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## Ulusal Travma ve Acil Cerrahi Dergisi

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Ulusal Travma ve Acil Cerrahi Dergisi

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# Contents - *İçindekiler*

## Experimental Studie - *Deneysel Çalışma*



## Original Articles - *Orijinal Çalışma*



## Case Reports - *Olgu Sunumu*

TURKISH JOURNAL OF TRAUMA & EMERGENCY SURGERY
*ULUSAL TRAVMA VE ACİL CERRAHİ DERGİSİ*
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## Contents - *İçindekiler*

EXPERIMENTAL STUDY

# Antifibrotic and anti-inflammatory properties of halofuginone in a rat craniectomy model

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## ABSTRACT

**BACKGROUND:** Cranioplasty is the process of closing a defect after craniectomy using various materials. This procedure carries risks due to adhesions formed by fibrous scar tissue after craniectomy, which can lead to complications such as cerebrospinal fluid (CSF) fistula from dural damage and cerebral hematoma contusion from parenchymal damage, which can have serious consequences. Halofuginone, a low-molecular-weight molecule derived from Dichroa febrifuga, has demonstrated antifibrotic and anti-inflammatory properties by inhibiting type I collagen synthesis and the transforming growth factor-beta (TGF-β) signaling pathway. This study aimed to investigate the effects of halofuginone on fibrotic tissue formation following craniectomy in a rat model.

**METHODS:** Twenty male Wistar rats underwent bilateral frontoparietal craniectomies and were divided into two groups: a control group treated with saline and a halofuginone group receiving oral halofuginone (1 mg/kg/day) for one week post-surgery. After 30 days, histopathological and ultrastructural analyses were performed to evaluate dura mater thickness, epidural fibrosis, arachnoid involvement, and bone regeneration.

**RESULTS:** Halofuginone significantly reduced dura mater thickness (19.3±6.51 µm vs. 51.29±14.3 µm in controls, $p<0.05$) and epidural fibrosis grades, with fewer arachnoid adhesions observed in the halofuginone group ($p<0.05$). Electron microscopy revealed fewer active fibroblasts and thinner, disorganized collagen fibers in halofuginone-treated rats, suggesting inhibition of fibroblast activity and collagen production. No significant difference in bone regeneration was observed between the groups.

**CONCLUSION:** These findings indicate that halofuginone effectively reduces fibrotic tissue formation at craniectomy sites, potentially by suppressing collagen synthesis and inflammatory responses. Further studies are warranted to explore its clinical applications in preventing postoperative fibrosis.

**Keywords:** Antifibrotic; cranioplasty; halofuginone; rat craniectomy model.

## INTRODUCTION

Cranioplasty is a surgical procedure performed to repair or reconstruct missing or damaged bone in the skull.[1] Surgical decompression is often required after severe traumatic brain injury (TBI), ischemic stroke, subarachnoid hemorrhage, dural sinus thrombosis, or infection, and cranioplasty is subsequently needed.[2] Cranioplasty not only protects the brain from external trauma but also restores cranial shape for cosmetic purposes. Furthermore, it serves as a therapeutic interven-

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tion by regulating cerebrospinal fluid (CSF) dynamics, cerebral blood flow, and metabolic activity within the brain. It improves patients' psychological well-being while enhancing their social performance.[3,4]

Fibrosis refers to the process in which normal tissue architecture is replaced by abnormal, dysfunctional, and excessive scar tissue. This excessive scar formation is associated with a range of clinical issues and health complications.[5] Following craniectomy, extensive adhesions may form between soft tissue structures, particularly the dura, temporal muscle, and galea, during cranioplasty. Fibrotic tissue that develops between bone surfaces after bone flap replacement can also inhibit bone fusion.[6]

Halofuginone, a low-molecular-weight compound isolated from Dichroa febrifuga, is a specific inhibitor of type I collagen synthesis. By inhibiting the transforming growth factor-beta (TGF-β) pathway, it may exert antifibrotic effects in vivo.[7] Since fibrosis results from elevated type I collagen levels, it has been proposed that synthesizing type I collagen could selectively hinder the development of fibrosis.[8] The goal of our research was to explore the impact of halofuginone on wound healing at the craniectomy site in a rat craniectomy model.

## MATERIALS AND METHODS

This study was conducted in accordance with the ethical standards of the Declaration of Helsinki.

### Animal Population

Twenty male Wistar rats, approximately 1 year old and weighing an average of 300 grams, were included. Ethical approval was obtained from the Local Ethics Committee (authorization number 774).

### Surgical Procedure

Prior to surgery, the frontal regions of the rats were shaved and disinfected with povidone. A drill system was used to create bilateral frontoparietal craniectomies, measuring 7-8 mm. The dura mater was exposed without damage. The rats were then randomly allocated into two distinct groups:

1. Control Group (n=10): Saline-soaked cotton pads (0.5×0.5 cm) were applied to the dura mater for 5 minutes.

2. Halofuginone Group (n=10): Following the procedure, halofuginone was administered via oral gavage at a daily dose of 1 mg/kg for one week.[9]

All rats demonstrated satisfactory postoperative recovery with no observable neurologic deficits. They were maintained under uniform conditions and fed a standard diet. Animals were euthanized 30 days after surgery. Cranial bones, including the scalp, were harvested in blocks; one hemisphere was fixed in 10% buffered formalin, while the other was placed in 2.5% glutaraldehyde for 48 hours and then post-fixed with osmium tetroxide.

### Epidural Fibrosis Evaluation

Before pathological analysis, tissue samples were processed through decalcification, dehydration, and paraffin embedding. Axial sections 4 µm thick were prepared and stained with hematoxylin-eosin and Masson's trichrome. The stained slides were examined by a pathologist who was unaware of the group assignments, ensuring a blinded assessment. The evaluation focused on quantifying dura mater thickness, assessing the density of epidural fibrosis, and determining whether the arachnoid mater was involved. Dura mater thickness was calculated as the average of four random measurements. Epidural fibrosis was graded according to the classification system established by He et al.:[10]

- Grade 0: No scar tissue,
- Grade I: Thin fibrous bands between fibrous tissue and dura mater,
- Grade II: Adhesions covering less than two-thirds of the craniectomy defect,
- Grade III: Extensive fibrous tissue with adhesions covering more than two-thirds of the craniectomy defect.

Additionally, the analysis included recording the presence or absence of arachnoid involvement and bone regeneration.

### Evaluation Using Transmission Electron Microscopy

Following fixation, the samples underwent dehydration through a graded series of alcohol concentrations before being embedded in Araldite CY212 resin. Sections approximately 2 µm thick were prepared and treated with 1% methylene blue stain. These sections, mounted on slides, were then heated on a hot plate at 100-110°C for 40-45 seconds and then rinsed with tap water. Preliminary examinations for descriptive analysis were performed using a light microscope. Regions deemed significant for ultrathin section preparation were pinpointed. Using a LEICA EM UC7 ultramicrotome, ultrathin sections measuring 60 x 90 nm were prepared. These sections were stained with uranyl acetate and lead citrate, and visualized with a HITACHI HT7800 transmission electron microscope operating at 120 kV.

### Statistical Analysis

Statistical analysis was performed using two methods. Dura mater thickness was assessed with the Mann-Whitney U test, while dura mater fibrosis and arachnoid involvement were evaluated with a chi-square test. A significance level of $p<0.05$ was set. Analyses were conducted with IBM SPPS Statistics for Windows, version 23 (IBM Corp., Armonk, NY, 2015).

## RESULTS

Examination of the surgical sites revealed no evidence of superficial or deep infections. No signs of erythema, hematoma, or CSF leakage were observed.

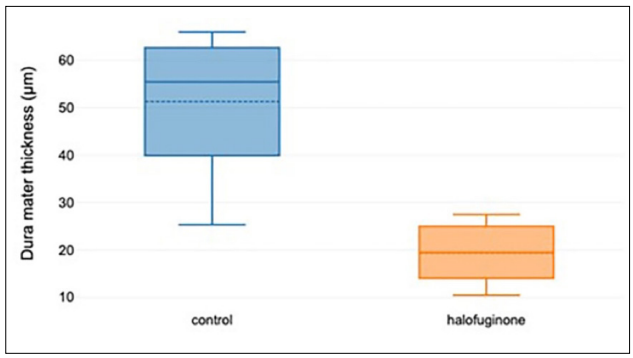


**Figure 1.** Box-plot graph showing differences in dura mater thickness between the halofuginone and control groups. The difference between the halofuginone group and the control group was statistically significant ($p<0.05$).

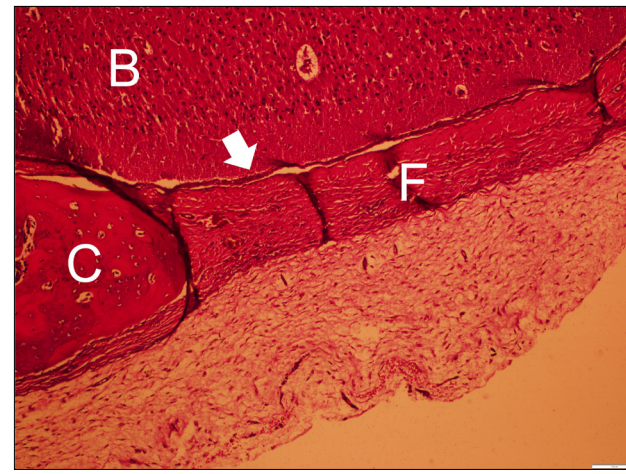


**Figure 2.** Grade 3 control group sections showing fibrous tissue with adhesions extending more than two-thirds of the craniectomy defect (Hematoxylin-Eosin). B: Brain tissue; C: Craniectomy defect; F: Fibrotic tissue; White arrow: Thickened dura mater.

Results regarding dura mater thickness are illustrated in Figure 1. On average, dura mater thickness in the halofuginone-treated group was 19.3±6.51 µm, compared to 51.29±14.3 µm in the control group. The difference in dura mater thickness between the halofuginone and control groups was statistically significant ($p<0.05$).

Analysis of axial sections stained using hematoxylin and eosin (HE) revealed grade 3 epidural fibrosis in seven rats from the control group (Fig. 2), while seven rats in the halofuginone group exhibited grade 1 epidural fibrosis (Fig. 3). Evaluation of the epidural fibrosis grades, detailed in Table 1, showed statistically significant differences between the two experimental groups ($p<0.05$). Assessment of arachnoidal involvement, presented in Table 2, also demonstrated statistically significant differences between the halofuginone-treated and control groups ($p<0.05$). In contrast, comparison of bone regeneration results showed no statistically significant difference between the experimental groups ($p>0.05$) (Table 3). In the electron microscopy samples, neural tissues were not evaluated due to improper fixation. The dural membrane and epidural ultrastructure were compared between the control and halofuginone groups. In the control group, active fibroblasts with rough endoplasmic reticulum occupying large cytoplasmic areas were observed. These cells were embedded in thick bundles of parallel collagen fibers (Fig. 4). In the halofuginone group, fibroblasts were less active, with sparse cytoplasm and few organelles. The collagen fibers in these

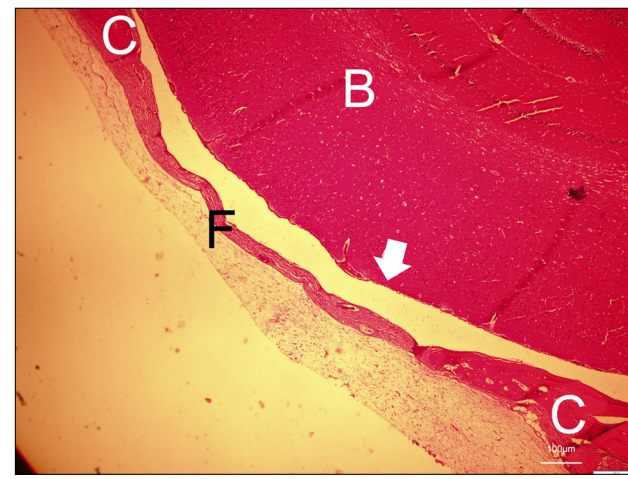


**Figure 3.** Grade 2 halofuginone group sections showing fibrotic adhesions covering less than two-thirds of the craniectomy defect with no dura mater adhesion. B: Brain tissue; C: Craniectomy defect; F: Fibrotic tissue; White arrow: Dura mater.

samples were thinner and oriented in multiple directions (Fig. 5). Ultrastructural examination indicated that halofuginone treatment prevents fibrosis and collagen formation, possibly by inhibiting fibroblast growth.

**Table 1.** Epidural fibrosis grades in the halofuginone and control groups

| Epidural Fibrosis Grades | N | Grade 0 | Grade 1 | Grade 2 | Grade 3 |
|---|---|---|---|---|---|
| Control Group | 10 | 0 | 1 | 2 | 7 |
| Halofuginone Group | 10 | 0 | 7 | 3 | 0 |

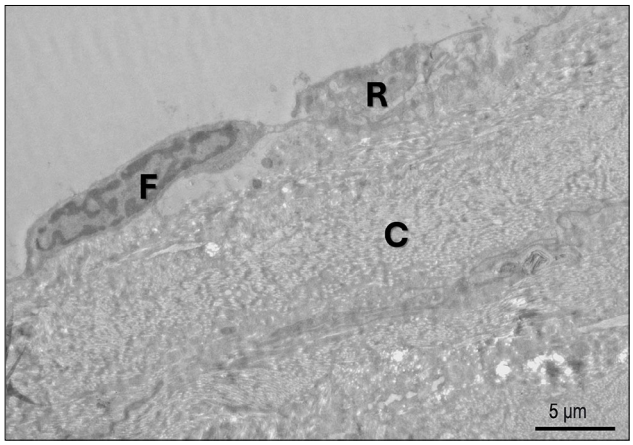


**Figure 4.** Fibroblast (F) with active rough endoplasmic reticulum (R) at the border of the dura mater. Thick bundles of collagen fibers (C) are observed below.

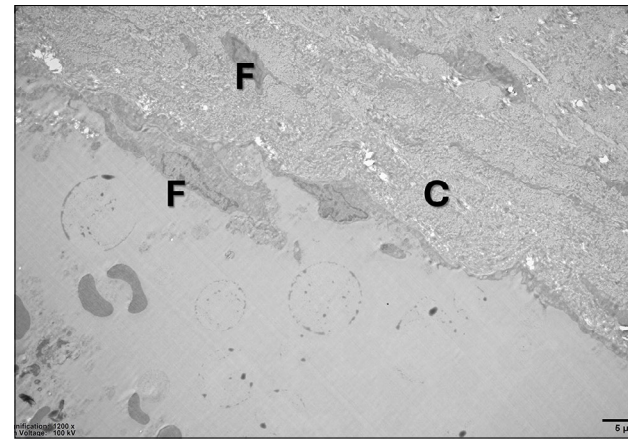


**Figure 5.** Inactive fibroblasts (F) with small or absent cytoplasm. Collagen fibers (C) beneath are oriented in various directions.

**Table 2.** Arachnoid adhesion results in the halofuginone and control groups

| Arachnoid Adhesion | N | Yes | No |
|---|---|---|---|
| Control Group | 10 | 9 | 1 |
| Halofuginone Group | 10 | 2 | 8 |

**Table 3.** Bone regeneration results in the halofuginone and control groups

| Bone Regeneration | N | Yes | No |
|---|---|---|---|
| Control Group | 10 | 7 | 3 |
| Halofuginone Group | 10 | 9 | 1 |

## DISCUSSION

In this study, we evaluated the advantageous effects of halofuginone in preventing fibrotic adhesions in the epidural space after craniectomy. Such adhesions form as a consequence of inflammation induced by surgical trauma, leading to increased synthesis of the extracellular matrix. This process can subsequently cause technical difficulties during tissue separation and negatively affect the operative course. As a result, operative time increases and the risk of dural perforation rises. Additionally, adhesions result in greater residual soft tissues beneath the bone flap and may contribute to poorer aesthetic outcomes of the surgery due to inadequate tissue coverage for the bone flap.[6]

Understanding the mechanism of adhesion formation at the craniectomy site is key to implementing effective preventive measures. Postoperative fibrotic tissue formation occurs in three phases. The first phase begins with an early inflammatory reaction characterized by immune cell infiltration and activation caused by hemostasis, coagulation, and chemokine release. This occurs within the first 3-5 days. The second phase, lasting 2-3 weeks, involves the development of fibrotic tissue. At this stage, extracellular matrix is formed at the injury site under the influence of fibroblasts responding to cytokines such as transforming growth factor- β1 (TGF-β1), interleukin-6 (IL-6), and fibroblast growth factor. Finally, tissue remodeling occurs over months to years.[11] Although granulation tissue that develops at the surgical site may be considered a normal component of wound healing,[12] it is now widely accepted to be non-physiologic.[13]

Halofuginone has many interrelated positive biological activities. It has been officially approved for use as an anti-protozoal agent in both poultry and ruminant animals.[14] Derived from febrifugine, halofuginone has also shown effectiveness in experimental models for treating malaria.[15] The compound demonstrates potent suppression of angiogenesis in diverse tumor types, frequently linked to inhibition of fibroblast-to-myofibroblast transformation and reduction of tumor extracellular matrix content.[16,17] Additionally, halofuginone exhibits anti-fibrotic, anti-inflammatory, and immune-regulating activities.[18,19] The scientific literature proposes two distinct mechanisms to account for these actions:

1. By preventing Smad3 phosphorylation, halofuginone interferes with TGF-β-driven induction of the extracellular matrix and regulates tissue inhibitor genes related to collagen, plasminogen activator inhibitor-1, and metalloprotease-1. This ultimately inhibits epithelial–mesenchymal transition (EMT) and exerts anti-fibrotic effects.

2. Halofuginone blocks the activity of prolyl-tRNA synthetase (ProRS) during the erythrocytic phase of malaria infection and limits Th17 cell differentiation. This mechanism reduces inflammation and autoimmune reactions through activation of the amino acid deprivation pathway and integrated stress

response pathways.[20]

As described above, halofuginone is involved in regulating extracellular matrix formation and reducing inflammation. Therefore, we hypothesized that halofuginone could have positive effects in preventing fibrosis following craniectomy. To investigate the potential mechanisms underlying the reduction of fibrosis by halofuginone treatment after craniectomy, we first examined modifications in extracellular matrix constituents at the craniectomy site. Halofuginone's capacity to inhibit fibrosis was initially discovered by chance and has since been evaluated in numerous animal models as well as human clinical studies.[18,21] Its anti-fibrotic effect is thought to derive from its ability to suppress collagen synthesis, particularly type I collagen.[22] In our research, we first assessed pathologically how halofuginone altered fibrosis grades at the craniectomy site and whether arachnoid adhesions were also present. We then extended this evaluation and, for the first time in published research, investigated at the cellular level how halofuginone affected the extracellular region within the cell. The results showed that halofuginone significantly reduced fibrosis grades and arachnoid adhesions. On electron microscopy, it was associated with decreased collagen fibers. These findings suggest that halofuginone may alleviate fibrotic tissue formation by suppressing collagen production at the craniectomy site. As documented in prior studies, halofuginone has been shown to inhibit activation of the TGF-β signaling pathway by reducing levels of p-Smad3. The TGF-β pathway plays a crucial role in regulating extracellular matrix turnover,[23] and halofuginone has been observed to suppress collagen synthesis induced by TGF-β.[24] In summary, halofuginone potentially reduces fibrosis formation by decreasing collagen production, likely through inactivation of the TGF-β signaling pathway.[25]

The formation of adhesions after craniectomy results not only from an imbalance between synthesis and degradation of extracellular matrix (ECM) components but also from activation of the inflammatory response. Halofuginone has been reported to act on inflammatory mechanisms, leading us to hypothesize that halofuginone treatment may reduce fibrotic tissue formation by inhibiting inflammation. In our study, thickening of the dura mater was quantitatively assessed, and inflammatory cell status was examined by pathology and electron microscopy. As a result, significantly thinner dura mater was observed in the halofuginone group. In addition, electron microscopic examination revealed fewer inflammatory cells in the halofuginone group. Halofuginone had no significant effect on new bone formation in our study. In conclusion, halofuginone treatment inactivates multiple signaling pathways and reduces levels of pro-inflammatory cytokines, which may contribute to the suppression of inflammation.

## CONCLUSION

Our study demonstrated that halofuginone effectively prevented fibrotic tissue formation in an experimental craniectomy model. Further research will help identify alternative agents capable of inhibiting the development of epidural fibrosis.

**Ethics Committee Approval:** This study was approved by the Health Sciences University Ankara Training and Research Hospital Ethics Committee (Date: 22.05.2024, Decision No: 774).

**Peer-review:** Externally peer-reviewed.

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

**Conflict of Interest:** None declared.

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DENEYSEL ÇALIŞMA - *ÖZ*

## Halofuginonun sıçan kraniyektomi modelinde antifibrotik ve anti-inflamatuar özellikleri

AMAÇ: Kranioplasti, kraniektomi sonrası oluşan defektin çeşitli materyaller ile kapatılması işlemidir. Bu işlemin kraniektomi sonrası fibröz skarın oluşturduğu yapışıklıklar nedeniyle bazı komplikasyonları vardır. Bu komplikasyonlar arasında dura hasarı sonucu BOS fistülü ve parankim hasarı sonucu, kontüzyo ve serebral hematom yer almaktadır. Dichroa febrifuga'dan elde edilen düşük molekül ağırlıklı bir molekül olan halofuginon, tip I kolajen sentezini ve TGF-β sinyal yolunu inhibe ederek antifibrotik ve anti-inflamatuar özellikler göstermiştir. Bu çalışmanın amacı, halofuginonun kraniyektomi sonrası fibrotik doku oluşumu üzerindeki etkilerini bir sıçan modelinde araştırmaktır.
GEREÇ VE YÖNTEM: 20 erkek Wistar sıçana bilateral frontoparietal kraniektomi uygulandı ve iki gruba ayrıldı: serum fizyolojik ile tedavi edilen kontrol grubu ve ameliyat sonrası bir hafta boyunca oral halofuginon (1 mg/kg/gün) alan halofuginon grubu. 30 gün sonra, dura mater kalınlığı, epidural fibrozis, araknoid tutulumu ve kemik rejenerasyonunu değerlendirmek için histopatolojik ve ultrastrüktürel analizler yapıldı.
BULGULAR: Sonuçlar halofuginonun dura mater kalınlığını (19.3±6.51 µm'ye karşı kontrollerde 51.29±14.3 µm, $p<0.05$) ve epidural fibrozis derecelerini önemli ölçüde azalttığını ve halofuginon grubunda daha az araknoid yapışıklık gözlendiğini gösterdi ($p<0.05$). Elektron mikroskobu, halofuginon ile tedavi edilen sıçanlarda daha az aktif fibroblast ve daha ince, dağınık kolajen lifleri ortaya çıkardı, bu da fibroblast aktivitesinin ve kolajen üretiminin inhibisyonunu düşündürdü. Gruplar arasında kemik rejenerasyonunda anlamlı bir fark gözlenmedi.
SONUÇ: Bu bulgular, halofuginonun kraniyektomi bölgelerinde fibrotik doku oluşumunu, potansiyel olarak kolajen sentezini ve enflamatuar yanıtları baskılayarak etkili bir şekilde azalttığını göstermektedir. Ameliyat sonrası fibrozisi önlemede klinik uygulamalarını araştırmak için daha fazla çalışma yapılması gerekmektedir.

Anahtar sözcükler: Antifibrotik; halofuginon, kraniyoplasti; sıçan kraniyektomi modeli.

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ORIGINAL ARTICLE

# Cannulated screw fixation in pediatric femoral neck fractures: outcomes and complication predictors

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## ABSTRACT

**BACKGROUND:** Pediatric femoral neck fractures (PFNFs) are rare but are associated with high complication rates due to the precarious vascularity of the femoral head. Cannulated screw fixation (CSF) is the most common surgical technique, though optimal strategies remain debated. The objective of this study was to evaluate the radiological and functional outcomes of proximal femoral neck fractures (PFNFs) treated with CSF and to identify predictors of postoperative complications.

**METHODS:** The retrospective study was performed of 28 patients (mean age 12.4 years; range 5–18) treated with CSF between June 2020 and December 2024. Fractures were classified using the Delbet–Colonna and Garden systems. Reduction quality was assessed radiographically, and functional outcomes were measured by the Harris Hip Score (HHS). Statistical analyses included univariate and multivariate logistic regression.

**RESULTS:** Radiographic union was achieved in 92.9% of patients. The overall complication rate was 42.9%, including coxa vara (17.8%), avascular necrosis (AVN, 14.3%), premature physeal closure (PPC, 10.7%), and non-union (7.1%). Patients with AVN (mean HHS 72.5) and non-union (mean HHS 70.0) had the lowest functional scores, while those with coxa vara (82.0) and PPC (85.0) maintained relatively better function. Patients without complications achieved the best outcomes (mean HHS 88.5). Multivariate analysis identified higher Garden grade (OR 4.1, p=0.038) and non-anatomical reduction (OR 3.75, p=0.046) as independent predictors. PPC was significantly associated with implant removal (p=0.003). Despite the small sample, a post-hoc power analysis based on HHS indicated approximately 85% power to detect large effects.

**CONCLUSION:** PFNFs remain a challenging pediatric injury with high complication rates despite surgical fixation. Precise anatomic alignment is essential to minimize complications, particularly AVN and coxa vara. Close monitoring is recommended for patients with PPC, as it may necessitate implant removal and carries a risk of hip deformity or leg length discrepancy. Larger prospective studies are needed to refine surgical strategies for this rare but clinically significant injury.

**Keywords:** Avascular necrosis; coxa vara; cannulated screw fixation; Harris Hip Score; pediatric femoral neck fracture; premature physeal closure.

## INTRODUCTION

Pediatric femoral neck fractures (PFNFs) are exceptionally rare, accounting for less than 1% of all pediatric fractures.[1] Despite their low incidence, these injuries are clinically significant because they carry a disproportionately high risk of serious complications. The vascular supply to the femoral head is particularly fragile, being primarily derived from the medial femoral circumflex artery.[2] Even minor trauma or surgical intervention can compromise this circulation, leaving the femoral head highly vulnerable to avascular necrosis (AVN).

Historically, PFNFs were managed conservatively with casting. In recent decades, however, early surgical fixation and anatomical reduction have become the standard of care, aimed at minimizing the risk of long-term sequelae. The Delbet–Colonna classification remains widely used for describing PFNFs,

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with fracture location correlating to the likelihood of AVN.[3] Nevertheless, complications extend beyond AVN and may include premature physeal closure (PPC), coxa vara, leg-length discrepancy, and non-union, all of which can compromise hip function.[4]

Cannulated screw fixation (CSF) has emerged as the most common surgical technique, favored for its minimally invasive approach and adaptability to skeletally immature patients. While biomechanical evidence supports the inverted triangle screw configuration for enhanced stability, clinical outcomes in the literature are inconsistent.[5]

The primary objective of this study was to evaluate the radiological and functional outcomes of PFNFs treated with CSF. The secondary objective was to identify predictors of postoperative complications.

## MATERIALS AND METHODS

### Study Design and Patient Selection

We retrospectively reviewed the medical records of 28 pediatric patients who underwent CSF for PFNFs at our institution between June 2020 and December 2024. The mean follow-up duration was 30.9 months (range, 12–60 months).

