.

In the buried K-wire group, no pin-site irritation or infection was observed due to the absence of external pin exposure. However, two patients (6.7%) experienced transient pulp tenderness related to the buried distal wire tip, which resolved without additional intervention. Apart from short-term sensitivity at the site of the small pulp incision during pin removal, no further complications were recorded. No patient in this group reported treatment-related dissatisfaction (Table 4).

Analysis of Patients with Failed Conservative Treatment (Group 4)

During the study period, 61 patients were initially managed with conservative treatment. Of these, 28 patients (45%) were excluded from the primary comparative analysis due to protocol deviations or conservative treatment failure.

Among these 28 patients, eight underwent delayed surgical intervention after the first week following injury due to unsuccessful conservative management. In an additional 10 patients, surgical treatment was recommended because of

Table 4. Complications according to treatment groups

Parameter	Group 1 (n=33)	Group 2 (n=30)	Group 3 (n=30)	Total (n=93)	p-value
Skin maceration	8 (24.2%)	0	0	8 (8.6%)	p<0.001
Pin-related irritation	0	4 (13.3%)	0	4 (4.3%)	p=0.006
Pulp tenderness	0	0	2 (6.6%)	2 (2.1%)	p=0.13
Superficial infection	0	2 (6.7%)	0	2 (2.1%)	p=0.13
Treatment dissatisfac-tion*	6 (18.2%)	4 (13.3%)	0	10 (10.7%)	—

Categorical variables were compared using Fisher's exact test. *Due to its subjective nature, treatment dissatisfaction was reported descriptively and was not included in statistical comparisons.

inadequate clinical response; however, surgery was declined due to low functional demands or patient preference.

Noncompliance with splint use was identified as a major contributing factor in a substantial proportion of excluded patients. Specifically, 15 patients failed to maintain continuous splint use as recommended; intermittent removal of the splint, unintended finger flexion, and inadequate protection during daily activities were documented. Furthermore, 14 patients used splint types other than the tape-reinforced Stack splint. These alternative splints were considered less stable and more difficult to monitor clinically, which may have adversely affected treatment outcomes. In several cases, more than one of these factors was present concurrently.

DISCUSSION

One notable aspect of the present study is the evaluation of clinical outcomes associated with a percutaneous IM pinning configuration in which the distal end of the K-wire is buried within the fingertip pulp in patients with acute tendinous MF. Although various surgical techniques, including open tendon repair, extension-block pinning, and percutaneous K-wire stabilization, have been described in the literature for the management of mallet finger injuries, the optimal treatment strategy for isolated acute tendinous mallet finger remains a matter of debate.[12-16] The present study therefore contributes to the existing literature by comparing conservative and surgical treatment approaches while also examining the potential impact of pin configuration within minimally invasive surgical management.

Another key finding of this study is that surgical stabilization using percutaneous pinning resulted in significantly lower residual distal interphalangeal joint extension lag and superior functional outcomes compared with conservative treatment. In contrast, no significant difference in residual extension loss was observed between the two surgical groups based on pin configuration (exposed versus buried). These findings suggest that stable fixation of the distal interphalangeal joint is the primary determinant of tendon healing and functional recovery, whereas pin configuration appears to influence patient comfort and the complication profile rather than extension lag outcomes.

The demographic characteristics of the patient cohort in the present study are consistent with the typical patient profile reported in the literature for acute tendinous MF.[4] Previous studies have shown that MF injuries most commonly occur following low-energy trauma during daily activities and are more frequently observed in middle-aged and elderly individuals.[4,5] Rubin et al.[4] emphasized that tendinous MF injuries generally occur in older patients and are predominantly associated with low-energy injury mechanisms. Similarly, Botero et al.[5] reported in their comprehensive review that low-energy domestic trauma represents a common etiological factor in tendinous MF injuries.

The patient distribution in our study aligns with these observations and reflects a clinically homogeneous population with acute tendinous MF in terms of injury mechanism and presentation. Moreover, the absence of a statistically significant difference in pre-treatment distal interphalangeal joint extension lag among the treatment groups indicates that the groups were comparable in baseline clinical severity. In the literature, initial extension lag in acute tendinous MF is typically reported to range between 20° and 35°.[10] In the study by Nagura et al.,[10] similar baseline extension lag values were observed in both surgical and conservative groups, consistent with the pre-treatment findings of the present study.

Taken together, these observations support the interpretation that the post-treatment outcomes in our cohort are primarily attributable to the treatment modality rather than differences in baseline injury severity.

In the study by Renfree et al.,[17] conservative treatment and percutaneous pinning techniques were compared, and the authors reported superior correction of extension lag in the surgical group; however, distal interphalangeal joint flexion was slightly reduced compared with the conservative group. In the present study, a homogeneous cohort of patients presenting in the acute phase with tendinous MF was evaluated. Consistent with previous findings, better extension control

was achieved in the surgically treated groups, whereas a mild reduction in flexion was observed compared with the conservative group (mean DIP flexion: 50° in the conservative group vs. 45° in both surgical groups). However, this difference did not reach statistical significance (p=0.28) (Table 2). Previous comparative studies have similarly shown that surgical pinning does not meaningfully compromise DIP joint flexion or overall functional outcomes.[10,17] The slight reduction in DIP joint flexion observed in surgically treated patients may be attributable to temporary joint immobilization and periarticular stiffness associated with distal interphalangeal joint transfixation.

From the perspective of patient satisfaction, Renfree et al.[17] reported that 93% of patients in the conservative group and 100% in the surgical group would choose the same treatment again. In our cohort, this rate was 81.8% in the conservative treatment group, 86.7% in the exposed pin group, and 100% in the buried pin group. These findings suggest that the buried pin configuration may enhance patient comfort and treatment acceptability, thereby improving overall satisfaction with surgical management. Patient satisfaction was assessed at the final follow-up visit through a non-standardized clinical interview, and treatment dissatisfaction was recorded descriptively, as summarized in Table 4.

Conservative treatment has long been recommended as the first-line management for patients with acute tendinous MF. However, its success is highly dependent on patient compliance, uninterrupted splint use, and appropriate splint selection. In the Cochrane review by Handoll et al.,[6] no clear functional superiority was demonstrated among different splint types; however, patient adherence was identified as the key determinant of successful treatment outcomes. Similarly, Botero et al.[5] reported that although conservative treatment is theoretically effective, failure rates increase substantially in routine clinical practice when adequate compliance cannot be maintained.

In the present study, modification of the initial treatment strategy was required in 45% of patients initially managed conservatively, either due to failure of conservative treatment or conversion to surgical intervention. This finding reflects the compliance-related challenges highlighted in the literature and underscores their clinical relevance in real-world practice.[6,7] In particular, intermittent splint use, use of splint types other than tape-reinforced Stack splints, and inadequate immobilization during daily activities were identified as key factors negatively affecting treatment success. Reported failure rates for conservative treatment vary across studies depending on the definition of failure, duration of follow-up, and level of patient compliance, with real-world series describing rates approaching 30%.[5,6] The relatively higher failure rate observed in our cohort (45%) may reflect stricter outcome definitions as well as real-world compliance challenges associated with prolonged splint immobilization. In our study, treatment failure also included protocol deviations and clinically significant residual extension lag, which may have contributed to the higher rate compared with previously reported series.

Insufficient patient education regarding the treatment process and the critical importance of continuous splint use may be a key contributor to conservative treatment failure. Limited awareness of the potential risk of permanent finger dysfunction associated with nonadherence may further compromise outcomes. In addition, based on our clinical observations, tape-reinforced Stack splints appear to provide more stable immobilization compared with aluminum or non-taped splint designs. However, in our cohort, the use of custom-made splints was not feasible due to cost constraints and limited availability.

In the study by Karadeniz et al.,[15] no statistically significant difference was observed between conservative treatment and K-wire pinning according to the Crawford criteria. This finding suggests that multicategorical functional scoring systems may have limited sensitivity in detecting clinically meaningful differences between treatment modalities. In particular, the four-level structure of the Crawford classification may reduce statistical power in comparative analyses. In contrast, dichotomization of the Crawford scale in the present study revealed a statistically significant advantage in favor of surgical treatment, highlighting a methodological approach that improves the clinical interpretability of functional assessment.

In the present study, only acute cases presenting within the first 7 days after injury were included and managed accordingly. A follow-up duration of 12 months was selected, as it is widely accepted in the literature as a reliable time frame for evaluating long-term functional outcomes in acute tendinous MF. Previous studies have frequently reported treatment outcomes in heterogeneous patient populations comprising both bony and tendinous MF injuries with variable presentation times, and early presentation has been associated with improved functional outcomes.[18] By exclusively including patients with acute tendinous MF, the present study established a homogeneous cohort, allowing a more precise evaluation of the effect of treatment modality on functional outcomes.

The lower residual extension lag observed in surgically treated patients likely reflects the mechanical advantage of stable DIP joint fixation during tendon healing. While conservative treatment relies on uninterrupted splint use to maintain joint stability, surgical stabilization with IM pinning preserves the extension position independently of patient compliance.[10]

Nagura et al.[10] reported that residual extension lag following conservative treatment is frequently associated with splint noncompliance and early flexion stress during the healing period, providing a plausible explanation for the greater extension lag observed in the conservative group in our cohort. Although numerous surgical techniques have been described for the management of bony MF injuries, there remains no clear consensus regarding the optimal treatment strategy for Doyle type I tendinous MF, which represents the most

common clinical presentation.[1,12] This lack of standardization may complicate treatment decision-making, particularly in patients presenting in the acute phase.

In the present study, no significant difference in residual extension lag was observed between buried and exposed pin configurations; however, notable differences were identified in patient comfort and complication profiles. Exposed pin fixation was more frequently associated with pin-site irritation, a catching sensation during daily activities, the need for regular dressing changes, and superficial infections.[10,15] In contrast, the buried pin technique minimized these issues. The principal advantage of buried pinning is the absence of an externally exposed pin tip, which improves patient comfort and may facilitate an earlier return to daily and occupational activities in selected patients.[10] Conversely, the requirement for a small pulp incision during pin removal may be considered a technique-specific drawback. In our cohort, this incision resulted only in transient tenderness without permanent complications, and all pin removal procedures were performed under outpatient conditions without the need for additional surgical intervention.

The majority of complications observed in this study were minor adverse events related to patient comfort rather than major clinical complications (Table 4). In the conservative treatment group, skin maceration and treatment dissatisfaction were primarily associated with prolonged splint use and limitations in daily activities. In the exposed pin group, irritation and superficial infections were attributable to external pin exposure. In contrast, the absence of pin-tract irritation or infection in the buried pin group further supports the potential advantages of this technique in terms of patient comfort and treatment tolerability. Importantly, none of the adverse events required additional surgical intervention, and all were successfully managed with conservative measures, indicating that all three treatment strategies are generally safe.

Future prospective randomized studies are warranted to confirm these findings and further clarify the optimal pin configuration for acute tendinous mallet finger. From a clinical perspective, the buried pin configuration may be preferable in patients for whom improved treatment comfort and reduced risk of pin-related irritation are priorities, whereas the exposed pin technique may remain a practical option when ease of outpatient removal and shorter procedural time are desired.

Limitations and Strengths

One of the main strengths of this study is the inclusion of only patients with isolated acute tendinous MF (Doyle type I), resulting in a clinically homogeneous study population. The absence of significant differences in baseline extension lag among treatment groups allows the observed outcomes to be more reliably attributed to the treatment modality. In addition, the separate evaluation of patients who initially underwent conservative treatment but later required surgical intervention reflects real-world clinical practice and enhances the interpretability of the findings.

Another strength of this study is the direct comparison of two different IM pin configurations within the surgical treatment group. The buried pin technique, for which clinical outcome data remain limited, was specifically evaluated in terms of patient comfort, complication profile, and functional outcomes. Furthermore, dichotomization of Crawford outcomes improved the clinical interpretability of functional assessment and enabled a more meaningful comparison between treatment strategies.

Nevertheless, several limitations should be acknowledged. The retrospective design and lack of randomization may have introduced treatment selection bias related to both patient and surgeon preferences. Although treatment selection was guided by a standardized clinical decision-making process, baseline functional expectations and motivation may have influenced the preference for surgical treatment in some patients, potentially introducing additional selection bias. The relatively small sample size may limit the detection of rare complications. In addition, long-term outcomes and patient-reported satisfaction beyond one year were not evaluated. The absence of routine postoperative radiographic follow-up may have limited the detection of asymptomatic wire migration or subtle joint penetration. However, the single-center design and use of standardized surgical and follow-up protocols strengthen the internal consistency of the results. Although pin configuration did not significantly influence extension outcomes, the buried pin technique was associated with improved patient comfort and fewer pin-related complications. These findings suggest that buried pinning may be particularly advantageous in active patients requiring better treatment tolerability and an earlier return to daily activities.

CONCLUSION

In patients with acute tendinous MF, surgical stabilization provides lower residual distal interphalangeal joint extension lag and more predictable functional outcomes compared with conservative treatment. Although pin configuration in IM pinning does not significantly influence extension outcomes, it has clinically relevant implications for patient comfort and complication profile. Percutaneous pinning with burial of the distal pin tip within the fingertip pulp offers improved patient comfort, fewer pin-related complications, and the potential for an earlier return to daily activities in selected patients. Treatment decisions should therefore be individualized based on clinical findings, expected patient compliance, and functional demands to optimize outcomes.

Ethics Committee Approval: This study was approved by the Elazığ Fethi Sekin City Hospital Non-Interventional Research Ethics Committee (Date: 16.10.2025, Decision No: 2025/17-07).

Peer-review: Externally peer-reviewed.

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

Informed Consent: 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*

Akut tendinöz çekiç parmakta konservatif tedavi ile perkütan intramedüller pinleme karşılaştırması: Pin konfigürasyonu önemli mi?

AMAÇ: Akut tendinöz çekiç parmak (Doyle tip I) olgularında tedavi genellikle distal interfalangeal (DIP) eklemin uzun süreli immobilizasyonuna dayanır; ancak tedavi başarısı büyük ölçüde hasta uyumuna bağlıdır. Perkütan intramedüller (IM) K-teli ile DIP eklem transfiksasyonu cerrahi bir alternatif olarak uygulanabilmekte, ancak farklı pin konfigürasyonlarının klinik sonuçlara etkisi net değildir. Bu çalışmada konservatif ve cerrahi tedavi yöntemleri karşılaştırılmış ve farklı pin konfigürasyonlarının klinik sonuçlara etkisi değerlendirilmiştir.

GEREÇ VE YÖNTEM: Bu retrospektif kohort çalışmaya, yaralanmadan sonraki ilk 7 gün içinde başvuran ve en az 12 ay süreyle takip edilen 93 erişkin akut tendinöz çekiç parmak hastası dahil edildi. Hastalar üç gruba ayrıldı: Bantlı Stack ateli ile konservatif tedavi (n=33), pinin dışarıda bırakıldığı perkütan IM K-teli ile DIP eklem transfiksasyonu (n=30) ve pinin parmak ucu pulpası içine gömülü bırakıldığı IM transfiksasyon (n=30). Primer sonlanım ölçütü son kontrolde ölçülen rezidüel DIP eklem ekstansiyon kaybıydı. Sekonder sonlanım ölçütleri Crawford kriterlerine göre fonksiyonel sonuçlar ve tedaviye bağlı komplikasyonlardı.

BULGULAR: Başlangıç DIP eklem ekstansiyon kaybı açısından gruplar arasında anlamlı fark saptanmadı (p=0.801). Son kontrolde rezidüel ekstansiyon kaybı konservatif tedavi grubunda anlamlı derecede daha yüksek bulunurken (medyan 4°), cerrahi gruplarda daha düşük değerler saptandı (0.5° ve 1°; p<0.001). Crawford kriterlerinin çok kategorili analizinde gruplar arasında anlamlı fark izlenmedi (p=0.095); ancak ikili analizde (mükemmel + iyi sonuçlar) cerrahi gruplarda başarı oranı konservatif tedaviye göre anlamlı derecede daha yüksekti (p=0.014). Konservatif tedavi grubunda cilt maserasyonu daha sık görülürken (p<0.001), pinle ilişkili irritasyon pinin dışarıda bırakıldığı grupta daha yüksek oranda izlendi (p=0.006). Gruplar arasında yüzeyel enfeksiyon açısından anlamlı fark saptanmadı.

SONUÇ: Akut tendinöz çekiç parmak olgularında perkütan IM K-teli ile DIP eklem transfiksasyonu, konservatif tedaviye kıyasla daha iyi ekstansiyon kontrolü ve daha yüksek fonksiyonel başarı oranları sağlamaktadır. Pin konfigürasyonu fonksiyonel sonuçları belirgin biçimde etkilememekle birlikte, hasta konforu ve komplikasyon profili üzerinde etkili olmaktadır. Tedavi seçimi hasta uyumu ve fonksiyonel beklentiler göz önünde bulundurularak bireyselleştirilmelidir.

Anahtar sözcükler: Akut tendinöz çekiç parmak; distal interfalangeal eklem; intramedüller K-teli; DIP transfiksasyonu; konservatif tedavi; perkütan pinleme.

Ulus Travma Acil Cerrahi Derg 2026;32(6):702-714 DOI: 10.14744/tjtes.2026.18598

ORIGINAL ARTICLE

Does double fluoroscopy reduce operative and radiation time in femoral neck fracture fixation?

Meliksah Uzakgider, Onur Süer, Recep Selçuk Eyceyurt, Mesut Tahta, Cemil Kayalı

Department of Orthopaedics and Traumatology, Izmir City Hospital, Izmir-*Türkiye*

ABSTRACT

BACKGROUND: This study aimed to evaluate the advantages of using double fluoroscopy during closed reduction and internal fixation of femoral neck fractures.

METHODS: In this prospective randomized study, 42 patients with femoral neck fractures treated between January 2021 and September 2022 were included. Patients were randomly assigned to one of two groups: double fluoroscopy (Group A, n=20) or single fluoroscopy (Group B, n=22). The groups were compared in terms of preparation time, operative time, preparatory radiation time, and intraoperative radiation time.

RESULTS: Baseline characteristics were comparable between the groups. There were no significant differences in age, sex, fracture side, fracture classification (Garden and Pauwels), mechanism of injury, anesthesia method, time to surgery, or duration of follow-up. The mean operative times were 73.1±7.25 minutes and 85.59±9.94 minutes for the double and single fluoroscopy groups, respectively ($p<0.001$). Total radiation times were 92.2±8.4 seconds and 113.27±18.1 seconds, respectively ($p<0.001$). Both operative and radiation times were significantly shorter in the double C-arm fluoroscopy group compared to the single C-arm fluoroscopy group.

CONCLUSION: The use of a double fluoroscopy technique was associated with a significant reduction in operative time and radiation exposure.

Keywords: Closed reduction; double C-arm; femoral neck fractures; fluoroscopy; internal fixation.

INTRODUCTION

The global incidence of hip fractures is increasing, largely driven by an aging population and the rising prevalence of osteoporosis. Current projections estimate that the number of hip fractures will reach 2.6 million by 2025 and may increase to 4.5 million by 2050.[1] The etiology of hip fractures demonstrates a bimodal distribution: the classic pattern of low-energy falls in osteoporotic elderly individuals and an emerging pattern of high-energy trauma leading to femoral neck fractures (FNF) in adults, typically aged 40–50 years.

Closed reduction and internal fixation (CRIF) is the preferred treatment modality for younger patients, as it preserves the joints and is relatively straightforward when performed under fluoroscopic (C-arm) guidance.[2,3] Internal fixation with cannulated screws exposes surgical teams to higher levels of radiation than most other orthopedic procedures. Consequently, prolonged exposure to elevated radiation levels may increase the risk of malignancy among orthopedic staff.[4]

Minimizing unnecessary radiation exposure during fluoroscopy is therefore essential. Single fluoroscopy is commonly used due to its availability and ease of operation. However, repeated repositioning to obtain anteroposterior (AP) and lateral (L) views may lead to workflow inefficiencies. The use of two fluoroscopy units in fixed positions could eliminate the need for intraoperative repositioning, potentially reducing both operative time and radiation exposure.

Cite this article as: Uzakgider M, Süer O, Eyceyurt S, Tahta M Kayalı C. Does double fluoroscopy reduce operative and radiation time in femoral neck fracture fixation? Ulus Travma Acil Cerrahi Derg 2026;32:715-721.

Address for correspondence: Meliksah Uzakgider

Department of Orthopaedics and Traumatology, Izmir City Hospital, Izmir, Türkiye

E-mail: meliksahu@gmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(6):715-721 DOI: 10.14744/tjtes.2026.72823

Submitted: 11.08.2025 Revised: 08.01.2026 Accepted: 16.01.2026 Published: 03.06.2026

This study presents the results of a trial comparing single versus double fluoroscopy for the placement of cannulated screws in the treatment of FNF. We hypothesize that double fluoroscopy results in shorter operative times and lower radiation exposure.