### Inclusion and Exclusion Criteria

Eligible patients were aged 5–18 years and sustained PFNFs due to either low- or high-energy trauma. All included cases were managed with closed reduction followed by CSF in an inverted triangle configuration. Patients were excluded if they had Delbet type IV fractures, open fractures, fractures requiring open reduction, concomitant lower-limb fractures, pathological fractures, metabolic bone disorders, or an age greater than 18 years.

### Fracture Classification and Reduction Assessment

Fractures were categorized using both the Delbet–Colonna and Garden classification systems. Postoperative radiographs were independently assessed to evaluate reduction quality. In this study, anatomical and acceptable (non-anatomical) reductions were both considered satisfactory. Anatomical reduction was defined as perfect alignment with no displacement or angular deformity, whereas acceptable (non-anatomical) reduction referred to cases with minimal displacement (<2 mm) or angulation ≤20° compared with the normal neck–shaft angle, representing a slight but clinically tolerable deviation from anatomical alignment.[6]

### Surgical Technique

All patients underwent three-screw inverted-triangle fixation as per institutional protocol; screw diameter was adjusted according to patient age and femoral neck size. Postoperatively, immobilization and non-weight-bearing were maintained for 8–12 weeks.

### Data Collection

The following data were recorded: patient demographics, mechanism of injury, fracture classification, reduction quality, complications, and Harris Hip Score (HHS). HHS was assessed at the final follow-up visit, which was at least 12 months postoperatively.

### Statistical Analysis

Descriptive statistics were expressed as mean ± standard deviation, median (range), or frequency (percentage). Normality was tested using the Kolmogorov–Smirnov and Shapiro–Wilk tests. The independent-samples t-test or Mann–Whitney U test was used for between-group comparisons, and categorical variables were compared using the Chi-square test. Univariable logistic regression was first performed to identify potential predictors, and variables with $p<0.1$ were entered into the multivariable logistic regression model, with the occurrence of any complication (yes/no) as the dependent variable. Given the limited number of events (n=12), the final model included two predictors (Garden classification and reduction quality) to avoid overfitting. A post-hoc power analysis based on HHS indicated a large effect size (Cohen's d=1.23) and an achieved power of approximately 85% ($\alpha$=0.05). Analyses were conducted using IBM SPSS Statistics for Windows, Version 28.0 (IBM Corp., Armonk, NY, USA)."

### Ethical Considerations

The study was approved by the institutional review board (approval no. 2025-04, date: 15.01.2025) and conducted in accordance with the principles of the Declaration of Helsinki.

## RESULTS

The study cohort included 28 patients (15 males, 13 females) with a mean age of 12.4 years (range, 5–18). More than half of the injuries (53.6%) resulted from high-energy trauma, while 46.4% followed low-energy mechanisms. Patient demographics and fracture characteristics are summarized in Table 1.

Most cases (82%, 23/28) involved isolated hip fractures. The remaining five patients (18%) sustained additional systemic injuries, including head, chest, abdominal, spinal, upper extremity, and pelvic trauma.

Surgical fixation was performed within 24 hours in 18 patients (64.3%) and after 24 hours in 10 patients (35.7%). Anatomical reduction was achieved in 13 patients (46.4%), while 15 (53.6%) had non-anatomical reductions. Capsulotomy and joint aspiration were not performed in any case. Surgical timing was not significantly associated with complications (p=0.413).

Radiographic union was achieved in 26 of 28 patients (92.9%). The overall complication rate was 42.9% (12 patients). The most frequent complications were coxa vara in 5 patients (17.8%), AVN in 4 patients (14.3%), PPC in 3 patients (10.7%), and non-union in 2 patients (7.1%). Two patients experienced

**Table 1.** Patient and injury characteristics

| Variable | Value |
|---|---|
| Number of patients | 28 |
| Age (years), mean (range) | 12.4 (5–18) |
| Sex, n (%) | Male: 15 (53.6%), Female: 13 (46.4%) |
| Side, n (%) | Right: 16 (57.1%), Left: 12 (42.9%) |
| Mechanism of injury | High-energy: 15 (53.6%), Low-energy: 13 (46.4%) |
| Associated injuries, n (%) | Present: 5 (17.9%), Absent: 23 (82.1%) |
| Delbet–Colonna classification, n (%) | Type I: 1 (3.6%), Type II: 22 (78.6%), Type III: 5 (17.9%) |
| Garden classification, n (%) | Type I: 2 (7.1%), Type II: 6 (21.4%), Type III: 4 (14.3%), Type IV: 16 (57.1%) |
| Surgical timing, n (%) | ≤24 h: 18 (64.3%), >24 h: 10 (35.7%) |
| Reduction quality, n (%) | Anatomical: 13 (46.4%), Non-anatomical: 15 (53.6%) |

two complications each: AVN with PPC and coxa vara with PPC. (Figure 1) Therefore, the total number of complications exceeds the number of patients affected.

Among the five patients who developed coxa vara, four (80%) had undergone non-anatomical reduction at the surgical procedure, while only one had an anatomical reduction.

Functional outcomes, stratified by complication type, are presented in Table 2. Patients with AVN (mean HHS 72.5) and non-union (mean HHS 70.0) had the lowest functional scores, while those with coxa vara (mean HHS 82.0) and PPC (mean HHS 85.0) retained relatively better function. Patients without complications demonstrated the best outcomes (mean HHS 88.5).

Univariate analysis identified right-sided fractures (p=0.008), higher Garden grade (p=0.013), and non-anatomical reduction (p=0.037) as significant predictors of complications. Implant removal was also significantly more frequent in patients with PPC (p=0.003) (Table 3). However, Delbet fracture type was not associated with complications (p=0.626).

Multivariate logistic regression, with the occurrence of any complication (yes/no) as the dependent variable, confirmed higher Garden grade (OR 4.1, 95% CI 1.08–15.6, p=0.038) and non-anatomical reduction (OR 3.75, 95% CI 1.02–13.8, p=0.046) as independent predictors (Table 3).

The mean HHS for the entire cohort was 83.7. Good-to-excellent outcomes (HHS ≥80) were achieved in 67.9% of patients, while 32.1% had fair outcomes (HHS 70–79).

## DISCUSSION

PFNFs are usually caused by high-energy trauma, such as traf-

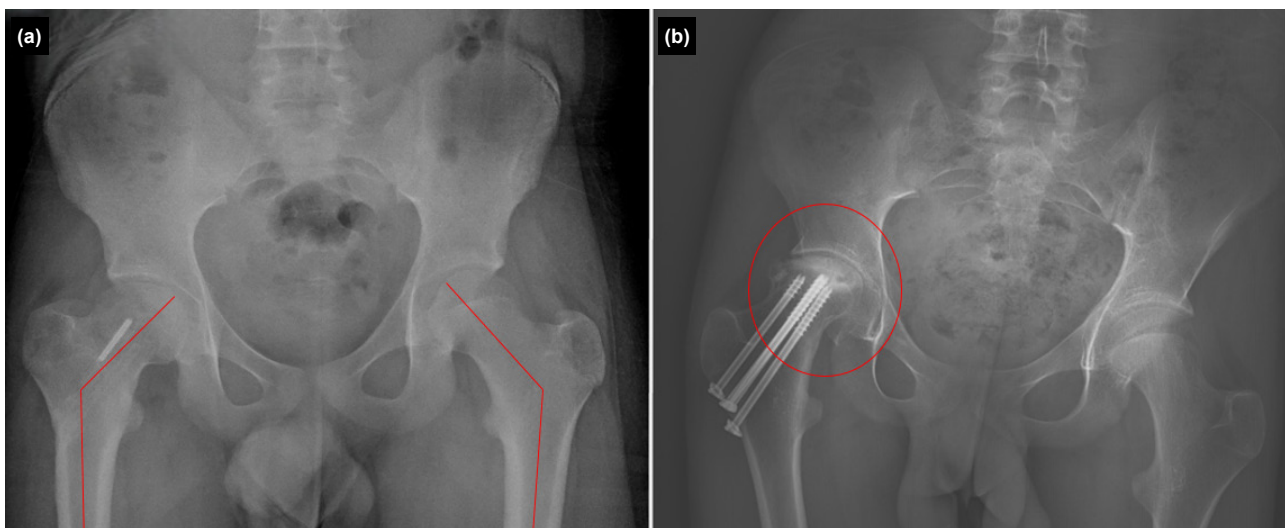


**Figure 1. a)** Coxa vara with premature physeal closure, 19 months postoperatively (neck–shaft angle <120°). **b)** Avascular necrosis with premature physeal closure, 21 months postoperatively.

**Table 2.** Radiological and functional outcomes

| Outcome | Value | HHS (Mean ± SD) |
|---|---|---|
| Mean follow-up (months) | 30.9 (range, 12–60) | – |
| Radiographic union, n (%) | 26/28 (92.9%) | – |
| Overall complications, n (%) | 12 (42.9%) | – |
| Coxa vara (n=5) | 17.8% | 82.0±5.2 |
| Avascular necrosis (n=4) | 14.3% | 72.5±4.8 |
| Premature physeal closure (n=3) | 10.7% | 85.0±4.0 |
| Nonunion (n=2) | 7.1% | 70.0±3.5 |
| No complication (n=16) | – | 88.5±3.7 |
| Mean Harris Hip Score (overall) | 83.7±8.3 | – |
| Functional outcome by HHS, n (%) | Good–Excellent (≥80): 19 (67.9%), Fair (70–79): 9 (32.1%) | – |

**Table 3.** Predictors of complications in pediatric femoral neck fractures

| Variable | Univariate p-value | Multivariate OR (95% CI) | Multivariate p-value |
|---|---|---|---|
| Right-sided fracture | 0.008 | 2.85 (0.84-9.7) | 0.089 (ns) |
| Higher Garden grade | 0.013 | 4.10 (1.08-15.6) | 0.038 * |
| Non-anatomical reduction | 0.037 | 3.75 (1.02-13.8) | 0.046 * |
| Implant removal (PPC) | 0.003 | — | — |

*Statistical significance at p<0.05; ns: not significant; OR: odds ratio; CI: confidence interval; PPC: premature physeal closure.

fic accidents or falls from a height. They are often accompanied by systemic injuries.[7] Careful evaluation for associated trauma and early involvement of a multidisciplinary team are therefore essential. In our series, 82% of cases were isolated hip fractures, while 18% were accompanied by other injuries, including head, chest, abdominal, spinal, upper extremity, and pelvic trauma.

PFNFs remain among the most challenging injuries in pediatric orthopedics due to the high risk of complications related to the fragile blood supply of the femoral head. Even with early anatomic reduction and stable fixation, complication rates remain higher than in most other pediatric fractures.[8] In our series, complications developed in 42.9% of patients, which is consistent with previously reported rates of 27–55%.[2,4] The most frequent complications were coxa vara (17.8%) and avascular necrosis (14.3%). Functional analysis based on Harris Hip Scores further demonstrated that AVN and nonunion were associated with the poorest outcomes, whereas patients with coxa vara and PPC maintained relatively better function.

### Predictors of Complications

Multivariate analysis identified higher Garden grade and non-anatomical reduction as independent predictors of complications, while right-sided fractures showed only a non-significant trend. These findings emphasize that fracture displacement and the precision of reduction are stronger determinants of outcome than fracture laterality. Reduction quality is the most important modifiable factor under surgical control.

### Coxa Vara

Coxa vara was the most frequent complication in our series, observed in 17.8% of patients. Previous studies have shown that conservative treatment increases the risk of this deformity.[1] Anatomical reduction remains the cornerstone of surgical management.[9] When closed reduction fails to achieve anatomical alignment, open reduction should be performed. Although earlier concerns suggested that open reduction might compromise femoral head vascularity, more recent studies and meta-analyses have demonstrated that it does not significantly increase the risk of AVN, non-union, or delayed union.[10,11]

In our series, 80% of coxa vara cases followed non-anatomical reduction, reinforcing the importance of precise anatomic alignment. While minor deformities may remodel during growth, more severe cases often require surgical correction. In our series, patients with mild coxa vara were managed conservatively with orthotics, as they demonstrated no limp and had a leg-length discrepancy of <1.5 cm.

Earlier reports indicate that loss of reduction predisposes patients to varus collapse.[12] To further minimize the risk of varus deformity, alternative fixation strategies, such as valgus-oriented constructs and locking plates, have been recommended.[13] Additionally, advanced intraoperative imaging tools, including 3D fluoroscopy, may optimize screw placement and alignment, thereby reducing the risk of malreduction.[14]

### Avascular Necrosis

PFNFs are strongly associated with AVN. The role of surgical timing remains controversial.[15,16] While some authors suggest early surgical intervention may reduce risk, systematic reviews have consistently identified patient age (older 10 years) fracture displacement, and reduction quality as the most important predictors, whereas gender, timing of surgery, reduction method, and mechanism of injury show no significant association.[17,18] In our series, surgery was delayed beyond 24 hours in 35% of patients, mainly due to late admission. Three patients with AVN underwent surgery within 24 hours, and one after 24 hours, suggesting that timing alone may not fully explain AVN development.

Capsulotomy and joint aspiration were not performed in our series. Although some studies propose that decompression may reduce AVN risk, our data cannot confirm or exclude this association.[19]

When analyzed by Delbet classification, AVN is generally reported as most common in type II fractures and least common in type IV, with types I and III showing similar rates.[20] However, multiple studies have emphasized that the Delbet–Colonna system has limited predictive value for AVN, non-union, delayed union, or PPC.[11,12] In our series, AVN developed in 14.3% of patients, all of whom had three Delbet type II and one Delbet type III fracture (all Garden type IV). This suggests that displacement severity may be more critical than fracture location alone. Recent studies have also identified medial–posterior comminution as an additional risk factor for AVN and impaired healing.[12,21]

The intramedullary nutrient vessels are another important source of femoral neck blood supply. Accordingly, the number, size, and positioning of fixation devices may further compromise perfusion and contribute to complications such as AVN, delayed union, non-union, or PPC.[22] Supporting this, a multicenter study reported significantly higher AVN rates with three-screw fixation compared with two.[23] Because all cases used three screws, between-construct comparisons were not possible; future studies should evaluate whether alternative constructs or lower screw burden mitigate AVN risk. All four patients who developed AVN were aged 13 years or older and were managed conservatively with weight-bearing restrictions and physical therapy.

### Premature Physeal Closure

Proximal femoral physis contributes about 15% of total femoral growth, and its premature closure can result in deformities such as leg-length discrepancy, coxa vara, or coxa valga.[2] PPC is a recognised complication of PFNFs. In children under 10 years old, epiphysis penetration has been shown to increase the rate of PPC.[9]

In our series, PPC occurred in three patients, two of whom had Delbet type II fractures and one of whom had a Delbet type III fracture. All were over 10 years old. Notably, PPC was found to be significantly associated with the need for implant removal. These patients require close clinical follow-up for growth disturbances, which may necessitate earlier implant removal and tailored management strategies.

### Non-Union

Non-union of PFNFs, though uncommon, remains a serious complication. In developed countries, the most common cause of non-union of a femoral neck fracture is failure of fixation or loss of reduction. In developing countries, however, it is delayed presentation.[24] Several studies have highlighted that anatomical reduction is the key factor in preventing delayed or non-union.[25,26]

Previous reports have also shown that non-union and PPC rates are comparable between patients treated with open and closed reduction.[6] In our series, non-union occurred in two patients, both with Delbet type II fractures, who were lost to follow-up after one year. This loss limits the interpretation of their long-term outcomes.

### Strengths and Limitations

Despite the limited sample size, a post-hoc power analysis based on HHS demonstrated a statistical power of approximately 85%, indicating that the cohort was sufficient to detect large effects of reduction quality on functional outcome. Nevertheless, several limitations should be acknowledged. The retrospective design, relatively small cohort, lack of standardized imaging protocols, and absence of a control group may all have influenced the findings. The post-hoc nature of the power analysis also reduces its generalizability, even though the achieved power supports the robustness of the results. Furthermore, logistic regression was constrained by the limited number of complication events (n=12); to minimize the risk of overfitting, only two predictors (Garden classification and reduction quality) were included, which restricted the scope of multivariable adjustment. Finally, although follow-up was at least 12 months in all patients, the heterogeneity in follow-up duration may have affected the assessment of long-term outcomes.

## CONCLUSION

Closed screw fixation remains an accepted and practical option for managing pediatric femoral neck fractures. However, complication rates remain substantial, particularly for AVN, coxa vara, PPC, and nonunion. In our series, higher Garden grade and non-anatomical reduction were independent pre-

dictors of complications. The significant association between PPC and implant removal highlights vigilant postoperative monitoring, as these patients may require earlier follow-up and individualized hardware management. At the same time, conclusions should be drawn cautiously, given the study's limitations. Larger prospective, multicenter studies are required to validate these predictors and refine treatment strategies in this rare but challenging pediatric injury.

**Ethics Committee Approval:** This study was approved by the Başakşehir Çam Sakura City Hospital Ethics Committee (Date: 15.01.2025, Decision No: 2025-04).

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ORİJİNAL ÇALIŞMA - *ÖZ*

# Pediatrik femur boynu kırıklarında kanüllü vida fiksasyonu: Sonuçlar ve komplikasyon belirleyicileri

AMAÇ: Pediatrik femur boyun kırıkları (PFNK) nadirdir ancak femur başının hassas vaskülaritesi nedeniyle yüksek komplikasyon oranları ile ilişkilidir. Kanüllü vida fiksasyonu (KVF) en sık kullanılan cerrahi yöntemlerdendir, ancak optimal tedavi stratejileri halen tartışmalıdır. Bu çalışmanın amacı, KVF ile tedavi edilen PFNK'lerin radyolojik ve fonksiyonel sonuçlarını değerlendirmek ve postoperatif komplikasyon öngördürücü faktörlerini belirlemektir.

GEREÇ VE YÖNTEM: Haziran 2020-Aralık 2024 arasında KVF ile tedavi edilen 28 hasta (ortalama yaş 12.4; dağılım 5-18) retrospektif olarak incelendi. Kırıklar Delbet–Colonna ve Garden sınıflamaları ile değerlendirildi. Redüksiyon kalitesi radyografik olarak incelendi, fonksiyonel sonuçlar Harris Kalça Skoru (HHS) ile ölçüldü. İstatistiksel analizlerde tek ve çok değişkenli lojistik regresyon kullanıldı.

BULGULAR: Radyografik kaynama %92.9 oranında sağlandı. Genel komplikasyon oranı %42.9 idi: coxa vara (%17.8), avasküler nekroz (AVN, %14.3), prematür epifiz kapanması (PEK, %10.7) ve kaynamama (%7.1). AVN (ortalama HHS 72.5) ve kaynamama (70.0) en düşük fonksiyonel skorlarla ilişkiliydi; coxa vara (82.0) ve PEK (85.0) ise göreceli olarak iyi sonuçlar gösterdi. Komplikasyonsuz hastalarda en iyi sonuçlar elde edildi (ortalama HHS 88.5). Çok değişkenli analizde yüksek Garden sınıflaması (OR 4.1; p=0.038) ve anatomik olmayan redüksiyon (OR 3.75; p=0.046) bağımsız risk faktörleri olarak belirlendi. PEK, implant çıkarımı ile anlamlı şekilde ilişkili bulundu (p=0.003). Küçük örneklem sayısına rağmen, HHS'ye dayalı bir post-hoc güç analizi, büyük etkileri tespit etmek için yaklaşık %85'lik bir güç olduğunu gösterdi.

SONUÇ: PFNK, cerrahi tedaviye rağmen yüksek komplikasyon oranları ile zorlayıcı bir pediatrik yaralanma olmaya devam etmektedir. Özellikle AVN ve coxa vara'yı azaltmak için anatomik redüksiyon kritik öneme sahiptir. PEK gelişen hastalarda implant çıkarımı gerektirebilmesi ve kalça deformitesi veya bacak boyu eşitsizliği gelişebilmesi riski nedeniyle yakın takip önerilir. Bu nadir ancak klinik açıdan önemli kırık tipinde cerrahi stratejilerin netleştirilmesi için daha geniş, prospektif çalışmalar gereklidir.

Anahtar sözcükler: Avasküler nekroz; coxa vara; erken fiziksel kapanma; Harris Kalça Skoru; kanüllü vida fiksasyonu; kaynamama; pediatrik femur boynu kırığı.

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ORIGINAL ARTICLE

# Early return to play after minimally invasive treatment of metacarpal fractures in elite football players

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## ABSTRACT

**BACKGROUND:** To evaluate the clinical outcomes of closed reduction and crossed retrograde intramedullary Kirschner wire (K-wire) fixation in professional football players with metacarpal fractures, specifically focusing on return to play and complication rates.

**METHODS:** A total of 27 elite professional football athletes with metacarpal fractures were treated using closed reduction and crossed retrograde K-wire fixation. All surgeries were performed by the same orthopedic surgeon. Postoperative rehabilitation included a standardized protocol and individualized braces designed by a single hand therapist. Clinical and functional outcomes were assessed using range of motion (ROM), grip strength, Visual Analog Scale (VAS) for pain, Disabilities of the Arm, Shoulder, and Hand (DASH) scores, time to return to training and competition, and radiographic healing.

**RESULTS:** The mean age of the cohort was 24 years. The fifth metacarpal was the most commonly affected site, and falling onto the pitch was the predominant injury mechanism. Mean return to training was 3.16 weeks, to competition 4.12 weeks, and to radiographic union 4.88 weeks. Mean DASH scores improved from 67.5 to 12.8, VAS from 5.78 to 0.75, MCP joint ROM from 66.75° to 89.25°, and grip strength from 44.87% to 95.55%.

**CONCLUSION:** Closed reduction and crossed retrograde K-wire fixation, with personalized postoperative care, appears to be a safe, reliable, and minimally invasive method in elite football athletes, enabling early return to play with excellent functional outcomes.

**Keywords:** Early return to play; functional outcomes; K-wire fixation; metacarpal fracture; professional football players.

## INTRODUCTION

Metacarpal fractures are one of the most common upper extremity injuries in athletes.[1] Although this rate is low in football players compared to contact sports in which the hand is used, it has been reported that metacarpal fractures constitute 15% of hand injuries among Northern European football players.[2] The mechanism of injury in contact sports occurs by direct impact or falling onto a clenched fist.[3] For treatment planning, the performed sport, the position of the athlete, and whether the injury occurs during the in-season are as important as the characteristics of the fracture.

Most metacarpal fractures are stable and are successfully treated with non-surgical methods. Significant angulation, rotation, instability, shortening, intra-articular fracture, open fracture, and multiple metacarpal fractures require surgical treatment.[4] The rate of conservative treatment after metacarpal fractures in American National Football League (NFL) athletes has been reported as 60%, which differs from the management of

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metacarpal fractures in the general population.[5] While the majority of metacarpal fractures are stable and can be managed nonoperatively, a more aggressive approach becomes necessary to expedite the return of athletes to play within a reasonable timeframe. Both the athlete's career and the financial investments of teams or organizations contribute to the strong desire for the earliest possible return following injury, which in turn influences the choice of treatment strategies.

In surgical treatment, closed reduction with K-wire or intramedullary cannulated screw fixation, and open reduction with plate and screw or lag screw fixation, are commonly preferred methods. For elite athletes engaged in high-demand sports, the chosen fixation method for metacarpal fractures should facilitate early mobilization, restore proper grip strength, regain rotation and range of motion, and address any angulation issues. Fixation with K-wires offers advantages such as being rapid, easily applicable, accessible, and minimally invasive; however, it is also associated with disadvantages, including insufficient stability and the risk of pin tract infection. Although open reduction with plate and screw fixation provides rigid stabilization, it is associated with higher complication rates and prolonged soft tissue healing time.[6]

In many sports, such as American football, basketball, baseball, Australian football, and lacrosse, there are few studies evaluating the success of treatment and the time to return to sports after metacarpal fractures.[6-10] It is seen that these studies usually include athletes from different levels or different sports branches. While many of these studies are based on the hypothesis that surgical treatment facilitates a faster return to sports, a greater number of studies have reported a shorter return-to-sport time following conservative management. The fact that surgical treatment was performed in more complex fracture types is seen as the main reason for this inference. In addition, soft tissue edema due to open surgery and prolongation of movement limitation are seen as another reason. In the systematic review reporting the treatment of 184 metacarpal fractures of athletes across many different sports branches and competitive levels, it was reported that 78 of them received surgical treatment and only 2 were treated with K-wire.[11] It was reported that the mean time to return to sports after surgical treatment and conservative treatment was 28.5 and 22 days, respectively.[11]

The study aimed to report the effect of closed reduction and minimally invasive cross-intramedullary fixation of metacarpal fractures with K-wire on the time to return to sport and post-treatment athletic performance in elite football players. Although there are studies evaluating the return to sports and performance of metacarpal fractures after surgery in elite athletes, to the best of our knowledge, this is the first study to report the results of surgical treatment of metacarpal fractures in elite football players.

## MATERIALS AND METHODS

Following the approval of the ethics committee, we retrospectively analyzed elite professional football players who underwent surgery for metacarpal fractures between 2011 and 2023. In the evaluation, it was observed that 36 football players had surgery for metacarpal fractures. A total of 27 patients who met the inclusion criteria were included in the study after the removal of patients with a follow-up period of less than one year, those with open fractures, intra-articular fractures, or who underwent a surgical method other than closed reduction and fixation with K-wire. This study was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Procedures were performed under general anesthesia by the senior orthopedic surgeon (Yİ), who has expertise in sports-related injuries. Fluoroscopy guidance was employed to assess the fracture site. At the beginning of the procedure, closed reduction of the fracture was performed through traction. If the fracture was reducible, K-wire placement was performed; if it was not reducible, open reduction and plate fixation were decided by the surgeon. K-wire placements were done in a retrograde fashion, with crossed insertion of two percutaneous K-wires of appropriate diameters through a small skin incision at the base of the affected metacarpal bone via the intramedullary canal. Surgical fracture reduction was performed by manipulating the inserted intramedullary K-wires. The stability and position of the K-wires were assessed under fluoroscopy. Subsequently, the K-wire was bent and cut, and the patients were immobilized with a customized brace for eight weeks (Figure 1).

The union of the fracture was monitored through repeated X-rays during weekly follow-up visits post-surgery. Range of motion exercises for the phalanges were initiated three days after surgery. Physical therapy, conducted on an outpatient basis with the assistance of a specialized hand physiotherapist, was initiated ten days after the operation. Athletes were not allowed to participate in contact training until three weeks postoperatively; they then started using a special soft brace during contact training and official matches (Figure 2).

Upon radiographic confirmation of fracture union, the K-wires were removed in the sixth postoperative week, and patients continued wearing the customized brace (Figure 1). Regular follow-up visits were scheduled until full union was achieved. Assessment measures, including range of motion (ROM), grip strength (expressed in comparison with the contralateral hand, with 100 being the best), Visual Analog Scale (VAS) for pain, and Disabilities of the Arm, Shoulder, and Hand (DASH) scoring, were performed for all patients. Anteroposterior and oblique X-rays were taken to evaluate complete bony healing and detect any incidence of deformity.