MATERIALS AND METHODS

Study Design and Patient Characteristics

This study was conducted between January 2021 and September 2022 and included patients who underwent closed reduction and internal fixation for femoral neck fractures at the Department of Orthopedic Surgery in our hospital. Ethical approval was obtained from the the Izmir Bozyaka Training and Research Hospital Medical Research Ethics Committee (Decision no : 2022/22, Date: 26.01.2022). Written informed consent was obtained from all participants, including consent for the use of their personal data. The study was conducted in accord-ance with the principles of the Declaration of Helsinki.

A total of 42 patients were enrolled and randomized into two treatment groups: Group A (n=20, mean age=51.1 years), treated using a double fluoroscopy technique, and Group B (n=22, mean age=47.64 years), treated using a single fluoroscopy technique. Randomization was performed using a sealed-envelope method with sequentially numbered, opaque envelopes prepared prior to enrollment to ensure allocation concealment. Patients with inflammatory rheumatic diseases, a history of prior hip surgery, multiple trauma, or age under 18 years were excluded from the study. Demographic and clinical characteristics were recorded, including age, sex, fracture side, fracture type (according to Garden and Pauwels classifications), mechanism of injury, anesthesia method, and time from injury to surgery (Table 1).

Table 1. Demographic and clinical characteristics of the study groups

	Group A (Double fluoroscopy)	Group B (Single fluoroscopy)	p
n	20	22	
Age (years)	51.1±11.7	47.64±13.9	0.3916
Sex, n (%)			
Female	8 (40)	8 (36.4)	0.8141
Male	12 (60)	14 (63.6)	
Side, n (%)			
Left	10 (50)	10 (45.4)	0.7750
Right	10 (50)	12 (54.6)	
Mechanism of injury, n (%)			
Motor vehicle accident	5 (25)	4 (18.2)	0.6013
Fall	15 (75)	18 (81.8)	
Garden classification, n (%)			
Type I	2 (10)	2 (9.1)	0.7301
Type II	3 (17.5)	3 (13.6)	
Type III	3 (17.5)	2 (9.1)	
Type IV	12 (60)	15 (68.2)	
Pauwels classification, n (%)			
Type I	4 (62.3)	6 (53.3)	0.5128
Type II	4 (31.1)	5 (30)	
Type III	12 (6.6)	11 (16.7)	
Anesthesia, n (%)			
General	2 (10)	4 (18.2)	0.5128
Spinal	18 (90)	18 (81.8)	0.8077
Time from injury to surgery, mean±SD (hours)	5.47±5.99	6.1±4.78	0.7542
Follow-up time (months) (min-max)	20.8±5.54	20.09±5.14	0.6694

SD: Standard deviation.

Surgical Technique

All procedures were performed using a standardized surgical protocol, with patients positioned on a fracture table and fractures managed by closed reduction. In the double fluoroscopy group, one image intensifier was positioned near the hip joint with approximately a 15° tilt along the sagittal plane. A second fluoroscope was positioned from the contralateral side, with the image intensifier oriented superiorly. During FNF surgery, both anteroposterior and lateral views were simultaneously available (Fig. 1), eliminating the need for fluoroscope repositioning.

In the single fluoroscopy group, the fluoroscope was positioned between the patient's legs to allow accurate AP and lateral visualization of the fracture (Fig. 2). The quality of fracture reduction was assessed in both planes prior to skin preparation. During the procedure, fluoroscope positioning was adjusted dynamically by a technician according to intraoperative requirements.

In FNF procedures, reduction was verified intraoperatively by adjusting the fracture table through internal and external rotation under fluoroscopic guidance. The surgical approach involved a 3-cm incision distal to the trochanter to expose the entry point. Three Kirschner wires were inserted in an inverted triangular configuration along the longitudinal axis of the femoral neck into the femoral head. The position and alignment of the K-wires were confirmed fluoroscopically, after which fracture fixation was achieved by insertion and tightening of three 6.5-mm cannulated screws (Fig. 3). The procedure was completed with wound closure using sutures.

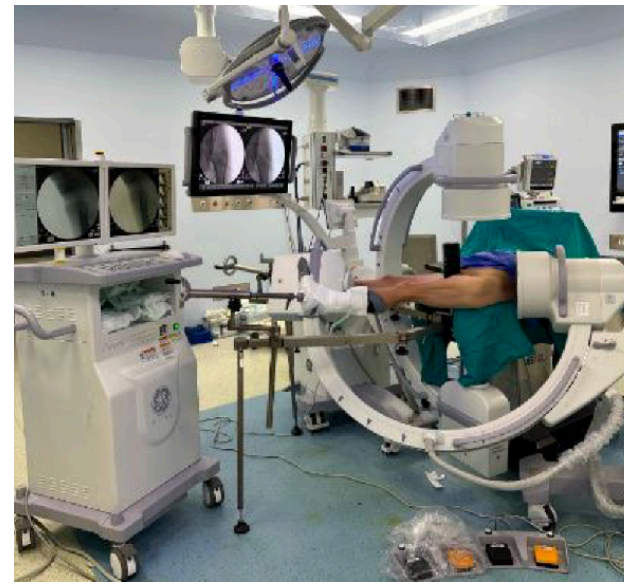

Figure 1. Patient positioning and double fluoroscopy setup prior to surgery.

Assessment of Parameters Between Groups

All procedures were performed by a single senior orthopedic surgeon. Data assessment was conducted independently by another senior surgeon and medical personnel who were not involved in the surgical procedures. Depending on fracture type and degree of displacement, some cases required additional reduction maneuvers, which could increase fluoroscopy usage.

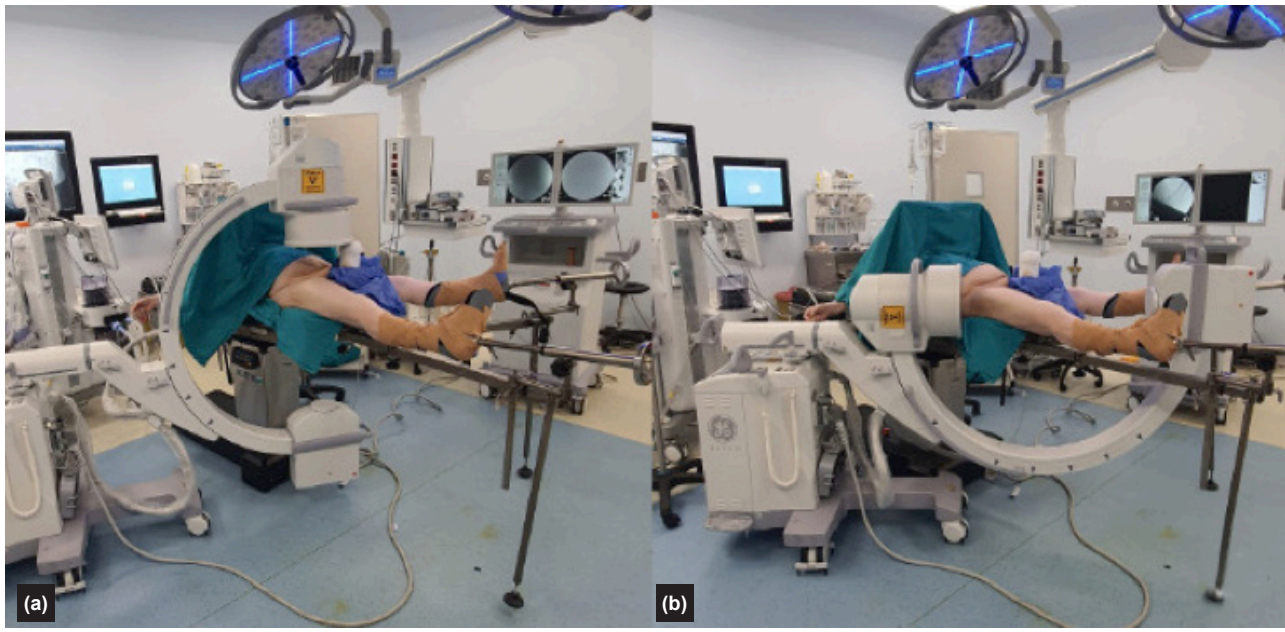

Figure 2. Patient positioning and single-fluoroscopy setup prior to surgery: (a) anteroposterior (AP) and (b) lateral fluoroscopic views of the fracture.

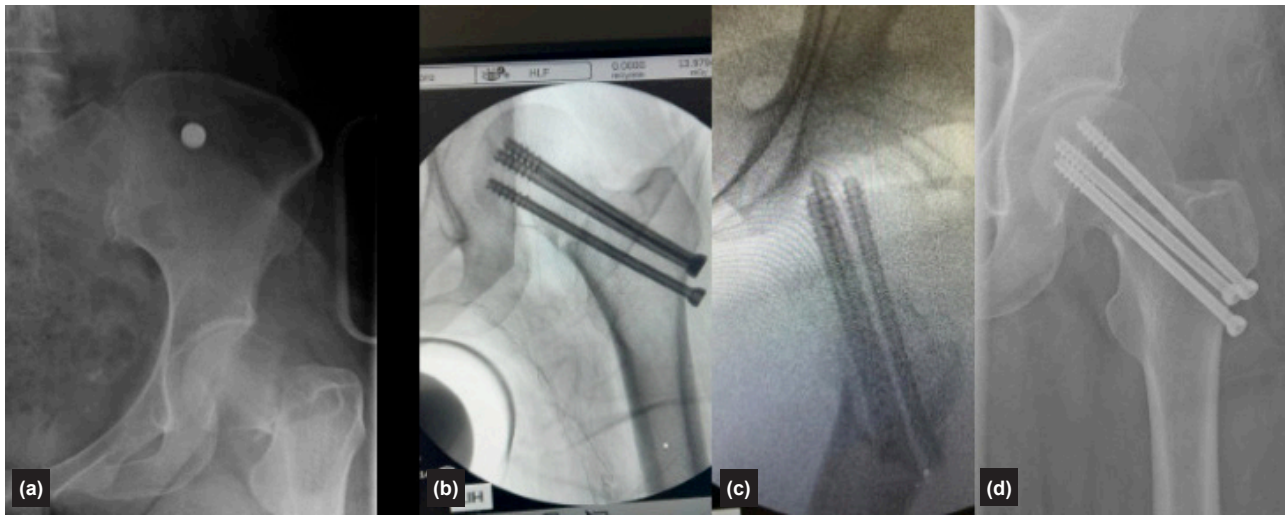

Figure 3. Surgical management of a femoral neck fracture: (**a)** preoperative X-ray, **(b)** intraoperative fluoroscopic images, and **(c)** postoperative X-ray.

Outcome Measures

The primary outcome measures were operative time and fluoroscopy time. Operative time was subdivided into preparation time (defined as the interval from induction of anesthesia to skin incision), surgical time (defined as the interval from skin incision to wound closure), and total operative time. Fluoroscopy time was recorded separately for the preparatory and intraoperative phases, and total fluoroscopy time was calculated as the sum of these two periods. Operative times were recorded in minutes, and fluoroscopy times in seconds.

Statistical Analysis

Categorical variables were expressed as frequencies and percentages and compared using Pearson's chi-square test or Fisher's exact test. Continuous variables were reported as mean±standard deviation (SD) for normally distributed data. Normality was assessed using the Shapiro–Wilk test, and homogeneity of variances using Levene's test. Between-group comparisons were performed using the independent samples t-test for parametric data and the Mann–Whitney U test for nonparametric data. A p-value <0.05 was considered statistically significant. Statistical analyses were performed using IBM SPSS Statistics, version 26.0 (IBM Corp., Armonk, NY, USA).

RESULTS

The study included 42 patients with femoral neck fractures who underwent surgery between January 2021 and September 2022. Double fluoroscopy was used in 20 patients, and single fluoroscopy in 22. The median follow-up duration was 20.4±5.28 months, and the mean age was 49.3±12.9 years. Baseline characteristics were comparable between the groups, with no significant differences in age, sex, fracture side, fracture type (according to Garden and Pauwels classifications), mechanism of injury, anesthesia method, time from injury to surgery, or follow-up duration (Table 1).

For both groups, the preparatory phase (minutes) was defined as the interval from completion of anesthesia to skin incision, while surgical time was defined as the interval from incision to wound closure. The mean preparatory times were 24.9±2 minutes in the double fluoroscopy group and 29.05±3.08 minutes in the single fluoroscopy group (p<0.001). The mean surgical times were 48.2±7.42 minutes and 56.14±7.45 minutes, respectively (p<0.001). Total operative times were 73.1±7.25 minutes in the double fluoroscopy group and 85.59±9.94 minutes in the single fluoroscopy group (p<0.001). Statistical analysis revealed significant differences between the groups for these parameters (Table 2), with shorter operative times observed in the double fluoroscopy group.

Preparatory radiation time (seconds) was defined as the interval from completion of anesthesia to skin incision. Radiation exposure during the operative phase (from incision to wound closure) was significantly lower in the double fluoroscopy group (14.99±2.11 seconds) compared to the single fluoroscopy group (20.77±3.64 seconds; p=0.0001). The mean intraoperative radiation times were 77.25±8 seconds for the double fluoroscopy group and 92.41±15.18 seconds for the single fluoroscopy group (p<0.001). Total radiation times were 92.2±8.4 seconds and 113.27±18.1 seconds for the double and single fluoroscopy groups, respectively (p<0.001). Comparative analysis demonstrated significantly shorter radiation times in the double fluoroscopy group (Table 2).

After a minimum follow-up of one year, nonunion was observed in two patients (10%) in the double fluoroscopy group, both of whom required total hip arthroplasty. In the single fluoroscopy group, three patients (13.6%) developed nonunion and subsequently underwent total hip arthroplasty. No wound infections were observed in either group.

Table 2. Operative and radiation exposure times of the study groups

	Group A (Double fluoroscopy)	Group B (Single fluoroscopy)	p
n	20	22	
Preparation time, mean±SD (min)	24.9±2	29.05±3.08	<0.001
Surgical time, mean±SD (min)	48.2±7.42	56.14±7.45	<0.001
Total operative time, mean±SD (min)	73.1±7.25	85.59±9.94	<0.001
Preparatory radiation time, mean±SD (s)	14.99±2.11	20.77±3.64	<0.001
Intraoperative radiation time, mean±SD (s)	77.25±8	92.41±15.18	<0.001
Total radiation time, mean±SD (s)	92.2±8.4	113.27±18.1	<0.001

SD: Standard deviation.

DISCUSSION

In this study, we evaluated the efficacy of double fluoroscopy in the closed reduction and internal fixation of femoral neck fractures. Our findings demonstrate that the use of a double fluoroscopy system significantly reduces both operative time and radiation exposure compared to a single fluoroscopy approach. This improvement is likely attributable to the simultaneous visualization of anteroposterior and lateral views, which minimizes the need for repositioning the imaging device and enhances surgical workflow efficiency.

In contemporary orthopedic practice, percutaneous screw fixation is a standard treatment for femoral neck fractures in appropriately selected patients.[5] Although various factors, such as fixation technique, number and diameter of screws, and screw configuration, have been widely discussed in the literature, they were not the focus of this study and did not influence our methodology.[6-9] Fluoroscopy is essential during percutaneous screw fixation; however, it may present challenges, particularly for less experienced surgeons. The use of double fluoroscopy may offer advantages by reducing both radiation exposure and operative time. Notably, our literature review identified only one study comparing single and double fluoroscopy in the treatment of femoral neck fractures.[10]

Radiation exposure is a critical concern for both the surgical team and the patient. Mahajan et al.[4] reported a significant positive correlation between operative time and radiation exposure, emphasizing the importance of radiation safety precautions for orthopedic surgeons. Similarly, Herscovici et al.[11] recommended regular calibration of radiographic equipment, the use of protective gear, maintaining a safe distance from the X-ray source, and minimizing exposure time. Additionally, Hardman et al.[12] demonstrated a linear relationship between radiation exposure and cancer risk, which accumulates over an individual's lifetime and across populations. They suggested that, due to this cumulative effect, even small reductions in fluoroscopy use may lead to significant decreases in risk for both patients and surgeons, both in the long term and at the population level. In the present study, total radiation exposure was significantly lower in the double fluoroscopy group compared to the single fluoroscopy group. This reduction not only benefits patients but also mitigates occupational risks for surgical staff who are routinely exposed to intraoperative radiation. Given the increasing awareness of the long-term health risks associated with radiation exposure, our findings support the use of double fluoroscopy as a safer alternative in orthopedic practice.

In addition to reducing radiation exposure, shortening operative time is another important advantage. Saad et al.[13] noted a general consensus that longer operative durations are associated with a higher risk of complications, highlighting the importance of minimizing surgical time. Likewise, Cheng et al.[14] emphasized that reducing operative time should be a shared goal among surgeons, hospitals, and policymakers due to its impact on complication rates. In our study, a significant reduction in operative time was observed in the double fluoroscopy group.

Despite differences in imaging techniques, no significant differences in nonunion rates were observed between the two groups. These findings are consistent with the existing literature on femoral neck fractures, indicating that surgical outcomes remain comparable regardless of the fluoroscopy technique used.[15-17] Liporace et al.[18] reported nonunion rates associated with implant failure ranging from 9% to 18%. In our study, no wound infections were observed, and a total of five patients (11.9%) required total hip arthroplasty due to nonunion.

The relatively small sample size represents a key limitation of this study and may affect the generalizability of the findings. With only 42 patients, the study may not fully capture the variability present in a broader population, potentially limiting statistical power and the ability to detect subtle differences between groups. Additionally, the limited cohort size may reduce the diversity of patient characteristics and fracture patterns, potentially affecting the applicability of the results

across different patient populations. Body mass index (BMI) was not evaluated in the study population and may represent a confounding factor, as it can influence image quality, operative complexity, and fluoroscopy requirements, potentially affecting both operative time and radiation exposure. Similarly, the lack of direct radiation dose measurements using dosimeters is a limitation of this study. Although fluoroscopy time serves as an indirect measure, it provides only a practical surrogate for radiation exposure; therefore, future studies incorporating direct dosimetry are needed for more precise evaluation. The absence of an a priori power analysis is another limitation. Although significant differences were observed in the primary outcomes, studies with predefined sample size calculations are needed to validate these findings. Larger-scale studies are required to confirm these results and to more comprehensively evaluate the benefits and limitations of double fluoroscopy in FNF management. The implications of our findings extend beyond operative efficiency. As the incidence of hip fractures continues to rise with an aging population, approaches that improve surgical outcomes while prioritizing safety will become increasingly important. In this context, the double fluoroscopy technique represents a promising advancement, balancing procedural effectiveness with reduced radiation exposure.

CONCLUSION

Double fluoroscopy appears to reduce both operative time and fluoroscopy time during femoral neck fracture fixation. However, larger, multicenter studies incorporating direct radiation dose measurements are required before widespread adoption can be recommended.

Ethics Committee Approval: This study was approved by the Izmir Bozyaka Training and Research Hospital Medical Research Ethics Committee (Date: 26.01.2022, Decision No: 2022/22).

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: There is no financial conflict of interest with any commercial organization of the results of which products are described, examined, evaluated or compared in the article. None of the authors hold any financial interest in the products, devices or drugs mentioned in this article. We declare that this article, in whole or in part, has not been presented or published elsewhere and is original work.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Femur boyun kırıklarının kapalı redüksiyon ve internal fiksasyonunda çift floroskopi belirgin avantajlar sağlar

AMAÇ: Bu çalışmanın amacı, femur boyun kırıklarının kapalı redüksiyon ve internal fiksasyonunda çift floroskopi kullanımının avantajlarını değerlendirmektir.

GEREÇ VE YÖNTEM: Bu prospektif randomize çalışmada, Ocak 2021 ile Eylül 2022 arasında opere edilen 42 femur boyun kırıklı hasta çalışmaya dahil edildi. Hastalar rastgele iki gruba ayrıldı: biri çift floroskopi cihazı kullanılan (Grup A, n=20), diğeri ise tek floroskopi cihazı kullanılan grup (Grup B, n=22). Gruplar hazırlık süresi, operasyon süresi, hazırlık radyasyon süresi ve operasyon radyasyon süresi açısından karşılaştırıldı.

BULGULAR: İki grup arasında yaş, cinsiyet, kırık tarafı, kırık tipi (Garden ve Pauwels sınıflamasına göre), yaralanma mekanizması, anestezi yöntemi, yaralanma ile cerrahi arasındaki süre ve takip süreleri açısından istatistiksel olarak anlamlı bir fark yoktu. Toplam operasyon süreleri çift ve tek C-kollu gruplar için sırasıyla 73.1±7.25 dakika ve 85.59±9.94 dakika idi (p=0.0001). Toplam radyasyon süreleri ise çift ve tek C-kollu gruplar için sırasıyla 92.2±8.4 saniye ve 113.27±18.1 saniye olarak ölçüldü (p=0.0001). Çift C-kollu grubun, tek C-kollu gruba kıyasla daha kısa operasyon ve radyasyon süresine sahip olduğu tespit edildi.

SONUÇ: Çift floroskopi tekniği, işlem sırasında hem cerrahi süreyi hem de radyasyon maruziyet süresini belirgin şekilde azaltabilmektedir.

Anahtar sözcükler: Femur boyun kırıkları; çift C-kollu floroskopi; kapalı redüksiyon; internal fiksasyon

Ulus Travma Acil Cerrahi Derg 2026;32(6):715-721 DOI: 10.14744/tjtes.2026.72823

ORIGINAL ARTICLE

Two versus three cannulated screws in pediatric Delbet type II femoral neck fractures: a retrospective comparative study

Furkan Erdoğan,[1] Tolgahan Cengiz,[2] Şafak Aydın Şimşek,[3] Bedirhan Albayrak,[1] Bahattin Çağdaş Akman,[4] Hüseyin Sina Coşkun[1]

[1]Department of Orthopedics and Traumatology, Ondokuz Mayıs University, Faculty of Medicine, Samsun-*Türkiye*
[2]Department of Orthopedics and Traumatology, Taşköprü State Hospital, Kastamonu-*Türkiye*
[3]Department of Orthopedics and Traumatology Samsun Education and Research Hospital, Samsun-*Türkiye*
[4]Department of Orthopedics and Traumatology, Vezirkopru State Hospital, Samsun-*Türkiye*

ABSTRACT

BACKGROUND: Pediatric femoral neck fractures are rare but carry a high risk of complications such as avascular necrosis (AVN), premature physeal closure, and coxa vara. Although stable internal fixation is essential, the optimal number of cannulated screws remains controversial. This study compares the clinical and radiological outcomes of two- versus three-screw fixation in a homogeneous cohort of Delbet type II fractures.

METHODS: Thirty-six children treated within three days of injury and followed for at least five years were retrospectively analyzed. All fractures were fixed using either two or three cannulated screws. Surgical variables included reduction quality, screw number, physeal penetration, screw-to-neck area ratio, and the presence of cortical comminution. Patients were stratified into two age groups (<10 and ≥10 years). Complications—AVN, premature physeal closure, and coxa vara—were assessed radiographically and classified using established criteria. Statistical comparisons were performed using appropriate parametric and nonparametric tests.

RESULTS: Older children (≥10 years) showed higher rates of total complications, AVN, and physeal closure; however, the differences were not statistically significant. Medial or posterior cortical comminution significantly increased complication rates. Physeal penetration markedly elevated the risk of premature physeal closure (p=0.045). Reduction quality strongly correlated with outcomes, with unacceptable reductions associated with significantly higher rates of AVN and physeal closure. The number of screws did not significantly influence overall complications or specific adverse outcomes. The screw-to-neck area ratio showed a nonsignificant trend toward higher values in patients with complications.

CONCLUSION: Anatomical reduction and avoidance of physeal penetration are the primary determinants of postoperative outcomes in pediatric Delbet type II femoral neck fractures. When reduction is adequate and biological structures are preserved, the use of two or three screws yields comparable long-term results.

Keywords: Avascular necrosis; cannulated screws; complications; pediatric femoral neck fractures; surgical outcomes.

INTRODUCTION

Pediatric femoral neck fractures account for approximately 1% of all childhood fractures; however, they are associated with disproportionately high rates of complications, including avascular necrosis (AVN), premature physeal closure, coxa vara, and nonunion.[1,2] These injuries most commonly occur in active children aged 10–13 years following high-energy

Cite this article as: Erdoğan F, Cengiz T, Şimşek ŞA, Albayrak B, Akman BÇ, Coşkun HS. Two versus three cannulated screws in pediatric Delbet type II femoral neck fractures: A retrospective comparative study. Ulus Travma Acil Cerrahi Derg 2026;32:722-726.

Address for correspondence: Tolgahan Cengiz
Department of Orthopaedics and Traumatology, Faculty of Medicine, Ondokuz Mayıs University, Samsun, Türkiye
E-mail: tolgahancengiz@hotmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(6):722-726 DOI: 10.14744/tjtes.2026.97273
Submitted: 05.03.2025 Revised: 24.12.2025 Accepted: 18.01.2026 Published: 03.06.2026

trauma and necessitate urgent anatomical reduction and stable internal fixation.[3]

Among the various technical factors influencing outcomes, the number and diameter of cannulated screws are critical determinants of both fixation stability and preservation of vascular integrity.[4] However, the optimal screw configuration remains controversial. While the use of three screws may theoretically provide greater mechanical stability, it has also been associated with increased risks of AVN and premature physeal closure.[5,6] In addition, the ratio between screw diameter and femoral neck width has been proposed as a factor influencing the likelihood of iatrogenic injury.[7,8]

Despite numerous studies, a clear consensus has not been established, largely due to heterogeneity in study populations, fracture classifications, and surgical techniques.[9] To reduce these confounding variables, the present study focuses exclusively on Delbet type II fractures and compares the long-term clinical and radiological outcomes of fixation using two versus three cannulated screws in a homogeneous pediatric cohort.

MATERIALS AND METHODS

The following surgical parameters were evaluated: type of reduction, number of cannulated screws used, epiphyseal penetration by the screws, the screw-to-femoral neck width ratio (screw-to-bone ratio), and quality of reduction. All included fractures were Delbet type II (transcervical), ensuring sample homogeneity and comparable vascular risk profiles. The area of the femoral neck was calculated using the elliptical section formula ($\pi \times$ short axis [mm]/ 2 × long axis [mm]/2), based on the narrowest diameters measured on anteroposterior (AP) and lateral hip radiographs. The total cross-sectional area of the screws was calculated as $n \times \pi r^2$, where n represents the number of screws and r the screw radius in millimeters. The screw-to-bone ratio was then derived to assess its potential association with postoperative complications. All radiographic measurements were performed by a single experienced observer. Reduction quality was graded according to Song's classification as anatomical, acceptable, or unacceptable.

Complications were defined as avascular necrosis, premature physeal closure, and coxa vara or coxa magna. For analytical purposes, a composite "total complication" variable was created to indicate the presence of any of these outcomes. Cases of nonunion were excluded from comparative analyses due to their low incidence and lack of statistical association. Complications were assessed using plain radiographs and magnetic resonance imaging (MRI). AVN was classified according to Ratliff criteria.[10]

To assess the potential influence of skeletal maturity on complication risk, patients were stratified into two age groups: <10 years and ≥10 years. This threshold was selected based on previous studies indicating that physeal vulnerability and vascular remodeling capacity differ substantially around this age in pediatric femoral neck fractures.[11] Demographic, surgical, and outcome parameters were compared between the two groups.

Inclusion criteria were early surgical fixation (within three days of injury), internal fixation using two or three cannulated screws, a minimum follow-up of five years, and complete clinical and radiological data. Patients with metabolic bone disorders, pathological or open fractures, or neuromuscular conditions were excluded.

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation (SD) or median (interquartile range [IQR]), as appropriate, and categorical variables as frequencies. Normality was assessed using the Shapiro–Wilk test. Between-group comparisons were performed using t-test, Mann–Whitney U test, or Fisher's exact test, as appropriate. Statistical significance was defined as $p<0.05$.

Ethics Approval

This study was approved by the Ondokuz Mayıs University Clinical Research Ethics Committee (Date: 23.11.2023, Decision no: 2023/382) and conducted in accordance with the ethical principles of the 1964 Declaration of Helsinki and its subsequent amendments. Written informed consent was obtained from all participants or their legal guardians.

Table 1. Demographic and injury characteristics

Characteristic	n (%) or Mean±SD
Sex	
Female	10 (27.8)
Male	26 (72.2)
Age (years)	9.2±3.4
<10 years	14 (38.9)
≥10 years	22 (61.1)
Follow-up time (months)	108.5±64.8
Bone healing time (weeks)	11.8±2.3
Mechanism of injury	
Traffic accident	17 (47.2)
Fall	13 (36.1)
Sports injury	6 (16.7)
Initial displacement*	
Type I	6 (16.7)
Type II	20 (55.6)
Type III	10 (27.7)
Medial or posterior cortex	
Comminuted	13 (36.1)
Without comminution	23 (63.9)

Continuous variables are presented as mean±standard deviation (SD); categorical variables as number (%). *Initial displacement was classified according to the Song and Wang system. SD: Standard deviation; AP: Anteroposterior.

RESULTS

A total of 36 pediatric patients with femoral neck fractures were included. Demographic and injury characteristics are presented in Table 1, and treatment-related parameters in Table 2. Complication rates were not significantly associated with sex, mechanism of injury, initial displacement, or reduction method (open versus closed reduction) (p>0.05). (Table 3).

When stratified by age, 14 patients (38.9%) were younger than 10 years and 22 (61.1%) were aged ≥10 years. The overall complication rate was lower in the younger group compared with the older group (28.6% vs. 50.0%), although this difference did not reach statistical significance (p=0.21) (Table 3). Similarly, rates of avascular necrosis (14.3% vs. 31.8%) and premature physeal closure (14.3% vs. 36.4%) were higher in older patients, but these differences were not statistically significant (p>0.05).

Fractures with medial or posterior cortical comminution demonstrated higher complication rates compared with those without comminution (Table 3). Similarly, physeal penetration by fixation screws was associated with an increased risk of premature physeal closure and overall complications (p=0.045) (Table 3). Physeal penetration asssociated with premature physeal closure (p=0.045). was a significant predictor of postoperative outcomes. Unacceptable reductions were associated with a markedly higher incidence of avascular necrosis and premature physeal closure compared with anatomical or acceptable reductions (p=0.034 and p=0.045, respectively).

In contrast, the number of screws used for fixation did not significantly influence complication rates. Although the three-screw group demonstrated a higher complication rate than the two-screw group (53.3% vs. 42.9%), the difference was not statistically significant (p=0.47) (Table 3). Similarly, no significant association was observed between screw number and specific complications, including avascular necrosis, premature physeal closure, or coxa vara (p>0.05). No cases of coxa magna were observed. When stratified by age, patients aged ≥10 years demonstrated higher overall complication rates compared with those <10 years (50.0% vs. 28.6%), including higher incidences of AVN (31.8% vs. 14.3%) and premature physeal closure (36.4% vs. 14.3%). However, these differences did not reach statistical significance. This trend may reflect reduced remodeling capacity and increased mechanical stress in older children, as skeletal maturity progresses and the vascular adaptability of the femoral head declines.

Table 2. Treatment-related characteristics

Characteristic	n (%)
Fixation method	
Two cannulated screws	21 (58.3)
Three cannulated screws	15 (41.7)
Physeal penetration	
Yes	19 (52.8)
No	17 (47.2)
Type of reduction	
Open reduction	7 (19.4)
Closed reduction	29 (80.6)
Reduction quality (Song classifica-tion)	
Anatomical	12 (33.3)
Acceptable	20 (55.6)
Unacceptable	4 (11.1)

DISCUSSION

The findings of the present study are largely consistent with previous literature; however, some differences warrant further consideration. Our results partially differ from those of Dai et al.,[11] who reported a stronger association between physeal penetration and complications in patients younger than 10 years. In contrast, the present study demonstrated a higher, although not statistically significant, tendency toward complications in older children. This discrepancy may be explained by methodological differences, as Dai et al.[11] included a heterogeneous cohort of Delbet types I–IV. In contrast,

Table 3. Univariate analysis of factors associated with postoperative complications

Variable	AVN	Premature physeal closure	Coxa vara	Any complication
Age (<10 vs ≥10 years)	0.261	0.194	0.473	0.211
Initial displace-ment (Song and Wang classifica-tion)	0.740	0.680	0.720	0.830
Cortical commi-nution (medi-al/posterior cor-tex)	0.110	0.037*	0.290	0.045*
Reduction meth-od (open vs closed)	0.960	0.820	0.440	0.610
Physeal penetra-tion (yes vs no)	0.320	0.045*	0.550	0.040*
Reduction quality (Song classifica-tion)	0.034*	0.045*	0.060	0.029*
Screw configura-tion (two vs three screws)	0.410	0.480	0.270	0.470

Values represent p values obtained from Fisher's exact test. AVN: Avascular necrosis. * Statistically significant (p<0.05).

our study was restricted to type II fractures treated within three days of injury, resulting in a more homogeneous population with early surgical fixation.

In our series, patients aged ≥10 years exhibited higher overall complication rates, including increased incidences of AVN and premature physeal closure; however these differences did not reach statistical significance. This trend may reflect reduced remodeling capacity and increased mechanical vulnerability associated with advancing skeletal maturity.

Similarly, İnan et al.[12] reported a nonsignificant increase in AVN risk with age, supporting the concept that biological maturity may adversely influence outcomes. Palocaren et al.[13] also emphasized that younger children possess greater potential for femoral head remodeling and vascular adaptation, which may contribute to lower deformity rates and improved long-term functional outcomes.

Medial or posterior cortical comminution was significantly associated with premature physeal closure and overall complications (p=0.03 and p=0.04, respectively). Loss of posteromedial support compromises both mechanical stability and femoral head perfusion, predisposing to varus deformity and early physeal injury. These findings are consistent with prior biomechanical studies highlighting the importance of cortical integrity in maintaining blood flow and load distribution across the femoral neck.[14]

Physeal penetration by fixation screws was also associated with an increased risk of premature physeal closure and overall complications (p=0.045). This relationship has been widely reported in the literature, as transphyseal fixation may disrupt the vascular network and growth plate architecture.[8,15] Bali et al.[14] similarly concluded that the occurrence of AVN is more closely related to vascular compromise than to fixation type, supporting the notion that biological factors may play a more dominant role than mechanical variables in determining complication risk. Hughes and Beaty further emphasized that, although stable fixation is essential, preservation of the physis should remain a key principle in the management of skeletally immature patients.[15]

Reduction quality emerged as a critical prognostic factor. Unacceptable reductions were strongly associated with AVN and premature physeal closure p=0.034 and p=0.045. Anatomical alignment facilitates revascularization and reduces intracapsular pressure, whereas residual displacement may compromise perfusion despite otherwise stable fixation.[16]

In contrast, the number of screws did not significantly influence complication rates. Although patients treated with three screws demonstrated a higher overall complication rate than those treated with two screws (53.3% vs. 42.9%), this difference was not statistically significant. Previous investigations have reported conflicting findings: Lim et al.[7] suggested that increased screw density may elevate the risk of avascular necrosis, whereas Li et al.[17] reported an overall AVN rate of 24.3% in a cohort of 115 pediatric femoral neck fractures, identifying older age and delayed fixation as significant risk factors. However, the present findings indicate that, when anatomical reduction is achieved and physeal penetration is avoided, the number of screws alone is unlikely to substantially affect postoperative outcomes. Comparable bone healing times between the two- and three-screw groups (11.5±1.9 vs. 12.3±2.4 weeks) further support the notion that both configurations can provide adequate stability when properly executed.

The screw-to-neck area ratio was higher in patients who developed complications (21.9% vs. 17.5%; p=0.092). Although this difference did not reach statistical significance, it suggests that the geometric occupancy of the femoral neck may play a relatively minor role compared with biological and technical factors, such as physeal preservation and reduction quality. In line with the findings of Wang et al.,[18] these results indicate that achieving adequate stability while minimizing vascular compromise remains essential for optimizing outcomes.

This study has several limitations. Its retrospective design and relatively small sample size limit the power to detect rare complications and may introduce selection bias. The number of screws was determined by the operating surgeon, resulting in potential heterogeneity in fixation technique. Additionally, radiographic measurements were performed by a single observer without interobserver validation, which may affect reproducibility. Despite these limitations, the inclusion of a pediatric cohort with a minimum follow-up of five years strengthens the reliability of long-term outcomes, including premature physeal closure and leg length discrepancy.

CONCLUSION

The present study suggests that, in pediatric femoral neck fractures, anatomical reduction and preservation of physeal integrity are more critical determinants of outcome than the number or configuration of screws. Older age may be associated with a modest increase in complication risk, underscoring the importance of meticulous reduction and preservation of physeal integrity during fixation.

Ethics Committee Approval: This study was approved by the Ondokuz Mayıs University Clinical Research Ethics Committee (Date: 23.11.2023, Decision No: 2023/382).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: F.E.; Design: T.C.; Supervision: H.S.C.; Resource: H.S.C.; Materials: Ş.A.Ş.; Data collection and/or processing: B.A.; Analysis and/or interpretation: B.Ç.A.; Literature review: T.C.; Writing: Ş.A.Ş.; Critical review: F.E.

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*

Delbet tip II pediatrik femur boyun kırıklarında iki ve üç kanüllü vida kullanımının karşılaştırılması: Retrospektif karşılaştırmalı bir çalışma

AMAÇ: Pediatrik femur boyun kırıkları nadirdir; ancak avasküler nekroz (AVN), erken fiz kapanması ve koksa vara gibi komplikasyon riski yüksektir. Stabil internal fiksasyon gerekli olmakla birlikte, optimum kanüllü vida sayısı hâlen tartışmalıdır. Bu çalışma, homojen bir Delbet tip II kırık kohortunda iki ve üç vidalı fiksasyonun klinik ve radyolojik sonuçlarını karşılaştırmayı amaçlamaktadır.

GEREÇ VE YÖNTEM: Yaralanmadan sonraki üç gün içinde tedavi edilen ve en az beş yıl takip edilen otuz altı çocuk retrospektif olarak analiz edildi. Tüm kırıklar iki veya üç kanüllü vida kullanılarak tespit edildi. Cerrahi değişkenler arasında redüksiyon kalitesi, vida sayısı, fiz penetrasyonu, vida-boyun alan oranı ve kortikal parçalanma varlığı yer aldı. Hastalar iki yaş grubuna (<10 ve ≥10 yaş) ayrıldı. Komplikasyonlar (AVN, erken fiz kapanması ve koksa vara) radyografik olarak değerlendirildi ve belirlenmiş kriterlere göre sınıflandırıldı. İstatistiksel karşılaştırmalar uygun parametrik ve parametrik olmayan testler kullanılarak yapıldı.

BULGULAR: Daha büyük çocuklarda (≥10 yaş) toplam komplikasyon, AVN ve fiz kapanması oranları daha yüksek bulundu; ancak farklar istatistiksel olarak anlamlı değildi. Medial veya posterior kortikal parçalanma komplikasyon oranlarını anlamlı ölçüde artırdı. Fiz penetrasyonu, erken fiz kapanması riskini belirgin şekilde artırdı (p=0.045). Redüksiyon kalitesi sonuçlarla güçlü korelasyon gösterdi; kabul edilemez redüksiyonlar anlamlı derecede daha yüksek AVN ve erken fiz kapanması oranları ile ilişkiliydi. Vida sayısı, genel komplikasyon oranlarını veya spesifik olumsuz sonuçları anlamlı olarak etkilemedi. Vida-boyun alan oranı, komplikasyon gelişen hastalarda daha yüksek değerlere eğilim gösterdi; ancak bu fark istatistiksel olarak anlamlı değildi.

SONUÇ: Pediatrik Delbet tip II femur boyun kırıklarında postoperatif sonuçların temel belirleyicileri anatomik redüksiyonun sağlanması ve fiz penetrasyonundan kaçınılmasıdır. Redüksiyonun yeterli olduğu ve biyolojik yapıların korunduğu durumlarda, iki veya üç vida kullanımı benzer uzun dönem sonuçlar vermektedir.

Anahtar sözcükler: Avasküler nekroz; cerrahi sonuçlar; kanüllü vida; komplikasyonlar; pediatrik femur boyun kırıkları.

Ulus Travma Acil Cerrahi Derg 2026;32(6):722-726 DOI: 10.14744/tjtes.2026.97273

ORIGINAL ARTICLE

Clinical and radiological outcomes of a cartilage-preserving pinhole transtibial technique versus standard pull-out repair for traumatic posterior meniscal root tears

Mehmet Can Gezer, Mahircan Demir

Department of Orthopedics and Traumatology, Mamak State Hospital, Ankara-*Türkiye*

ABSTRACT

BACKGROUND: Traumatic posterior meniscal root tears disrupt normal load transmission, resulting in meniscal extrusion and accelerated osteoarthritis. Although transtibial pull-out repair is widely used, creation of a 4.5-mm tibial tunnel at the joint surface may cause iatrogenic chondral and subchondral bone damage at the root footprint. This study aimed to compare the clinical and radiological outcomes of a modified aperture-preserving pinhole technique, designed to avoid reaming at the tibial joint surface, with those of the standard transtibial pull-out repair.