### Statistical Analysis

Descriptive statistics were conducted using the SPSS 21.0 program (SPSS Inc., Chicago, IL, USA). Paired t-test, post-hoc

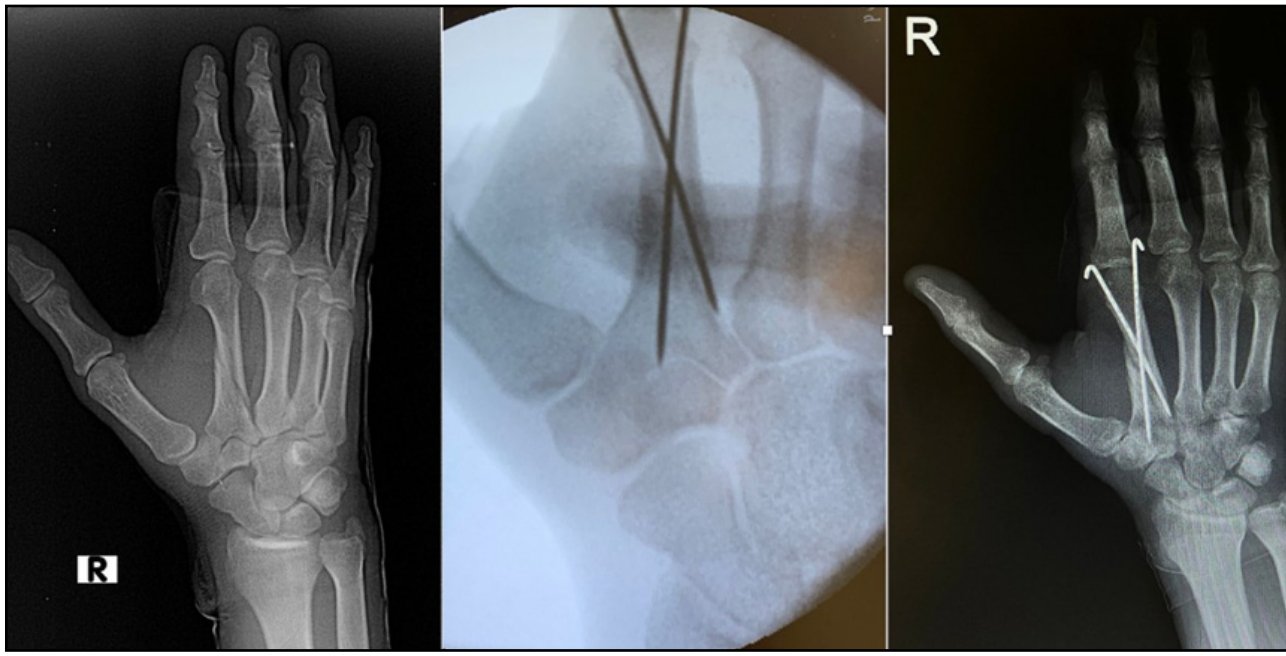


**Figure 1.** Preoperative, intraoperative, and immediate postoperative photographs of a male patient who is 21 years old at the time of the injury.

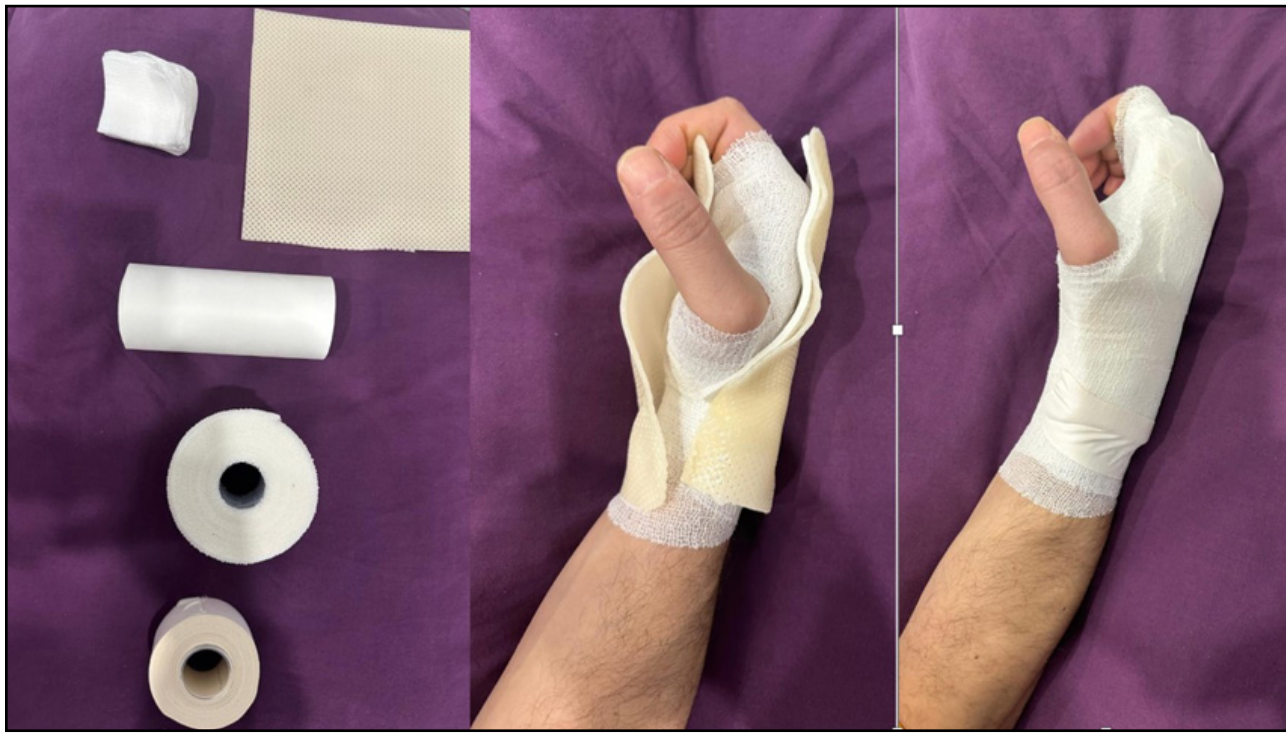

**Figure 2.** Preparation of a customized soft brace, which allows for use during official matches.

test, and Kruskal-Wallis test were performed to show the significance of differences for related variables. A statistical significance level of <0.05 was considered indicative of a significant correlation between variables.

## RESULTS

A total of 27 athletes were included in the study, with a mean age of 24±3.64 years and a mean follow-up duration of

**Table 1.** Demographics, means of return to sport, and healing

| n: 27 | m±sd |
|---|---|
| Age (y) | 24±3.64 |
| Follow up (m) | 18±4.80 |
| Return to sport (w) | 3.16±0.72 |
| Return to competition (w) | 4.12±1.26 |
| Radiological healing (w) | 4.88±0.58 |

n: number, y: years, m: months, w: weeks, m: mean, sd: standard deviation.

**Table 2.** Comparison of pre- and post-operative clinical parameters

| Parameter | Pre-op±sd | Post-op±sd | p |
|---|---|---|---|
| DASH | 67.5±8.98 | 12.8±5.48 | p<0.05 |
| VAS | 5.78±0.96 | 0.75±1.55 | p<0.05 |
| MCP-ROM | 66.75±6.25 | 89.25±2.35 | p<0.05 |
| Grip strength (%) | 44.87±9.14 | 95.55±6.23 | p<0.05 |

sd: standard deviation; p: probability-statistical significance; DASH: Disabilities of the arm; shoulder, and hand score; VAS: Visual analog scale; MCP-ROM: Metacarpophalangeal joint range of motion.

18±4.80 months. The mean return to sports was 3.16±0.72 weeks, while the return to competition occurred at 4.12±1.26 weeks. Radiological healing was observed at 4.88±0.58 weeks (Table 1).

The distribution of metacarpal bone involvement revealed that the fifth metacarpal was most commonly affected (n=12, 44.4%), followed by the fourth (n=8, 29.6%).

The primary mechanism of trauma was downfall, accounting for the majority of cases (n=18, 66.6%). Direct force (n=7, 26.0%) and other causes (n=2, 7.4%) contributed to a smaller proportion of fractures.

The preoperative DASH score was 67.5±8.98, which significantly improved to 12.8±5.48 at the last follow-up (p<0.05). Similarly, the VAS score reduced from 5.78±0.96 preoperatively to 0.75±1.55 at the last follow-up (p<0.05). ROM of the MCP joint increased from 66.75±6.25° preoperatively to 89.25±2.35° at the last follow-up (p<0.05). Grip strength of the opposite side showed a substantial improvement, increasing from 44.87%±9.14 preoperatively to 95.55%±6.23 at the last follow-up (Table 2, p<0.05).

No malalignments, nonunion, or malunion were encountered. All patients returned to their competition levels prior to the injury by the end of the follow-up period.

## DISCUSSION

The return to sport after metacarpal fractures treated with closed reduction and K-wire fixation in elite football players was determined to be 3 to 4 weeks, in accordance with studies in the literature. The return of all athletes to their pre-injury competitive level demonstrates the effectiveness of the treatment, with results that are comparable to or even superior to those reported for other treatment approaches. This is the first study conducted on this subject in elite football players, and a satisfactory number of patients is reported when compared to the literature, with 27 patients who received the same treatment in this specific patient group.

In a survey study conducted with surgeons treating athletes in professional football, basketball, and baseball leagues in the USA, it was reported that these elite athletes can return to sports in 3-4 weeks with protective equipment and achieve a full return to sport without a brace in 4–8 weeks.[12] Results of the current study support this survey. In professional athletes, the primary goal is to achieve a full return to sport as rapidly as possible while minimizing financial and performance losses; therefore, there has been an increasing tendency toward surgical treatment.

Yalizis et al., in their study detecting metacarpal fractures in Australian rules football players treated with open reduction and plate screws, reported that the average time to return to sports was 2 weeks. In the same study, similar improvement in DASH scores was reported compared to our study, and radiographic improvement was seen in an average of 6 weeks, similar to our study.[8]

In another study, Etier et al. reported that in high school and college American football athletes, re-accommodation to sports after fixation of metacarpal fractures with a plate and screw occurred in an average of 1 week with a protective splint.[10] The fact that the study group consisted of very young athletes may have influenced this result. In the same study, they reported that the trauma mechanism was contact collision in 60% of cases, and the fracture occurred in the middle finger in 55% of cases.[10] Compared with our study, this highlights differences in the mechanisms of metacarpal fracture formation in different sports and the differences in affected metacarpals.

In a study in which the performance of metacarpal fractures in National Basketball Association (NBA) players was followed for two years after surgical treatment, it was observed that there was no difference in the performance of athletes before and after the injury.[9] In the same study, a comparison was made between a paired control group and the athletes who did not have an injury, and it was reported that there was no difference in performance. Although the effect of hand dexterity on performance in football players is limited compared to basketball, our study supports these results.

In a study comparing surgical and conservative treatment of metacarpal fractures in 24 Major League Baseball players, Pagani et al. reported that although the nonoperatively treated group returned to sports significantly earlier, the surgically treated group showed superior results in long-term follow-up of athletic performance.[7]

Contrary to these studies, Carender et al., in their study examining metacarpal and phalanx fractures in American college athletes, reported that the rate of athletes returning to sports in the same season after surgical treatment of metacarpal fractures was significantly lower than in the conservatively treated group.[13] This study is a nationwide data study and has significant limitations because it consists of patients from different sports, different types of fractures, and treatment by different surgeons.

In a systematic review of Level 3-4 studies, Geoghegan et al. reported that the time to return to sports after surgical treatment of metacarpal fractures was longer in athletes than after conservative treatment (28.5 days vs. 22 days).[11] Sports branches, competitive levels, treatment methods, and rehabilitation protocols differ in the included studies, and fracture types are not reported. It is important to acknowledge that fractures requiring surgical intervention are typically more complex. Furthermore, the study by Morse et al., which was included in this review, reported an extended return-to-sport duration, with a mean time of 56 days.[14]

It is worth noting that specific requirements vary within sports, with athletes in certain positions or disciplines, such as goalkeepers and basketball players, placing a higher emphasis on hand dexterity for optimal athletic performance. These considerations underscore the need for a personalized and sport-specific approach in determining the most effective treatment strategy for metacarpal fractures in athletes.

## CONCLUSION

Our study has certain limitations, including its retrospective design and the relatively small sample size. Moreover, the absence of a control group treated with an alternative surgical or conservative approach limits the ability to draw comparative conclusions. Although further randomized prospective studies are warranted in this area, conducting such trials in this highly specific population of elite athletes presents considerable challenges. Nonetheless, the operative management of metacarpal fractures in professional football players using retrograde intramedullary crossed K-wires, combined with a customized brace, appears to be a reliable technique, offering favorable functional outcomes and facilitating an early return to sport.

**Ethics Committee Approval:** This study was approved by the Nişantaşı University Ethics Committee (Date: 01.02.2024, Decision No: 2024/02).

**Peer-review:** Externally peer-reviewed.

**Authorship Contributions:** Concept: Y.İ., O.Ç., A.C., G.U.D., T.K.; Design: Y.İ., O.Ç., A.C., G.U.D., T.K.; Supervision: Y.İ., O.Ç., A.C., G.U.D., T.K.; Resource: Y.İ., O.Ç., A.C., G.U.D., T.K.; Materials: Y.İ., O.Ç., A.C., G.U.D., T.K.; Data collection and/or processing: Y.İ., O.Ç., A.C., G.U.D., T.K.; Analysis and/or interpretation: Y.İ., O.Ç., A.C., G.U.D., T.K.; Literature review: Y.İ., O.Ç., A.C., G.U.D., T.K.; Writing: Y.İ., O.Ç., A.C., G.U.D., T.K.; Critical review: Y.İ., O.Ç., A.C., G.U.D., T.K.

**Conflict of Interest:** None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

## Elit futbolcularda metakarp kırıklarının minimal invaziv tedavisi sonrası erken spora dönüş

AMAÇ: Metakarp kırığı bulunan profesyonel futbolcularda kapalı redüksiyon ve çapraz retrograd intramedüller Kirschner teli (K-teli) tespiti yönteminin klinik sonuçlarını değerlendirmek; özellikle spora dönüş süresi ve komplikasyon oranlarına odaklanmak.

GEREÇ VE YÖNTEM: Metakarp kırığı olan toplam 27 elit profesyonel futbolcu, kapalı redüksiyon ve çapraz retrograd K-teli tespiti yöntemiyle tedavi edildi. Tüm cerrahiler aynı ortopedi cerrahı tarafından gerçekleştirildi. Ameliyat sonrası rehabilitasyon süreci, standart bir protokol ve tek bir el terapisti tarafından tasarlanan kişiye özel atelleri içeriyordu. Klinik ve fonksiyonel sonuçlar; eklem hareket açıklığı (ROM), kavrama kuvveti, Ağrı için Görsel Analog Skala (VAS), Kol, Omuz ve El Engellilik Anketi (DASH) skorları, antrenmana ve müsabakaya dönüş süresi ile radyografik kaynama açısından değerlendirildi.

BULGULAR: Çalışmaya katılan grubun ortalama yaşı 24'tü. En sık etkilenen bölge beşinci metakarptı ve saha üzerinde düşme en yaygın yaralanma mekanizmasıydı. Antrenmana ortalama dönüş süresi 3.16 hafta, müsabakaya dönüş 4.12 hafta ve radyografik kaynama 4.88 hafta olarak belirlendi. Ortalama DASH skoru 67.5'ten 12.8'e, VAS skoru 5.78'den 0.75'e, MCP eklem hareket açıklığı 66.75°'den 89.25°'ye ve kavrama kuvveti %44.87'den %95.55'e yükseldi.

SONUÇ: Kişiselleştirilmiş ameliyat sonrası bakım ile uygulanan kapalı redüksiyon ve çapraz retrograd K-teli tespiti, elit futbolcularda güvenli, etkili ve minimal invaziv bir yöntem olup, mükemmel fonksiyonel sonuçlarla erken spora dönüşü sağlamaktadır.

Anahtar sözcükler: Metakarp kırığı, K-teli tespiti, profesyonel futbolcular, erken spora dönüş, fonksiyonel sonuçlar

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ORIGINAL ARTICLE

# Comparing clinical and functional outcomes of anterior cruciate ligament reconstruction using sonoelastography

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## ABSTRACT

**BACKGROUND:** Injuries to the anterior cruciate ligament (ACL) are prevalent, particularly following athletic incidents. Most clinicians use MRI for diagnostic purposes and therapy assessment, but it can present challenges in terms of cost and accessibility. While ultrasound guidance (USG) is more readily available, it is inadequate for diagnosing ACL injury in isolation. Therefore, our study aimed to evaluate the effectiveness of sonoelastography, a novel method for assessing tendon injuries, in the context of anterior cruciate ligament (ACL) injuries.

**METHODS:** This study involved a cohort of 45 patients who fulfilled the designated inclusion criteria. We selected the patients from a cohort of 105 individuals who underwent anatomical ACL restoration at the orthopedics and traumatology clinic between 2017 and 2020. The clinical examination results and the stability and quality of the ACL in patients who underwent ACL reconstruction were compared with those from magnetic resonance imaging (MRI) and stress echo laxity (SEL) testing.

**RESULTS:** The study comprised 40 individuals with a mean age of 30.7±1.4 years. The patients' Lysholm scores exhibited considerable enhancement post-operation, with a mean increase from 2.2±0.9 pre-operation to 6.1±1.6 post-operation. The Lachman, anterior drawer, and pivot-shift tests demonstrated improvements relative to the preoperative values. No substantial difference was observed in the single-leg hop test relative to the unaffected side. The SEL findings indicated that 15.6% of the healthy ACL instances were categorized as type 2a, 68.9% as type 2b, and 15.6% as type 3a. In the reconstructed ACL cohort, 17.8% were categorized as type 2a, 62.2% as type 2b, and 20% as type 3a. No substantial statistical difference was detected between the healthy ACL and the reconstructed ACL. No occurrences of type 3b or type 4 were identified in any of the patients.

**CONCLUSION:** We used SEL to find a torn ACL and check its stability and condition after the ligament was reconstructed with a graft. We utilize SEL, or stress sonoelastography, to monitor graft viability and evaluate the progression of ACL injuries. It is also beneficial in evaluating whether the restored ligament possesses a functional structure akin to that of a normal ligament. Moreover, considering its accessibility, cost-effectiveness, replicability, and patient preference, it may provide a more advantageous alternative to MRI.

**Keywords:** ACL reconstruction; ACL rupture; sonoelastography; ultrasound.

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## INTRODUCTION

Anterior cruciate ligament (ACL) injuries represent one of the most frequent clinical problems encountered in orthopedic surgery. Accurate diagnosis and timely initiation of appropriate treatment are critical to prevent progressive joint damage and functional deterioration of the knee joint.[1,2] Although magnetic resonance imaging (MRI) remains the gold standard in evaluating ACL pathology, ultrasonography (US) has gained increasing attention due to its accessibility, cost-effectiveness, and ability to allow real-time dynamic assessment in conjunction with clinical examination.[3] However, conventional US often demonstrates similar echogenicity between normal and pathological tissues, particularly in cases of tendinopathy, thereby limiting its diagnostic superiority over MRI.[4]

Magnetic resonance imaging (MRI) provides excellent soft-tissue contrast and multiplanar capability,[2] but its use is limited by high cost, reduced availability in some clinical settings, longer acquisition times, and contraindications such as metallic implants or claustrophobia.[3] In contrast, ultrasonography (US) offers a rapid, inexpensive, and readily accessible alternative that can be performed alongside dynamic physical examination.[5-7] However, US is highly operator-dependent, and conventional gray-scale imaging may fail to detect subtle changes in tissue integrity, especially in partial ligament tears or tendinopathy.[8] These limitations highlight the potential value of advanced US-based techniques, such as sonoelastography (SEL), which combine accessibility with objective biomechanical evaluation.

Sonoelastography (SEL) is a recently developed diagnostic technique that enables evaluation of tissue stiffness and mechanical integrity by measuring elasticity.[9,10] It has been increasingly applied in musculoskeletal practice to assess conditions such as Achilles tendinopathy, biceps tendinopathy, epicondylitis, plantar fasciitis, and muscle disorders.[8,11-13] Despite its expanding use, evidence regarding the application of SEL in ACL injuries is still limited. A review of the current literature reveals an absence of studies specifically addressing the use of SEL in postoperative ACL evaluation. Therefore, SEL may represent a valuable, objective, and reproducible method to assess graft integrity following ACL reconstruction.

The present study aims to evaluate graft integrity in comparison with the contralateral healthy ACL using SEL in patients undergoing ACL reconstruction with hamstring autografts. In addition, clinical and functional outcomes were assessed to determine the reliability of SEL in postoperative graft monitoring. We hypothesize that SEL can serve as a rapid and effective imaging modality to evaluate graft integrity during the postoperative follow-up period.

## MATERIALS AND METHODS

This prospective study was approved by the Clinical Research Ethics Committee of Kırıkkale University Faculty of Medicine (approval number: 10/03, date: 27.04.2015) and conducted in accordance with the principles of the Declaration of Helsinki. All participants were thoroughly informed about the study protocol, and written informed consent was obtained from each patient. The study did not receive any external funding, and all expenses were personally covered by the investigators.

A total of 45 patients who met the inclusion criteria were enrolled from a larger cohort of 105 individuals who underwent anatomical ACL reconstruction in our Orthopedics and Traumatology Clinic between 2017 and 2020. The inclusion criteria were unilateral and isolated ACL rupture, ACL reconstruction performed with four-strand hamstring tendon autograft, presence of a healthy contralateral knee, absence of previous knee surgery, closed growth plates, and patient age younger than 40 years at the time of surgery. Exclusion criteria included fractures involving the knee joint surface, lower limb malalignment, history of knee surgery, systemic connective tissue disorders, and a follow-up period shorter than six months.

Baseline demographic characteristics were recorded, and clinical as well as functional assessments were performed both preoperatively and at the sixth postoperative month. These assessments included knee joint range of motion (ROM), Lachman test, anterior drawer test, pivot-shift test, Lysholm knee scoring system, Tegner activity score, thigh circumference measurements, and the single-leg hop test.

At the six-month follow-up, stress sonoelastography (SEL) examinations were conducted bilaterally, enabling comparative evaluation of reconstructed and contralateral ACL integrity. Correlations between SEL findings and clinical examination results were subsequently analyzed.

### Sonoelastography Examination Protocol

All sonoelastography examinations were performed by either M.H.Ş. or V.B., both of whom had three years of experience in elastography and more than twelve years of expertise in conventional ultrasonography. A LOGIQ E9 system (GE Healthcare, Chicago, IL, USA) equipped with elastography software and a linear array probe (frequency range: 6–15 MHz, model 9L) was utilized.

Patients were examined in the supine position with the knee flexed to approximately 70-80°. The transducer was placed on the anterior aspect of the knee, slightly proximal to the tibial tuberosity, aligned with the patellar tendon (Figure 1). B-mode and elastographic images were displayed simultaneously in a split-screen mode. Gentle manual compression was applied using the transducer, and image acquisition was performed when the optimal compression level was achieved, as monitored by the on-screen compression bar.

Elastographic images were represented using a color-coded map corresponding to tissue stiffness: red (softest), green (in-

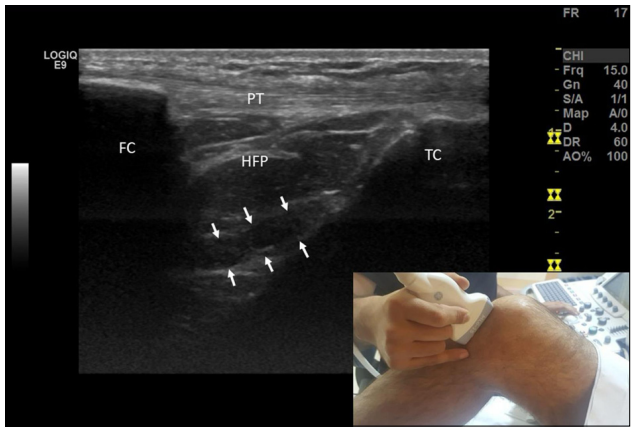


**Figure 1.** Longitudinal grayscale ultrasound image of the anterior cruciate ligament. The small inset image demonstrates the anatomical orientation of the transducer and knee position (FC: femoral condyle, TC: tibial condyle, PT: patellar tendon, HFP: Hoffa's fat pad).

**Table 1.** SEL color mapping of the ACL strain

| | | |
|---|---|---|
| Type 1 | Hardest tissue | Mostly blue |
| Type 2a | Hard tissue | Blue-green (main color blue) |
| Type 2b | Hard tissue | Blue-green (main color green) |
| Type 3a | İntermediate tissue | Mostly Green (blue-green-yellow) |
| Type 3b | Intermediate tissue | Mostly Green (green-yellow) |
| Type 4 | Soft tissue | Yellow-green-red |

termediate), and blue (hardest) (Figure 2,3). ACL strain patterns were classified into three major categories with two additional subtypes (Table 1). Image interpretation was conducted independently by two radiologists, and consensus was reached for all cases.

## Surgical Procedure

All patients received prophylactic intravenous antibiotics preoperatively. Surgeries were performed under regional anesthesia with patients in the supine position and a pneumatic tourniquet applied.

Anatomic ACL reconstruction was performed using a standard anteromedial portal technique with four-strand hamstring tendon autografts. Femoral fixation was achieved with a ToggleLoc ZipLoop endobutton system (Biomet Sports Medicine, Warsaw, IN, USA). Tibial fixation was accomplished using a biocomposite interference screw in combination with a staple (Biomet Sports Medicine). During fixation, the graft was tensioned with the knee maintained at 10°–20° of flexion.

## Rehabilitation

Postoperative rehabilitation was initiated on the first postoperative day. Patients were instructed to achieve knee flexion of 30° within the first week, 60° by weeks 1–2, 90° by weeks 3–4, and up to 120° by weeks 4–6. A structured exercise program was implemented, focusing on quadriceps and hamstring strengthening, hip stabilization, and progressive range-of-motion exercises.

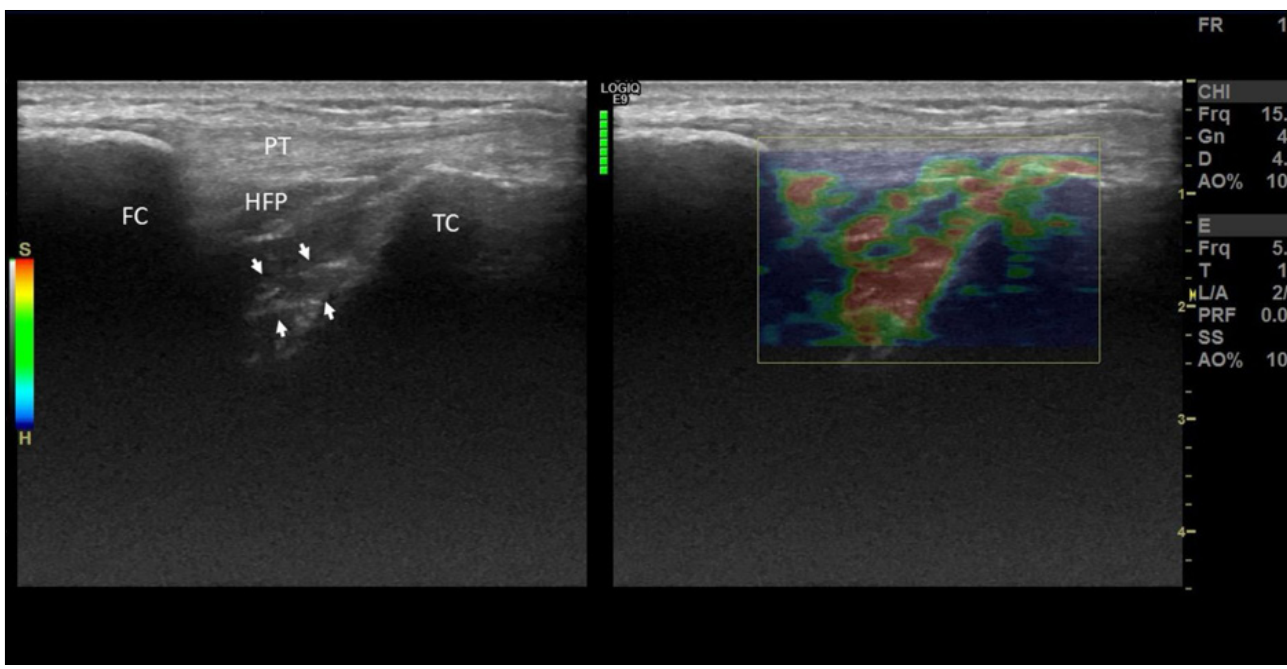


**Figure 2.** Preoperative longitudinal B-mode grayscale ultrasound and strain elastography images of the anterior cruciate ligament (FC: femoral condyle, TC: tibial condyle, PT: patellar tendon, HFP: Hoffa's fat pad).