METHODS: A total of 60 patients with symptomatic posterior meniscal root tears treated between December 2021 and December 2024 were retrospectively analyzed. Patients were divided into two groups according to the surgical technique used. The standard pull-out group (n=30) underwent transtibial repair using a 4.5-mm tibial tunnel created by reaming at the joint surface for suture passage. The modified pinhole group (n=30) was treated with an aperture-preserving technique in which fixation was achieved through a narrow pinhole channel without reaming or drilling at the tibial articular surface, thereby preserving the subchondral bone at the root footprint. In both groups, final fixation was performed using a cortical post-fixation screw. Clinical evaluations were performed preoperatively and at 6 and 12 months postoperatively using the Lysholm Knee Score, International Knee Documentation Committee (IKDC) score, Knee Injury and Osteoarthritis Outcome Score (KOOS), and Visual Analog Scale (VAS) for pain. Radiological assessment was conducted using magnetic resonance imaging to evaluate meniscal extrusion and healing status, classified as complete healing, partial (loose) healing, or failed healing.

RESULTS: Both groups demonstrated significant improvement in all functional outcome scores compared with preoperative values ($p<0.001$). At the 12-month follow-up, the modified pinhole group showed significantly higher Lysholm, IKDC, and KOOS scores than the standard pull-out group, whereas improvements in VAS pain scores were comparable between groups. Meniscal extrusion decreased postoperatively in both groups, with a significantly greater reduction observed in the modified pinhole group. Complete healing was observed in 80% of patients in the modified pinhole group and 60% in the standard pull-out group. No major complications were recorded during the follow-up period.

CONCLUSION: Both surgical techniques resulted in satisfactory clinical and radiological outcomes for posterior meniscal root repair. However, the aperture-preserving modified pinhole technique was associated with superior functional outcomes, reduced progression of meniscal extrusion, and a higher rate of complete healing. Preservation of the subchondral bone and minimization of iatrogenic joint surface damage may positively contribute to meniscal root healing.

Keywords: Arthroscopic repair; meniscal extrusion; meniscal root tear; pinhole technique; transtibial pull-out.

Cite this article as: Gezer MC, Demir M. Clinical and radiological outcomes of a cartilage-preserving pinhole transtibial technique versus standard pull-out repair for traumatic posterior meniscal root tears. Ulus Travma Acil Cerrahi Derg 2026;32:727-734.

Address for correspondence: Mehmet Can Gezer

Department of Orthopedics and Traumatology, Mamak State Hospital, Ankara, Türkiye

E-mail: mehmetcangezer9121@gmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(6):727-734 DOI: 10.14744/tjtes.2026.68654

Submitted: 23.10.2025 Revised: 18.01.2026 Accepted: 19.02.2026 Published: 03.06.2026

INTRODUCTION

The menisci play a critical role in load distribution, shock absorption, and joint stability within the knee joint.[1] Traumatic meniscal root tears are defined as disruptions of the meniscus at its tibial footprint attachment and occur most frequently in the posterior horn of the medial meniscus.[2] These injuries compromise the hoop stress mechanism of the meniscus, resulting in meniscal extrusion, increased tibiofemoral contact pressures, and accelerated cartilage degeneration.[3] Increasing biomechanical and clinical evidence indicates that meniscal root tears functionally resemble total meniscectomy rather than partial meniscectomy, because loss of the root attachment abolishes hoop stress transmission and leads to a marked increase in joint contact pressures.[4]

The transtibial pull-out technique, which relies on cortical fixation by passing sutures through a tibial tunnel, is currently the most widely used surgical method for treating meniscal root tears.[5] Alternatively, suture anchor–based techniques have been described and are proposed to provide more anatomical fixation at the joint surface.[6] However, the technical complexity of anchor-based repairs and their proximity to neurovascular structures may increase the risk of iatrogenic complications.[7] Although the transtibial tunnel technique is generally considered technically less demanding, concerns have been raised that creation of a 4-5 mm tunnel at the joint surface may cause iatrogenic cartilage and subchondral bone damage at the meniscal root footprint.[8,9]

In the classic transtibial pull-out technique, a 4.5-mm cannulated reamer is used to create a tibial tunnel over a guide wire. Sutures passed through the meniscal root are subsequently retrieved through this tunnel and secured using a cortical button or a post-fixation screw.[10] However, the relatively large aperture at the joint surface may increase the risk of local cartilage and subchondral bone injury.[11] In the modified technique described in this study, the pinhole opening created by the guide pin at the joint surface was used directly without reaming. Sutures were retrieved through this minimal aperture with the aid of a loop and then fixed with a post-fixation screw at the distal cortex. This approach was designed to preserve the fixation strength of the transtibial technique while minimizing iatrogenic damage to the joint surface and subchondral bone.

The purpose of this study was to compare the clinical and radiological outcomes of two transtibial techniques for the surgical treatment of traumatic posterior meniscal root tears: the conventional technique using a 4.5-mm tibial tunnel and a cartilage-preserving modified technique that avoids reaming at the joint surface. We hypothesized that the aperture-preserving technique would provide at least equivalent outcomes in terms of meniscal extrusion and functional recovery at 12-month follow-up compared with the standard transtibial pull-out method.

MATERIALS AND METHODS

This single-center retrospective study was conducted following approval by the Ankara Provincial Health Directorate Non-Interventional Ethics Committee (Date: October 17, 2025; Decision no: 2025-10-1) and in accordance with the principles of the Declaration of Helsinki. A total of 60 patients who underwent arthroscopic repair for traumatic posterior medial meniscal root tears between December 2021 and December 2024 were included.

Patients were divided into two groups according to the transtibial repair technique used. In Group A (n=30), a standard transtibial pull-out technique was performed in which a tibial tunnel was created using a 4.5-mm cannulated reamer over a guide pin. Sutures passed through the meniscal root were retrieved through the tunnel using a shuttle loop and fixed with a post-fixation screw at the distal cortex. In Group B (n=30), an aperture-preserving modified technique was used. After the tibial guide pin exited the joint surface, the pinhole opening was utilized directly without reaming. Sutures were retrieved through this minimal aperture using a loop and similarly fixed with a post-fixation screw at the distal cortex.

Meniscal centralization was not performed in either group, and no additional sutures or anchors were used for meniscal body stabilization. Surgical intervention in all cases was limited strictly to posterior meniscal root repair using the respective techniques.

Inclusion criteria were: age between 18 and 65 years; symptomatic posterior meniscal root tear of traumatic origin; confirmation of the root tear on magnetic resonance imaging (MRI); Kellgren–Lawrence osteoarthritis grade ≤2; and mechanical axis deviation ≤5°.

Exclusion criteria included previous surgery on the same knee; requirement for concomitant high tibial osteotomy or ligament reconstruction; associated ligament injuries; advanced cartilage lesions (Outerbridge grade ≥3); degenerative meniscal root tears; or inability to comply with regular postoperative follow-up.

Traumatic posterior meniscal root tears were defined using a composite diagnostic approach incorporating clinical history, magnetic resonance imaging findings, and intraoperative assessment. Patients were required to have a clearly documented history of acute knee trauma. Preoperative MRI had to demonstrate features suggestive of an acute root injury, including sharp tear margins and/or associated bone marrow edema. In addition, intraoperative arthroscopic examination was required to confirm an acute avulsion-type tear of the posterior meniscal root at its tibial footprint. Only patients fulfilling all three criteria were classified as having traumatic posterior meniscal root tears and included in the traumatic group.

All procedures were performed arthroscopically by a single experienced orthopedic surgeon using standard anteromedial and anterolateral portals. Two high-strength sutures were

passed through the meniscal root using a standardized suture configuration. The tibial tunnel entry point was located anteromedially, just medial to the tibial tuberosity and slightly proximal to the pes anserinus.

In Group A, a 4.5-mm cannulated reamer was advanced over the guide pin to create a tibial tunnel through which the sutures were retrieved externally using a shuttle loop (Fig. 1). In Group B, after the guide pin exited the joint surface, a loop suture was passed through the pinhole opening, allowing retrieval of the sutures without reaming (Fig. 2). In both groups, final fixation was achieved using a post-fixation screw placed at the distal cortex.

Postoperatively, all patients followed the same standardized rehabilitation protocol. During the first 6 weeks, a knee brace limiting flexion to 0-90° was used, and partial weight-bearing was permitted. Full weight-bearing was initiated between weeks 6 and 12. Deep squatting and kneeling were prohibited for 3 months. Strengthening and proprioceptive exercises were initiated after the fourth postoperative month, and return to sports activities was permitted between 6 and 9 months according to individual functional recovery.

Clinical evaluations were performed preoperatively and at 6 and 12 months postoperatively. Functional outcomes were assessed using the Lysholm Knee Score, International Knee Documentation Committee (IKDC) score, and Knee Injury and Osteoarthritis Outcome Score (KOOS). Pain intensity was evaluated using the Visual Analog Scale (VAS).

Radiological evaluation was conducted using MRI in the coronal, sagittal, and axial planes. Meniscal extrusion was measured in millimeters on coronal images as the distance between the outer edge of the tibial plateau and the peripheral margin of the meniscus. The difference between preoperative and 12-month postoperative extrusion values was analyzed, and extrusion ≥3 mm was considered pathological.

MRI assessments were performed independently by two observers blinded to both the surgical technique and clinical outcomes. Interobserver reliability was evaluated using the intraclass correlation coefficient (ICC).

Meniscal root healing was assessed on postoperative MRI and classified into three categories according to predefined radiological criteria.

Complete healing was defined as anatomical continuity of the repaired meniscal root with its native tibial attachment, restoration of normal meniscal morphology, and absence of displacement or a gap at the footprint. Partial (loose) healing was defined as continuity between the meniscal root and tibial attachment with incomplete integration, mild displacement, or persistent increased signal intensity at the repair site, indicating incomplete biological healing. Failed healing was defined as persistent discontinuity, redisplacement, re-avulsion of the root, or absence of structural continuity on MRI. All MRI evaluations were performed using standardized protocols.

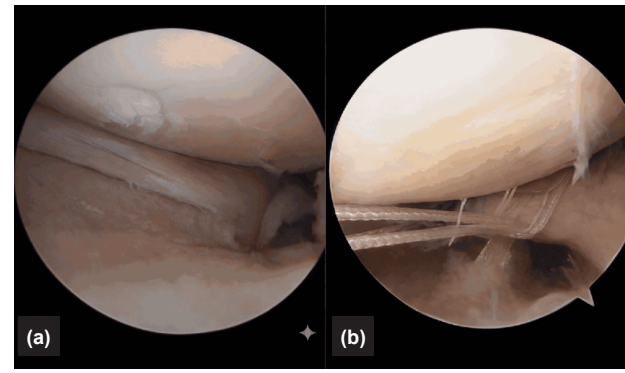

Figure 1. Arthroscopic images demonstrating a posterior meniscal root tear **(a)** and creation of a 4.5-mm tibial tunnel for standard pull-out repair **(b)**.

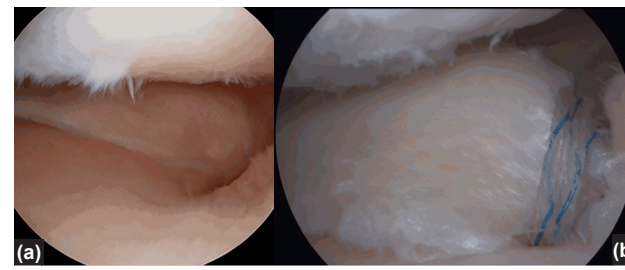

Figure 2. Arthroscopic images demonstrating a posterior meniscal root tear **(a)** and the aperture-preserving pinhole transtibial repair technique performed using only the guide pin without additional reaming **(b)**.

Patient allocation to each surgical technique was not randomized. The choice of technique was based on the surgeon's clinical preference and intraoperative assessment rather than chronological order. All procedures were performed by a single surgeon experienced in both techniques before the study period; therefore, the potential influence of a learning curve was considered minimal.

Representative MRI images demonstrating complete, partial (loose), and failed healing were prepared and provided as supplementary material to improve the reproducibility and clarity of radiological assessment (Fig. 3).

Statistical Analysis

All statistical analyses were performed using SPSS software (IBM Corp., version 11.5, Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation, whereas categorical variables were presented as frequencies and percentages. Normality of data distribution was assessed using the Kolmogorov–Smirnov test.

For intergroup comparisons, Student's t-test was used for continuous variables with normal distribution, whereas the Mann–Whitney U test was applied for variables that did not meet normality assumptions. Categorical variables were analyzed using the chi-square test or Fisher's exact test, as appropriate.

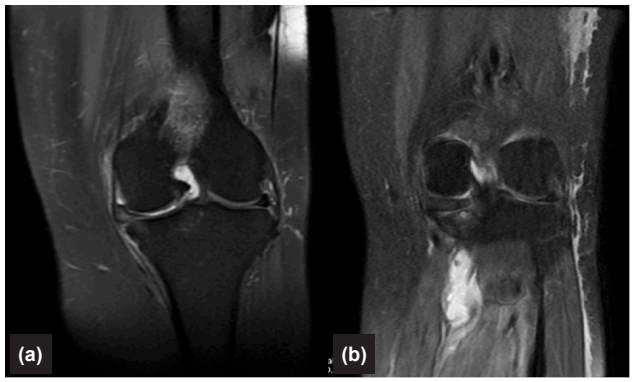

Figure 3. Coronal magnetic resonance imaging demonstrating posterior medial meniscal root pathology and postoperative appearance. **(a)** Preoperative image showing meniscal extrusion associated with a posterior medial meniscal root tear. **(b)** Postoperative image obtained after arthroscopic repair, demonstrating reduction of meniscal extrusion and restoration of meniscal position at the tibial plateau.

Changes in clinical and radiological parameters over time were evaluated using repeated-measures analysis of variance (ANOVA). When statistically significant differences were detected, Bonferroni-adjusted post hoc tests were performed for pairwise comparisons. Interobserver reliability for radiological measurements was assessed using the intraclass correlation coefficient. A p value <0.05 was considered statistically significant for all analyses.

RESULTS

A total of 60 patients were included in the study, with 30 patients in Group A (transtibial pull-out technique) and 30 patients in Group B (pinhole technique). No statistically significant differences were observed between the groups regarding age, sex distribution, body mass index, affected side, or follow-up duration (p>0.05) (Table 1). The mean follow-up period was 26.4±3.1 months in Group A and 25.9±2.8 months in Group B.

Table 1. Demographic characteristics of the patients

Characteristic	Group A (n=30)	Group B (n=30)	p
Age (years, mean±SD)	56.8±6.2	55.9±6.5	0.62
Gender (female/male)	14/16	13/17	0.79
BMI (kg/m², mean±SD)	27.6±2.9	27.3±3.1	0.74
Affected side (right/left)	17/13	18/12	0.80
Follow-up duration (months)	26.4±3.1	25.9±2.8	0.58

BMI: Body mass index.

Table 2. Comparison of clinical outcome scores between groups at preoperative and postoperative follow-up

Score	Group	Preoperative (mean±SD)	6 months (mean±SD)	12 months (mean±SD)	p (within-group)	p (between groups at 12 months)
Lysholm score	A	52.1±7.8	78.4±6.5	83.9±6.1	0.001	
	B	51.6±8.2	82.6±6.3	88.7±5.7	0.001	0.021
IKDC score						
	A	47.8±8.0	72.9±7.1	78.6±6.4	0.001	
	B	48.4±7.6	77.2±6.8	83.4±6.0	0.001	0.018
KOOS						
	A	46.2±8.7	71.8±7.4	76.9±6.9	0.001	
	B	47.1±8.3	75.9±7.2	81.8±6.7	0.001	0.026
VAS score (0–10)	A	6.8±1.0	2.7±0.9	2.1±0.8	0.001	
	B	6.7±0.9	2.4±0.8	1.8±0.7	0.001	0.19

IKDC: International Knee Documentation Committee; KOOS: Knee Injury and Osteoarthritis Outcome Score; VAS: Visual Analog Scale.

No significant differences were observed between the groups in preoperative Lysholm, International Knee Documentation Committee, Knee Injury and Osteoarthritis Outcome Score, or Visual Analog Scale scores (p>0.05). Both groups demonstrated significant improvement in all clinical outcome scores at postoperative follow-up compared with preoperative values (p<0.001). Improvements observed at the 6-month follow-up were comparable between groups. However, at the 12-month evaluation, Lysholm (88.7±5.7 vs. 83.9±6.1; p=0.021), IKDC (83.4±6.0 vs. 78.6±6.4; p=0.018), and KOOS (81.8±6.7 vs. 76.9±6.9; p=0.026) scores were significantly higher in Group B than in Group A. VAS scores decreased significantly in both groups compared with preoperative values (p<0.001), with no statistically significant difference between the groups at final follow-up (p=0.19) (Table 2).

Effect size analysis demonstrated a large effect for Lysholm scores (Cohen's d=0.81), a moderate-to-large effect for IKDC scores (d=0.77), a moderate effect for KOOS scores (d=0.72), and a small effect for VAS scores (d=0.40), all favoring Group B (Table 3). Although the absolute differences in mean functional scores did not exceed the reported minimal clinically important difference thresholds, a consistent trend toward higher functional outcome scores was observed in the pinhole technique group.

Radiological evaluation revealed no significant difference in preoperative meniscal extrusion between Group A (4.0±0.9 mm) and Group B (4.6±1.0 mm; p=0.68). At the 12-month follow-up, meniscal extrusion decreased significantly in both groups compared with preoperative values. The magnitude of extrusion reduction was significantly greater in Group B than in Group A (Δ extrusion: 1.4±0.6 mm vs. 0.9±0.5 mm; p=0.008). In addition, mean meniscal extrusion at 12 months was lower in Group B than in Group A (3.1±1.0 mm vs. 3.2±0.9 mm; p=0.031) (Table 4).

Regarding meniscal root healing status, complete healing was observed in 18 patients (60%) in Group A, partial (loose) healing in eight patients (26.7%), and failed healing in four

Table 3. Effect size analysis (Cohen's d) and minimal important difference (MID) thresholds for functional outcome scores

Score	Group A (mean±SD)	Group B (mean±SD)	Mean difference	Pooled SD	Cohen's d	Effect magnitude	Reported MID	Clinical interpretation
Lysholm score	83.9±6.1	88.7±5.7	4.8	5.9	0.81	Large	8–10 points	Borderline clinical relevance
IKDC score	78.6±6.4	83.4±6.0	4.8	6.2	0.77	Moderate-to-large	9–11 points	Borderline clinical relevance
KOOS	76.9±6.9	81.8±6.7	4.9	6.8	0.72	Moderate	8–10 points	Borderline clinical relevance
VAS score	2.1±0.8	1.8±0.7	0.3	0.75	0.40	Small	1.0–1.5 cm	Clinically minor difference

IKDC: International Knee Documentation Committee; KOOS: Knee injury and Osteoarthritis Outcome Score; VAS: Visual Analog Scale; MID: Minimal important difference; SD: Standard deviation.

Table 4. Radiological findings and meniscal healing status at 12-month follow-up

Characteristic	Group A (n=30)	Group B (n=30)	p
Preoperative extrusion (mm)	4.0±0.9	4.6±1.0	0.68
Extrusion at 12 months (mm)	3.2±0.9	3.1±1.0	0.031
Δ Extrusion (mm)	0.9±0.5	1.4±0.6	0.008
Complete healing, n (%)	18 (60.0%)	24 (80.0%)	0.047
Partial (loose) healing, n (%)	8 (26.7%)	5 (16.7%)	
Failed healing, n (%)	4 (13.3%)	1 (3.3%)	

BMI: Body mass index.

Table 5. Postoperative complications observed in both groups

Characteristic	Group A (n=30)	Group B (n=30)
Cartilage degeneration around the tunnel	2	0
Suture failure	1	0
Suture abrasion	0	1
Revision surgery required	1	1
Major complication (infection, neurovascular injury, thromboembol-ic events)	0	0

patients (13.3%). In Group B, complete healing was observed in 24 patients (80%), partial healing in five patients (16.7%), and failed healing in one patient (3.3%). The difference in complete healing rates between the groups was statistically significant (p=0.047) (Table 4).

With respect to complications, cartilage degeneration around the tibial tunnel was observed in two patients and suture failure in one patient in Group A. In Group B, one patient required revision surgery because of suture abrasion. No major complications, including infection, thromboembolic events, or neurovascular injury, were observed in either group (Table 5).

DISCUSSION

The present study compared the clinical and radiological outcomes of two transtibial techniques used for repair of traumatic posterior meniscal root tears. The principal finding was that, although both techniques resulted in significant postoperative improvement in functional outcomes, the aperture-preserving pinhole technique demonstrated superior Lysholm, IKDC, and KOOS scores at 12-month follow-up. In addition, this technique was associated with a greater reduction in meniscal extrusion and a higher rate of complete meniscal root healing on magnetic resonance imaging. These findings suggest that avoiding reaming at the tibial joint surface may provide advantages in both functional recovery and meniscal healing.

Despite the statistically significant differences observed between the groups, it is important to acknowledge that the absolute improvements in Lysholm and IKDC scores did not exceed established minimal clinically important difference thresholds. Nevertheless, the consistent trend toward higher patient-reported outcome scores and the moderate-to-large effect sizes observed in the pinhole group suggest a meaningful functional advantage at the group level. These findings highlight the importance of interpreting statistical significance in conjunction with effect size and overall functional patterns rather than relying solely on absolute score differences.

Untreated meniscal root tears are known to disrupt knee biomechanics, leading to loss of hoop stress transmission, increased contact pressures, and accelerated osteoarthritic degeneration.[12] Consequently, contemporary treatment strategies emphasize anatomic restoration of the meniscal root attachment to the tibial footprint.[13] Previous studies have demonstrated that meniscal root repair yields superior functional outcomes and lower rates of progression to total knee arthroplasty compared with partial meniscectomy.[14,15] Consistent with this literature, both repair techniques in the present study resulted in significant functional improvement. However, patients treated with the pinhole technique demonstrated higher functional scores and a greater proportion of complete healing at final follow-up, suggesting that preservation of the native root footprint may enhance biological and biomechanical restoration.

Although this study specifically focused on traumatic posterior meniscal root tears, degenerative root tears are more frequently encountered in older patient populations. Degenerative tears often develop in the absence of a distinct traumatic event and are commonly associated with compromised tissue quality, cartilage degeneration, and early osteoarthritis. These biological differences may influence healing capacity and clinical outcomes. Therefore, the results of the present study should be interpreted primarily in the context of traumatic meniscal root injuries, and caution is warranted when extrapolating these findings to degenerative root tears. Further studies specifically addressing degenerative etiologies are needed to improve generalizability.

From a safety perspective, the absence of major complications in the pinhole group suggests that this technique represents a reliable surgical option. Preservation of the joint surface may be particularly advantageous in younger and physically active patients, for whom long-term joint preservation is a key consideration. Nevertheless, both techniques demonstrated acceptable safety profiles and appear to be dependable when performed appropriately.

Previous reports have indicated that large-diameter tibial tunnels created during standard transtibial pull-out repair may contribute to iatrogenic cartilage and subchondral bone damage, potentially promoting postoperative meniscal extru-

sion.[15] Although suture anchor–based techniques have been proposed to preserve the joint surface and limit extrusion, their technical complexity and associated risks may restrict widespread adoption.[14,16] The pinhole technique evaluated in the present study avoids additional reaming at the joint surface while maintaining the fixation principles of transtibial repair. This modification may combine the joint surface–preserving advantages of anchor-based techniques with the technical simplicity and strong fixation associated with transtibial methods.[17]

Biomechanical studies have further supported the rationale for minimizing tibial tunnel diameter. Cinque et al.[18] demonstrated that larger bony defects at the tibial footprint can lead to micromotion at the fixation site, described as the "bungee" and "windshield-wiper" effects, which may promote progressive meniscal extrusion. Similarly, Kim et al.[9] reported that modified techniques using smaller tunnels resulted in reduced extrusion and improved biomechanical stability. The greater reduction in meniscal extrusion observed in the pinhole group in the present study is consistent with these biomechanical findings and supports the concept that aperture preservation contributes to a more stable repair construct.

Meniscal extrusion is widely regarded as a surrogate marker of meniscal dysfunction and altered load transmission. In the present study, postoperative extrusion decreased in both groups, with a more pronounced reduction observed in the pinhole technique group. This finding suggests that preservation of tibial bone stock and minimization of iatrogenic joint surface damage may facilitate improved meniscal positioning and functional restoration.

Several limitations of this study should be acknowledged. First, its retrospective, single-center design introduces an inherent risk of selection bias, and patient allocation to surgical technique was not randomized. Second, although the mean follow-up duration exceeded 24 months, the primary outcome analyses focused on 12-month data. Consequently, the study was not designed to evaluate long-term cartilage preservation, osteoarthritis progression, or conversion to total knee arthroplasty. In addition, biomechanical testing and second-look arthroscopy were not performed to directly confirm mechanical stability or biological healing. Nevertheless, the use of standardized surgical techniques performed by a single experienced surgeon, a homogeneous patient cohort, and blinded assessment of both clinical and radiological outcomes represent important strengths of the study.

CONCLUSION

Both the standard transtibial tunnel technique and the aperture-preserving modified pinhole technique yielded satisfactory clinical and radiological outcomes in the arthroscopic treatment of traumatic posterior medial meniscal root tears. The modified pinhole technique, performed without reaming at the tibial joint surface, was associated with lower postoperative meniscal extrusion, a higher rate of complete healing, and superior functional scores at 12-month follow-up.

Although statistically significant differences were observed between the techniques, these findings should be interpreted in the context of their absolute magnitude and clinical relevance. The observed advantages of the pinhole technique may not translate into clinically meaningful benefits for every patient, and treatment decisions should take into account individual patient characteristics, functional demands, and surgeon experience. Nevertheless, joint surface–preserving modifications of transtibial meniscal root repair may represent a valuable and safe alternative to conventional techniques in appropriately selected patients.

Ethics Committee Approval: This study was approved by the Ankara Provincial Health Directorate Non-Interventional Ethics Committee (Date: 17.10.2025, Decision No: 2025-10-1).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: M.C.G.; Design: M.C.G.; Data collection and/or processing: M.C.G.; Analysis and/or interpretation: M.D.; Literature review: M.D.; Writing: M.C.G.; Critical review: M.D.

Informed Consent: 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*

Travmatik posterior menisküs kök yırtıklarında artriküler yüzeyi koruyan pinhole transtibial teknik ile standart pull-out onarımın klinik ve radyolojik karşılaştırması

AMAÇ: Travmatik Posterior menisküs kök yırtıkları menisküsün stres mekanizmasını bozarak menisküsün ekstrüzyonuna ve erken dönemde osteoartrit gelişimine yol açmaktadır. Transtibial pull-out onarımı menisküs kök tamiri için yaygın olarak kullanılan bir yöntemdir; ancak 4,5 mm çapında tibial tünel açılması kök ayak izi bölgesinde iyatrojenik kıkırdak ve kemik defektlerine neden olabilmektedir. Bu çalışmanın amacı eklem yüzeyinde frezleme gerektirmeyen, açıklığı koruyan modifiye tekniğin standart pull-out yöntemi ile karşılaştırılarak klinik ve radyolojik sonuçlarının değerlendirilmesidir.

GEREÇ VE YÖNTEM: Aralık 2021 ile Aralık 2024 tarihleri arasında travmatik posterior menisküs kök yırtığı bulunan 60 hasta retrospektif olarak çalışmaya dahil edilmiştir. Hastalar iki gruba ayrılmıştır. Birinci gruba 4.5 mm çapında tibial tünel açılarak standart pull-out onarımı yapılan 30 hasta dahil edildi. İkinci gruba eklem yüzeyinde frezleme yapılmadan modifiye pinhole tekniği uygulanan 30 hasta dahil edildi. Her iki grupta da fiksasyon kortikal postfiksasyon vidası ile yapıldı. Hastaların klinik değerlendirmeleri ameliyat öncesinde, ameliyat sonrası altıncı ve on ikinci aylarda yapılmıştır. Fonksiyonel değerlendirmede Lysholm diz skoru (Lysholm), Uluslararası Diz Dokümantasyon Komitesi skoru (International Knee Documentation Committee), Diz Yaralanması ve Osteoartrit Sonuç Skoru (Knee Injury and Osteoarthritis Outcome Score) ve görsel analog ağrı skoru (Visual Analogue Scale) kullanılmıştır. Radyolojik değerlendirme manyetik rezonans görüntüleme ile yapılmış ve menisküs ekstrüzyonu ile iyileşme durumu (tam, kısmi, başarısız) incelenmiştir.

BULGULAR: Her iki grupta da fonksiyonel skorlar ameliyat öncesine göre anlamlı düzeyde artış göstermiştir ($p<0.001$). On ikinci ay değerlendirmesinde modifiye pinhole tekniği uygulanan grupta Lysholm diz skoru, Uluslararası Diz Dokümantasyon Komitesi skoru ve Diz Yaralanması ve Osteoartrit Sonuç Skoru standart pull-out grubuna göre anlamlı olarak daha yüksek bulunmuştur. Görsel analog ağrı skorundaki iyileşme ise iki grup arasında benzer bulunmuştur. Menisküs ekstrüzyonu her iki grupta da artmış olmakla birlikte, artış miktarı modifiye pinhole grubunda daha düşük saptanmıştır. Tam iyileşme oranı modifiye pinhole grubunda %80, standart pull-out grubunda ise %60 bulunmuştur. Çalışma süresince majör komplikasyon izlenmemiştir.

SONUÇ: Posterior menisküs kök yırtıklarının onarımında her iki teknik de tatmin edici sonuçlar sağlamaktadır. Bununla birlikte eklem yüzeyinde açıklığı koruyan ve frezleme gerektirmeyen modifiye pinhole tekniği daha iyi fonksiyonel iyileşme, daha düşük menisküs ekstrüzyon progresyonu ve daha yüksek tam iyileşme oranı ile üstünlük göstermektedir. Eklem yüzeyinde iyatrojenik hasarın en aza indirilmesi menisküs kök onarımının başarısını artırabilir.

Anahtar sözcükler: Artroskopik onarım; menisküs ekstrüzyonu; menisküs kök yırtığı; pinhole tekniği; transtibial pull-out.

Ulus Travma Acil Cerrahi Derg 2026;32(6):727-734 DOI: 10.14744/tjtes.2026.68654

ORIGINAL ARTICLE

Age-stratified mortality after hip fracture surgery: A retrospective cohort study comparing hemiarthroplasty and osteosynthesis

Murat Gök,[1] Tuna Koçoğlu,[2] Fatih Işık,[1] Ali Bozdemir,[3] Onur Çetin,[4] Cemil Kayali[5]

[1]Department of Orthopedics and Traumatology, University of Health Sciences, Balıkesir Atatürk City Hospital, Balıkesir-*Türkiye*
[2]Department of Orthopedics and Traumatology, İstanbul Medipol University, Pendik Hospital, İstanbul-*Türkiye*
[3]Department of Orthopedics and Traumatology, Bursa Karacabey State Hospital, Bursa-*Türkiye*
[4]Department of Orthopedics and Traumatology, İstanbul Medipol University, Çamlıca Hospital, İstanbul-*Türkiye*
[5]Department of Orthopedics and Traumatology, University of Health Sciences, İzmir Faculty of Medicine, İzmir-*Türkiye*

ABSTRACT

BACKGROUND: Hip fractures are a major public health problem associated with substantial mortality and morbidity, particularly among older adults. More than 90% of hip fractures occur in individuals aged 50 years and older, and the incidence increases with age because of osteoporosis and declining bone quality. This study aimed to examine the association between surgical treatment method and short- and long-term mortality after hip fracture, with an emphasis on age-stratified outcomes.

METHODS: This retrospective cohort study included patients aged 65 years and older who underwent surgery for hip fracture at a tertiary care center. Age and time to surgery were analyzed as continuous variables, whereas sex, surgical method, comorbidities, and follow-up status were analyzed as categorical variables. Baseline characteristics were compared between surgical treatment groups using the independent samples t-test or Mann–Whitney U test for continuous variables and the chi-square test for categorical variables, as appropriate. Cumulative mortality at predefined time points was assessed descriptively, and overall survival was evaluated using Kaplan–Meier survival analysis with comparisons performed using the log-rank test.

RESULTS: A total of 885 patients met the inclusion criteria; 509 patients (57.5%) underwent hemiarthroplasty and 376 patients (42.5%) underwent osteosynthesis. There was no significant difference in one-year cumulative mortality between the groups (p=0.984). At five years, cumulative mortality was higher in the hemiarthroplasty group than in the osteosynthesis group (68.1% vs. 58.5%, p=0.003). Among patients with a Charlson Comorbidity Index ≤5, five-year cumulative mortality was also higher following hemiarthroplasty (61.1% vs. 50.1%, p=0.010). Kaplan–Meier analysis demonstrated significant differences in overall survival between the surgical treatment groups.

CONCLUSION: Higher long-term mortality following hemiarthroplasty was more evident among younger elderly patients and those with a lower comorbidity burden, whereas differences were less pronounced in older patients or those with greater comorbidity.

Keywords: Arthroplasty; hip fracture; mortality; osteosynthesis.

INTRODUCTION

Hip fractures are a major public health concern associated with high rates of mortality and morbidity, and their incidence continues to increase with rising life expectancy. Worldwide, approximately 1.6 million individuals sustain a hip fracture each year, and this number is projected to exceed 7 million in the coming decades.[1] Owing to the substantial mortality,

Cite this article as: Gök M, Koçoğlu T, Işık F, Bozdemir A, Çetin O, Kayali C. Age-stratified mortality after hip fracture surgery: a retrospective cohort study comparing hemiarthroplasty and osteosynthesis. Ulus Travma Acil Cerrahi Derg 2026;32:735-744.

Address for correspondence: Murat Gök
Department of Orthopedics and Traumatology, University of Health Sciences, Balıkesir Atatürk City Hospital, Balıkesir, Türkiye
E-mail: dr.muratgok@yahoo.com

Ulus Travma Acil Cerrahi Derg 2026;32(6):735-744 DOI: 10.14744/tjtes.2026.38852
Submitted: 21.01.2026 Revised: 24.03.2026 Accepted: 29.03.2026 Published: 03.06.2026

morbidity, and disability associated with hip fractures, these injuries pose a considerable burden on healthcare systems and society. Previous studies have reported mortality rates of 6%–11% within the first month and 14%–36% within the first year after hip fracture, while many survivors experience a loss of functional capacity. In addition to the suffering experienced by patients, hip fractures create caregiving challenges and impose social burdens on family members and caregivers.[2,3] Furthermore, studies have demonstrated that hip fractures continue to affect mortality for up to 10 years after surgery.[4] Therefore, optimal management of patients with hip fractures is of critical importance from a public health perspective.

More than 90% of hip fractures occur in individuals aged 50 years and older. The incidence rises progressively with age because of osteoporosis and deterioration in bone quality. As life expectancy continues to increase, the incidence of hip fractures is expected to rise substantially, creating additional challenges for healthcare systems.[5]

Surgical treatment is the standard of care for hip fractures, with the primary options being arthroplasty or osteosynthesis. Although both techniques are well established, selecting the most appropriate treatment approach can be complex. Existing literature suggests that treatment decisions are influenced by multiple factors, including fracture pattern, bone quality, preinjury functional status, and overall patient frailty. However, despite the widespread use of these techniques, the comparative effects of hemiarthroplasty and osteosynthesis on mortality remain controversial. Previous studies have reported conflicting findings, often limited by heterogeneous patient populations, variable follow-up durations, or inadequate adjustment for comorbidities and baseline functional status. Consequently, uncertainty remains regarding which surgical strategy provides a survival advantage in elderly patients with hip fractures.[6]

Given these gaps in the literature, a clearer understanding of short- and long-term mortality outcomes associated with different surgical approaches is needed. This retrospective cohort study aimed to compare short- and long-term mortality in patients aged 65 years and older with hip fractures treated with either hemiarthroplasty or osteosynthesis. Improved understanding of these outcomes may help guide surgical decision-making and optimize patient care.

MATERIALS AND METHODS

This study was designed as a retrospective observational cohort study. Patients aged 65 years and older who were treated for hip fractures at a tertiary referral center between 2013 and 2018 were evaluated. Eligible patients had sustained fractures resulting from low-energy trauma, defined as a simple fall from standing height, and underwent surgical intervention within 48 hours of injury.

Patients were excluded if they were younger than 65 years; had subtrochanteric fractures; presented with additional traumatic injuries; had incomplete or irregular follow-up; were managed nonoperatively; underwent revision procedures; died before surgery; or could not undergo surgical treatment within the first 48 hours after fracture occurrence (Fig. 1).

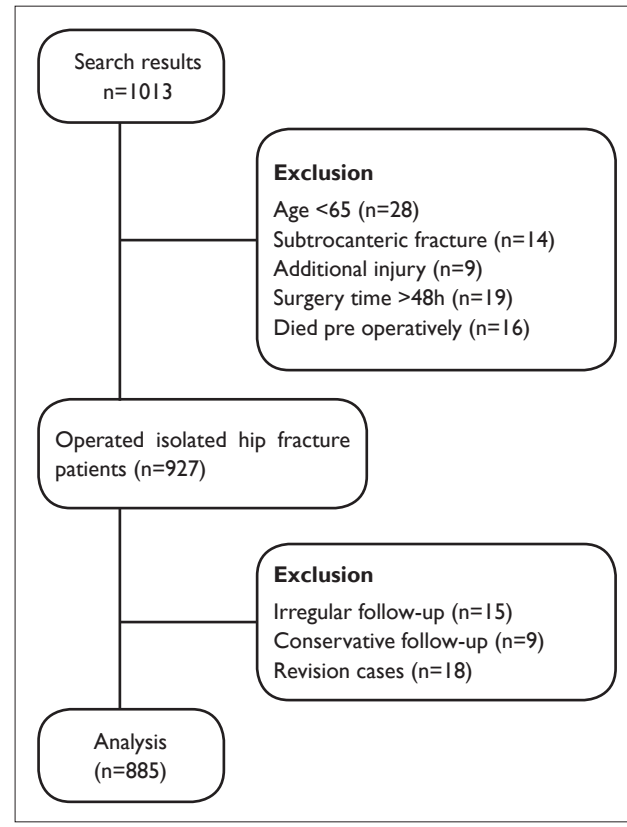

Figure 1. Flowchart of patient inclusions and exclusion criteria.

All patients were initially evaluated in the emergency department. Following a detailed medical history and radiological assessment, treatment planning was performed after consultation with the relevant specialties regarding patient comorbidities.

Patients underwent surgical treatment with a proximal femoral nail (PFN), dynamic hip screw (DHS), osteosynthesis with cancellous screws, or hemiarthroplasty (Fig. 2). The choice of surgical procedure was based on fracture type, fracture location, degree of displacement, patient age, general medical condition, and pre-fracture activity level. All procedures were performed under regional or general anesthesia. Prophylactic antibiotics consisting of a first-generation cephalosporin were administered before surgical incision in all patients.

In patients with intertrochanteric femoral fractures, proximal femoral nailing was preferred in most cases, whereas hemiarthroplasty was favored in comminuted fractures and in patients with severe osteoporosis who were considered at high risk for implant failure following osteosynthesis. Proximal femoral nailing was performed on a traction table under fluoroscopic guidance in all cases.

Hemiarthroplasty was performed in selected patients with

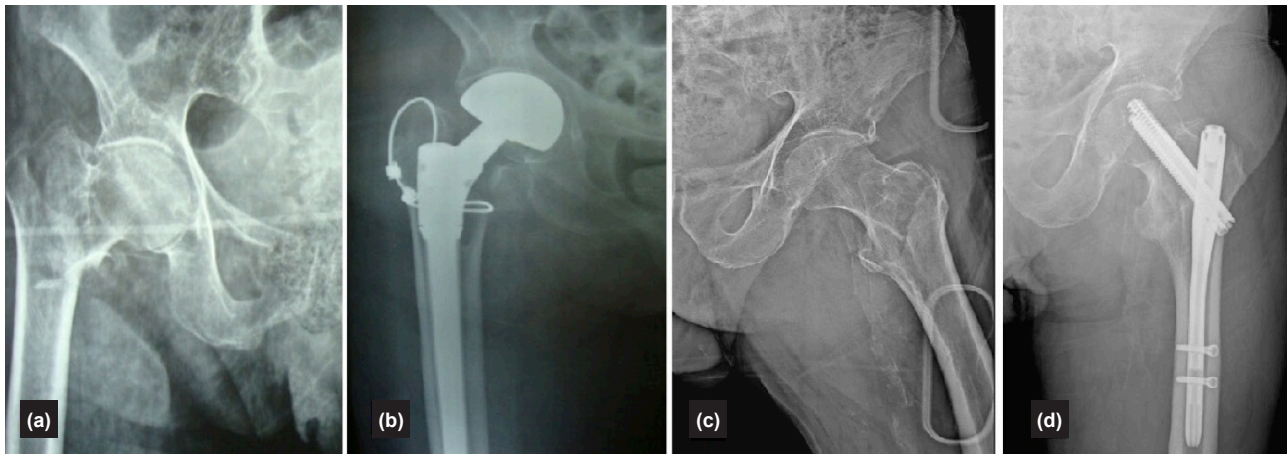

Figure 2. Representative preoperative and postoperative radiographs of hip fracture treatments. **(a)** Preoperative radiograph of a displaced femoral neck fracture. **(b)** Postoperative radiograph following hemiarthroplasty. (**c**) Preoperative radiograph of an intertrochanteric femoral fracture. **(d)** Postoperative radiograph after osteosynthesis with a proximal femoral nail.

intertrochanteric femoral fractures. The greater trochanter was fixed with a cerclage cable when necessary.[7] In all patient groups, mobilization was initiated on the first postoperative day in patients whose general condition permitted and as early as possible in those whose condition did not permit immediate mobilization. Patients ambulated with crutches or walkers and were allowed weight-bearing as tolerated. Antibiotic prophylaxis was continued for 24 hours postoperatively in all patients. Additionally, all patients received deep vein thrombosis prophylaxis with low-molecular-weight heparin for three months after surgery.