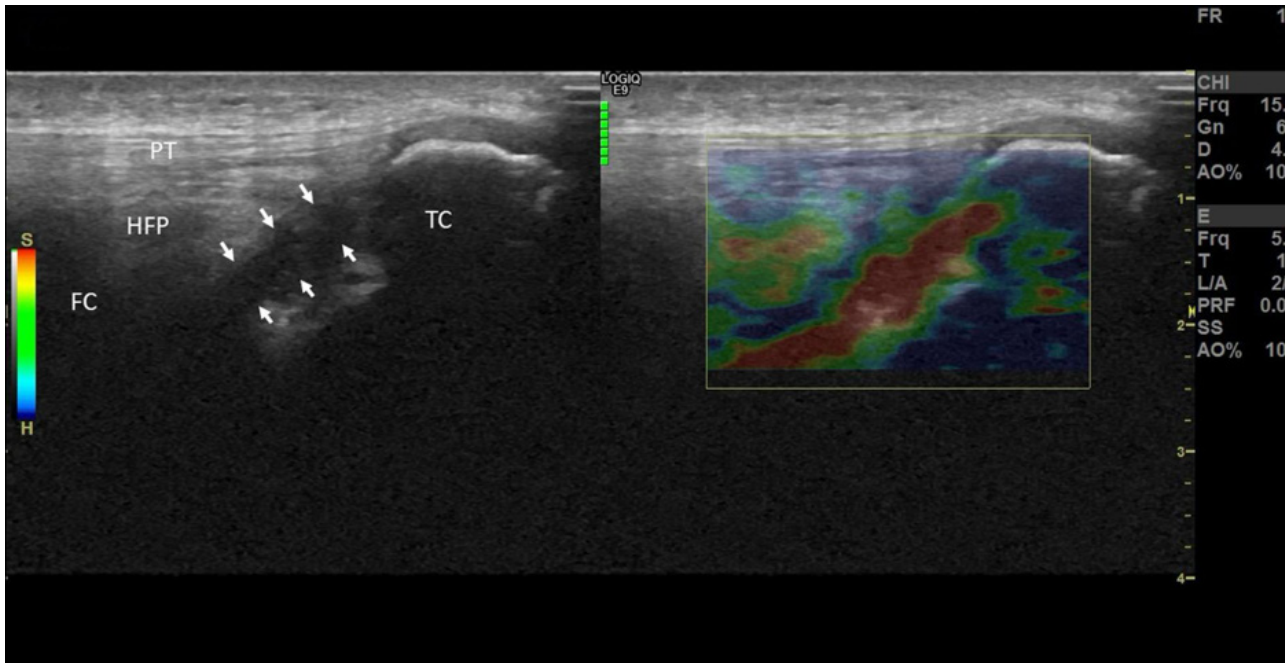


**Figure 3.** Postoperative longitudinal B-mode grayscale ultrasound and strain elastography images of the anterior cruciate ligament (FC: femoral condyle; TC: tibial condyle; PT: patellar tendon; HFP: Hoffa's fat pad).

The rehabilitation protocol included isometric and isotonic strengthening, progression from closed-chain to open-chain exercises, and hamstring stretching. Patients were encouraged to ambulate with crutches as tolerated and to discontinue crutch use once normal gait was achieved. Proprioceptive training and neuromuscular re-education exercises were gradually incorporated during the later phases of rehabilitation.

### Statistical Analysis

Statistical analyses were performed using the chi-square test for categorical variables and paired Student's t-test for continuous variables. A p-value <0.05 was considered statistically significant. No formal sample size calculation was performed.

## RESULTS

A total of 45 patients (40 males, 5 females) with a mean age of 30.7±1.4 years were included in the study. Clinical and functional outcomes were compared between the preoperative and postoperative periods.

The Lysholm knee score demonstrated significant improvement, increasing from a mean of 51.7±13.8 preoperatively to 91.0±8.4 postoperatively (p<0.001). Similarly, the Tegner activity score increased from 2.2 ± 0.9 before surgery to 6.1±1.6 after surgery (p<0.001). Clinical stability tests, including the Lachman, anterior drawer, and pivot-shift tests, also revealed significant improvement compared with preoperative findings (Table 2).

Functional evaluations demonstrated no statistically significant differences between the operated and contralateral healthy knees. The single-leg hop test showed comparable outcomes between both sides (p>0.05). Thigh circumference measurements indicated a slight increase on the uninjured side compared with the reconstructed side, though the difference was not statistically significant (Table 3).

**Table 2.** Functional and clinical findings of the patients

| | Pre-op | Post-op | p |
|---|---|---|---|
| Lysholm score | 51.7±13.8 | 91,0± 8.4 | 0.0001 |
| Tegner activity score | 2.2 ±0.9 | 6.1±1.6 | 0.0001 |
| Lachman | (0/1/2/3) | 0/19/22/4 | 40/4/0/0 |
| Pivot shift | 30 | 2 | 0.0001 |
| Anterior drawe | (0/1/2/3) | 0/14/26/5 | 37/8/0/0 |

**Table 3.** Clinical findings compared with the healthy side

| | Operated side | Healhty side | p |
|---|---|---|---|
| Single leg jump score | 114.2±17.5 | 106.2±21.6 | 0.19 |
| Thigh diameter difference (average cm) | 2.1±0.8 | 2.7±0.3 | 0.12 |

**Table 4.** SEL findings

| | Type 2a | Type 2b | Type 3a |
|---|---|---|---|
| Reconstructed anterior cruciate ligament | 8 (17.8 %) | 28 (62.2 %) | 9 (20%) |
| Intact anterior cruciate ligament | 7 (15.6 %) | 31 (68 %) | 7 (15.6 %) |

Stress sonoelastography (SEL) analysis of the contralateral healthy ACL demonstrated type 2a patterns in 15.6% (n=7), type 2b in 68.9% (n=31), and type 3a in 15.6% (n=7) of cases. On the reconstructed side, SEL revealed type 2a in 17.8% (n=8), type 2b in 62.2% (n=28), and type 3a in 20.0% (n=9) of cases (Table 4). The distribution of SEL classifications did not differ significantly between the reconstructed and healthy ACLs (p=0.189).

Notably, no cases demonstrated type 3b or type 4 SEL patterns. These findings suggest that postoperative graft integrity and biomechanical stability were generally comparable to those of the contralateral healthy ACL.

## DISCUSSION

The present study demonstrates that sonoelastography (SEL) is a feasible and reliable method for evaluating graft quality and stability following anterior cruciate ligament (ACL) reconstruction. When compared with the contralateral healthy ligament, the reconstructed graft exhibited similar SEL patterns, suggesting that this modality provides objective information regarding graft integrity. These findings were corroborated by significant improvements in both clinical examination results and functional outcome measures.

Conventional clinical tests, such as the Lachman, anterior drawer, and pivot-shift, remain widely used in the diagnosis of ACL insufficiency. Nevertheless, these examinations are inherently subjective and may be influenced by examiner experience, pain, swelling, and muscle spasm.[1-3] Although the Lachman test has been reported as the most sensitive (85–98%) and specific (94%) method, variability remains a concern.[4,9,10] In this study, SEL findings demonstrated strong agreement with the results of these clinical tests, supporting its role as an objective adjunct in postoperative assessment of ACL grafts.

Our SEL analysis revealed that both the reconstructed and contralateral ACLs were most frequently classified as type 2 patterns, reflecting preserved elasticity and biomechanical stability. Importantly, no cases exhibited type 3b or type 4 SEL patterns, which are typically associated with impaired ligamentization and reduced structural integrity. These results indicate that the reconstructed grafts demonstrated maturation patterns comparable to the native ACL.

Magnetic resonance imaging (MRI) has traditionally been utilized to monitor graft maturation after ACL reconstruction, particularly through signal intensity and graft volume analysis.[14-18] However, MRI assessments are limited by variability in acquisition protocols, scanner differences, and subjective interpretation of signal-to-noise ratios. While MRI provides indirect information about vascularization and remodeling, it does not directly assess biomechanical properties such as stiffness and elasticity. In contrast, SEL offers real-time, dynamic, and reproducible measurements of tissue elasticity, thereby reflecting the functional mechanical status of the graft. Recent reports suggest that SEL may provide superior insight into graft elasticity and functional stability compared with MRI, although this hypothesis requires confirmation through prospective comparative studies.[19-21]

Several studies have investigated MRI as a tool for monitoring graft maturation after ACL reconstruction, focusing on changes in signal intensity and vascularization patterns.[14-18] While MRI provides valuable morphological information, its correlation with clinical outcomes and graft biomechanical strength remains inconsistent.[17,18] By contrast, SEL directly evaluates tissue elasticity, which is more closely related to the mechanical properties essential for knee stability. Emerging evidence suggests that SEL may detect early alterations in graft stiffness not apparent on MRI, thereby offering a more functionally relevant assessment of graft integrity.[19-21]

Previous investigations, including the study by Lutz et al., have shown that MRI can effectively monitor graft maturation fol-

lowing hamstring autograft reconstruction; however, correlations with clinical outcomes remain inconsistent.[17] Similarly, Yau and Chan recently highlighted that MRI can demonstrate ligamentization but may not reliably predict graft rupture or functional stability.[18] Our findings suggest that SEL, by directly assessing graft stiffness, may complement or even surpass MRI in postoperative evaluation.

The process of tendon-to-ligament transformation (ligamentization) after ACL reconstruction is central to long-term graft survival. MRI has been widely used to visualize this process, but its sensitivity in detecting mechanical deterioration is limited.[17,18] In our study, SEL demonstrated that reconstructed grafts retained mechanical properties comparable to the contralateral ACL, and none progressed to advanced degeneration. These observations suggest that SEL may be better suited to evaluate the biomechanical consequences of ligamentization than MRI.

Although there is limited literature on the use of SEL in ACL pathology, previous reports have described its application in posterior cruciate ligament evaluation,[19] patellar tendon donor site monitoring after ACL reconstruction,[20,21] and tendinopathy assessment.[8] Our study represents the first to demonstrate the feasibility of SEL in monitoring ACL graft integrity postoperatively, combining imaging with clinical and functional outcomes.

This study has several limitations that must be acknowledged. First, the relatively small sample size may have limited the statistical power to detect subtle differences in SEL classifications. Second, the follow-up duration of six months is relatively short for evaluating long-term graft maturation and functional outcomes. Previous studies have suggested that graft ligamentization and remodeling may continue for up to two years postoperatively;[17,18] therefore, extended follow-up is necessary to determine the predictive value of SEL. Third, direct comparison with MRI was not performed in this study. Although the literature suggests that MRI is the most widely accepted modality for postoperative graft evaluation, the absence of parallel MRI data restricted our ability to directly validate SEL findings. Future research incorporating both imaging modalities will be critical to clarify the comparative diagnostic performance of SEL.[16] Finally, the study design was limited to a single center, and all examinations were performed by experienced musculoskeletal radiologists. While this approach ensured consistency, it may limit the generalizability of our findings to less experienced practitioners or different clinical settings. Multicenter studies with broader operator variability are needed to confirm reproducibility.

In summary, our results indicate that SEL provides valuable, objective, and reproducible data on graft integrity following ACL reconstruction. Given its accessibility, cost-effectiveness, and ability to evaluate tissue elasticity in real time, SEL may serve as a practical alternative or complement to MRI in routine postoperative monitoring.

## CONCLUSION

In this study, stress sonoelastography (SEL) was applied to evaluate graft integrity and biomechanical stability following anterior cruciate ligament (ACL) reconstruction with hamstring autografts. Our findings demonstrated that SEL patterns of reconstructed grafts were comparable to those of the contralateral native ACL, supporting its validity as a postoperative assessment tool.

SEL offers several advantages, including accessibility, cost-effectiveness, reproducibility, and the ability to provide dynamic and objective measurements of tissue elasticity. These features suggest that SEL may serve as a valuable adjunct, or even a practical alternative, to magnetic resonance imaging in the postoperative follow-up of ACL reconstruction.

Further studies with larger cohorts, longer follow-up periods, and direct comparisons with MRI are warranted to confirm the diagnostic and prognostic value of SEL in monitoring graft maturation and functional outcomes.

**Ethics Committee Approval:** This study was approved by the Kırıkkale University Faculty of Medicine Ethics Committee (Date: 27.04.2015, Decision No: 10/03).

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**Conflict of Interest:** None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

## Sonoelastografi kullanılarak ön çapraz bağ rekonstrüksiyonunun klinik ve fonksiyonel sonuçlarının karşılaştırılması

AMAÇ: Ön çapraz bağ (ACL) yaralanmaları, özellikle atletik spor yaralanmaları arasında yaygındır. Çoğu klinisyen, tanı amacıyla ve tedavi değerlendirmesi için manyetik rezonans görüntüleme (MRG) kullanır; ancak maliyet ve erişilebilirlik açısından zorluklar çıkarabilir. Ultrason (USG) rehberliği daha erişilebilir olsa da, ACL yaralanmasını tek başına teşhis etmek için yetersizdir. Bu nedenle, çalışmamız, tendon problemlerini incelemek için yeni bir yöntem olan sonoelastografinin, ön çapraz bağ yaralanmaları üzerindeki etkinliğini test etmeyi amaçladı.

GEREÇ VE YÖNTEM: Bu çalışma, belirlenen dahil etme kriterlerini karşılayan 45 hastadan oluşan bir kohortu kapsadı. Hastaları, 2017 ile 2020 yılları arasında ortopedi ve travmatoloji kliniğinde anatomik ACL onarımı geçiren 105 bireyden oluşan bir kohorttan seçtik. Klinik muayene sonuçları ve ACL rekonstrüksiyonu yapılan hastalarda ACL'nin stabilitesi ve kalitesi, manyetik rezonans görüntüleme (MRG) ve stres eko gevşekliği (SEL) test sonuçlarıyla karşılaştırıldı.

BULGULAR: Çalışma, ortalama yaşı 30.7±1.4 yıl olan 40 bireyden oluşuyordu. Hastaların Lysholm puanları, ameliyat sonrası önemli bir iyileşme gösterdi ve ortalama olarak ameliyat öncesi 2.2±0.9'dan ameliyat sonrası 6.1±1.6'ya yükseldi. Lachman, anterior drawer ve pivot-shift testleri, preoperatif değerlere göre iyileşmeler gösterdi. Tek bacak zıplama testinde, etkilenmeyen tarafa göre önemli bir fark gözlemlenmedi. SEL bulguları, sağlıklı ACL örneklerinin %15,6'sının tip 2a, %68.9'unun tip 2b ve %15.6'sının tip 3a olarak kategorize edildiğini gösterdi. Rekonstrükte ACL kohortunda, %17.8'i tip 2a, %62.2'si tip 2b ve %20'si tip 3a olarak kategorize edildi. Sağlıklı ACL ile rekonstrükte ACL arasında önemli bir istatistiksel fark tespit edilmedi. Hiçbir hastada tip 3b veya tip 4 vakası tespit edilmedi.

SONUÇ: Yırtılmış bir ACL tespit etmek ve bağ rekonstrüksiyonu yapıldıktan sonra stabilitesini ve durumunu kontrol etmek için SEL kullandık. SEL veya stres sonoelastografi kullanarak greftin canlılığını izliyoruz ve ACL yaralanmalarının ilerlemesini değerlendiriyoruz. Ayrıca, onarılan bağın normal bir bağa benzer işlevsel bir yapıya sahip olup olmadığını değerlendirmede de faydalıdır. Bunların yanında, erişilebilirliği, maliyet etkinliği, tekrarlanabilirliği ve hasta tercihini göz önünde bulundurulduğunda, MRG'ye göre daha avantajlı bir alternatif sunabilir.

Anahtar sözcükler: ÖÇB rüptürü; ÖÇB rekonstrüksiyonu; sonoelastografi; ultrason.

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ORIGINAL ARTICLE

# Comparison of obstetric and non-obstetric anal sphincter injuries: Surgical outcomes and Jorge Wexner score analysis

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## ABSTRACT

**BACKGROUND:** This study aimed to compare the long-term continence outcomes of patients who underwent surgical repair for obstetric anal sphincter injuries (OASIS) and non-OASIS, based on the Jorge Wexner score. Additionally, predictive factors associated with complete continence restoration versus persistent fecal incontinence were analyzed.

**METHODS:** A retrospective analysis was conducted on 13 patients treated surgically for anal sphincter injuries at Erciyes University Faculty of Medicine between 2016 and 2019, with a minimum follow-up duration of five years. Patients were categorized into obstetric (n=8) and non-obstetric (n=5) groups. Functional outcomes were assessed using the Jorge Wexner score at 6 months, 1 year, and 5 years postoperatively. Continuous variables were analyzed using the Mann-Whitney U test, categorical variables with Fisher's exact test, longitudinal changes with the Friedman test, and potential predictors of full continence were assessed via binary logistic regression.

**RESULTS:** The non-OASIS group exhibited significantly higher mean age (p=0.045) and longer hospital stays (p=0.006) compared to the obstetric group. Perineal examination revealed more extensive tissue loss and contamination in non-OASIS cases, often requiring fecal diversion, whereas obstetric injuries were typically cleaner and linear in nature. Although higher Wexner scores were observed in the non-OASIS group at all time points, between-group differences were not statistically significant. Wexner scores varied significantly over time within the non-OASIS group (p=0.014) but not within the obstetric group (p=0.257). No individual factor showed a significant association with complete continence restoration. The logistic regression model was statistically significant overall (p=0.027), though none of the independent predictors reached significance.

**CONCLUSION:** Compared with obstetric injuries, non-OASIS cases tend to involve a more prolonged recovery course and longer hospitalization. These findings suggest a more complex clinical trajectory in non-OASIS patients.

**Keywords:** Anal sphincter injury; Jorge Wexner score; surgical continence results; fecal incontinence.

## INTRODUCTION

The maintenance of anal continence depends on a complex neuromuscular mechanism that directly influences an individual's quality of life.[1] This mechanism relies on the integrity of the internal and external anal sphincters, the puborectalis muscle, and the pelvic floor structures. Among these, the external anal sphincter plays a central role in voluntary continence control. Disruption of this anatomical integrity can result in fecal incontinence, which often results in social withdrawal, psychological distress, and a substantial decline in quality of life.[2]

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Anal sphincter injuries are broadly categorized into two groups based on etiology: obstetric and non-obstetric injuries.[3] Obstetric anal sphincter injuries (OASIS) represent a major complication of vaginal delivery, typically caused by excessive mechanical stress to the perineal region during spontaneous labor.[4] These injuries, most commonly classified according to the Sultan classification as third- or fourth-degree perineal tears (3a–3c and fourth-degree), are among the leading causes of postpartum fecal incontinence.[5] Despite advances in diagnostic techniques, a significant proportion of such injuries may go unrecognized in the acute setting and later present with complex continence disorders.

In contrast, non-OASIS injuries are relatively less common and arise from a broader range of etiologies, including penetrating trauma, pelvic surgical complications, sexual assault, and traffic accidents.[6] These injuries are typically associated with more extensive tissue damage, delayed presentation, and a more heterogeneous patient population, often complicated by comorbid conditions. The literature on non-OASIS remains limited, and comparative data between obstetric and non-obstetric etiologies are particularly scarce.[7,8]

Surgical sphincteroplasty remains the standard treatment for both types of injuries. However, factors such as timing of surgery, presence of systemic comorbidities, use of adjunctive procedures (e.g., diverting colostomy), and wound healing dynamics can significantly influence functional outcomes.[9] Quantitative tools such as the Jorge Wexner fecal incontinence score are widely used to assess long-term continence, providing objective insight into the patient's recovery trajectory.[10] Yet, the relationship between score progression, injury type, and prognostic indicators has not been fully elucidated.

Against this background, the present study aims to comparatively analyze demographic characteristics, hospital stay durations, and long-term continence outcomes in patients undergoing surgical repair for obstetric versus non-OASIS injuries. The longitudinal trajectory of Jorge Wexner scores was evaluated using appropriate statistical methods, and patients with complete continence restoration were compared to those experiencing persistent incontinence. Potential predictive factors were further analyzed using logistic regression modeling. Through this approach, the study seeks to contribute to the limited body of literature on non-OASIS sphincter injuries and to enhance understanding of long-term surgical outcomes in this patient population.

## MATERIALS AND METHODS

This retrospective study was conducted in the Department of General Surgery, Erciyes University Faculty of Medicine, and included patients who underwent surgical repair for anal sphincter injuries between 2016 and 2019. Ethical approval was obtained from the Erciyes University Non-Interventional Clinical Research Ethics Committee, and all procedures were performed in accordance with the principles of the Declaration of Helsinki (Approval number: 2024/227).

Eligible patients were those who had sustained external and/or internal anal sphincter injuries, had undergone surgical intervention, and had a minimum of five years of documented clinical follow-up. The obstetric group consisted of female patients who sustained third- or fourth-degree perineal tears, classified according to the Sultan classification (3a: <50% external anal sphincter [EAS] torn; 3b: >50% EAS torn; 3c: both EAS and internal anal sphincter [IAS] torn; 4th: EAS, IAS, and anal mucosa torn), during spontaneous vaginal delivery and underwent sphincter repair in the early postpartum period.[5] In the obstetric group, continence evaluations were performed at 6 months, 1 year, and 5 years following primary sphincter repair. The non-OASIS group included patients with sphincter injuries secondary to penetrating trauma, traffic accidents, sexual assault, or other non-obstetric causes who received surgical management. Patients younger than 18 years, those with incomplete postoperative follow-up data, and individuals with significant concomitant neurological or malignant conditions were excluded from the study.

All patients underwent external and/or internal sphincteroplasty, depending on the extent of the injury and associated tissue loss. None of the patients required grafting or flap-based reconstruction. In the non-OASIS group, diverting loop colostomies were performed in selected cases with a high risk of contamination. For patients in this group who underwent fecal diversion, continence assessments were initiated at equivalent time points—6 months, 1 year, and 5 years—following stoma reversal, thereby standardizing follow-up durations between groups.

Clinical data, including demographic characteristics, comorbidities, length of hospital stay, and whether surgical intervention was performed within six hours of injury, were obtained from patient medical records. Functional outcomes were assessed using the Jorge Wexner fecal incontinence score at 6 months, 1 year, and 5 years postoperatively. In this scoring system, a score of 0 indicated complete continence, whereas scores greater than 0 reflected varying degrees of incontinence.[11]

All statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY, USA). The normality of continuous variables was assessed using the Shapiro-Wilk test. The Mann-Whitney U test was used to compare non-parametric continuous data, while categorical variables were analyzed using Fisher's exact test. Longitudinal changes in Jorge Wexner scores within each group were evaluated using the Friedman test, with post-hoc analyses planned for statistically significant results. To identify potential predictors of complete continence restoration, binary logistic regression analysis was performed. In this model, the dependent variable was defined as complete continence (Wexner score=0) versus persistent incontinence (Wexner score>0). A p-value <0.05 was considered statistically significant.

## RESULTS

A total of 13 patients who underwent surgical treatment for anal sphincter injury were included in this retrospective study. Of these, eight patients had obstetric anal sphincter injuries, while five patients had non-OASIS etiologies. Nine patients were female and four were male. All obstetric cases involved female patients, whereas the non-OASIS group comprised four males and one female. Since the obstetric group consisted exclusively of female patients, and the non-OASIS group also included one female, the total number of female patients reflects contributions from both groups.

The mean age was significantly higher in the non-OASIS group compared with the obstetric group (48.4±15.3 years vs. 27.6±6.0 years; p=0.045). Similarly, the mean length of hospital stay was significantly longer in the non-OASIS group (10.4±3.9 days vs. 4.75±1.0 days; p=0.006) (Tables 1 and 2).

When patients who achieved complete continence (Wexner score=0) were compared with those who had persistent incontinence (Wexner score>0), no statistically significant associations were found with sex (p=0.559), type of trauma (p=0.266), presence of comorbidities (p=0.462), or surgical intervention within the first six hours (p=1.000) (Table 3).

Functional continence outcomes were evaluated using the Jorge Wexner score at 6 months, 1 year, and 5 years postoperatively. The mean scores in the obstetric group at these time points were 0.75±1.04, 1.50±2.33, and 1.13±1.89, respectively, whereas in the non-OASIS group, the corresponding values were 3.00±4.12, 4.80±3.90, and 4.00±3.74, respectively. Although Wexner scores were consistently higher in the non-OASIS group at all time points, the differences between groups did not reach statistical significance (p=0.354,

**Table 1.** Age, hospital stay, and Wexner scores by injury type

| Variable | Group | n | Mean±SD | Median | Min-Max |
|---|---|---|---|---|---|
| Age (years) | Obstetric | 8 | 27.6±6.0 | 27.5 | 19-35 |
| | Non-obstetric | 5 | 48.4±15.3 | 55 | 24-60 |
| Hospital stay (days) | Obstetric | 8 | 4.75±1.0 | 4.5 | 4-7 |
| | Non-obstetric | 5 | 10.4±3.9 | 10 | 5-16 |
| Jorge Wexner Score - 6 months | Obstetric | 8 | 0.75±1.04 | 0.5 | 0-3 |
| | Non-obstetric | 5 | 3.00±4.12 | 2.0 | 0-10 |
| Jorge Wexner Score - 1 year | Obstetric | 8 | 1.50±2.33 | 0.0 | 0-6 |
| | Non-obstetric | 5 | 4.80±3.90 | 5.0 | 1-11 |
| Jorge Wexner Score - 5 years | Obstetric | 8 | 1.13±1.89 | 0.0 | 0-5 |
| | Non-obstetric | 5 | 4.00±3.74 | 4.0 | 0-10 |

Wexner scores in non-obstetric cases were assessed after colostomy closure. SD: Standard deviation.

**Table 2.** Comparison of age, hospital stay, and Wexner scores by injury type

| Variable | Group | Mean Rank | Sum of Ranks | Mann-Whitney U | Exact p-value |
|---|---|---|---|---|---|
| Age (years) | Obstetric | 5.25 | 42.00 | 6.000 | 0.045 |
| | Non-obstetric | 9.80 | 49.00 | | |
| Hospital stay (days) | Obstetric | 4.81 | 38.50 | 2.500 | 0.006 |
| | Non-obstetric | 10.50 | 52.50 | | |
| Wexner Score - 6 months | Obstetric | 6.19 | 49.50 | 13.500 | 0.354 |
| | Non-obstetric | 8.30 | 41.50 | | |
| Wexner Score - 1 year | Obstetric | 5.44 | 43.50 | 7.500 | 0.065 |
| | Non-obstetric | 9.50 | 47.50 | | |
| Wexner Score - 5 years | Obstetric | 5.69 | 45.50 | 9.500 | 0.127 |
| | Non-obstetric | 9.10 | 45.50 | | |

Age and hospital stay were significantly higher in the non-obstetric group. U: Mann-Whitney U statistic; SD: Standard deviation.

**Table 3.** Comparison of categorical variables based on normalization of Wexner scores

| Variable | Category | Wexner=0 (n) | Wexner>0 (n) | Exact p-value |
|---|---|---|---|---|
| Sex | Female/Male | 5/4 | 4/1 | 0.559 |
| Trauma type | Obstetric/Non-obstetric | 5/1 | 3/4 | 0.266 |
| Comorbidity | None/DM+HT | 5/1 | 7/0 | 0.462 |
| Surgery <6 h | Yes/No | 4/2 | 4/3 | 1.000 |

DM: Diabetes mellitus; HT: Hypertension.

**Table 4.** Temporal changes in Jorge Wexner scores at 6 months, 1 year, and 5 years in non-obstetric and obstetric groups (analyzed using the Friedman test)

| Group | Time Point | Mean Rank | N | p-value (Friedman) |
|---|---|---|---|---|
| Non-obstetric | 6 months | 1.20 | 5 | |
| | 1 year | 2.90 | | |
| | 5 years | 1.90 | | 0.014 |
| Obstetric | 6 months | 1.81 | 8 | |
| | 1 year | 2.31 | | |
| | 5 years | 1.88 | | 0.257 |

N: Number of patients.

p=0.065, and p=0.127, respectively) (Table 4).

Friedman test results demonstrated a statistically significant change in Wexner scores over time within the non-OASIS group (p=0.014), indicating a dynamic course of continence recovery. Although post-hoc pairwise comparisons were planned, no statistically significant differences were detected, likely due to the small sample size. No significant temporal change in Wexner scores was observed in the obstetric group (p=0.257). Continence assessments in patients who underwent diverting colostomy were initiated only after stoma reversal, beginning with the 6-month postoperative follow-up (Table 4 footnote). Three patients in the non-OASIS group underwent intraoperative colostomy due to a high risk of contamination.

A visual comparison of perianal examination findings between groups is presented in Figure 1. Non-OASIS injuries were characterized by deep tissue defects and irregular wound margins, often necessitating complex reconstruction and fecal diversion. In contrast, obstetric injuries appeared as cleaner, linear sphincter disruptions with less tissue loss. Figure 2 demonstrates the intraoperative repair of OASIS. End-to-end sphincter approximation was performed using delayed-absorbable sutures, with anatomical continuity restored prior to skin closure.

To identify potential predictors of complete continence resolution (Wexner score=0), a binary logistic regression analysis was performed, including age, early surgical intervention (<6 hours), presence of comorbidities, and type of trauma as covariates. The overall model was statistically significant (p=0.027), with a Nagelkerke $R^2$ value of 0.760, indicating good model fit (Table 5). However, none of the individual predictors reached statistical significance (p>0.05). The analysis also revealed extremely high standard errors and inestimable

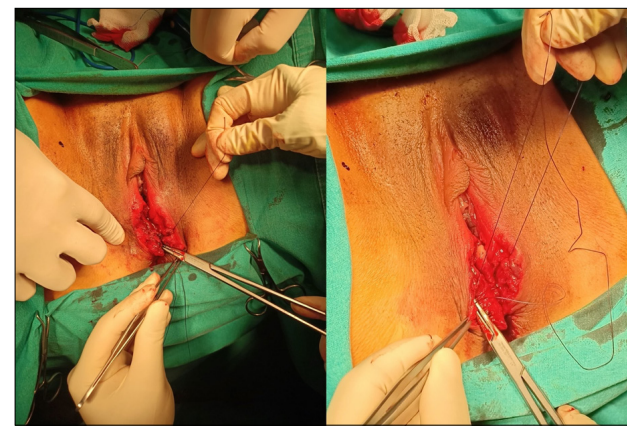

**Figure 1.** Perianal examination findings in non-obstetric anal sphincter injuries; the left image shows a superficial laceration, while the right demonstrates significant tissue loss and a full-thickness sphincter defect.

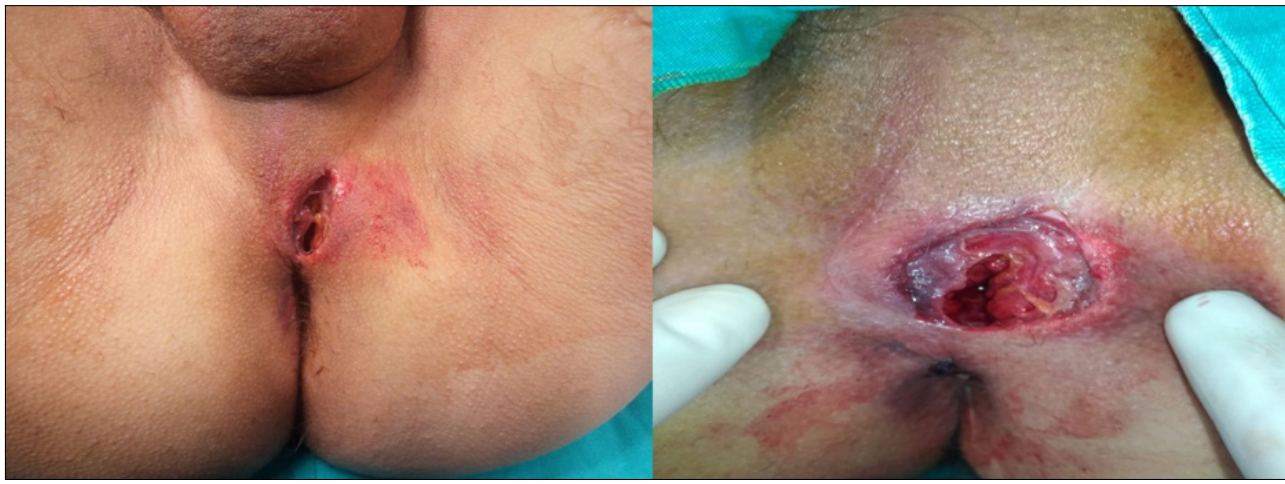

**Figure 2.** Intraoperative views of obstetric anal sphincter repair; the left image shows end-to-end sphincter suturing, while the right depicts the final stage of reconstruction.

**Table 5.** Binary logistic regression analysis of factors potentially predicting complete normalization of Jorge Wexner score after surgery

| Variable | B | SE | Wald | p-value | OR (Exp(B)) |
|---|---|---|---|---|---|
| Age | -0.261 | 0.202 | 1.657 | 0.198 | 0.771 |
| Surgery <6 h | -18.685 | 23,879.934 | 0.000 | 0.999 | 0.000 |
| Comorbidity | -20.402 | 21,631.138 | 0.000 | 0.999 | 0.000 |
| Trauma Type (Obstetric) | -47.323 | 28,747.196 | 0.000 | 0.999 | 0.000 |
| Constant | 93.014 | 57,107.012 | 0.000 | 0.999 | 2.485E+40 |

B: Regression coefficient; SE: Standard error; OR: Odds ratio; Exp(B): Exponentiated B.

odds ratios for several variables, suggesting model instability and possible overfitting due to the limited sample size.

## DISCUSSION

Anal sphincter injuries represent a complex pathology that can significantly impact an individual's physical, social, and psychological well-being. This study provides valuable insights by comparing long-term continence outcomes in patients who underwent surgical repair for both OASIS and non-OASIS. Previous literature reports that 15% to 25% of women with OASIS may experience persistent fecal incontinence in the long term.[12] In our cohort, the mean Jorge Wexner score at the five-year follow-up in the obstetric group was 1.13±1.89, which aligns with previously published data. This finding supports the notion that early surgical repair may yield satisfactory functional outcomes in OASIS cases.

In contrast, evidence regarding non-OASIS remains scarce and is primarily limited to case reports and small observational studies. While several publications have highlighted the complexity and morbidity associated with penetrating or blunt perineal trauma, high-quality comparative data are lacking.[13] In the present study, patients in the non-OASIS group had a mean five-year Wexner score of 4.00±3.74—numerically higher than that of the obstetric group, although the difference did not reach statistical significance. Notably, the non-OASIS group also demonstrated significantly longer hospital stays, which may reflect more extensive tissue disruption, delayed presentation, and the frequent need for additional surgical procedures such as fecal diversion. These findings underscore the heterogeneous and often protracted clinical course of non-OASIS, for which standardized treatment protocols and long-term outcome data remain limited in the current literature.

Analysis of continence dynamics over time using the Friedman test revealed a statistically significant trend of improvement in the non-OASIS group (p=0.014). This suggests that although initial Wexner scores were higher, functional recovery and compensatory mechanisms may become more effective over time.[14] Conversely, the obstetric group exhibited low and relatively stable scores across all time points (p=0.257), further supporting the advantage of early surgical repair in this

population.

Binary logistic regression was used to explore potential predictors of complete continence restoration, including age, trauma type, presence of comorbidities, and whether surgical intervention occurred within the first six hours. Although the overall model reached statistical significance (p=0.027), none of the individual variables were independently associated with the outcome. The model exhibited signs of overfitting and instability, including excessively large standard errors and non-estimable odds ratios, which are likely attributable to the small sample size. These findings should therefore be interpreted with caution and warrant validation through prospective, large-scale studies. Although the logistic regression model achieved statistical significance, the instability of odds ratios and standard errors likely reflects the limitations of small-sample modeling. These findings should be interpreted as exploratory and require confirmation in larger, prospective studies.

It is also noteworthy that Wexner score assessments in patients with diverting colostomies in the non-OASIS group were initiated only after stoma reversal, potentially introducing heterogeneity in follow-up timing. Nevertheless, the use of a protective stoma is often preferred to facilitate perineal wound healing and to minimize infectious complications in high-risk cases.[15]

The major strength of this study lies in its systematic and quantitative evaluation of long-term functional outcomes following non-OASIS—an area underrepresented in the current literature.[16] Moreover, it provides one of the first direct, long-term comparative analyses of surgical and functional outcomes in obstetric versus non-OASIS etiologies. However, several limitations must be acknowledged. Most notably, the study included a relatively small cohort (n=13), with only five patients in the non-OASIS group. This limited sample size may have reduced statistical power and contributed to the lack of significant between-group differences, particularly in the regression analysis. Although the overall logistic regression model achieved statistical significance, evidence of overfitting (e.g., large standard errors, wide confidence intervals, and non-estimable odds ratios) suggests that the findings should be interpreted cautiously. Despite these limitations, the study contributes valuable preliminary evidence to a poorly explored area and highlights important trends that may inform clinical decision-making. Future prospective, multicenter studies with larger patient cohorts are essential to validate these observations and establish more definitive conclusions.

## CONCLUSION

The etiology of anal sphincter injury appears to influence functional recovery, with non-OASIS cases exhibiting a more complex clinical course than obstetric injuries. In this patient population, early diagnosis, a multidisciplinary treatment approach, and structured long-term follow-up strategies may enhance therapeutic efficacy. However, these findings should be interpreted in light of the limited sample size, which remains a major limitation. Further multicenter, prospective studies with larger cohorts are warranted to validate and expand upon these results.

**Ethics Committee Approval:** This study was approved by the Erciyes University Faculty of Medicine Ethics Committee (Date: 02.10.2024, Decision No: 2024/227).

**Peer-review:** Externally peer-reviewed.

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

**Conflict of Interest:** None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

## Obstetrik ve non-obstetrik anal sfinkter yaralanmalarının karşılaştırılması: Cerrahi sonuçlar ve jorge wexner skoru analizi

AMAÇ: Bu çalışmanın amacı, obstetrik ve non-obstetrik anal sfinkter yaralanmaları nedeniyle cerrahi onarım uygulanan hastalarda Jorge Wexner skoru temelinde uzun dönem kontinens sonuçlarını karşılaştırmaktır. Ayrıca, tam kontinens sağlanması ile kalıcı fekal inkontinans arasında ilişkili olabilecek öngörücü faktörler analiz edilmiştir.

GEREÇ VE YÖNTEM: Bu retrospektif analizde, 2016–2019 yılları arasında Erciyes Üniversitesi Tıp Fakültesi'nde anal sfinkter yaralanması nedeniyle cerrahi tedavi uygulanan ve en az beş yıllık takip süresi olan 13 hasta değerlendirilmiştir. Hastalar obstetrik (n=8) ve obstetrik dışı (n=5) olmak üzere iki gruba ayrılmıştır. Fonksiyonel sonuçlar, ameliyat sonrası 6. ay, 1. yıl ve 5. yılda Jorge Wexner skoru ile değerlendirilmiştir. Sürekli değişkenler Mann–Whitney U testi ile, kategorik değişkenler Fisher exact testi ile, zamana bağlı değişiklikler Friedman testi ile analiz edilmiştir. Tam kontinens sağlanmasını öngören olası faktörler ise ikili lojistik regresyon analizi ile değerlendirilmiştir.

BULGULAR: Obstetrik dışı grupta ortalama yaş anlamlı olarak daha yüksek (p=0.045) ve hastanede yatış süresi daha uzundu (p=0.006). Perineal muayenede, obstetrik dışı olgularda daha fazla doku kaybı ve kontaminasyon saptanmış olup genellikle fekal diversiyon gereksinimi doğmuştur. Buna karşılık, obstetrik yaralanmalar genellikle daha temiz ve lineer yapıda izlenmiştir. Tüm zaman noktalarında obstetrik dışı grupta Wexner skorları daha yüksek olmakla birlikte, gruplar arası farklar istatistiksel olarak anlamlı bulunmamıştır. Obstetrik dışı grupta Wexner skorları zaman içinde anlamlı değişkenlik göstermiştir (p=0.014), ancak obstetrik grupta bu değişim anlamlı değildir (p=0.257). Hiçbir bireysel değişken, tam kontinens sağlanması ile istatistiksel olarak anlamlı ilişki göstermemiştir. Lojistik regresyon modeli genel olarak anlamlı bulunmuş (p=0.027), ancak bağımsız değişkenlerin hiçbiri anlamlı düzeye ulaşmamıştır.

SONUÇ: Obstetrik yaralanmalara kıyasla, obstetrik dışı anal sfinkter yaralanmaları daha uzun iyileşme süreci ve daha uzun hastanede yatış süresi ile karakterizedir. Bu bulgular, obstetrik dışı olguların daha karmaşık bir klinik seyir izlediğini düşündürmektedir.

Anahtar sözcükler: Anal sfinkter yaralanması; cerrahi kontinens sonuçları; fekal inkontinans; Jorge Wexner skoru.

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ORIGINAL ARTICLE

# A comparison of the minimally invasive and traditional lateral approaches for hemiarthroplasty following a femoral neck fracture: Reduced postoperative pain and fewer blood transfusions

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## ABSTRACT

**BACKGROUND:** This study aimed to investigate the effects of the minimally invasive direct lateral approach, performed using standard hip surgery instruments, on operation duration, early postoperative pain, postoperative blood loss, and hospital stay in the treatment of femoral neck fractures with hemiarthroplasty (HA), compared with the standard Hardinge direct lateral approach (referred to in this study as the conventional group, CG).

**METHODS:** We retrospectively collected clinical data from the medical records of our hospital. Inclusion criteria were a diagnosis of femoral neck fracture resulting from low-energy trauma and treatment with HA surgery. Patients were divided into two groups based on the surgical approach: the conventional group (CG) and the mini-incision group (MG). Twenty-four patients comprised the MG (case group), while 18 patients were in the CG (control group). The average wait time for surgery was 3.8 days for the MG and 3.6 days for the CG. Statistical analyses were conducted to evaluate differences in postoperative pain scores, hospital stay, postoperative blood transfusion, operation duration, hemoglobin, and hematocrit levels between the groups.

**RESULTS:** There was no significant difference in age or gender distribution between the case and control groups ($p>0.05$). The average age of the mini-incision group was 83.8 years, while the average age of the CG was 86.9 years. In both groups, the fracture types were equally distributed between Garden type III and IV. However, the visual analog scale (VAS) scores on the first and third postoperative days were significantly lower in the case group than in the CG ($p<0.05$). Patients in the MG required significantly fewer postoperative blood transfusions compared to the control group. Hospitalization duration, as well as hemoglobin and hematocrit levels both preoperatively and at discharge, were comparable between the groups.

**CONCLUSION:** The data from this study indicate that the mini-incision technique is an effective and reliable method for treating femoral neck fractures. Compared with the conventional group, the minimally invasive direct lateral approach for femoral neck fractures significantly reduces early postoperative pain, results in less blood loss, offers better cosmetic outcomes, and maintains a similar length of hospital stay. Clinical studies with larger sample sizes and assessments of long-term postoperative outcomes are necessary.

**Keywords:** Case-control study; direct lateral approach; femoral neck fractures; minimally invasive surgery; postoperative pain.

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## INTRODUCTION

Minimally invasive (MI) surgical methods remain highly favored by orthopedic surgeons. Several studies in the literature have compared traditional surgical techniques with MI methods in total hip arthroplasty.[1-3] These MI approaches decrease soft tissue trauma and postoperative adhesions, shorten hospital stays, and promote easier rehabilitation.[4]

In trauma surgery, hemiarthroplasty (HA) is used to treat femoral neck fractures when osteosynthesis is not feasible or suitable. Common approaches for this procedure include the direct lateral (Hardinge), anterolateral, and posterior (Moore) techniques. These conventional methods are associated with greater tissue damage, increased postoperative pain, more blood loss, and prolonged rehabilitation. The aim of this study is to evaluate the outcomes of MI surgical techniques performed using standard hip surgery instruments readily available to surgeons, rather than relying on specialized mini-incision hip surgery instruments. This study evaluates how a MI technique impacts postoperative bleeding, hospital stay duration, and early pain levels following HA. We hypothesize that this approach will result in considerably lower postoperative pain scores, shorter hospital stays, and reduced blood loss during surgery compared to the conventional lateral approach. If confirmed, these findings may significantly improve patient outcomes and reduce healthcare costs.

## MATERIALS AND METHODS

### Research Framework

This retrospective observational study was conducted in the Department of Orthopedics and Traumatology at Kanuni Sultan Suleyman Training and Research Hospital, with approval from the hospital's ethics committee (document number: KAEK/2024.09.179). It adhered to the principles of the Declaration of Helsinki and followed STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines during manuscript preparation. All data were collected and analyzed by the authors.

### Inclusion criteria were:

1. Patients diagnosed with recent femoral neck fractures (Garden type III or IV) managed with partial hip endoprosthesis by the senior author between March 2020 and August 2024.

2. Patients with a body mass index (BMI) under 30.

3. Patients older than 65 years.

4. Patients without prior orthopedic surgery on the same hip.

Exclusion criteria were:

1. Patients with incomplete medical records.

2. Patients with pathological fractures.

3. Patients who used warfarin or clopidogrel preoperatively.

4. Patients who experienced intraoperative fracture complications.

5. Patients monitored in the postoperative intensive care unit.

6. Patients who received intraoperative blood transfusions.

7. Patients with cognitive impairment or dementia.

A flow diagram detailing the patient inclusion and exclusion process is shown in Figure 1.

Patients were categorized into two groups according to the surgical method used. Those who underwent HA via the modified Hardinge approach were assigned to the conventional group (CG), whereas those treated with a mini-incision direct lateral approach were assigned to the mini-incision group (MG).

The clinical data collected from patient records included Visual Analogue Scale (VAS) scores for postoperative days 1 to 3, duration of hospital stay, number of postoperative blood transfusions, operative time (in minutes), and hemoglobin and hematocrit levels on postoperative day 3.

### Sample Size and Power Considerations

The sample size for this study was determined through a power analysis using a 5% margin of error, 80% power, and a standard effect size of 1, indicating that each group required at least 16 patients. The number of patients remaining after applying the exclusion criteria exceeded the minimum required for each group.

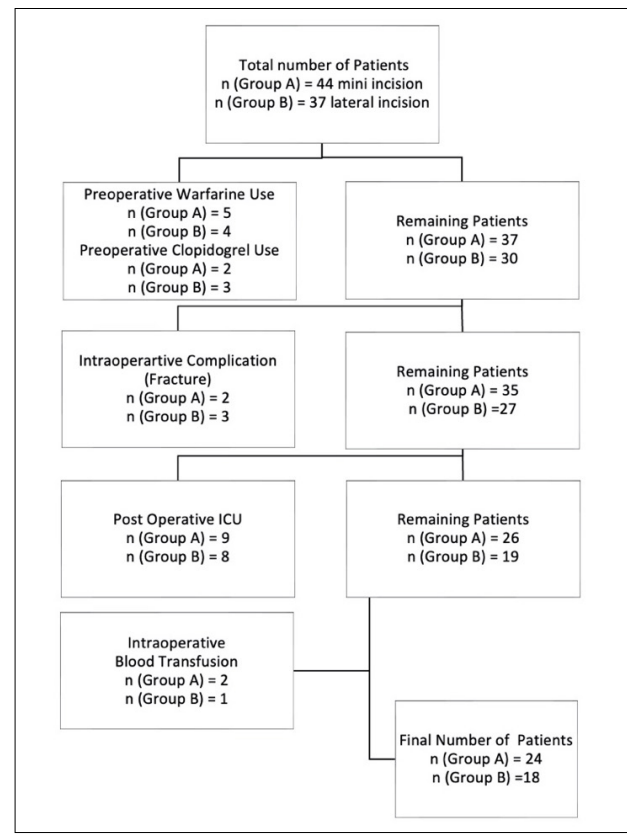


**Figure 1.** Flow diagram of patient inclusion in the study according to exclusion criteria.

### Minimally Invasive Surgical Approach Technique

The patient is placed in the standard lateral decubitus position, with the operative hip positioned in slight adduction, 45-60 degrees of flexion, and 10-20 degrees of internal rotation. Spinal anesthesia is preferred unless contraindicated. Standard hip surgery instruments are used, without employing tools designed for mini-open surgery. A skin incision is made along a longitudinal line starting from the tip of the trochanter, extending 5-7 cm proximally along the femur. The length of the incision is determined from the preoperative direct pelvic radiograph by measuring the diameter of the femoral head (Fig. 2a). The incision is located anterior to the midpoint between one-third and one-half of the transverse length of the greater trochanter on the sagittal plane. Subcutaneous tissue and fascia are dissected. Upon reaching the tensor fascia lata, the soft tissue is mobilized 1.5 cm inward from the wound margins circumferentially before proceeding to the next anatomical layer. The tensor fascia lata is split proximally and distally along the midline, parallel to the skin incision. The trochanteric bursa is resected. The anterior third of the gluteus medius muscle fibers is detached from the bone, along with the anterior half of the vastus lateralis, and shifted forward to reveal the joint capsule using a Cobb elevator. The hip capsule is incised from the saddle of the femoral neck using a traditional T-incision. Blunt Hohman retractors are

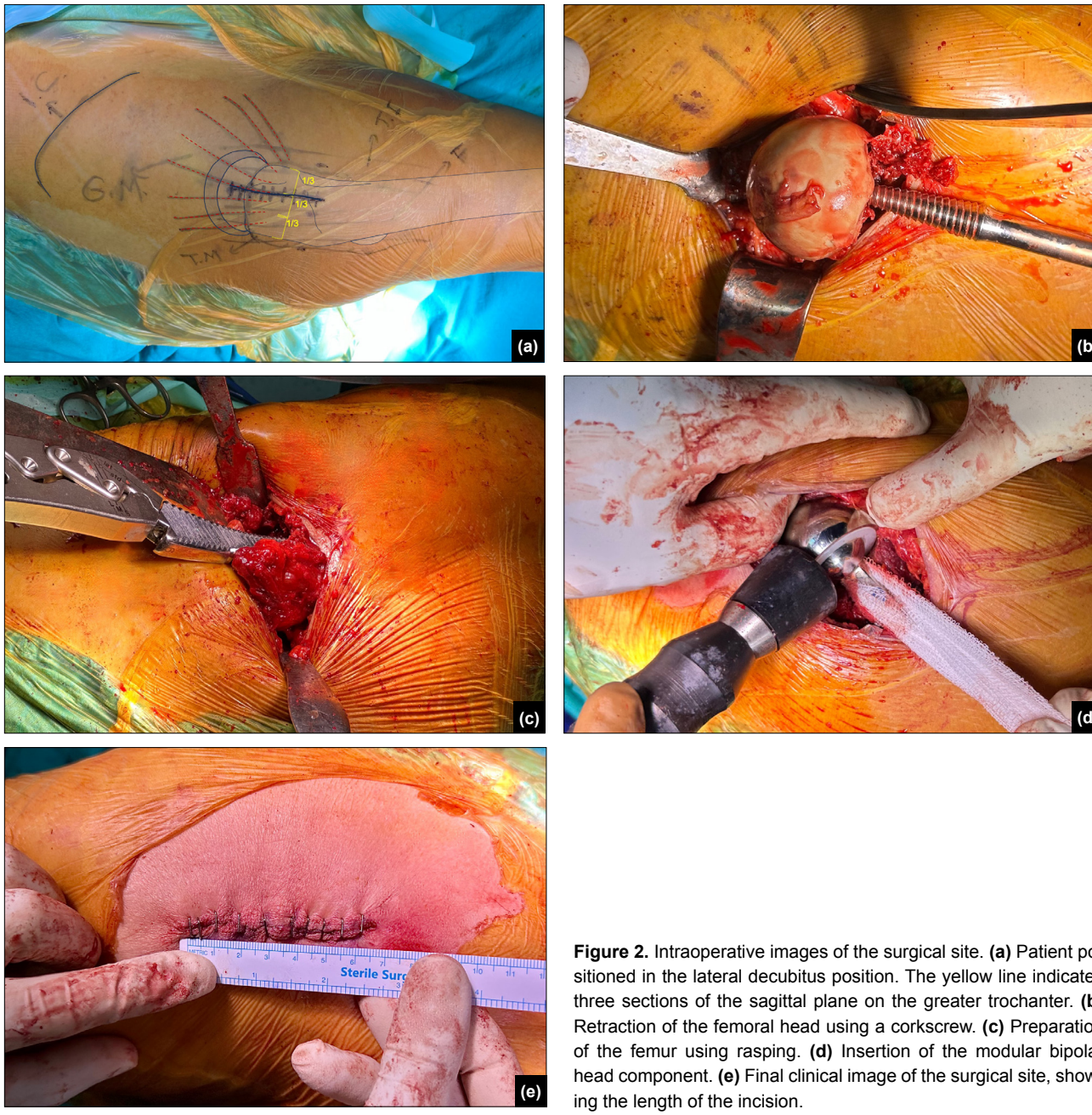


**Figure 2.** Intraoperative images of the surgical site. **(a)** Patient positioned in the lateral decubitus position. The yellow line indicates three sections of the sagittal plane on the greater trochanter. **(b)** Retraction of the femoral head using a corkscrew. **(c)** Preparation of the femur using rasping. **(d)** Insertion of the modular bipolar head component. **(e)** Final clinical image of the surgical site, showing the length of the incision.