Patient demographics and clinical characteristics, including age, sex, surgical method, time from fracture onset to surgery, preoperative and postoperative comorbidities, American Society of Anesthesiologists (ASA) score, outpatient follow-up data, and time of death for deceased patients, were retrospectively obtained from the hospital electronic medical records system. Subgroup analyses were performed according to age and Charlson Comorbidity Index (CCI) categories to evaluate the consistency of observed associations across different risk strata. Age was dichotomized as ≤75 years and >75 years according to the World Health Organization report, while CCI was categorized as low risk (≤5) and high risk (>5) based on estimated five-year life expectancy.[8,9] Charlson Comorbidity Index scores at initial presentation were calculated by considering both age and comorbidities. Medical records, including hospitalization reports, outpatient clinic notes, medication histories, and physician-recorded diagnostic codes, were reviewed in detail. To evaluate both short-term and mid- to long-term outcomes, mortality was assessed at one-year, three-year, and five-year follow-up intervals. Mortality rates at these time points and their relationship with surgical method were analyzed according to age groups and comorbidity status. Fractures were additionally classified as stable or unstable according to the Evans classification, and subgroup analyses were conducted to assess mortality outcomes based on fracture stability and surgical method.

Statistical Analysis

The distribution of continuous variables was assessed using the Kolmogorov–Smirnov test. Variables with a normal distribution were expressed as mean ± standard deviation and analyzed using the independent samples t-test. Variables that did not meet the assumption of normality were presented as median and interquartile range and compared using the Kruskal–Wallis test. Categorical variables were reported as frequencies and percentages, and comparisons between groups were performed using the chi-square test or Fisher's exact test, as appropriate.

Survival outcomes were evaluated using Kaplan–Meier survival analysis, and comparisons between groups were performed using the log-rank test. To control for Type I error inflation resulting from multiple comparisons in analyses of baseline and clinical variables, adjusted p-values were calculated using the Benjamini–Hochberg false discovery rate (FDR) method. Both unadjusted and adjusted p-values were reported. Statistical analyses were performed using IBM SPSS Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY, USA).

This study was approved by the Izmir Bozyaka Training and Research Hospital Local Clinical Research Ethics Committee (21.06.2023, decision no: 2023/88). Data collection was conducted in accordance with the principles of the Declaration of Helsinki and the regulations of the ethics committee.

RESULTS

A total of 1,013 patients underwent surgery for hip fracture during the study period. Of these, 885 patients met the inclusion criteria, while 128 patients were excluded according to the predefined exclusion criteria. Among the included patients, 287 (32.4%) were male and 598 (67.6%) were female.

Age was normally distributed, with a mean age of 79.3±8.6 years. Intertrochanteric femoral fractures were identified in 601 patients (67.9%), whereas femoral neck fractures were present in 284 patients (32.1%). Hemiarthroplasty was performed in 509 patients (57.5%), and osteosynthesis was performed in 376 patients (42.5%) (Table 1).

Preoperative characteristics were compared between patients who underwent osteosynthesis and those who underwent hemiarthroplasty. No significant differences were observed between the groups with respect to age, ASA classification, or CCI scores. The mean age was 78.89±9.23 years in the osteosynthesis group and 79.6±8.76 years in the hemiarthroplasty group (p=0.244). The mean ASA score was 2.49±0.88 in patients treated with osteosynthesis and 2.47±0.91 in those treated with hemiarthroplasty, with no statistically significant difference between the groups (p=0.694). Similarly, CCI scores were comparable between groups, with a mean value of 4.96±1.44 in both groups (p=0.216).

Mortality Outcomes

At one year of follow-up, 97 of 376 patients (25.7%) in the osteosynthesis group and 131 of 509 patients (25.7%) in the hemiarthroplasty group had died. No statistically significant difference in one-year mortality was observed between the groups (p=0.984) (Table 2).

At three years, cumulative mortality was 52.6% (198/376) in the osteosynthesis group and 60.5% (308/509) in the hemiarthroplasty group (p=0.023). However, after adjustment for multiple comparisons using the Benjamini–Hochberg FDR method, this difference did not remain statistically significant

Table 1. Baseline characteristics of patients undergoing osteosynthesis or hemiarthroplasty

Variable	Total (n=885)	Osteosynthesis (n=376)	Hemiarthroplasty (n=509)	p
Age, years (mean±SD)	79.3±8.6	78.9±9.2	79.6±8.8	0.244
Age catego-ry, n (%)				
≤75 years	266 (30.0)	143 (38.0)	123 (24.2)	0.121
>75 years	619 (70.0)	233 (62.0)	386 (75.8)	
Sex, n (%)				0.586
Female	598 (67.6)	249 (66.2)	349 (68.6)	
Male	287 (32.4)	127 (33.8)	160 (31.4)	
ASA score (mean±SD)	2.48±0.90	2.49±0.88	2.47±0.91	0.694
Charlson Comorbidity Index (mean±SD)	4.96±1.44	4.96±1.44	4.96±1.44	0.216
CCI catego-ry, n (%)				
≤5	574 (64.8)	255 (67.8)	319 (62.7)	
>5	311 (35.2)	121 (32.2)	190 (37.3)	

*Charlson Comorbidity Index; *American Society of Anesthesiologists. Continuous variables were compared using the independent samples t-test. Categorical variables were compared using the chi-square test. SD: Standard deviation; CCI: Charlson Comorbidity Index.

Table 2. Comparison of one-year mortality between osteosynthesis and hemiarthroplasty groups

	One-year mortality					
	Osteosynthesis		Arthroplasty			
Group, n	Total, n	Mortality, n (%)	Total, n	Mortality, n (%)	p	FDR
Overall (n=885)	376	97 (25.7%)	509	131 (25.7%)	0.984	0.994
Age ≤75 years (n=266)	143	17 (11.8%)	123	23 (18.6%)	0.121	0.227
Age >75 years (n=619)	233	80 (34.3%)	386	108 (27.9%)	0.105	0.225
CCI* ≤5 (n=574)	255	48 (18.8%)	319	66 (20.6%)	0.578	0.730
CCI >5 (n=311)	121	49 (40.4%)	190	65 (34.2%)	0.279	0.465

CCI: Charlson Comorbidity Index.

Table 3. Comparison of three-year mortality between osteosynthesis and hemiarthroplasty groups

	Three-year mortality					
	Osteosynthesis		Arthroplasty			
Group, n	Total, n	Mortality, n (%)	Total, n	Mortality, n (%)	p	FDR
Overall (n=885)	376	198 (52.6%)	509	308 (60.5%)	0.020	0.057
Age ≤75 years (n=266)	143	42 (29.3%)	123	59 (47.9%)	0.002	0.015
Age >75 years (n=619)	233	156 (66.9%)	386	249 (64.5%)	0.535	0.730
CCI* ≤5 (n=574)	255	109 (42.7%)	319	171 (53.6%)	0.010	0.037
CCI >5 (n=311)	121	89 (73.5%)	190	137 (72.1%)	0.780	0.900

CCI: Charlson Comorbidity Index.

Table 4. Comparison of five-year mortality between osteosynthesis and hemiarthroplasty groups

	Five-year mortality					
	Osteosynthesis		Arthroplasty			
Group, n	Total, n	Mortality, n (%)	Total, n	Mortality, n (%)	p	FDR
Overall (n=885)	376	220 (58.5%)	509	347 (68.1%)	0.003	0.015
Age ≤75 years (n=266)	143	52 (36.3%)	123	70 (56.9%)	0.001	0.015
Age >75 years (n=619)	233	168 (72.1%)	386	277 (71.7%)	0.927	0.994
CCI* ≤5 (n=574)	255	128 (50.1%)	319	195 (61.1%)	0.01	0.037
CCI >5 (n=311)	121	92 (76.0%)	190	152 (80.0%)	0.480	0.720

CCI: Charlson Comorbidity Index; FDR: False discovery rate.

at the predefined threshold (FDR-adjusted p=0.057) (Table 3).

At five years, cumulative mortality was higher in the hemiarthroplasty group (68.1%; 347/509) than in the osteosynthesis group (58.5%; 220/376) (p=0.003). This difference remained statistically significant after FDR adjustment (FDR-adjusted p=0.015) (Table 4).

Overall survival was evaluated using Kaplan–Meier survival analysis. Comparison of survival curves across the entire follow-up period demonstrated a significant difference between the surgical method groups (log-rank p=0.013) (Figure 3).

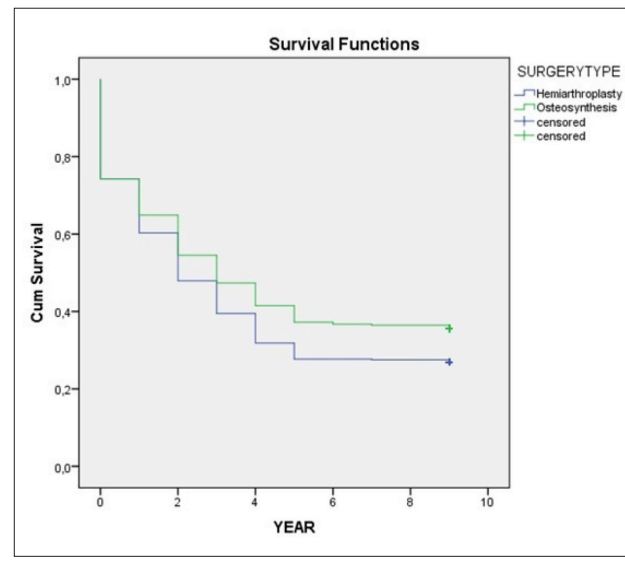

Figure 3. Kaplan–Meier survival curves comparing hemiarthroplasty and osteosynthesis over a five-year follow-up period.

Age-Stratified Analyses

Patients were stratified into two age groups (≤75 years and >75 years).[8] Among patients aged ≤75 years (n=266), cumulative mortality at one year was 11.8% in the osteosynthesis group and 18.6% in the hemiarthroplasty group (p=0.121). At three years, cumulative mortality was higher in the hemiarthroplasty group than in the osteosynthesis group (47.9% vs. 29.3%, p=0.002). At five years, cumulative mortality remained higher in the hemiarthroplasty group (56.9% vs. 36.3%, p=0.001). Among patients older than 75 years (n=619), cumulative mortality rates at one, three, and five years were similar between the osteosynthesis and hemiarthroplasty groups (34.3% vs. 27.9%, p=0.105; 66.9% vs. 64.5%, p=0.543;

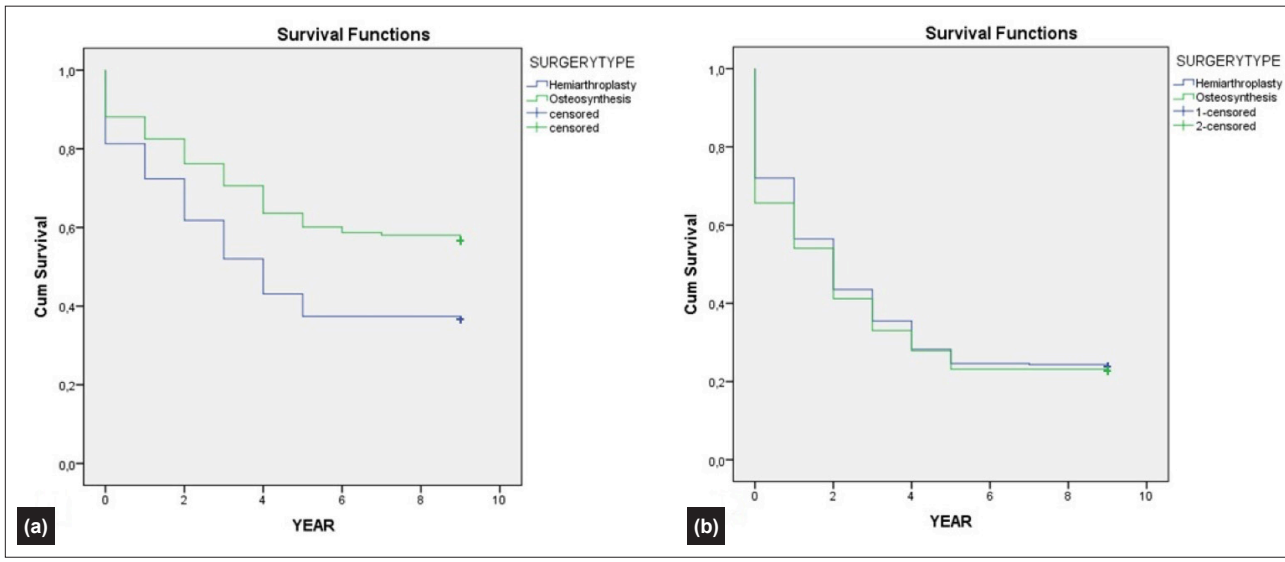

Figure 4. Kaplan–Meier survival curves stratified according to age group. **(a)** Patients aged ≤75 years. **(b)** Patients aged >75 years.

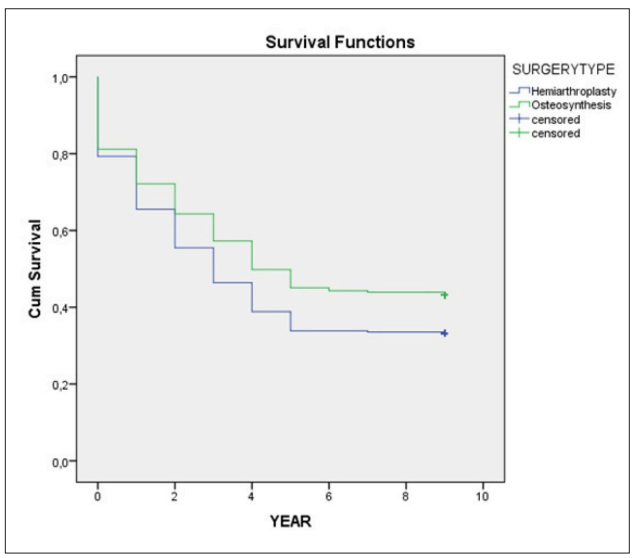

Figure 5. Kaplan–Meier survival curves stratified according to Charlson Comorbidity Index (CCI) ≤5.

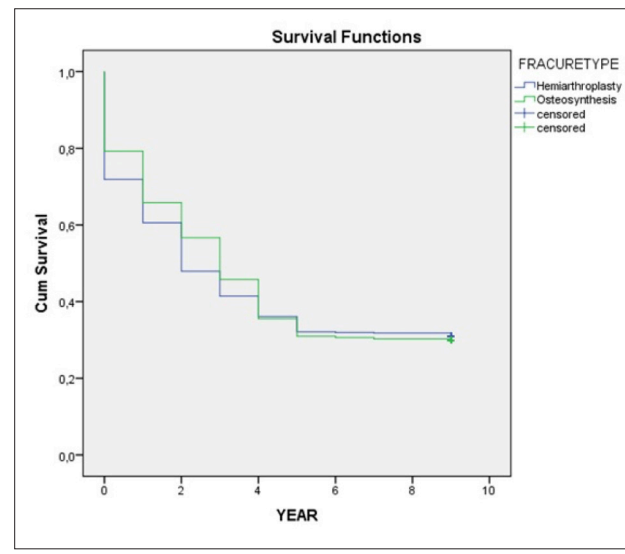

Figure 6. Kaplan–Meier survival curves stratified according to Charlson Comorbidity Index (CCI) >5.

and 72.1% vs. 71.7%, p=0.927, respectively). Kaplan–Meier survival analysis demonstrated a significant difference in overall survival between surgical methods among patients aged ≤75 years (log-rank p=0.010), whereas no significant difference was observed in patients aged >75 years (log-rank p=0.535) (Fig. 4).

CCI-Stratified Analyses

Patients were also stratified according to estimated five-year life expectancy based on the Charlson Comorbidity Index (CCI ≤5 vs. >5).[9] Among patients with CCI ≤5 (n=574), no significant difference between surgical methods was observed in one-year mortality (p=0.578). However, cumulative mortality at both three years (p=0.012) and five years (p=0.010) was higher in the hemiarthroplasty group. Kaplan–Meier analysis also demonstrated a significant difference in overall survival between treatment groups (log-rank p=0017) (Fig. 5).

Among patients with CCI >5 (n=311), cumulative mortality rates at one, three, and five years were similar between the osteosynthesis and hemiarthroplasty groups, with no statistically significant differences (p=0.279, p=0.443, and p=0.480, respectively). Survival analysis likewise demonstrated comparable outcomes between the two treatment modalities, as Kaplan–Meier curves showed no significant separation (log-rank p=0.844) (Fig. 6).

Table 5. Mortality outcomes stratified by surgical method and fracture stability

Group	n	One-year mortality	p	Three-year mortality	p	Five-year mortality	p
Osteosynthesis + stable fracture	239	59 (24.6%)	0.541	125 (52.3%)	0.854	138 (57.7%)	0.745
Osteosynthesis + unstable fracture	137	38 (27.7%)		73 (53.2%)		82 (59.8%)	
Arthroplasty + stable fracture	217	57 (26.2%)	0.102	134 (61.7%)	0.621	151 (69.5%)	0.443
Arthroplasty + unstable fracture	292	74 (25.3%)		174 (59.5%)		196 (67.1%)	
Total stable fractures	456	116 (25.4%)	0.399	259 (56.7%)	0.815	289 (63.3%)	0.779
Total unstable fractures	429	112 (26.1%)		247 (57.5%)		278 (64.8%)	

Fracture Type–Stratified Analysis

A total of 456 patients (51.5%) had stable fractures, whereas 429 patients (48.5%) had unstable fractures. Within the osteosynthesis group, no significant difference in mortality was observed between stable and unstable fractures. Five-year mortality rates were 57.7% in patients with stable fractures and 59.8% in those with unstable fractures (p=0.745). Similarly, among patients treated with hemiarthroplasty, mortality rates did not differ significantly according to fracture stability. Five-year mortality was 69.5% in stable fractures and 67.1% in unstable fractures (p=0.443) (Table 5).

Among patients with stable fractures, one-year mortality rates were comparable between the osteosynthesis and hemiarthroplasty groups (p=0.411). However, at three and five years, mortality rates were significantly higher in the hemiarthroplasty group than in the osteosynthesis group (61.7% vs. 52.3%, p=0.04; and 69.5% vs. 57.7%, p=0.008, respectively).

Among patients with unstable fractures, one-year mortality rates were also similar between treatment groups. At three years, the difference in mortality between hemiarthroplasty and osteosynthesis did not reach statistical significance (59.5% vs. 53.2%, p=0.218). However, at five years, mortality was significantly higher in the hemiarthroplasty group (67.1% vs. 59.8%, p=0.04).

Multivariable Survival Analysis

In unadjusted Cox proportional hazards analysis, hemiarthroplasty was associated with a higher risk of mortality compared with osteosynthesis (hazard ratio [HR]=1.213, 95% confidence interval [CI]: 1.031–1.427; p=0.019). After adjustment for age, sex, Charlson Comorbidity Index, ASA score, and fracture type, this association was attenuated and no longer statistically significant (adjusted HR=1.112, 95% CI: 0.913–1.337; p=0.19).

In age-stratified Cox proportional hazards analyses, models were adjusted for sex, Charlson Comorbidity Index, ASA score, and fracture type, without including age as a covariate. In the ≤75-year age group, patients treated with hemiarthroplasty demonstrated a significantly higher mortality risk than those managed with osteosynthesis (adjusted HR=1.757, 95% CI: 1.131–2.730; p=0.012). In contrast, no significant association between surgical method and mortality was observed among patients aged >75 years (adjusted HR=1.032, 95% CI: 0.837–1.272; p=0.768).

DISCUSSION

This study provides important data regarding the relationship between surgical treatment choice and mortality in elderly patients with hip fractures, a condition that represents a major public health problem. Our findings suggest that the type of surgical treatment may influence mortality, particularly in patients younger than 75 years and in those with fewer comorbidities. The relatively large sample size and minimum follow-up duration of five years strengthen the value of the findings. Nevertheless, the retrospective design and single-center nature of the study should be considered limitations.

Hip fracture is a significant public health issue that predominantly affects the elderly population and is associated with substantial morbidity, mortality, and healthcare costs.[10] Recent evidence suggests that hip fracture rates may have stabilized or even declined, possibly reflecting improvements in osteoporosis management. In a large population-based study from the United States covering the years 2002–2015, Lewiecki et al.[11] reported stabilization in hip fracture incidence between 2012 and 2015. However, increasing global life expectancy continues to raise concerns regarding the worldwide burden of hip fractures. Previous studies have shown that hip fractures occur 2–8 times more frequently in women than in men.[12] Consistent with these reports, most patients in our cohort were female (67.6%).

The primary goal in the treatment of hip fractures is early mobilization while minimizing mortality and morbidity. Therefore, surgical treatment is generally preferred whenever the patient's overall condition permits.[13-16] The optimal timing of surgery has not been clearly established in the current literature, and no clear consensus exists regarding whether acceptable surgical delay should be limited to 24, 48, or 72

hours, or even longer. Some studies have associated early surgery with lower mortality and morbidity, whereas others suggest that delaying surgery until adequate clinical stabilization may reduce complications.[2,17-21] Because operative timing itself may influence mortality outcomes, our study included only patients who underwent surgery within 48 hours of fracture occurrence, and the effect of surgical delay on mortality was not specifically evaluated.

Several studies have compared osteosynthesis and hemiarthroplasty in the treatment of fractures.[22,23] Osteosynthesis has been associated with reduced blood loss, shorter operative time, lower transfusion requirements, and fewer wound-related complications.[24] However, fixation failure is more common after osteosynthesis than after arthroplasty. From a cost perspective, osteosynthesis may be less expensive during the initial hospitalization but can become more costly over time because of revision procedures.[25] According to Frihagen et al.,[26] hospital length of stay did not differ significantly between osteosynthesis and hemiarthroplasty groups.

Although previous studies have investigated postoperative mortality and morbidity following arthroplasty and osteosynthesis, findings have remained inconsistent. Jensen et al.[27] compared osteosynthesis with cannulated screw with hemiarthroplasty and reported lower mortality following osteosynthesis, whereas surgical site infections and medical complications were more common after arthroplasty. Similarly, Parker et al.[23] suggested that osteosynthesis caused less surgical trauma than arthroplasty in patients with displaced intracapsular hip fractures, particularly among older individuals and those with lower functional status.

Davison et al.[28] reported higher one-year mortality following arthroplasty compared with osteosynthesis. However, other studies have found no significant difference in mortality between osteosynthesis and arthroplasty.[29,30] In our study, when all patients were evaluated regardless of age, the surgical method did not affect one-year mortality. However, three-year and five-year mortality rates were significantly higher among patients who underwent hemiarthroplasty.

Jiang et al.[9] demonstrated that a Charlson Comorbidity Index greater than 5 was associated with reduced five-year life expectancy and increased mortality in patients older than 65 years with hip fractures. In our cohort, when patients were stratified into CCI ≤5 and CCI >5 groups, three-year and five-year mortality rates were significantly higher in patients with better estimated five-year life expectancy who underwent hemiarthroplasty, whereas no significant differences were observed among patients with poorer estimated life expectancy.

Similarly, in patients younger than 75 years, three-year and five-year mortality rates were higher in the hemiarthroplasty group. The absence of a significant difference in older patients may be related to their limited overall survival time. Additionally, in the ≤75-year subgroup, the increased mortality observed after hemiarthroplasty may partly reflect selection-related factors, as hemiarthroplasty was more frequently chosen for comminuted fractures or markedly poor bone quality. Furthermore, hemiarthroplasty is a more invasive procedure that involves greater soft-tissue dissection and blood loss, potentially resulting in increased perioperative physiological stress. In contrast, osteosynthesis preserves native bone and may facilitate earlier and more physiological mobilization, potentially reducing postoperative complications. These combined clinical and procedural differences may help explain the increased mortality risk observed in this younger subgroup.

CONCLUSION

In this retrospective cohort study, differences in one-, three-, and five-year mortality were observed between hemiarthroplasty and osteosynthesis, with the association varying according to age and comorbidity subgroups. Although hemiarthroplasty was associated with higher long-term mortality in patients younger than 75 years and in those with a lower comorbidity burden, the two procedures demonstrated comparable outcomes in older patients and in those with greater comorbidity burden. These findings should be interpreted cautiously because of the retrospective design of the study and the potential for residual confounding and selection bias. Further prospective studies are needed to clarify the long-term impact of surgical treatment choice in the management of hip fractures.

Ethics Committee Approval: This study was approved by the Izmir Bozyaka Training and Research Hospital Local Clinical Research Ethics Committee (Date: 21.06.2023, Decision No: 2023/88). Data collection was conducted in accordance with the principles of the Declaration of Helsinki and the regulations

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: M.G., T.K., F.I., A.B., O.C., C.K.; Design: M.G., T.K., F.I., A.B., O.C., C.K.; Data collection and/or processing: M.G., T.K., F.I., A.B., O.C., C.K.; Analysis and/or interpretation: M.G., T.K., F.I., A.B., O.C., C.K.; Writing: M.G., T.K., F.I., A.B., O.C., C.K.; Critical review: M.G., T.K., F.I., A.B., O.C., C.K.

Informed Consent: Retrospective study.

Conflict of Interest: The authors declared 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*

Kalça kırığı cerrahisi sonrası yaşa göre mortalitenin değerlendirilmesi: Hemiartroplasti ve osteosentezin karşılaştırıldığı retrospektif bir kohort çalışması

AMAÇ: Kalça kırıkları, özellikle ileri yaşlı bireylerde yüksek mortalite ve morbidite ile ilişkili önemli bir halk sağlığı sorunudur. Kalça kırıklarının %90'ından fazlası 50 yaş ve üzerindeki bireylerde görülmekte olup, osteoporoz ve kemik kalitesindeki bozulmaya bağlı olarak insidans yaşla birlikte artmaktadır. Bu çalışmanın amacı, kalça kırığı sonrası uygulanan cerrahi tedavi yöntemleri ile kısa ve uzun dönem mortalite arasındaki ilişkiyi, yaşa göre alt grup analizlerine odaklanarak incelemektir.

GEREÇ VE YÖNTEM: Bu retrospektif kohort çalışmasına, üçüncü basamak bir sağlık merkezinde kalça kırığı nedeniyle cerrahi tedavi uygulanan 65 yaş ve üzerindeki hastalar dâhil edildi. Yaş ve cerrahiye kadar geçen süre sürekli değişkenler olarak; cinsiyet, cerrahi yöntem, komorbiditeler ve takip durumu kategorik değişkenler olarak analiz edildi. Başlangıç özellikleri, cerrahi yöntem grupları arasında sürekli değişkenler için bağımsız örneklem t testi veya Mann–Whitney U testi, kategorik değişkenler için ise ki-kare testi kullanılarak karşılaştırıldı. Önceden belirlenmiş zaman noktalarındaki kümülatif mortalite tanımlayıcı olarak değerlendirildi; genel sağkalım ise Kaplan–Meier sağkalım analizi ile incelendi ve gruplar log-rank testi kullanılarak karşılaştırıldı.

BULGULAR: Toplam 885 hasta çalışma kriterlerini karşıladı; bunların 509'u (%57.5) hemiartroplasti, 376'sı (%42.5) ise osteosentez ile tedavi edilmişti. Gruplar arasında 1 yıllık kümülatif mortalite açısından anlamlı fark saptanmadı (p=0.984). Beş yıllık takipte ise hemiartroplasti grubunda kümülatif mortalite, osteosentez grubuna kıyasla daha yüksekti (%68.1 ve %58.5; p=0.003). Charlson Komorbidite İndeksi ≤5 olan hastalarda da 5 yıllık kümülatif mortalite, hemiartroplasti sonrası daha yüksek bulundu (%61.1 vs %50.1; p=0.010). Kaplan–Meier analizine göre genel sağkalım, cerrahi yöntem grupları arasında farklılık göstermekteydi.

SONUÇ: Hemiartroplasti sonrası uzun dönem mortalitenin daha yüksek olması, özellikle daha genç hastalarda ve komorbidite yükü daha düşük olan bireylerde belirginken; ileri yaşlı veya daha fazla komorbiditesi olan hastalarda cerrahi yöntemler arasındaki fark daha sınırlı bulunmuştur.

Anahtar sözcükler: Artroplasti; kalça kırığı; mortalite; osteosentez.

Ulus Travma Acil Cerrahi Derg 2026;32(6):735-744 DOI: 10.14744/tjtes.2026.38852

ORIGINAL ARTICLE

Comparison of negative pressure wound therapy and wet-to-dry dressing after fasciotomy in earthquake victims: A retrospective cohort study

Muhammed Kazez, Gökhan Önce, Orhan Ayas, Ali Sami Şeker, Hüseyin Kürüm

Department of Orthopedics and Traumatology, Elazığ Fethi Sekin City Hospital, Elazığ-*Türkiye*

ABSTRACT

BACKGROUND: This study aimed to compare the clinical effectiveness of negative pressure wound therapy (NPWT) with traditional wet-to-dry dressings in patients undergoing fasciotomy for acute compartment syndrome of the lower extremities following the February 6, 2023 earthquakes in Kahramanmaraş, Türkiye.

METHODS: This retrospective cohort study included 28 patients (15 males, 13 females) admitted to our hospital between February 6 and March 6, 2023, who underwent fasciotomy for lower extremity acute compartment syndrome. A total of 109 fasciotomy incisions were performed across 60 extremities. Of these, 78 wounds were managed with NPWT and 31 with wet-to-dry dressings. Group allocation was determined by NPWT device availability during the disaster period. All patients were managed using a standardized wound closure protocol, including serial debridement followed by primary closure or split-thickness skin grafting when indicated. Outcomes compared between groups included number of debridements, infection rate, primary wound closure, graft requirement, dressing-related complications, and length of hospital stay.

RESULTS: The NPWT group required significantly fewer debridements ($p<0.05$). Dressing-related complications and the need for additional dressing interventions were significantly higher in the wet-to-dry group ($p<0.05$). No significant differences were observed between groups in infection rate, primary wound closure, graft requirement, or length of hospital stay ($p>0.05$). Among pediatric patients, infection rates were lower than in adults, whereas unplanned dressing changes were significantly more frequent ($p<0.05$).

CONCLUSION: NPWT is an effective wound management modality in fasciotomy patients, even under disaster conditions. It significantly reduced the need for debridement and dressing-related complications compared to traditional methods, despite similar outcomes in infection and wound closure. These findings support the preferential use of NPWT in mass-casualty settings, where healthcare personnel and resources may be limited. In addition to its clinical benefits, NPWT offers logistical advantages by simplifying wound care and reducing healthcare workload. Future prospective, randomized, multicenter studies are needed to confirm these findings and evaluate the broader applicability and cost-effectiveness of NPWT in both disaster and routine clinical settings.

Keywords: Compartment syndrome; fasciotomy; gradual approximation; negative pressure wound therapy; wet-to-dry dressing.

INTRODUCTION

Acute compartment syndrome (ACS) is a condition that arises from increased compartment pressure in the extremities and requires emergency fasciotomy to reduce this pressure.[1,2] Following fasciotomy, wound closure and dressing strategies vary depending on tissue status, surgeon preference, and resource availability.[3] Common wound closure approaches include early primary closure, staged closure, skin grafting, and negative pressure wound therapy (NPWT), also known as vacuum-assisted closure (VAC).[4] Traditionally, wet-to-dry dressing has been the standard method for wound management

Cite this article as: Kazez M, Önce G, Ayas O, Şeker AS, Kürüm H. Comparison of negative pressure wound therapy and wet-to-dry dressing after fasciotomy in earthquake victims: A retrospective cohort study. Ulus Travma Acil Cerrahi Derg 2026;32:745-753.

Address for correspondence: Muhammed Kazez

Department of Orthopedics and Traumatology, Elazığ Fethi Sekin City Hospital, Elazığ, Türkiye

E-mail: mkzz23@hotmail.com

Ulus Travma Acil Cerrahi Derg 2026;32(6):745-753 DOI: 10.14744/tjtes.2025.20250

Submitted: 23.09.2025 Revised: 21.12.2025 Accepted: 25.12.2025 Published: 03.06.2026

following emergency fasciotomy for acute compartment syndrome, while NPWT has emerged as a potential alternative.[5] There is currently no consensus regarding the optimal wound closure and dressing strategy.[6] Although numerous studies[7] have been conducted in recent years to establish evidence-based approaches for managing musculoskeletal injuries following earthquakes, variability in clinical practice persists. Specifically, differences in wound closure and dressing techniques among surgeons highlight a lack of consensus on optimal management strategies.[8] The February 2023 Kahramanmaraş earthquake resulted in a substantial increase in patients presenting with acute compartment syndrome, underscoring the urgent need for rapid, efficient, and resource-conscious wound care approaches. In disaster settings, treatment strategies must be not only effective but also reproducible and feasible under constrained conditions. In this context, the benefits of NPWT have not been adequately explored.

The aim of this retrospective cohort study was to compare NPWT with wet-to-dry dressing in patients who underwent fasciotomy following the earthquake. Outcomes of interest included infection rates, frequency of debridement, dressing-related complications, and wound closure success under a standardized closure protocol.

We hypothesized that compared with traditional wet-to-dry dressing, NPWT would reduce infection rates, decrease the need for repeated surgical debridement, and lower the incidence of dressing-related complications.

MATERIALS AND METHODS

Study Design and Patients

This study employed a retrospective cohort design and was conducted in strict accordance with the ethical principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all participants, as well as from the parents of underage participants. This study was approved by the Fırat University Non-Interventional Research Ethics Committee (Date: June 6, 2024, Decision No: 2024/09-26).

Patients admitted to our hospital following the February 6 Kahramanmaraş earthquake were included. The following variables were compared between two dressing groups: demographic characteristics, number of extremities undergoing fasciotomy, number of debridements, dressing-related complications, primary wound closure rate, graft requirement, infection rate, and length of hospital stay.

Primary and Secondary Endpoints

The primary endpoints were the number of debridements and dressing-related complications (defined as unplanned additional dressing changes). Secondary endpoints included infection rate, primary wound closure, graft requirement, and length of hospital stay.

Level of Analysis

Demographic characteristics were analyzed at the patient level. In contrast, debridement count, dressing-related complications, infection, wound closure outcomes, and graft requirement were analyzed at the wound level.

Figure 1. Renewal of wet-to-dry dressing on the extremity following fasciotomy using the gradual approximation method.

Treatment Protocol and Dressing Groups

Wet-to-Dry Dressing Group: In the first group, following fasciotomy of the extremity, sterile gauze dressings impregnated with bacitracin and neomycin-containing creams were applied to fill the fasciotomy site and then covered with dry gauze. Dressings were changed every 8 hours (Fig. 1). Antibiotic-impregnated gauze was used exclusively in this group.

NPWT Group: In the second group, NPWT was initiated immediately after fasciotomy. The vacuum device was operated in intermittent mode (5 minutes on, 2 minutes off) at a mean pressure of 125 mmHg (Fig. 2). Polyurethane (PU) foam was used in all applications, and wounds were sealed with standard transparent medical adhesive drapes. Treatment was delivered using the single portable NPWT device available in our hospital during the disaster period.

In both groups, a gradual approximation technique was used for wound closure, taking into account the progression of wound healing and the presence of tissue edema at the fasciotomy site. Primary wound closure was performed when-

Figure 2. Dressing of a fasciotomized extremity using negative pressure wound therapy (NPWT).

Figure 3. Saturation of the wet-to-dry dressing and exposure to the external environment due to bleeding and edema in the fasciotomy area, necessitating re-dressing.

Figure 4. Requirement for re-dressing due to device blockage caused by hemorrhage and edema, as well as loosening of adhesives, in a patient treated with negative pressure wound therapy (NPWT).

ever feasible; otherwise, closure using a partial-thickness skin graft was planned and applied as needed. Serial debridements were initially conducted every 48 hours and subsequently every 72 hours under sedation anesthesia in the operating room. During debridement, tissue samples were collected for microbiological analysis when infection was suspected. Antibiotic therapy was initiated in consultation with infectious disease specialists in the patients with positive culture results. In the first group, early postoperative complications such as bleeding, hematoma formation, and soft tissue edema were observed within the initial hours following fasciotomy. Additional dressing changes outside the scheduled intervals were required due to dressing saturation from edema and exposure of the wound to the external environment. These events were recorded as dressing-related complications (Fig. 3). In the second group, dressing-related complications included device occlusion due to hemorrhage and edema, detachment of adhesive components, and the need for reapplication of dressings (Fig. 4).

Due to the emergency conditions following the February 6 Kahramanmaraş earthquake, patient allocation to dressing methods was not randomized but was determined by the availability of NPWT devices during the initial disaster response. The first ten patients received NPWT as devices were readily available in the hospital. As supplies became scarce, the subsequent eight patients were treated with wet-to-dry dressings. Following the arrival of additional NPWT devices from neighboring provinces, the final ten patients were again managed with NPWT (Fig. 5). Although this non-randomized

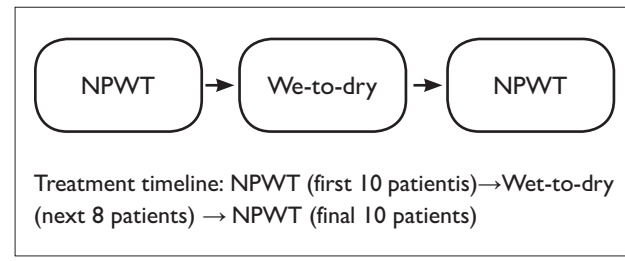

Figure 5. Flow diagram illustrating the sequential allocation of dressing methods during the disaster period.

allocation may introduce selection bias, the sequential treatment approach, combined with the use of consistent surgical teams and standardized wound management protocols, helped preserve internal consistency. Nevertheless, the potential for temporal confounding inherent in this design has been acknowledged in the interpretation of the study findings.

Inclusion and Exclusion Criteria

Patients were included in the study if all of the following criteria were met:

- Diagnosis of acute compartment syndrome confirmed clinically by two orthopedic surgeons.
- Emergency fasciotomy performed at our institution following the February 6, 2023 earthquake.
- Fasciotomy limited to the lower extremity (anterolateral and/or posteromedial incisions for leg compartments; lateral incision for the thigh).
- Continuation of treatment with a single designated dressing method (either NPWT or wet-to-dry dressings) until definitive wound closure.
- Wound debridement and closure procedures performed by the same orthopedic surgical team.
- Availability of complete clinical, microbiological, and follow-up data throughout hospitalization.

Patients were excluded if any of the following criteria were present:

- Fasciotomy performed outside the lower extremity (e.g., upper limb, gluteal region, isolated foot involvement, etc.).
- Initial fasciotomy performed at an external facility prior to transfer.
- Presence of a bone fracture in the same limb as the fasciotomy.
- Requirement for intensive care due to multitrauma or shock, precluding scheduled wound management.
- Contraindication to repeated anesthesia or inability to undergo serial debridement.
- Incomplete hospitalization records or loss to follow-up prior to wound closure.

Due to the retrospective study design and the natural pattern of patient admissions following the earthquake, no patients aged 15–18 years who met the inclusion criteria were identified in the study cohort.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics 22 (IBM SPSS, Türkiye). The normality of data distribution was assessed using the Shapiro–Wilk test. Descriptive statistics were presented as mean ± standard deviation or frequency and percentage. For quantitative variables that did not follow a normal distribution, the Mann–Whitney U test was used. Non-normally distributed data were reported as median and interquartile range (IQR), and exact p-values were provided for all analyses. Qualitative data were compared using Fisher's exact test or the Fisher–Freeman–Halton test. A p value of <0.05 was considered statistically significant.