**Table 1.** Comparison of demographics and variables between groups

| | Mini-Incision (n=24) | | Conventional (n=18) | | | |
|---|---|---|---|---|---|---|
| | Mean±SD/n (%) | Median | Mean±SD/n (%) | Median | p | |
| Patient age | 83.8±86.5 | 9.8 | 86.9±88.5 | 9.1 | 0.296 | t |
| Gender | | | | | | |
| Female | 11 | 45.8% | 9 | 50.0% | 0.789 | $X^2$ |
| Male | 13 | 54.2% | 9 | 50.0% | | |
| VAS Score | | | | | | |
| Postoperative day 1 | 6.3±6.0 | 1.0 | 7.2±7.0 | 0.9 | 0.006 | m |
| Postoperative day 2 | 4.8±5.0 | 1.0 | 5.2±5.0 | 0.8 | 0.238 | m |
| Postoperative day 3 | 2.7±2.0 | 1.0 | 4.0±4.0 | 1.1 | 0.000 | m |
| Postoperative hospitalization (days) | 3.3±3.0 | 0.8 | 3.0±3.0 | 0.6 | 0.247 | m |
| More than 3 days of hospitalization | | | | | | |
| (-) | 23 | 95.8% | 17 | 94.4% | 1.000 | $X^2$ |
| (+) | 1 | 4.2% | 1 | 5.6% | | |
| HGB g/dL | | | | | | |
| Preoperative | 10.3±10.2 | 1.5 | 10.0±9.7 | 1.5 | 0.437 | m |
| Discharge | 10.3±10.2 | 0.9 | 10.0±9.8 | 1.0 | 0.252 | t |
| HCT % | | | | | | |
| Preoperative | 31.3±30.1 | 3.7 | 30.3±29.2 | 3.0 | 0.401 | m |
| Discharge | 31.5±30.9 | 1.7 | 30.6±30.3 | 1.7 | 0.154 | m |
| Postoperative blood transfusion (units) | 1.4±1.0 | 1.2 | 2.7±3.0 | 1.2 | 0.003 | m |
| Operation duration (minutes) | 58.0±57.0 | 7.0 | 59.3±59.0 | 5.1 | 0.511 | t |

[t]Independent Samples t-test; mMann-Whitney U test; $X^2$ Chi-square test (Fisher's test).

placed anteriorly and posteriorly around the femoral neck. The femoral head is extracted using a corkscrew, followed by femoral neck osteotomy with an oscillating saw, irrigation, and placement of a sponge (Fig. 2b). The lower extremity is then repositioned in a figure-four position within a sterile pocket. Retractors are placed on the lesser trochanter, behind the greater trochanter, and posterosuperiorly to elevate the proximal femur. Standard rasping is performed, and the proximal femur is prepared to the appropriate size (Fig. 2c). Following trial reduction, the ranges of motion are: flexion (100°-120°), extension (5°-10°), internal rotation (30°-40°), and external rotation (30°-40°). Limb movements are then assessed. The trial implants are replaced with the definitive femoral stem and modular bipolar head component, and stability is checked again (Fig. 2d). Finally, the capsule is sutured, the anterior musculotendinous flap is reattached, and the tensor fascia lata, subcutaneous tissue, and skin are sutured (Fig. 2e).

### Early Postoperative Care

At our orthopedic clinic, daily VAS scores are recorded for all patients after arthroplasty procedures until discharge. Patients undergoing hip arthroplasty with the minimally invasive approach are mobilized on the second postoperative day, while on antiaggregant therapy and without a drain. In contrast, for those treated with the conventional direct lateral approach, the drain is removed on the first postoperative day. None of the patients treated by the senior author received tranexamic acid, either intravenously or locally. Patients are typically discharged once their hemoglobin and hematocrit levels have normalized, usually by the third postoperative day, and after they have completed their mobilization exercises.

### Statistical Analysis

Data were analyzed using IBM's Statistical Package for the Social Sciences (SPSS), version 27.0 (IBM SPSS Statistics, IBM Corporation, Chicago, IL), with statistical significance set at $p<0.05$. Descriptive statistics included the mean, standard deviation, median, minimum and maximum values, frequency, and percentage. The Kolmogorov-Smirnov and Shapiro-Wilk tests were used to evaluate variable distribution. Independent samples t-tests were applied to normally distributed quantitative variables, while Mann-Whitney U tests were used for non-normally distributed variables. A chi-square test was

used to compare qualitative data.

## RESULTS

The MG included 11 males and 13 females, aged 67-99 years, with an average age of 83.8 years. Their BMIs ranged from 18.1 to 25.4 kg/m² (mean 21.5 kg/m²), and their American Society of Anesthesiologists (ASA) scores averaged 2.3±0.4. The CG consisted of nine males and nine females, also aged 67-99 years, with an average age of 86.9 years. Their BMIs ranged from 17.1 to 29.5 kg/m² (mean 23.2 kg/m²), and their ASA scores averaged 2.7±0.3. No statistically significant differences were found between the two groups in terms of sex, age, BMI, or ASA score. The average wait time for surgery was 3.8 days for the MG and 3.6 days for the CG. No intraoperative complications occurred in either group. Wound healing after surgery was better and more aesthetically pleasing in the mini-incision group, whereas in the CG, minor drainage was noted over several days.

In comparison to the MG, the CG exhibited significantly higher VAS scores on the first and third postoperative days ($p<0.05$). Although VAS scores on the second day were also higher in the CG, the difference was not statistically significant ($p>0.05$) (Fig. 3, Table 1). Due to lower pain scores, MG patients mobilized more easily than CG patients. The mean duration of hospitalization was slightly longer in the MG (3.3 days) than in the CG (3.0 days) (Table 1). Drops in hemoglobin (HGB) and hematocrit (HCT) were smaller in the MG. The CG required significantly more postoperative blood transfusions, averaging 2.7 units, compared with 1.4 units in the MG (Fig. 4, Table 1). Although the mean operation time was slightly longer in the CG (59.3 minutes) than in the MG (58.0 minutes), the difference was not statistically significant (Table 1).

## DISCUSSION

An increasing number of studies have focused on arthroplasty surgical methods, which have gained popularity due to advancements in robotic instruments and technology.[5] Surgeons and patients alike consider incision length during orthopedic procedures.[6] In cases of femoral neck fractures, timely surgical intervention is crucial, particularly given patients' underlying medical conditions and advanced age.[7] The length of the incision is primarily associated with postoperative pain, which can influence early mobilization.[5,8]

This study found that patients undergoing mini-incision surgery experienced less postoperative pain and required fewer blood transfusions compared to those who had conventional incisions. However, there was no significant difference in operation time between the two approaches. The learning curve associated with total hip arthroplasty and HA represents a significant challenge.[9] Experienced surgeons typically prefer shorter incisions during hip arthroplasty, whereas less experienced surgeons may place greater emphasis on incision length during procedures.[10] This study provides insights into these factors influencing the surgical approach.

A study comparing patients with femoral neck fractures who underwent hemiarthroplasty using minimally invasive anterolateral and conventional anterolateral techniques found that

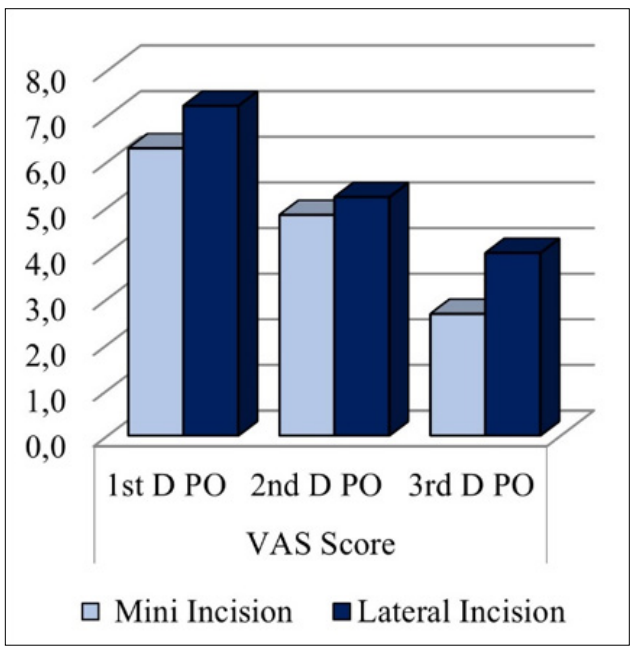


**Figure 3.** Graphical representation of Visual Analogue Scale (VAS) score parameters.

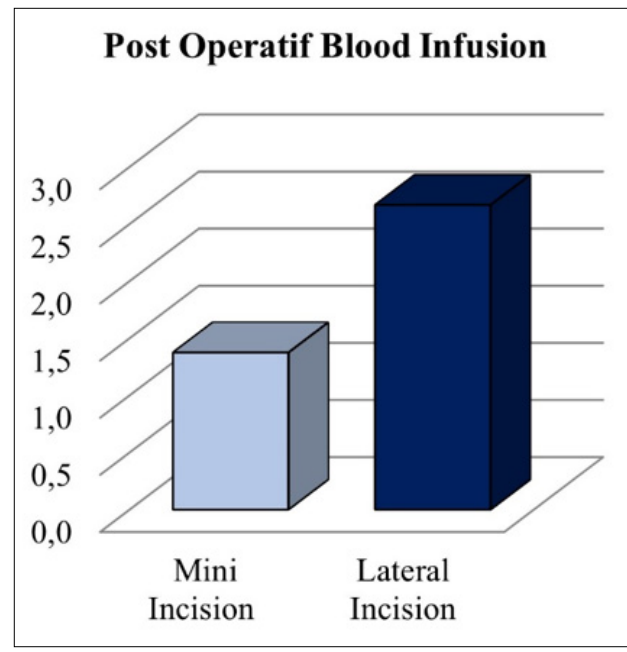


**Figure 4.** Graphical representation of postoperative blood transfusion parameters.

only the operative time was slightly shorter in the minimally invasive group, while postoperative complications and clinical outcomes remained unchanged.[11] In our study, we compared mini-incision and conventional lateral approaches, finding that postoperative pain and bleeding were reduced, and the operative time was slightly shorter for hemiarthroplasties performed with mini-incisions in patients with femoral neck fractures.

Surgeons typically use a specific set of tools to perform minimally invasive hip hemiarthroplasty for femoral neck fractures.[12,13] In our cases, minimally invasive hemiarthroplasty for femoral neck fractures was performed using a standard hip surgery set, without any specialized instruments.

The literature indicates that a minimally invasive approach does not significantly affect the length of hospital stay in hemiarthroplasty.[14] Our study also found no statistically significant difference.

Tranexamic acid is considered effective and safe for reducing transfusion rates in patients undergoing hip hemiarthroplasty. However, the optimal timing, dosage, and method of administration remain uncertain.[15,16] None of the patients who underwent mini-incision hemiarthroplasty in our study required tranexamic acid.

Previous studies suggest that the direct lateral hip approach carries a risk of heterotopic ossification.[17] Long-term follow-up is therefore recommended for cases performed with the mini-incision technique.

The literature also indicates that surgical drains are not required for elderly patients with femoral neck fractures.[18] In our mini-incision cases, drains were not used.

This study has several limitations, including a short follow-up period, lack of functional outcome data, a limited number of cases, uncertainty regarding the sustained clinical effectiveness of the surgery, and a retrospective design. Additionally, we did not obtain serum biomarkers such as C-reactive protein, erythrocyte sedimentation rate, or creatine kinase levels. The standard postoperative follow-up protocol does not include these markers unless specifically indicated. Furthermore, assessing hip scores after the follow-up period could provide greater insight into differences between groups. These limitations should be addressed in future prospective studies.

## CONCLUSION

The data from this study indicate that the mini-incision technique is an effective and reliable method for treating femoral neck fractures. Compared to the conventional group using the standard lateral approach, the minimally invasive direct lateral approach for femoral neck fractures significantly reduces postoperative pain in the early recovery period, results in less blood loss, offers better cosmetic outcomes, and maintains a similar length of hospital stay. Clinical studies with larger sample sizes and long-term postoperative outcome assessments are necessary.

**Ethics Committee Approval:** This study was approved by the Kanuni Sultan Suleyman Training and Research Hospital Ethics Committee (Date: 25.09.2024, Decision No: KAEK/2024.09.179).

**Peer-review:** Externally peer-reviewed.

**Authorship Contributions:** Concept: B.K.; Design: S.A., B.K.; Supervision: B.K.; Data collection and/or processing: F.Ş., M.C., B.H.K.; Analysis and/or interpretation: S.S., B.K., E.M., F.Ş.; Literature review: S.S., S.A., M.C., E.M.; Writing: M.C., S.A., B.K., B.H.K.; Critical review: B.K., M.C., F.Ş., S.S., E.M., S.A., B.H.K.

**Conflict of Interest:** None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

## Femoral boyun kırığı sonrası hemiartroplasti için minimal invaziv ve geleneksel lateral yaklaşımların karşılaştırılması, ameliyat sonrası ağrının azaldığını ve daha az kan transfüzyonu gerektiğini göstermektedir

AMAÇ: Bu çalışmanın amacı, hemiartroplasti (HA) ile tedavi edilen femoral boyun kırıklarının tedavisinde standart kalça cerrahisi aletleri ile uygulanan minimal invaziv direkt lateral yaklaşımın, çalışmada konvansiyonel grup (CG) olarak adlandırılan standart Hardinge direkt lateral yaklaşıma kıyasla operasyon süresi, erken postoperatif ağrı, postoperatif kan kaybı ve hastanede kalış süresi üzerindeki etkilerini araştırmaktır.
GEREÇ VE YÖNTEM: Hastanemizin tıbbi kayıtlarından klinik verileri retrospektif olarak topladık. Seçilen hastaları dahil etme kriterleri; düşük enerjili travmadan kaynaklanan femoral boyun kırığı tanısı almış ve HA cerrahisi ile tedavi edilmiş olmak. Hastalar cerrahi yaklaşıma göre iki gruba ayrıldı: konvansiyonel grup (CG) ve mini kesi grubu (MG). Yirmi dört hasta MG'yi (vaka grubu) oluştururken, on sekiz hasta CG'de (kontrol grubu) yer aldı. Ameliyat için ortalama bekleme süresi MG için 3.8 gün ve CG için 3.6 gündür. İstatistiksel analizler, gruplar arasında postoperatif ağrı skorları, hastanede kalış süreleri, postoperatif kan infüzyonu, operasyon süresi, hemoglobin ve hematokrit seviyelerindeki farklılıkları değerlendirmek için yürütüldü.
BULGULAR: Çalışmamızda vaka ve kontrol grupları arasında yaş ve cinsiyet dağılımında anlamlı bir fark bulunmadı ($p>0.05$). Mini kesi grubunun ortalama yaşı 83.8 yıl iken, diğer grubun ortalama yaşı 86.9 yıldı. Her iki grupta da kırık tipleri eşit olarak Garden tip III ve IV idi. Ancak, birinci ve üçüncü postoperatif günlerdeki görsel analog skala (VAS) skorları vaka grubunda CG grubuna göre anlamlı derecede düşüktü ($p<0.05$). MG' deki hastalar kontrol grubuna kıyasla anlamlı derecede daha az postoperatif kan transfüzyonuna ihtiyaç duydu. Hastanede kalış süresi, hemoglobin ve hematokrit seviyeleri hem operasyon öncesi hem de taburculuk sırasında gruplar arasında benzerdi.
SONUÇ: Bu çalışmadan elde edilen veriler, mini kesi tekniğinin femur boynu kırıklarının tedavisinde etkili ve güvenilir bir yöntem olduğunu göstermektedir. Geleneksel grupla karşılaştırıldığında; femur boyun kırıkları için minimal invaziv direkt lateral yaklaşım, standart lateral yaklaşıma kıyasla erken iyileşme döneminde postoperatif ağrıyı önemli ölçüde azaltır, daha az kan kaybına, daha iyi kozmetik sonuçlara ve benzer bir hastanede kalış süresine yol açar. Daha büyük vaka sayılarını içeren ve uzun vadeli postoperatif sonuçları değerlendiren klinik çalışmalar gereklidir.

Anahtar sözcükler: Direkt lateral yaklaşım; femoral boyun kırıkları; minimal invaziv cerrahi; postoperatif ağrı, vaka kontrol çalışması.

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ORIGINAL ARTICLE

# Prediction of massive transfusion and mortality in early trauma care: A retrospective analysis of scoring systems

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## ABSTRACT

**BACKGROUND:** Hemorrhagic shock is a leading cause of preventable trauma deaths, particularly within the first hours following injury. Early identification of patients requiring massive transfusion or with high mortality risk is critical to optimizing trauma management. Early identification of massive transfusion needs supports timely blood product preparation. Likewise, predicting mortality risk early can influence therapeutic planning and clinical decisions. Numerous trauma and transfusion scoring systems have been developed to guide such early decisions; however, their comparative predictive performance remains unclear. This study aimed to evaluate the effectiveness of trauma and transfusion scoring systems in predicting massive transfusion requirements and in-hospital mortality within the first four hours of trauma.

**METHODS:** This retrospective study included 117 trauma patients who received at least one unit of red blood cell transfusion within the first four hours of admission to a tertiary care center between 2018 and 2022. Data on demographics, trauma mechanism, clinical and laboratory findings were collected. Each patient was evaluated using 16 trauma and transfusion scoring systems. Patients were categorized based on the need for massive transfusion, defined as receiving ≥5 units of blood products within four hours. Receiver Operating Characteristic (ROC) analysis was used to assess the performance of each scoring system, and optimal cut-off values were determined using the Youden Index.

**RESULTS:** Massive transfusion was required in 23 patients (19.7%), with firearm injuries being the most common mechanism among these cases. All 16 scoring systems significantly differentiated patients with and without massive transfusion. The Shock Index demonstrated the highest predictive accuracy for massive transfusion (area under the curve [AUC]=0.911). For in-hospital mortality, all scoring systems except the Schreiber Score showed significant predictive ability. The Trauma Related Injury Severity Score (TRISS) achieved the highest predictive value for mortality (AUC=0.975). Several scoring systems required revised threshold values for optimal performance in this cohort, highlighting the need for population-specific calibration.

**CONCLUSION:** Early-phase application of trauma and transfusion scoring systems provides valuable insights for predicting clinical outcomes in trauma patients. Among the systems analyzed, the Shock Index was the most reliable predictor of massive transfusion. Separately, TRISS demonstrated superior accuracy in forecasting in-hospital mortality. These findings emphasize the importance of rapid, score-based assessment in early trauma care and support further validation of scoring systems across diverse patient populations.

**Keywords:** Damage control resuscitation; hemorrhagic shock/therapy (MeSH ID: D012798); resuscitation (MeSH ID: D012137); massive transfusion (MeSH ID: D056278); trauma severity indices (MeSH ID: D049232).

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## INTRODUCTION

According to data from the World Health Organization, trauma causes more than 4.5 million deaths worldwide each year.[1] Mortality due to trauma typically occurs within the first four hours and rarely after 24 hours.[2,3] To prevent and manage hemorrhagic shock, a major cause of mortality, an algorithm defined as damage control resuscitation (DCR) is implemented, starting at the scene of the injury and continuing in healthcare facilities.[4,5] Hemostatic resuscitation, a critical component of DCR, also involves early blood product replacement.[6,7]

The need to predict prognosis in patients presenting to the hospital following trauma is a critical concern; prompt assessment of the patient's condition and preparation for potential blood product transfusion are essential. This need for prediction has led to the development of numerous trauma and transfusion scoring systems (Table 1).[8-35] The massive transfusion protocol (MTP) refers to the administration of a blood transfusion equal to the patient's entire blood volume within 24 hours, or half of their blood volume within the first four hours. For practical purposes, it is often defined as the transfusion of ≥10 units of blood in 24 hours or ≥5 units in four hours (some sources define it as ≥4 units in one hour).[36-39] Predicting which patients will require MTP is important, and there is limited research on the early prediction of MTP necessity in trauma patients.[40]

Timely anticipation of massive transfusion facilitates early blood product allocation, whereas recognizing mortality risk in the early phase can shape therapeutic approaches and guide clinical decision-making. This study aimed to determine the success of scoring systems used in evaluating trauma and transfusion needs in predicting early massive transfusion requirements and mortality.

## MATERIALS AND METHODS

Patients who presented to the Emergency Department (ED) of a tertiary care hospital due to trauma between January 1, 2018 and December 31, 2022, were retrospectively screened, and 1,097 patients followed up with a trauma diagnosis were identified. The inclusion criteria for the study were presentation to the ED due to trauma, administration of at least 1 unit of red blood cell suspension transfusion within the first four hours, and complete documentation of initial vital signs, descriptions of the trauma, and examination results. Patients with incomplete data, those under 18 years of age, those who received initial intervention at an external center and presented to the study hospital more than four hours later, those who did not receive blood transfusion in the ED, and those brought to the ED with cardiopulmonary arrest were excluded from the study. For the 117 patients included in the study, the date of admission, demographic information (gender, height, weight, blood group), trauma mechanism and injury locations, initial vital signs (systolic and diastolic blood pressure, pulse, respiratory rate, oxygen saturation), level of consciousness, blood tests (leukocyte count, hemoglobin, hematocrit, platelet count, lactate dehydrogenase, alanine aminotransferase, alkaline phosphatase, sodium, potassium, calcium, albumin, chloride, C-reactive protein, prothrombin time, International Normalized Ratio [INR], activated partial thromboplastin time, blood gas pH, lactate, bicarbonate, and base deficit), and imaging results (Focused Assessment with Sonography for Trauma [FAST], ultrasound, and computed tomography [CT]) were recorded, and various trauma and transfusion scores were calculated. Patients were divided into two groups based on whether they received ≥5 units of blood within the first four hours: massive transfusion and non-massive transfusion. It was also noted whether the transfusion continued after the initial four-hour period. Intensive care unit (ICU) and ward length of stay, as well as the occurrence of mortality, were recorded. This study received approval from the relevant local clinical research Ethics Committee with the document number 2020/20. The study was conducted in accordance with the Declaration of Helsinki.

### Statistical Analysis

Statistical analyses were performed using the SPSS software package (IBM Statistical Package for the Social Sciences, version 22.0, Armonk, New York). Descriptive statistics were presented as number (n), percentage (%), mean ± standard deviation, and median (minimum-maximum). The normality of continuous variables was assessed using histograms, probability plots, and statistical analytical methods (Kolmogorov-Smirnov and Shapiro-Wilk tests). Normally distributed numerical variables were compared between two groups using the Independent Samples t-test, while non-normally distributed variables were analyzed with the Mann-Whitney U test. The Chi-square test and Fisher's Exact test were used to compare categorical variables. The Kruskal-Wallis test was employed to examine the median values of non-parametric numerical variables across multiple groups. Where significant differences were observed with the Kruskal-Wallis test, post-hoc analysis was conducted to determine which specific groups differed significantly for the nominal variable. Factors potentially associated with in-hospital mortality and massive transfusion were evaluated using Receiver Operating Characteristic (ROC) curve analysis. The area under the ROC curve (AUC) and its 95% confidence interval were reported. Following the ROC analyses, the Youden Index was used to identify the optimal cut-off values for each trauma and transfusion scoring system. The diagnostic performance (sensitivity and specificity) for mortality and massive transfusion was then calculated for these identified cut-off values across all scoring systems. In the statistical analyses conducted in this study, a p-value of less than 0.05 was considered statistically significant.

## RESULTS

Between 2018 and 2022, 1,097 patients who presented to the ED were followed up and treated with a trauma diagnosis were identified through screening. Among these, 117 patients

**Table 1.** Trauma and transfusion scoring systems

| Scoring System | Year and Source | Parameters | Score Range | Score Interpretation |
|---|---|---|---|---|
| Glasgow Coma Scale (GCS) (8–10) | 1974, Teasdale & Jennett | Eye, motor, verbal responses | 3-15 | Lower scores indicate higher mortality |
| Shock Index (SI) (11,12) | 1967, Allgöwer et al. | Pulse/systolic blood pressure | Variable | ≥0.9: High probability of transfusion |
| Abbreviated Injury Scale (AIS) (13) | 1969, Association for the Advancement of Automotive Medicine (AAAM) | Injury severity by body region | 1-6 | Higher score indicates more severe injury |
| Injury Severity Score (ISS) (14–17) | 1974, Baker et al. | Sum of squares of three most serious AIS scores | 0-75 | 9-15: moderate; 16-24: severe; ≥25: very severe |
| Revised Trauma Score (RTS) (18,19) | 1989, Champion et al. | GCS, systolic blood pressure (SBP), respiratory rate | 0-7.8408 | Lower scores indicate higher mortality |
| Trauma and Injury Severity Score (TRISS) (20,21) | 1987, Boyd et al. | RTS, Injury Severity Score (ISS), age, mechanism of injury | 0-100% | Probability of mortality (%) |
| Emergency Trauma Score (EMTRAS) (22,23) | 2009, Raum et al. | Age, GCS, base excess, prothrombin time | 0-12 | Higher scores indicate increased risk |
| Assessment of Blood Consumption Score (ABCS) (24,25) | 2010, Nunez et al. | SBP, pulse, penetrating mechanism, Focused Assessment with Sonography for Trauma (FAST) | 0-4 | ≥2: 90% probability of massive transfusion |
| Massive Transfusion Score (MTS) (26) | 2013, Holcomb et al. | Pulse, SBP, penetrating mechanism, FAST, International Normalized Ratio (INR), hemoglobin, base excess | 0-7 | ≥3: massive transfusion |
| Vandromme Score (VS) (27) | 2011, Vandromme et al. | Pulse, SBP, hemoglobin, INR, lactate | 0-5 | ≥3: massive transfusion |
| Larson Score (LS) (28) | 2010, Larson et al. | Pulse, SBP, hemoglobin, base excess | 0-4 | ≥2: massive transfusion |
| Schreiber Score (SS) (29) | 2007, Schreiber et al. | Hemoglobin, INR, penetrating mechanism | 0-3 | ≥1: massive transfusion |
| Trauma Associated Severe Hemorrhage (TASH) Score (30) | 2006, German Trauma Society | Gender, pulse, SBP, fracture, FAST, hemoglobin, base excess | 0-28 | ≥16: >50% probability of massive transfusion |
| Prince of Wales Hospital Risk Score (PWHRS) (31) | 2011, Rainer et al. | Pulse, SBP, disrupted pelvic fracture, GCS, free abdominal fluid in ultrasonography (USG), base excess, hemoglobin | 0-10 | >6: elevated risk of massive transfusion |
| Emergency Transfusion Score (ETS) (32,33) | 2006, Ruchholtz et al. | SBP, free abdominal fluid (USG), pelvic instability, age, resuscitation center type, trauma mechanism | 0-9.5 | <3: massive transfusion unlikely |
| Traumatic Bleeding Severity Score (TBSS) (34) | 2014, Ogura et al. | Age, SBP, USG, pelvic fracture, lactate | 0-57 | >15: elevated risk of massive transfusion |
| Trauma-Induced Coagulopathy Clinical Score (TICCS) (35) | 2014, Tonglet et al. | SBP, resuscitation status, injured body regions | 0-18 | ≥10: elevated risk of massive transfusion |

**Table 2.** Descriptive characteristics of patients

| Feature | n (%) | Mean±SD |
|---|---|---|
| Age | 41.3±18.4 | |
| Gender* | | |
| Male | 88 (75.2) | |
| Female | 29 (24.8) | |
| Height (cm) | | 174±7 |
| Weight (kg) | | 79.0±10.8 |
| BMI (kg/m2) | | 25.8±2.8 |
| At Admission | | |
| Pulse (bpm) | | 113±17 |
| SBP (mmHg) | | 94.3±19.5 |
| DBP (mmHg) | | 59.9±15.5 |
| RR (/min) | | 20.9±7.2 |
| GCS | | 12.0±3.7 |
| SpO2 (%) | | 92.8±5.3 |
| Mechanism of Injury | | |
| Pedestrian Traffic Accident | 27 (23.1) | |
| Vehicle Traffic Accident | 22 (18.8) | |
| Stab/Cut Injury | 28 (23.9) | |
| Firearm Injury | 12 (10.3) | |
| Fall from Height | 25 (21.4) | |
| Blunt Trauma/Assault | 3 (2.6) | |
| Penetrating Injury | 40 (34.2) | |
| FAST (+) | 53 (45.3) | |

†SBP: Systolic blood pressure; DBP: Diastolic blood pressure; RR: Respiration rate; GCS: Glasgow Coma Scale; $SpO_2$: Oxygen saturation; BMI: Body Mass Index.