RESULTS

A total of 28 patients (patient-level analysis) with 109 fasciotomy wounds (wound-level analysis) were included in the study. Demographic characteristics were analyzed at the patient level, while wound-related outcomes—including the number of debridements, infection status, wound closure type, graft requirement, and dressing-related complications—were evaluated at the wound level. The study retrospectively analyzed 28 earthquake victims treated between February 6, 2023 and March 6, 2023. The cohort included 15 males (53.6%) and 13 females (46.4%), with a mean age of 31.11±12.8 years (range: 12–54 years) (Table 1). Patients were categorized according to dressing method: eight patients (28.6%) received wet-to-dry dressings (Group 1), and 20 patients (71.4%) were treated with NPWT (Group 2). Fasciotomy distribution was as follows: 7 patients (25%) underwent fasciotomy in one leg, 14 patients (50%) in both legs, three patients (10.7%) in both legs and one thigh, and four patients (14.3%) in both legs and both thighs. In total, 60 extremities underwent fasciotomy, resulting in 109 fasciotomy wounds (two fasciotomy incisions per leg and one per thigh). Of these, 78 wounds were managed with NPWT and 31 with wet-to-dry dressings (Table 2). No infection was detected in 67.9% of patients, whereas 32.1% developed infections based on culture results. The number of limbs undergoing fasciotomy, infection rates, fasciotomy sites, and the numbers of limbs achieving primary wound closure or requiring graft closure were compared between the two dressing methods (Table 2). No statistically significant differences were observed between groups ($p>0.05$). Culture-based infection rates were evaluated at the wound level, with infection recorded per fasciotomy incision rather than per patient.

The number of debridements and the frequency of additional dressings beyond the planned schedule (defined as dressing-

Table 1. Patients demographics

	Min-Max	Mean±SD (median)
Age	12-54	31.11±12.8
	n	%
Sex		
Male	15	53.6
Female	13	46.4
Age group		
12-14	7	25
19-54	21	75

SD: Standard deviation.

Table 2. Comparison of wound-related outcomes between wet-to-dry dressing and negative pressure wound therapy (NPWT) groups (wound-level data)

Variable	Wet-to-dry (n=8)	NPWT (n=20)	p-value
Number of fasciotomized ex-tremities[1]	2 (1–4)	2 (1–4)	0.680
Number of debridements[1]	3 (2–6)	2 (1–6)	0.049
Wound infection[2]	Absent: 5 (62.5%)	Absent: 14 (70%)	
	Present: 3 (37.5%)	Present: 6 (30%)	0.516
Fasciotomy location[3]			0.406
One leg	3 (37.5%)	4 (20%)	
Two legs	3 (37.5%)	11 (55%)	
Two legs + one thigh	0 (0%)	3 (15%)	
Two legs + two thighs	2 (25%)	2 (10%)	
Additional dressing interven-tions[3]			0.034
1	1 (16.7%)	4 (80%)	
2	1 (16.7%)	1 (20%)	
3	2 (33.3%)	0 (0%)	
4	1 (16.7%)	0 (0%)	
5	1 (16.7%)	0 (0%)	
Primary closure[2]	0: 24 (77.2%)	0: 63 (80.4%)	
	1: 5 (16.4%)	1: 9 (11.8%)	
	2: 1 (6.4%)	2: 3 (7.6%)	1.000
Graft requirement[3]	1: 10 (32.2%)	1: 20 (25.6%)	
	2: 4 (25.8%)	2: 20 (51.5%)	
	3: 2 (19.2%)	3: 1 (3.6%)	0.179

[1]Mann–Whitney U test; [2]Fisher's exact test; [3]Fisher–Freeman–Halton test. NPWT: Negative pressure wound therapy.

related complications) were significantly higher in the wet-to-dry dressing group (Group 1) compared to the NPWT group ($p<0.05$) (wound-level analysis) (Table 2).

Patients were stratified in two age groups (12–14 years and 19–54 years) based on the available dataset. Due to the retrospective design and post-disaster admission pattern, no eligible patients aged 15–18 years were identified. There was no statistically significant difference in the distribution of dressing methods between age groups ($p>0.05$) (Table 3). In the pediatric group (12–14 years), a total of six wounds in three patients were treated with wet-to-dry dressings, while 10 wounds in four patients were managed with NPWT. When comparing age groups across both treatment methods, no statistically significant differences were observed between pediatric patients and adults (19–54 years) in terms of debridement count or primary wound closure rates ($p>0.05$). Pediatric and adult subgroups were analyzed at both the wound and patient levels, as appropriate. The infection rate was lower in the pediatric group compared to adults, whereas the frequency of cases requiring additional dressings beyond the planned schedule was significantly higher in the pediatric group ($p<0.05$) (Table 4). No statistically significant differences were found in the length of hospital stay between patients treated with NPWT and those receiving wet-to-dry dressings, nor between age groups ($p>0.05$) (Table 5). Length of stay was evaluated at the patient level.

Table 3. Distribution of dressing methods by age group

Dressing method	Age group		p*
	12–14 years n (%)	19–54 years n (%)	
Wet-to-dry dressing	3 (42.9%)	5 (23.8%)	0.306
NPWT	4 (57.1%)	16 (76.2%)	–

*Fisher's exact test. *Due to the retrospective study design and the pattern of patient admissions following the earthquake, no patients aged 15–18 years met the inclusion criteria and were therefore excluded from the analysis. NPWT: Negative pressure wound therapy.

DISCUSSION

This study is among the limited number of investigations

Table 4. Comparison of debridement, infection, primary closure, and dressing-related complications between age groups

Parameter	12–14 years	19–54 years	p-value
Number of debridements	2 (2–3)	2 (2–3)	0.977[1]
Wound infection	Absent: 6 (85.7%)	Absent: 13 (61.9%)	
	Present: 1 (14.3%)	Present: 8 (38.1%)	0.025[2]
Number of wounds with primary closure	0: 12 (75%)	0: 74 (79.5%)	
	1: 2 (12.5%)	1: 9 (9.7%)	0.425[2]
	2: 1 (12.5%)	2: 5 (10.8%)	
Dressing-related problems	1: 1 (20%)		
	2: 1 (20%)		
	3: 1 (20%)	1: 4 (66.7%)	
	4: 1 (20%)	2: 1 (16.7%)	0.035[3]
	5: 1 (20%)	3: 1 (16.7%)	

[1]Mann–Whitney U test; [2]Fisher's exact test; [3]Fisher–Freeman–Halton test.

Table 5. Comparison of length of hospital stay by dressing method and age group

Parameter	12–14 years	19–54 years	p-value
Dressing method (overall)	Wet-to-dry (n=8): 15 (15–26)	NPWT (n=20): 20 (17–20)	0.564
Age groups (overall)	12–14 years (n=7): 18 (15–20)	19–54 years (n=21): 20 (15–20)	0.511
Wet-to-dry subgroup	12–14 years (n=3): 15 (15–23)	19–54 years (n=5): 15 (15–25)	0.873
NPWT subgroup	12–14 years (n=4): 19 (16–20)	19–54 years (n=16): 20 (17–20)	0.455

[1]Mann–Whitney U test. IQR: interquartile range; NPWT: Negative pressure wound therapy.

evaluating the effectiveness of NPWT and conventional wet-to-dry dressings in a stepwise wound closure approach for patients who developed compartment syndrome of the thigh and leg following an earthquake and underwent emergency fasciotomy at our institution. Our findings demonstrate that NPWT and wet-to-dry dressings result in comparable clinical outcomes in terms of wound healing. However, our findings indicate that NPWT dressings should be favored whenever feasible, as they require less debridement and are associated with fewer dressing-related complications compared to wet-to-dry dressings. Another key observation of our study is that pediatric patients who underwent fasciotomy for acute compartment syndrome exhibited lower infection rates than adults, although they experienced a higher incidence of dressing-related complications. Furthermore, the stepwise use of NPWT, standard dressings, and wet-to-dry dressings produced comparable outcomes in terms of primary wound closure and graft requirements. This study is among the few in the literature to evaluate the effectiveness of wound care strategies following fasciotomy. It also offers insights from our experience managing fasciotomy wounds in pediatric and adult patients after disasters, which we hope will contribute to the literature.

Unlike controlled environments in randomized trials, this study provides real-world data obtained under mass-casualty conditions following a major natural disaster. The logistical challenges—such as limited device availability, personnel shortages, and prolonged inpatient stays due to housing destruction—underscore the practicality and feasibility of NPWT in disaster settings. Despite comparable infection and closure rates, NPWT facilitated more efficient wound management by reducing the number of dressing changes and surgical debridements. This advantage is particularly valuable in overwhelmed hospitals where time, equipment, and healthcare personnel are limited.

Acute compartment syndrome is a condition requiring urgent intervention to prevent the death of muscle and nerve cells.[9] Fasciotomy is essential to prevent irreversible necrosis of muscle and nerve tissue caused by impaired tissue perfusion.[10] By immediately reducing compartment pressure and restoring perfusion, early fasciotomy can prevent muscle and nerve tissue necrosis.[11] In our study, patients included those who arrived in our city or neighboring areas within the first 12 hours after the earthquake and were diagnosed with acute compartment syndrome in the emergency department. Diag-

nosis was established by two orthopedic and traumatology specialists, and all patients underwent emergency fasciotomy. Patients who presented later and were diagnosed with crush injuries were excluded from the study.

There is no clear consensus in the literature regarding optimal closure methods and dressing techniques for fasciotomy wounds.[12] Most approaches depend on the surgeon's preference, the condition of the surrounding tissue, the availability of materials and equipment, and institutional and financial resources.[12] Typically, fasciotomy wounds are left open and managed with moist sterile dressings to prevent tissue drying and retraction.[11] Alternatively, NPWT may be applied.[13] In a study of 227 patients evaluating the impact of dressing type on clinical outcomes following fasciotomy, NPWT was associated with higher primary closure rates and shorter hospital stays compared with traditional wet-to-dry dressings. The average hospital stay was 21 days for primarily closed wounds and 27 days for wounds requiring grafting.[14] In our study, hospital stays ranged from 10 to 30 days, with a mean duration of 20 days. According to the literature, we believe that the prolonged hospital stays observed in some patients in our study were partly attributable to social factors, particularly the destruction of patients' homes following the earthquake.

Previous studies have shown that NPWT promotes early granulation, reduces edema, and decreases the need for debridement.[15] Consistent with these findings, the number of debridements in our study was higher in patients treated with the wet-to-dry dressing method than in those treated with NPWT. This difference may be explained by the negative pressure provided by NPWT, which facilitates early reduction of tissue edema and thereby decreases the need for debridement. The use of the same gradual approximation protocol in both groups likely contributed to the similar infection and closure outcomes. We believe that discrepancies between our findings and those reported in the literature may be related to our use of NPWT as a dressing method rather than a definitive wound closure technique, while a stepwise approach was employed as the closure method in both groups. In contrast to previous reports, no statistically significant difference in infection rates was observed between the two dressing methods in our study; however, infection rates were lower in pediatric patients compared to adults. The comparable infection rates between groups may be attributed to the fact that all patients underwent wound debridement under sedation anesthesia in sterile operating theatre conditions. The lower infection rate in pediatric patients may reflect their greater healing capacity and tissue viability. During the follow-up of fasciotomy wounds, various techniques can be used for stepwise wound closure, aiming to gradually approximate the skin edges as soft tissue edema resolves.[16] In our study, NPWT was applied to the first 10 consecutive patients who underwent fasciotomy. Subsequently, due to supply limitations, the wet-to-dry dressing method was used in eight patients. During serial debridements performed in the operating theatre, the stepwise wound closure approach was used in both groups.

Although the literature suggests that NPWT improves local blood flow, maintains a moist wound environment, prevents wound edge retraction, and reduces infection rates,[2,12] our findings did not demonstrate a difference in infection rates between the two treatment groups. This may be explained by the fact that all patients underwent sterile wound debridement under sedation anesthesia in operating theatre conditions, as well as the frequent dressing changes in patients treated with wet-to-dry dressings, which are exposed to the external environment.

The literature also indicates that NPWT may prevent hematoma and seroma formation in the wound area, facilitating earlier closure of fasciotomy wounds and reducing the need for skin grafts.[17] In our study, although NPWT was associated with reduced hematoma and seroma formation, no statistically significant difference was observed between the NPWT and wet-to-dry dressing groups in terms of primary wound closure rates or skin graft requirements ($p>0.05$). This finding may be related to the fact that NPWT was not used as a stepwise wound closure technique in our study; however, no definitive conclusion can be drawn, as the same stepwise closure approach was applied to all patients in our study.

In contrast to many reports emphasizing its advantages, some studies have highlighted potential disadvantages of NPWT compared to other closure techniques, including increased morbidity, higher costs, and longer treatment duration.[14] A randomized controlled trial reported that using NPWT as part of a stepwise approach increased the need for skin grafts, raised costs, and prolonged treatment duration.[13] Another study reported that NPWT could cause excessive granulation tissue formation, which may delay epithelialization in the wound area.[18] In cases of large muscle swelling, which are more common in patients undergoing fasciotomy due to acute compartment syndrome following an earthquake, NPWT may not sufficiently approximate the wound edges, and the tissues may gradually harden due to granulation, further limiting complete skin edge closure.[19] In this study, NPWT served only as a dressing method, while gradual approximation was uniformly used for closure, preventing an independent assessment of NPWT's effect on closure time.

After fasciotomy, the wound should be closed as soon as possible, taking into account the condition of the wound area, soft tissue edema, and infection status, to reduce the risk of complications.[19] However, it should be borne in mind that early primary wound closure may lead to increased muscle pressure and recurrent compartment syndrome; therefore, caution is required.[20] In a similar study comparing the effectiveness of NPWT with wet-to-dry dressing, the NPWT group had a higher primary closure rate and shorter treatment duration and hospital stay than the wet-to-dry dressing group.[14,21] Another study evaluating the clinical outcomes

of 52 patients who underwent fasciotomy concluded that NPWT reduced the primary skin closure rate, increased the need for grafts, and was comparable to the stepwise approach and wet-to-dry dressing in terms of wound closure time and infection rates.[19]

Partial-thickness skin grafts reduce patient morbidity and lower infection rates associated with wound complications. They also help minimize delays in rehabilitation compared to primary or secondary closure of fasciotomy wounds. Owing to these advantages, partial-thickness skin grafts are widely used for the closure of fasciotomy wounds.[22] In our study, consistent with the literature, we aimed to achieve early wound closure in all patients. Wounds were managed either by primary closure or, when necessary, by split-thickness skin grafting, depending on the condition of the wound, degree of tissue edema, and presence of infection.

A study evaluating the closure and management of fasciotomy wounds in pediatric patients reported that the use of NPWT reduced both infection rates and the number of required debridements.[4] Additionally, primary wound closure rates were higher in pediatric patients compared to adults, while infection rates and length of hospital stay were lower in the pediatric population.[23,24] In our study, in agreement with the literature, infection rates in fasciotomy wounds were lower in pediatric patients than in adults. Although the rate of primary wound closure was higher in the pediatric group in our study, this difference did not reach statistical significance, in contrast to previous reports in the literature. We speculate that this finding may be related to the increased number of debridements performed in pediatric patients, particularly in the early postoperative period, due to bleeding and tissue edema. Furthermore, no statistically significant difference was observed in the duration of hospitalization between pediatric and adult patients in our study. This finding may be attributable to hospital admissions driven by social factors rather than clinical necessity.

Limitations and Strengths

This study has certain limitations, primarily its retrospective design and relatively small sample size. Due to the unplanned nature of the disaster, dressing allocation was not randomized but instead determined by equipment availability. Nevertheless, the quasi-randomized sequence (NPWT → wet-to-dry → NPWT), along with the use of a standardized surgical team, minimized allocation bias. Additionally, cost analysis could not be performed due to the lack of consistent data on material usage and billing in the emergency setting. Despite these limitations, the study provides valuable insight into real-world wound care practices during mass-casualty events. Furthermore, the exclusive use of bacitracin/neomycin-impregnated gauze in the wet-to-dry dressing group should be acknowledged as a potential confounding factor that may have influenced dressing-related complications.

A key strength of this study is the homogeneity of the patient population: all fasciotomies involved the lower extremity, all wound closures were performed using the same gradual approximation technique, and all surgical procedures were conducted by the same orthopedic team. Additionally, the inclusion of pediatric patients and the comparison across age groups offer a unique contribution to the existing literature.

CONCLUSION

In this cohort of earthquake victims who underwent fasciotomy for acute compartment syndrome, both NPWT and wet-to-dry dressing methods yielded comparable outcomes in terms of primary wound closure, graft requirement, and infection rates when used alongside a standardized gradual approximation technique. However, NPWT demonstrated clear advantages, significantly reducing the number of required debridements and dressing-related complications. These benefits may simplify wound care and reduce the burden on healthcare systems, particularly in disaster settings with limited personnel and resources.

Based on these findings, NPWT may be considered a preferred dressing method for fasciotomy wounds in mass-casualty situations, not only for its clinical benefit but also for its logistical advantages. Future prospective, randomized, multicenter studies are needed to validate these results and to further assess the cost-effectiveness and broader applicability of NPWT across diverse healthcare settings.

Ethics Committee Approval: This retrospective cohort study was approved by the Fırat University Non-Interventional Clinical Research Ethics Committee (Date: 06.06.2024, Decision No: 2024/09-26).

Peer-review: Externally peer-reviewed.

Informed Consent: Written informed consent was obtained from all participants, as well as from the parents of underage participants.

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

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*

Depremzedelerde fasyotomi sonrası negatif basınçlı yara tedavisi ile ıslak-kuru pansumanın karşılaştırılması: Retrospektif bir kohort çalışması

AMAÇ: Bu çalışmada, 6 Şubat 2023 Kahramanmaraş depremleri sonrası akut kompartman sendromu nedeniyle alt ekstremitelerine fasyotomi uygulanan hastalarda negatif basınçlı yara tedavisi (NPWT) ile geleneksel ıslak-kuru pansuman yönteminin klinik etkinliği karşılaştırılmıştır.

GEREÇ VE YÖNTEM: Çalışma retrospektif kohort tasarımda yürütülmüş olup, 6 Şubat–6 Mart 2023 tarihleri arasında hastanemize başvuran ve alt ekstremite akut kompartman sendromu nedeniyle fasyotomi uygulanan 28 hasta (15 erkek, 13 kadın) dahil edilmiştir. Bu hastalara toplam 109 fasyotomi yapılmış, 60 ekstremite tedavi edilmiştir. Fasyotomi uygulanan 78 yara NPWT, 31 yara ise ıslak-kuru pansuman yöntemi ile tedavi edilmiştir. Pansuman grupları cihaz erişilebilirliğine göre belirlenmiştir. Her iki grup, standart yara kapama protokolüyle (seri debridmanlar sonrası primer veya greft ile kapama) tedavi edilmiştir. Karşılaştırmalar; debridman sayısı, enfeksiyon oranı, primer yara kapama, greft ihtiyacı, pansumanla ilişkili komplikasyonlar ve hastanede kalış süresi parametreleri üzerinden yapılmıştır.

BULGULAR: NPWT uygulanan hastalarda ortalama debridman sayısı anlamlı şekilde daha düşüktü ($p<0.05$). Islak-kuru pansuman grubunda ek pansuman gereksinimi ve pansumanla ilişkili komplikasyonlar anlamlı olarak daha yüksekti ($p<0.05$). Enfeksiyon oranı genel grupta %32.1 olup, iki pansuman yöntemi arasında enfeksiyon, primer kapama ve greft ihtiyacı açısından istatistiksel fark saptanmadı ($p>0.05$). Hastanede kalış süresi de gruplar arasında benzerdi ($p>0.05$). Çocuk hastalarda enfeksiyon oranı erişkinlere göre daha düşük, ancak planlanan dışında ek pansuman ihtiyacı anlamlı olarak daha yüksekti ($p<0.05$).

SONUÇ: NPWT, afet koşullarında dahi uygulanabilirliği yüksek, komplikasyonları azaltan ve debridman ihtiyacını düşüren etkili bir yara bakım yöntemidir. Yara kapama başarıları benzer olsa da, NPWT ile daha az işlem gereksinimi gözlenmiştir. Bu doğrultuda, kısıtlı personel ve kaynakla çalışılan afet senaryolarında NPWT'nin öncelikli tercih edilmesi önerilmektedir. Ayrıca, ileriye dönük randomize, prospektif ve çok merkezli çalışmalara ihtiyaç vardır.

Anahtar sözcükler: Fasyotomi; ıslak-kuru pansuman; kademeli yaklaştırma; kompartman sendromu; negatif basınçlı yara tedavisi.

Ulus Travma Acil Cerrahi Derg 2026;32(6):745-753 DOI: 10.14744/tjtes.2025.20250