(10.7%) who received at least 1 unit of red blood cell suspension within the first four hours were included in the study. The descriptive characteristics of the cases are presented in Table 2.

Trauma and transfusion assessment scoring systems were applied to the patients. Literature regarding massive transfusion prediction was utilized to determine the cut-off values for the scores. The results of the trauma and transfusion scoring systems for the cases are presented in Table 3.

Trauma and transfusion scoring systems were compared based on the presence of massive transfusion. All scoring systems were found to be significantly different between the groups with and without massive transfusion (Table 4).

The predictive value of trauma and transfusion scoring systems in patients with massive transfusion was evaluated with ROC analyses. In the ROC analysis, all scoring systems were observed to be predictive for massive transfusion. The most predictive scores were observed as the Shock Index

**Table 3.** Trauma and transfusion scoring systems in the study cohort

| Feature | n (%) | Mean±SD |
|---|---|---|
| Shock Index* | | 1.29±0.51 |
| <1 | 39 (33.3) | |
| ≥1 | 78 (66.7) | |
| ISS* | | 30.2±14.2 |
| Moderate (9-15) | 16 (13.7) | |
| Severe (16-24) | 31 (26.5) | |
| Very Severe (>24) | 70 (59.8) | |
| TRISS* | | 72.1±33.2 |
| RTS* | | 6.5±1.6 |
| Mild | 59 (50.4) | |
| Urgent | 15 (12.8) | |
| Very Urgent | 40 (34.2) | |
| Fatal | 3 (2.6) | |
| EMTRAS* | | 3.3±2.0 |
| ABCS* | | 1.5±1.1 |
| Low (<2) | 55 (47.0) | |
| High (≥2) | 62 (53.0) | |
| MTS* | | 2.6±1.8 |
| Low (<3) | 62 (53.0) | |
| High (≥3) | 55 (47.0) | |
| Vandromme Score* | | 2.4±1.4 |
| Low (<5) | 111 (94.9) | |
| High (≥5) | 6 (5.1) | |
| Larson Score* | | 2.2±1.4 |
| Low (<2) | 37 (31.6) | |
| High (≥2) | 80 (68.4) | |
| Schreiber Score* | | 0.95±0.74 |
| TASH Score* | | 11.8±6.0 |
| Low (<16) | 80 (68.4) | |
| High (≥16) | 37 (31.6) | |
| PWHRS* | | 3.3±2.9 |
| Low (<6) | 98 (83.8) | |
| High (≥6) | 19 (16.2) | |
| ETS* | | 5.3±1.5 |
| Low (<4) | 17 (14.5) | |
| High (≥4) | 100 (85.5) | |
| TBSS* | | 17.2±9.3 |
| Low (<15) | 58 (49.6) | |
| High (≥15) | 59 (50.4) | |
| TICCS* | | 7.4±4.3 |
| Low (<10) | 78 (66.7) | |
| High (≥10) | 39 (33.3) | |

†SI: Shock Index; ISS: Injury Severity Score; TRISS: Trauma and Injury Severity Score; RTS: Revised Trauma Score; EMTRAS: Emergency Trauma Score; ABCS: Assessment of Blood Consumption Score; MTS: Massive Transfusion Score; TASH: Trauma-Associated Severe Hemorrhage Score; ETS: Emergency Transfusion Score; TBSS: Traumatic Bleeding Severity Score; TICCS: Trauma-Induced Coagulopathy Clinical Score.

**Table 4.** Comparison of trauma and transfusion scoring results of patients based on the presence of massive transfusion

| Score Subtype | MT (+) (n=23) | MT (-) (n=94) | P† |
|---|---|---|---|
| SI | 1.9±0.5 | 1.1±0.3 | <0.001 |
| ISS | 42.5±11.6 | 27.2±13.2 | <0.001 |
| TRISS | 44.3±29.1 | 78.9±30.7 | <0.001 |
| RTS | 5.0±1.5 | 6.9±1.4 | <0.001 |
| EMTRAS | 4.8±1.3 | 2.9±1.9 | <0.001 |
| ABCS | 2.9±0.9 | 1.2±1.0 | <0.001 |
| MTS | 4.8±1.2 | 2.1±1.4 | <0.001 |
| Vandromme Score | 3.9±0.6 | 2.1±1.3 | <0.001 |
| Larson Score | 3.7±0.5 | 1.9±1.4 | <0.001 |
| Schreiber Score | 1.5±0.7 | 0.8±0.6 | <0.001 |
| TASH Score | 18.3±4.0 | 10.3±5.4 | <0.001 |
| PWHRS | 6.5±3.7 | 2.5±2.1 | <0.001 |
| ETS | 6.2±1.4 | 5.1±1.5 | =0.003 |
| TBSS | 27.2±6.2 | 14.8±8.3 | <0.001 |
| TICCS | 10.9±3.6 | 6.5±4.0 | <0.001 |

*MT: Massive Transfusion; SI: Shock Index; ISS: Injury Severity Score; TRISS: Trauma and Injury Severity Score; RTS: Revised Trauma Score; EMTRAS: Emergency Trauma Score; ABCS: Assessment of Blood Consumption Score; MTS: Massive Transfusion Score; TASH: Trauma-Associated Severe Hemorrhage Score; ETS: Emergency Transfusion Score; TBSS: Traumatic Bleeding Severity Score; TICCS: Trauma-Induced Coagulopathy Clinical Score. †Independent Samples t-test was used for all analyses.

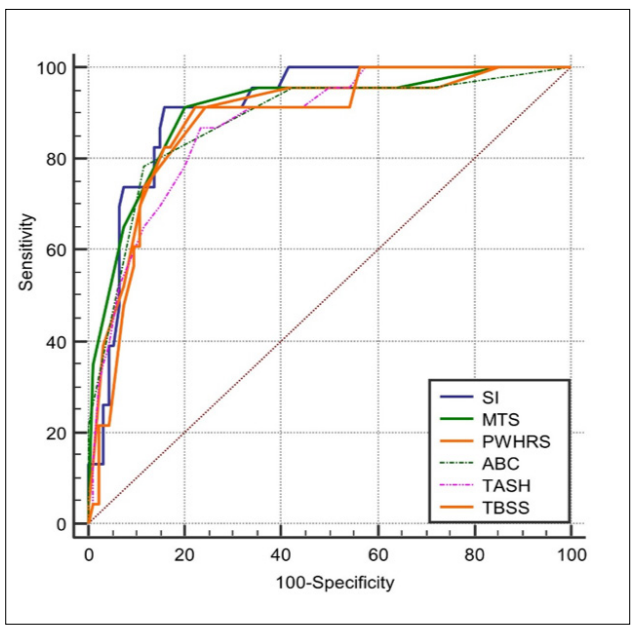


**Figure 1.** Receiver Operating Characteristic (ROC) curve showing the predictive value of scoring systems in massive transfusion.

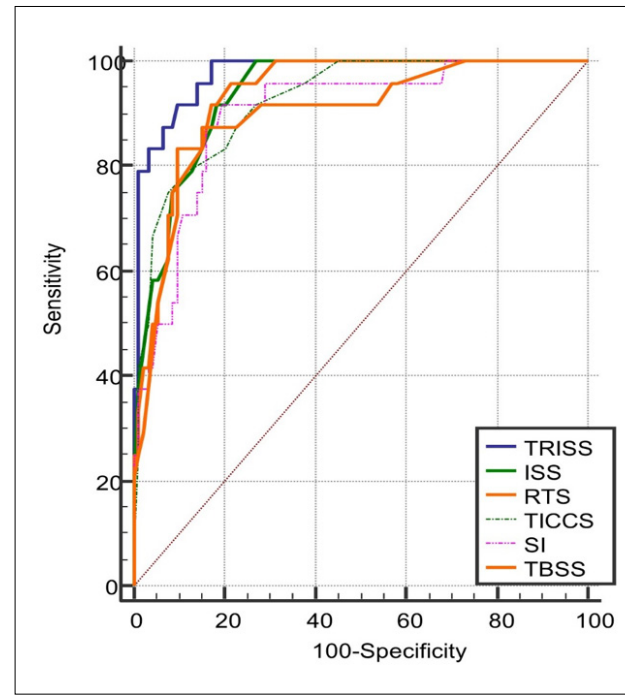


**Figure 2.** Receiver Operating Characteristic (ROC) curve showing the predictive value of scoring systems in mortality.

**Table 5.** Determinacy of scoring systems in massive transfusion

| Scoring System | AUC | 95% CI | P† |
|---|---|---|---|
| SI | 0.911 | 0.844-0.956 | <0.001 |
| MTS | 0.905 | 0.837-0.951 | <0.001 |
| PWHRS | 0.886 | 0.814-0.937 | <0.001 |
| ABCS | 0.883 | 0.810-0.935 | <0.001 |
| TASH Score | 0.877 | 0.803-0.930 | <0.001 |
| TBSS | 0.877 | 0.804-0.931 | <0.001 |
| Vandromme Score | 0.869 | 0.794-0.924 | <0.001 |
| Larson Score | 0.861 | 0.785-0.918 | <0.001 |
| RTS | 0.847 | 0.769-0.907 | <0.001 |
| TRISS | 0.815 | 0.733-0.881 | <0.001 |
| EMTRAS | 0.808 | 0.725-0.875 | <0.001 |
| ISS | 0.804 | 0.720-0.871 | <0.001 |
| TICCS | 0.781 | 0.695-0.852 | <0.001 |
| Schreiber Score | 0.739 | 0.650-0.816 | <0.001 |
| ETS | 0.705 | 0.613-0.785 | <0.001 |

*SI: Shock Index; ISS: Injury Severity Score; TRISS: Trauma and Injury Severity Score; RTS: Revised Trauma Score; EMTRAS: Emergency Trauma Score; ABCS: Assessment of Blood Consumption Score; MTS: Massive Transfusion Score; TASH: Trauma-Associated Severe Hemorrhage Score; ETS: Emergency Transfusion Score; TBSS: Traumatic Bleeding Severity Score; TICCS: Trauma-Induced Coagulopathy Clinical Score; AUC: Area Under the Curve; CI: Confidence Interval.

**Table 6.** Effectiveness of scoring systems in predicting massive transfusion

| Scoring System | Threshold (%) | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%) |
|---|---|---|---|---|---|
| SI | >1.42 | 91.3 | 84.0 | 58.3 | 97.5 |
| MTS | >3 | 91.3 | 79.7 | 52.5 | 97.4 |
| PWHRS | >3 | 91.3 | 75.5 | 47.7 | 97.3 |
| ABCS | >2 | 78.2 | 88.3 | 62.1 | 94.3 |
| TASH Score | >14 | 86.9 | 76.6 | 47.6 | 96.0 |
| TBSS | >21 | 91.3 | 77.6 | 50.0 | 97.3 |
| Vandromme Score | >2 | 100 | 59.5 | 37.7 | 100 |
| Larson Score | >3 | 78.2 | 81.9 | 51.4 | 93.9 |
| RTS | ≤6.9 | 95.6 | 67.0 | 41.5 | 98.4 |
| TRISS | ≤84.6 | 91.3 | 71.2 | 43.7 | 97.1 |
| EMTRAS | >2 | 100 | 51.0 | 33.3 | 100 |
| ISS | >38 | 69.5 | 77.6 | 43.2 | 91.2 |
| TICCS | >7 | 86.9 | 71.2 | 42.6 | 95.7 |
| Schreiber Score | >1 | 52.1 | 86.1 | 48.0 | 88.0 |
| ETS | >5.5 | 73.9 | 65.9 | 34.7 | 91.2 |

*SI: Shock Index; ISS: Injury Severity Score; TRISS: Trauma Related Injury Severity Score; RTS: Revised Trauma Score; EMTRAS: Emergency Trauma Score; ABCS: Assessment of Blood Consumption Score; MTS: Massive Transfusion Score; TASH: Trauma-Associated Severe Hemorrhage Score; ETS: Emergency Transfusion Score; TBSS: Traumatic Bleeding Severity Score; TICCS: Trauma-Induced Coagulopathy Clinical Score; PPV: Positive Predictive Value; NPV: Negative Predictive Value.

(SI) (AUC=0.911, 95% confidence interval [CI]: 0.844-0.956), the Massive Transfusion Score (MTS) (AUC=0.905, 95% CI: 0.837-0.951), and the Prince of Wales Hospital Risk Score (PWHRS) (AUC=0.886, 95% CI: 0.814-0.937), respectively (Table 5).

Figure 1 shows the ROC curve of the most predictive scoring systems (SI, MTS, PWHRS, Assessment of Blood Consumption Score [ABC] Score, Trauma-Associated Severe Hemorrhage Score [TASH] Score, and Trauma Blood Supply Score [TBSS]) for massive transfusion.

The performance of trauma and transfusion scoring systems in predicting massive transfusion was analyzed. An SI score above 1.42 had a sensitivity of 91.3% and a specificity of 84% for predicting massive transfusion. An MTS score above 3 had a sensitivity of 91.3% and a specificity of 79.7%, while a PWHRS score above 3 had a sensitivity of 91.3% and a specificity of 75.5% (Table 6).

The predictive value of trauma and transfusion scoring systems in mortality was analyzed. In the ROC analyses, all scoring systems except Schreiber were observed to be predictive for mortality. The most predictive scores were the Trauma and Injury Severity Score (TRISS) (AUC=0.975, 95% CI: 0.927-0.995), the Injury Severity Score (ISS) (AUC=0.937, 95% CI: 0.876-0.973), and the Revised Trauma Score (RTS) (AUC=0.934, 95% CI: 0.873-0.972), respectively (Table 7).

**Table 7.** Determinacy of scoring systems in mortality

| Scoring System | AUC | 95% CI | P† |
|---|---|---|---|
| TRISS | 0.975 | 0.927-0.995 | <0.001 |
| ISS | 0.937 | 0.876-0.973 | <0.001 |
| RTS | 0.934 | 0.873-0.972 | <0.001 |
| TICCS | 0.924 | 0.860-0.965 | <0.001 |
| SI | 0.899 | 0.830-0.947 | <0.001 |
| TBSS | 0.897 | 0.828-0.946 | <0.001 |
| PWHRS | 0.862 | 0.785-0.918 | <0.001 |
| TASH Score | 0.826 | 0.745-0.890 | <0.001 |
| ETS | 0.823 | 0.742-0.888 | <0.001 |
| EMTRAS | 0.808 | 0.725-0.87 | <0.001 |
| MTS | 0.783 | 0.698-0.854 | <0.001 |
| Vandromme Score | 0.771 | 0.685-0.844 | <0.001 |
| Larson Score | 0.768 | 0.681-0.841 | <0.001 |
| ABCS | 0.728 | 0.638-0.806 | <0.001 |
| Schreiber Score | 0.572 | 0.477-0.663 | 0.273 |

*SI: Shock Index; ISS: Injury Severity Score; TRISS: Trauma and Injury Severity Score; RTS: Revised Trauma Score; EMTRAS: Emergency Trauma Score; ABCS: Assessment of Blood Consumption Score; MTS: Massive Transfusion Score; TASH: Trauma-Associated Severe Hemorrhage Score; ETS: Emergency Transfusion Score; TBSS: Traumatic Bleeding Severity Score; TICCS: Trauma-Induced Coagulopathy Clinical Score; AUC: Area Under the Curve; CI: Confidence Interval.

**Table 8.** Effectiveness of scoring systems in predicting mortality

| Scoring System | Threshold (%) | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%) |
|---|---|---|---|---|---|
| TRISS | ≤68.66 | 100 | 82.8 | 60.0 | 100 |
| ISS | >36 | 91.6 | 81.7 | 56.4 | 97.4 |
| RTS | ≤5.97 | 91.6 | 82.8 | 57.9 | 97.5 |
| TICCS | >11 | 75.0 | 92.4 | 72.0 | 93.5 |
| SI | >1.39 | 91.6 | 80.6 | 55.0 | 97.4 |
| TBSS | >22 | 87.5 | 84.9 | 60.0 | 96.3 |
| PWHRS | >4 | 70.8 | 88.1 | 60.7 | 92.1 |
| TASH Score | >16 | 70.8 | 86.0 | 56.7 | 92.0 |
| ETS | >5.5 | 83.3 | 68.8 | 40.8 | 94.1 |
| EMTRAS | >2 | 100 | 51.0 | 33.3 | 100 |
| MTS | >2 | 91.6 | 64.5 | 40.0 | 96.8 |
| Vandromme Score | >2 | 87.5 | 56.9 | 34.4 | 94.6 |
| Larson Score | >2 | 87.5 | 62.3 | 37.5 | 95.1 |
| ABCS | >1 | 83.3 | 54.8 | 32.3 | 92.7 |
| Schreiber Score | >1 | 33.3 | 81.7 | 32.0 | 82.6 |

*SI: Shock Index; ISS: Injury Severity Score; TRISS: Trauma and Injury Severity Score; RTS: Revised Trauma Score; EMTRAS: Emergency Trauma Score; ABCS: Assessment of Blood Consumption Score; MTS: Massive Transfusion Score; TASH: Trauma-Associated Severe Hemorrhage Score; ETS: Emergency Transfusion Score; TBSS: Traumatic Bleeding Severity Score; TICCS: Trauma-Induced Coagulopathy Clinical Score; PPV: Positive Predictive Value; NPV: Negative Predictive Value.

Figure 2 shows the ROC curve of the most predictive scoring systems (TRISS, ISS, Revised Trauma Score (RTS), Trauma-Induced Coagulopathy Clinical Score (TICCS), SI, TBSS) for mortality.

The diagnostic performances of the trauma and transfusion scoring systems in predicting mortality were analyzed. A TRISS score below 68.6 showed 100% sensitivity and 82.8% specificity for mortality. An ISS score above 36 had 91.6% sensitivity and 81.7% specificity, while an RTS score below 5.97 had 91.6% sensitivity and 82.8% specificity (Table 8).

## DISCUSSION

This study, which included 117 patients, aimed to evaluate the effectiveness of scoring systems in assessing patients who required blood product transfusion due to trauma. The demographic profile of the study population revealed a mean age of 41.3 years and a male-to-female ratio of approximately 3:1. Regarding the mechanism of injury, penetrating-incisive instrument injuries were the most frequent, accounting for 23.9% of cases, followed by blunt trauma. Notably, a third of the patients presented with penetrating injuries to body cavities due to penetrating-incisive instruments or other causes. The observation that falls from height, which are frequently reported as the leading trauma mechanism in many studies, ranked third in this cohort may be attributable to the exclusion of patients who did not require blood transfusion.[41]

When cut-off values consistent with the literature were applied to assess trauma severity using trauma and transfusion scoring systems, it was observed that the majority of patients in the Assessment of Blood Consumption Score (ABCS), MTS, Laboratory Score (LS), Schreiber Score (SS), Emergency Transfusion Score (ETS), and TBSS scores exceeded these thresholds, indicating classification as severe trauma.[25,26,28,29,33,34] The observation of very low rates of severe trauma according to the Vital Signs Score (VS) and PWHRS scores was interpreted as indicating that the cut-off values defined for these scores in the literature may not be appropriate for the patient group included in this study.[27,31]

Regarding the discriminative power of trauma scoring systems on patient parameters, the Shock Index was found to be effective in differentiating mortality. While SI is a physiological scoring system and its ability to reflect differences in patient vital signs is expected, the fact that the Injury Severity Score, an anatomical scoring system, also demonstrated this differentiation is noteworthy. Considering the injury mechanism, the ISS was significantly higher in blunt trauma due to traffic accidents and falls from height, which better represent multiple traumas; conversely, it was significantly lower in penetrating-incisive instrument injuries and the penetrating injury group, which involve single-region injuries. This may reflect a limitation of this scoring system.[42] When patients were grouped according to RTS scores, two groups with an

equal number of patients emerged, and in this seemingly homogeneous distribution, RTS was observed to effectively differentiate not only mortality and massive transfusion but also patients requiring follow-up.[19,43] The average TRISS score of 72.1% for the entire patient group implies that the TRISS scoring system predicted a mortality rate of 27.9%. Considering that the actual mortality rate was 20.5%, this might not be considered an inaccurate prediction. However, this observation, along with the fact that TRISS involves a logarithmic calculation and its constant coefficients are updated through periodic cohort studies, could suggest the need for a comprehensive and regional study to refine the TRISS methodology for this specific setting.[44,45]

When trauma and transfusion scoring systems were evaluated in terms of their success in predicting massive transfusion, as expected, a significant difference was found in the mean values between the groups with and without massive transfusion for all systems. This is an anticipated outcome given that these scores are designed for this purpose.

When the predictive value of all trauma and transfusion scoring systems for massive transfusion was evaluated, all were found to have statistically significant results, and this success is also evident in the ROC curves. The systems with the highest predictive value were SI, MTS, and PWHRS, in descending order. In this study, there are several scores that rely on multiple physiological and anatomical patient data, and sometimes even complex calculations based on this data. It is noteworthy that SI, a simple physiological score, topped the list in massive transfusion prediction. A review of the literature also easily reveals the confusion regarding the importance of SI; while some studies argue that it provides insufficient information, others—similar to this study—have obtained significant results regarding its predictive value.[46,47]

It was mentioned that there was a significant difference between the trauma and transfusion scores of the massive transfusion and non-massive transfusion groups according to all scoring systems. However, this analysis based on averages does not necessarily mean that the cut-off values in the literature are accurate for our study. When the most accurate cut-off values of the scores for massive transfusion are determined based on the ROC curves, the following conclusions are reached:

- For trauma scoring systems, there are no definitive established cut-off values for predicting massive transfusion. In this study, the probability of massive transfusion increases when the SI is >1.42, ISS is >38, RTS is <6.9, TRISS is <84.6, and the Emergency Trauma Score (EMTRAS) is >2. For transfusion prediction scoring systems, the following values appear to be more suitable as massive transfusion thresholds based on the data from this study: >3 for MTS (instead of >2), >3 for PWHRS (instead of >6), >14 for TASH (instead of >16), >21 for TBSS (instead of >15), >2 for VS (instead of >4), >1 for SS, and >5.5 for ETS.[26,27,29–31,33,34]

- The values >2 for ABCS, >10 for TICCS, and >2 for LS were found to be consistent with the cut-off values reported in the literature.[25,28,35]

Regarding the predictive value of trauma and transfusion scoring systems for mortality, all except SS demonstrated remarkable results. As anticipated, trauma scores ranked highest; TRISS, ISS, and RTS were identified as scoring systems with the highest predictive value for mortality. TRISS, with a value of <68.66, reached a sensitivity of 100% and a specificity of 82.8%. The cut-off values for ISS and RTS were >36 and <5.97, respectively. The reason for SS alone failing to predict mortality is thought to be its design as a military-based scoring system primarily focused on penetrating injuries for rapid triage.

Limitations of the Study: This study has several limitations. One is its retrospective design and the small sample size resulting from the inclusion of only trauma patients who received transfusion. This situation may have hindered the homogenization of groups and limited the identification of further meaningful results. Additionally, the exclusion of ongoing transfusions and patient data after the initial four-hour period can be considered another limitation.

## CONCLUSION

In trauma patients requiring blood product transfusion, all analyzed scoring systems exhibited significant early predictive ability. Notably, the Shock Index emerged as the top predictor for massive transfusion, while the highest accuracy in forecasting mortality was observed with the TRISS score. These findings underscore the significant potential of these scoring systems for guiding early clinical decisions in the emergency management of trauma. However, further large-scale, multicenter studies are warranted to validate these findings and potentially refine the cut-off values for optimal clinical application across diverse trauma populations.

**Ethics Committee Approval:** This study was approved by the SBÜ Gülhane Ethics Committee (Date: 25.10.2022, Decision No: 2022/20).

**Peer-review:** Externally peer-reviewed.

**Authorship Contributions:** Concept: B.T., B.K., D.Ö., A.Ü.; Design: B.T., M.V.T., Ş.K. A.Ü.; Supervision: B.T., B.K., Ş.K. A.Ü.; Resource: B.T., M.D.Y., H.M.T., M.V.T., D.Ö.; Materials: B.T., M.D.Y., H.M.T., M.V.T., D.Ö.; Data collection and/or processing: B.T., M.D.Y., H.M.T., M.V.T., D.Ö.; Analysis and/or interpretation: B.T., B.K., M.V.T. D.Ö.; Literature review: B.T., B.K., Ş.K., A.Ü.; Writing: B.T., D.Ö., A.Ü.; Critical review: B.T., M.D.Y., H.M.T., Ş.K., A.Ü.

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ORİJİNAL ÇALIŞMA - *ÖZ*

## Travma sonrası erken dönemde masif transfüzyon ve mortalite öngörüsü: Skorlama sistemlerinin retrospektif bir analizi

AMAÇ: Hemorajik şok, özellikle travmanın ilk saatlerinde, önlenebilir travma ölümlerinin başlıca nedenlerinden biridir. Masif transfüzyon gereksinimi olan veya yüksek mortalite riski taşıyan hastaların erken dönemde tanımlanması, travma yönetiminin optimize edilmesi açısından kritik öneme sahiptir. Masif transfüzyonun erken öngörülmesi, kan ürünlerinin hazırlanmasına zaman kazandırır. Ayrıca, mortalite riskinin erken dönemde belirlenmesi, tedavi yaklaşımını yönlendirme potansiyeline sahiptir. Bu amaçla birçok travma ve transfüzyon skorlama sistemi geliştirilmiş olsa da bu sistemlerin erken dönemdeki karşılaştırmalı öngörü performansı hâlâ net değildir. Bu çalışmada, travmadan sonraki ilk 4 saat içinde masif transfüzyon gereksinimi ve hastane içi mortaliteyi öngörmede travma ve transfüzyon skorlama sistemlerinin etkinliği değerlendirildi.
GEREÇ VE YÖNTEM: 2018- 2022 yılları arasında üçüncü basamak bir sağlık merkezinin acil servisine travma nedeniyle başvurup ilk 4 saat içinde en az 1 ünite eritrosit süspansiyonu verilen 117 hasta retrospektif olarak incelendi. Demografik veriler, travma mekanizmaları, klinik ve laboratuvar bulguları toplandı. Her hastaya 16 farklı travma ve transfüzyon skorlama sistemi uygulandı. Masif transfüzyon, ilk 4 saat içinde ≥5 ünite kan ürünü verilmesi olarak tanımlandı. ROC analizi ile her bir skorun öngörü gücü değerlendirildi ve optimal eşik değerler Youden İndeksi ile belirlendi.
BULGULAR: Masif transfüzyonun 23 hastaya uygulandığı görüldü (%19.7); bu grup içerisinde en yaygın travma mekanizması ateşli silah yaralanmalarıydı. Tüm 16 skorlama sistemi, masif transfüzyon alan ve almayan hastaları anlamlı şekilde ayırt etti. Masif transfüzyonu öngörmede en yüksek doğruluk Şok İndeksi'ne (AUC=0.911) aitti. Hastane içi mortaliteyi öngörmede, Schreiber Skoru dışındaki tüm sistemler anlamlı öngörü kabiliyeti gösterdi. TRISS, mortalite için en yüksek öngörü gücüne sahipti (AUC=0.975). Bazı skorların eşik değerlerinin kohorta özgü olarak yeniden belirlenmesi gerektiği görüldü.
SONUÇ: Travma hastalarında skorlama sistemlerinin erken dönemde uygulanması, klinik sonuçların öngörülmesinde değerli bilgiler sağlar. İncelenen sistemler arasında, Şok İndeksi masif transfüzyonu öngörmede en güvenilir sistem olarak öne çıkarken, TRISS hastane içi mortaliteyi tahmin etmede en başarılı sistem olmuştur. Bu bulgular, travmanın erken yönetiminde hızlı ve skora dayalı değerlendirme yöntemlerinin önemini vurgulamakta ve bu sistemlerin farklı hasta gruplarında daha geniş çaplı çalışmalarla doğrulanması gerektiğini göstermektedir.

Anahtar sözcükler: Hasar kontrol resüsitasyonu; hemorajik şok/tedavisi; masif transfüzyon; resüsitasyon; travma şiddet skorları.

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ORIGINAL ARTICLE

# Kahramanmaraş earthquake: A microsurgical perspective from an orthopedic hand surgery unit

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## ABSTRACT

**BACKGROUND:** Earthquakes stand as the most devastating form of natural disaster. Türkiye, situated within a fault zone, has witnessed numerous catastrophic earthquakes throughout its history. On February 6, a powerful earthquake severely impacted eleven cities in the southeastern part of the country. The purpose of this study is to evaluate the treatment management of a specific group of patients who were initially advised amputation but rejected this procedure and were referred to our clinic for reconstruction.

**METHODS:** This single-center retrospective analysis included 15 patients (8 female, 7 male) with 17 flaps. Cases not requiring microsurgery were excluded. Data on admission conditions, time spent under debris, debridement surgeries, flap surgeries, anastomosis details, lab values, angiography, reoperations, wound closure times, complications, flap outcomes, hospitalization duration, and amputations or death were collected.

**RESULTS:** The average age of the 15 patients was 30.67±18.51, with 5 patients being pediatric (33.33%). Patients spent an average of 41.77±40.68 hours under debris, with an 11.40±5.80-day admission delay. They underwent an average of 4.41±3.02 debridement surgeries before flap surgery, which occurred around 21.06±18.24 days post-admission. Wound closure took about 37.93±37.58 days on average, with an average hospital stay of 77.33±36.67 days. Forty-six percent received hyperbaric oxygen treatment. Various flap types were used, with no failures in anterolateral thigh (ALT) or sural artery flaps. Latissimus dorsi + serratus anterior chimeric flaps were used for larger defects, required more blood product replacements, and were fraught with difficulties. In total, 4 of the flaps failed, 3 patients required amputation despite all efforts, and 1 patient died.

**CONCLUSION:** Earthquake victims with injuries that are "worse than they seem" due to vascular and infectious concerns require careful microsurgery. Proximal anastomosis, venous complication monitoring, meticulous debridement, VAC therapy, and adjuvant treatments such as hyperbaric oxygen therapy are crucial in managing these complex cases.

**Keywords:** Crush injury; earthquake; flap; microsurgery.

## INTRODUCTION

Earthquakes remain among the most devastating natural disasters and are frequently associated with a high incidence of extremity injuries. On February 6, 2023, a 7.7 Mw earthquake struck southeastern Türkiye, severely affecting eleven cities with a combined population of more than 16 million people.[1] A substantial proportion of the injured sustained orthopedic trauma, often requiring surgical management including fracture fixation and soft tissue reconstruction.

Extremity injuries, particularly open fractures and crush injuries, are a major cause of morbidity following such disasters. These wounds are often complex, with significant soft tissue contamination, muscle loss, and a risk of compartment syndrome.[2] In many cases, fasciotomies are performed under emergency conditions and may be inadequate, leaving large

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open wounds that require advanced reconstructive procedures.[3] Following stabilization of life-threatening conditions, management of soft tissue defects becomes a major component of definitive treatment.

Microsurgical reconstruction plays a critical role in limb salvage, particularly for patients with complex soft tissue defects or unsuccessful primary closure.[4] In our tertiary referral centers in Ankara, a significant number of post-earthquake patients were referred specifically for microsurgical soft tissue coverage. These patients often presented with large fasciotomy wounds, crush-related tissue loss, or delayed reconstruction needs.

In this study, we aimed to evaluate the treatment outcomes of patients who had initially been recommended for amputation at other centers but were referred to our tertiary hospitals after refusing the procedure. These patients subsequently underwent complex soft tissue reconstruction as part of an aggressive limb salvage strategy.

## MATERIALS AND METHODS

This single-center, retrospective study evaluated a select cohort of earthquake victims from the February 6, 2023 Kahramanmaraş Earthquake who were referred to our tertiary care orthopedic center for limb salvage. All patients included had previously been advised to undergo amputation but explicitly declined, opting instead for advanced reconstructive procedures involving free or pedicled flap coverage.

From a total of 194 referred or admitted patients, 15 patients (eight females, seven males; mean age 30.67±18.51 years) who underwent 17 microsurgical soft tissue reconstructions were included. Patients with closed injuries, open wounds not requiring microsurgery, or those treated by the Plastic and Reconstructive Surgery Department were excluded. Inclusion and exclusion criteria are shown in Figure 1.

Collected data included demographic information, time under debris, time to tertiary hospital admission, number of debridements prior to flap surgery, timing of flap reconstruction, computed tomography (CT) angiography results, details of vascular anastomosis, pre- and perioperative laboratory values, early reoperation (within 72 hours), total wound closure time, hospitalization duration, complications, flap survival/failure, secondary amputation, and mortality.

### Surgical Technique and Postoperative Protocol

**Reconstructive techniques included:**

• **Anterolateral Thigh (ALT) Flaps (n=3):** Performed in the supine position under general anesthesia. Perforators were identified using Doppler ultrasonography. The flap was harvested based on the descending branch of the lateral circumflex femoral artery. In all cases, dual perforators were used, avoiding muscle inclusion. Donor sites were closed primarily, except in one case requiring skin grafting.

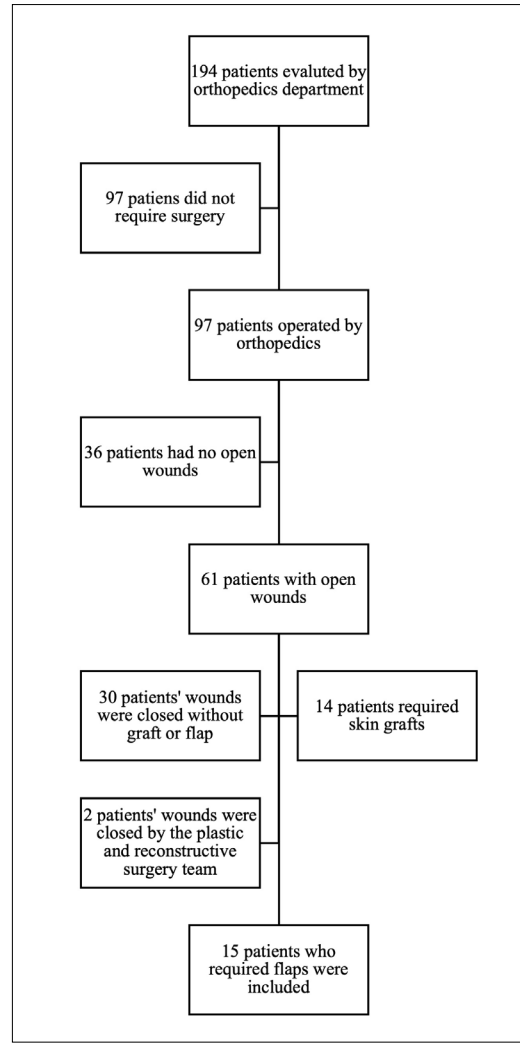


**Figure 1.** Detailed explanation of the included and excluded patients.

• **Latissimus Dorsi–Serratus Anterior (LD-SA) Chimeric Flaps (n=6):** Harvested in the floppy lateral position. The thoracodorsal pedicle was dissected to the subscapular artery. Skin islands were preserved for monitoring. Donor sites were closed primarily and reinforced with subcutaneous sutures and drains; partial-thickness skin grafts were used for muscle coverage.

• **Sural Artery Perforator Flaps (MSAP, LSAP) (n=3):** Preferred for smaller defects. Performed under general anesthesia in the supine position, guided by ultrasonography. Flaps were elevated based on the medial or lateral sural arteries. No flap failures occurred.

• **Pedicled Flaps (n=5):** Utilized based on defect location and patient-specific factors. Flaps were harvested under general anesthesia in the supine position.

**Table 1.** Summary of demographic, timing, laboratory, and replacement data

| | |
|---|---|
| Age | 30.66±18.51 (8-64) |
| Adult | 10 (66.67%) |
| Pediatric | 5 (33.33%) |
| Gender | |
| Female | 8 (53.33%) |
| Male | 7 (46.67%) |
| Timing | |
| Time under debris (hours) | 41.77±40.68 (0-100) |
| Time to tertiary center admission (days) | 11.40±5.80 (3-20) |
| Debridement surgery before flap surgery | 4.41±3.02 (1-11) |
| Time from admission to flap surgery (days) | 21.06±18.24 (4-60) |
| Time to complete closure of all wounds (days) | 37.93±37.58 (4-140) |
| Duration of hospitalization (days) | 81.33±46.98 (31-210) |
| Other treatments | |
| Hyperbaric oxygen therapy | 7 (46.67%) |
| Dialysis | 1 (5.88%) |
| Fracture fixation | 4 (26.67%) |
| Laboratory values at admission | |
| Hemoglobin (Hb) | 10.33±1.80 (7.80-13.90) |
| Creatine kinase (CK) | 1310.00±2092.03 (41.00-7636.00) |
| Creatinine (Cr) | 0.56±0.32 (0.25-1.36) |
| C-reactive protein (CRP) | 117.57±80.19 (14.70-255.00) |
| Albumin (Alb) | 3.12±0.55 (2.50-4.24) |
| Laboratory values before flap surgery | |
| Hemoglobin (Hb) | 9.44±1.10 (7.60-11.50) |
| Creatine kinase (CK) | 130.65±149.92 (22.00-612.00) |
| Creatinine (Cr) | 0.45±0.18 (0.12-0.84) |
| C-reactive protein (CRP) | 58.66±53.66 (1-209) |
| Albumin (Alb) | 3.08±0.78 (1.76-4.78) |
| Replacement* | |
| Erythrocyte suspension (ES) | 9 (60.00%), 7.22±7.31 (1-22) |
| Platelet (PLT) | 1 (6.67%), 6 |
| Fresh frozen plasma (FFP) | 3 (20.00%), 9.00±13.86 (1-25) |
| Albumin (Alb) | 7 (46.67%), 3.71±2.75 (1-8) |
| Flap | |
| Free | 12 (70.59%) |
| Anterolateral thigh (ALT) | 3 (17.65%) |
| Latissimus dorsi+serratus anterior | 6 (35.29%) |
| Sural artery flaps (MSAP/LSAP) | 3 (17.5 %) |
| Pedicled | 5 (29.41%) |
| Peroneal artery perforator flap | 1 (5.88%) |
| Medial plantar artery perforator flap | 1 (5.88%) |
| Ulnar artery perforator flap | 1 (5.88%) |
| Radial forearm flap | 1 (5.88%) |
| Reverse sural artery (cross-leg) flap | 1 (5.88%) |

Data are presented as N (%) or mean±standard deviation (minimum–maximum). N refers to the number of patients requiring the replacement, and % is the percentage of these patients. Mean, standard deviation, minimum, and maximum values are reported for the number of replacement products administered.

**Table 2.** Summary of patients treated with an anterolateral thigh (ALT) flap

| Patient # | Age<br>Gender | TUD<br>DoA (d)<br>AtF (d)<br>TCT (d)<br>Hosp (d) | Admission condition | Other surgery /treatment | BT angiography findings | Anastomosis | Replacement | Complications<br>Reoperation<br><72 hours<br>Flap failure | Amputation<br>Death |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 12<br>M | 100 hours<br>7<br>8<br>9<br>115 | Left foot crush injury; 10×10 cm open wound on dorsum of the foot | Closed reduction and percutaneous pinning of the 1st metatarsal; Hyperbaric $O_2$ | - | Level: Ankle<br>A: LFCD - TA (E-S)<br>V: LFCD - TA (E-E) | 1 Alb | Limited ROM; superficial necrosis of the flap | -<br>- |
| 2 | 48<br>M | 20 minutes<br>3<br>7<br>9<br>44 | Right foot crush injury; 15×10 cm wound on dorsum of the foot | - | Bilateral lower extremity arteries intact | Level: Ankle<br>A: LFCD - TA (E-S)<br>V: LFCD - TA (E-E)<br>+ GS (E-E) | - | - | - |
| 3 | 63<br>M | 15 minutes<br>4<br>4<br>4<br>31 | Left hand crush injury; no circulation in digits 3-5 | Amputation of digits 3-5 and metacarpals; wrist arthrodesis | Laceration of ulnar artery at mid-forearm with no opacification afterwards; laceration of basilic vein with only proximal opacification | Level: Forearm<br>A: LFCD – ulnar (E-E)<br>V: LCFD – ulnar (E-E) | 2 ES | Peripheral necrosis of flap | Amputation of digits 3-5 and corresponding metacarpals |

TUD: Time under debris; DoA: Day of admission; AtF: Admission-to-flap time; TCT: Total closure time; Hosp: Duration of hospitalization; A: Artery; V: Vein; LCFD: Lateral circumflex femoral artery descending branch; TA: Tibialis anterior; TP: Tibialis posterior; GS: Great saphenous; E-S: End-to-side; E-E: End-to-end; ES: Erythrocyte suspension; PLT: Platelet; FFP: Fresh frozen plasma; Alb: Albumin.

**Table 3.** Summary of patients treated with latissimus dorsi+serratus anterior chimeric flaps

| Patient # | Age Gender | TUD DoA (d) AtF (d) TCT (d) Hosp (d) | Admission condition | Other surgery /treatment | BT angiography findings | Anastomosis | Replacement | Complications Reoperation <72 hours Flap failure | Amputation Death |
|---|---|---|---|---|---|---|---|---|---|
| 4 | 9<br>F | 96<br>16<br>6<br>78<br>96 | Open wound on medial left leg (thigh to ankle); fasciotomies on dorsum of both feet; soft tissue defect on medial right foot | Hyperbaric $O_2$ | No opacification of TP artery after trifurcation; no opacification of DP artery | Level: Poplitea<br>A: TD-popliteal (E-S)<br>V: TD-popliteal (E-E) | 9 ES<br>1 FFP<br>3 Alb | Parasitic infection<br>-<br>Disrupted foot circulation | TTA |
| 5 | 13<br>F | 20 minutes<br>50<br>19<br>47<br>61 | Bilateral fasciotomies at medial and lateral cruris with soft contamination; soft tissue defects on dorsum of both feet | Nerve transfer for 18 cm tibialis posterior nerve defect; hyperbaric $O_2$ | Loss of opacification at TA artery. | Level: Middle cruris<br>A: TD-TA (E-S)<br>V: TD-TA (E-E) | 8 ES<br>8 Alb | -<br>- | |
| 6 | 8<br>F | 100<br>20<br>4<br>-*<br>58 | Right TFA, residual limb not closed (VAC applied); left thigh llateral, medial and lateral cruris fasciotomies with soft tissue defects and contamination; TTA skin incisions on left leg | -<br>-<br>- | No opacification of peroneal artery 8 cm<br>V: LCFD – ulnar (E-E) distal to trifurcation; irregularity of TA artery | Level: Middle cruris<br>A: TD-TP (E-S)<br>V: TD-TP (E-E) | 22 ES<br>6 PLT<br>25 FFP<br>7 Alb | Tibialis anterior arterial rupture<br>-<br>Flap failure | TTA<br>EX |
| 7 | 26<br>M | 24<br>8<br>25<br>22<br>57 | Fasciotomy at lateral cruris and dorsum of foot with soft tissue defect; soft tissue defect with contamination at the medial cruris due to crush injury | - | No opacification of TA artery beyond mid-crural level; TP and peroneal arteries open proximally; weak opacification of DP | Level: Distal cruris<br>A: TD-TP (E-S)<br>V: TD-TP (E-E) | 1 ES | Donor site hematoma; wound infection<br>- | |
| 8 | 33<br>F | 44<br>17<br>10<br>54<br>56 | Necrotic right ankle, foot, and toes sparing heel region | Hyperbaric $O_2$ | No opacification of TA artery after mid-crural level; no opacification of DP artery | Level: Ankle<br>A: TD-TP (E-S)<br>V: TD-TP (E-E) | 1 ES<br>3 Alb | Arterial thrombosis<br>Reoperation at 4 and 36 hours<br>Flap failure | Syme's amputation |
| 9 | 41<br>M | 5<br>7<br>20<br>65<br>71 | Necrotic tissue and soft tissue defect at anterolateral ankle and dorsum of foot | Left hindfoot arthrodesis; ORIF for right lateral malleolus fracture; leech therapy; hyperbaric $O_2$ | | Level: Distal cruris<br>A: TD-TP (E-S)<br>V: TD-TP (E-E) | 6 ES<br>1 Alb | Donor site hematoma<br>Venous congestion of the flap Reoperation at 12 hours<br>Partial flap failure | |

TUD: Time under debris; DoA: Day of admission; AtF: Admission-to-flap time; TCT: Total closure time; Hosp: Duration of hospitalization; A: Artery; V: Vein; TD: Thoracodorsal; TA: Tibialis anterior; TP: Tibialis posterior; DP: Dorsalis pedis; E-S: End-to-side; E-E: End-to-end; ES: Erythrocyte suspension; PLT: Platelet; FFP: Fresh frozen plasma; Alb: Albumin.

All procedures were performed under loupe magnification using standard microsurgical techniques.

Postoperative monitoring included:

- Hourly flap checks on the day of surgery
- Every two hours on postoperative day one
- Every three hours on day two
- Three times daily thereafter.

Systolic blood pressure was maintained at ≥120 mmHg, diastolic at ≥80 mmHg, and hemoglobin at >10 g/dL. First dressing changes were performed on postoperative day 2 or 3 under sterile conditions in the operating room.

Statistical analysis was conducted using StataMP13 (StataCorp, College Station, TX), with descriptive statistics.

Ethics approval was obtained from the Ankara University Ethics Committee (Application No: 2023/451, Decision No: İ07-484-23). The study was conducted in accordance with the Declaration of Helsinki. Informed consent was obtained from all participants.

## RESULTS

Of the 15 patients included, five (33.3%) were pediatric. The average time under debris was 41.77±40.68 hours, and the mean duration from injury to tertiary center admission was 11.40±5.80 days. The average number of debridement procedures prior to flap surgery was 4.41±3.02, with a mean time to flap surgery of 21.06±18.24 days. Complete wound closure was achieved in an average of 37.93±37.58 days. The mean hospital stay was 77.33±36.67 days.

Supportive treatments included hyperbaric oxygen therapy in seven patients (46.7%) and dialysis in one patient. Four patients underwent concurrent fracture fixation. Blood product usage included erythrocyte suspension (n=9), platelets (n=1), fresh frozen plasma (n=3), and albumin (n=7). Detailed demographics and clinical data are summarized in Table 1.

### Flap-Specific Outcomes

**ALT Flaps (n=3):** No total flap loss was observed. Two patients developed minor necrosis (peripheral and superficial), which was managed successfully with hyperbaric oxygen therapy. One donor site required skin grafting. Outcomes are detailed in Table 2.

**LD-SA Flaps (n=6):** Selected for large defects. Two patients required reoperation within 72 hours (one arterial, one venous thrombosis). Flap-related complications included venous congestion (n=5) and the need for leech therapy (n=1). Two total and one partial flap failures were recorded. Two patients required secondary amputation (one transtibial, one Syme), and one underwent salvage with a pedicled perforator flap. One patient required reoperation for vascular compromise (Table 3).

**Sural Artery Flaps (n=3):** No failures occurred. These cases were associated with shorter hospital stays and uncomplicated postoperative courses. Data are presented in Table 4.

**Pedicled Flaps (n=5):** Outcomes varied depending on flap type and defect location. Individual case details are shown in Table 5.

Intraoperative and postoperative images for representative cases are provided in Figures 2 and 3.

## DISCUSSION

The most important finding of this study is that limb salvage through microsurgical reconstruction is feasible and can be successful even in high-risk earthquake victims who initially refused amputation, despite a relatively high complication rate. Among the 17 flaps performed in 15 patients, 13 survived either fully or partially, and only two patients required secondary amputation. This demonstrates that with proper surgical planning and intensive postoperative care, microsurgical reconstruction can achieve meaningful outcomes in this challenging population.

Compared to previously published studies, our flap failure rate (4/17) is higher than the 5% reported by Thiele et al.[5] for ALT flaps and the 0% failure rate reported by Ha et al.[6] for latissimus dorsi flaps used around the knee. However, our patient group was composed of earthquake victims, many of whom suffered extensive crush injuries, prolonged ischemia, and systemic complications, factors that made them a higher-risk population. Similar to Besmens et al.,[7] who noted worse outcomes in older, female, and comorbid patients, we observed that delayed reconstructions and vascular fragility significantly increased failure rates in our cohort.

This study also highlights key technical and perioperative considerations. Intraoperative findings frequently revealed more extensive vascular damage than preoperative CT angiograms suggested, underscoring the limitations of imaging alone in assessing recipient vessel quality. This discrepancy highlights the importance of direct surgical exploration and emphasizes the need for cautious interpretation of preoperative imaging findings in complex cases.

Proximal arterial anastomoses, particularly to the popliteal artery, were found to be more reliable than distal sites. The posterior tibial artery with its comitant veins, or the superficial venous system, was commonly used for anastomosis. Venous complications were more frequent than arterial ones in crushed extremities. Dual venous anastomoses (superficial and deep) were associated with better outcomes, with no flap failures observed in patients who received two venous outflows (Patients 2, 10, 11, and 12). Patient 2, the only ALT flap case without venous congestion, also had dual venous

**Table 4.** Summary of patients treated with sural artery free flaps

| Patient # | Age<br>Gender | TUD<br>DoA (d)<br>AtF (d)<br>TCT (d)<br>Hosp (d) | Admission condition | Other surgery /treatment | BT angiography findings | Anastomosis | Replacement | Complications<br>Reoperation<br><72 hours<br>Flap failure | Amputation<br>Death |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 13<br>F | 0<br>7<br>48<br>35<br>49 | 15 cm oblique scar on dorsum of right foot | Percutaneous pinning of 2-5 metatarsal fractures; Hyperbaric $O_2$ | Bilateral lower extremity arteries intact | Level: Foot<br>A: MSA-TA (E-E)<br>V: Concomitant-TA (E-E<br>DP (E-E) | - | -<br>-<br>- | -<br>- |
| 11 | 23<br>M | 13<br>15<br>40<br>28<br>36 | 15×10 cm soft tissue defect on lateral right foot | | Bilateral lower extremity arteries intact | Level: Cruris<br>A: MSA-TA (E-E)<br>V: Concomitant-TA (E-E) +<br>DP (E-E) | - | - | - |
| 12 | 29<br>M | 7<br>19<br>28<br>26<br>90 | Open fasciotomy scars on right lateral thigh, medial and lateral cruris with significant necrotic tissue and contamination; Closed fasciotomy scars on left lateral thigh, medial and lateral cruris, and dorsum of foot | Dialysis | No opacification of TA artery; pseudoaneurysm at DP artery due opacification retrograde circulation | Level: Cruris<br>A: LSA-TA (E-E)<br>V: Concomitant-TA (E-E) +<br>DP (E-E) | 1 ES | -<br>-<br>- | -<br>- |

TUD: Time under debris; DoA: Day of admission; AtF: Admission-to-flap time; TCT: Total closure time; Hosp: Duration of hospitalization; A: Artery; V: Vein; MSA: Medial sural artery; LSA: Lateral sural artery; DP: Dorsalis pedis; TA: Tibialis anterior; TP: Tibialis posterior; E-S: End-to-side; E-E: End-to-end; ES: Erythrocyte suspension; PLT: Platelet; FFP: Fresh frozen plasma; Alb: Albumin.

**Table 5.** Summary of patients treated with pedicled flaps

| Patient # | Age Gender | TUD DoA (d) AtF (d) TCT (d) Hosp (d) | Admission condition | Other surgery /treatment | BT angiography findings | Flap | Replacement (ES, PLT, TDP, Alb) | Complications Reoperation <72 hours Flap failure | Amputation Death |
|---|---|---|---|---|---|---|---|---|---|
| 4 | 9<br>F | 96<br>16<br>53<br>78<br>96 | Open wound on medial left leg, from thigh to ankle. Fasciotomies on dorsum of both feet. Soft tissue defect on medial right foot. | Latissimus + serratus flap on contralateral leg | All lower extremity arteries intact | Medial plantar artery perforator flap | 9 ES<br>1 TDP<br>3 Alb | | TTA (other leg) |
| 9 | 41<br>M | 5<br>7<br>31<br>65<br>71 | Necrotic tissue and soft tissue defect at anterolateral ankle and dorsum of foot | Previous latissimus + serratus flap (partial failure) | Bilateral lower extremity arteries intact | Peroneal artery perforator flap | 6 ES<br>1 Alb | Venous congestion | |
| 13 | 34<br>F | 73<br>10<br>60<br>140<br>210 | Open, inappropriate fasciotomies on lateral left thigh and cruris. Significant necrotic tissue necrosis at cruris. Open fasciotomy at medial knee. Necrotic left heel. Open fasciotomies on dorsum of right foot. | Nerve transfer | Thrombosis of GS vein and deep femoral vein. Loss of opacification of TP and peroneal arteries at mid-crural level. | Reverse sural artery flap (cross-leg) Sliding transpositional flap | 15 ES<br>1 TDP<br>3 Alb | Reoperation at 12 hours Venous thrombosis Cross-leg Flap failure Heel pressure wound treated with full-thickness skin graft for closure | TTA EX |
| 14 | 44<br>F | 96<br>12<br>6<br>4<br>131 | Amputation of digits 2–5 distal to PIP joints, necrotic distal parts. Open fasciotomy scars on dorsum of hand. 10×5 soft tissue defect on wrist flexor side. Wrist in flexion. | Amputation of digits 2–5 at PIP level. Skin graft coverage on dorsum. | All upper extremity arteries intact | Ulnar artery perforator flap | - | Flexion contracture and syndactyly of digits 2-5 | Amputation of digits 2-5 at PIP level |
| 15 | 64<br>F | 18<br>7<br>10<br>10<br>115 | Left thumb is ecchymotic and swollen from MCP joint. Oblique scar on flexor side of MCP joint. | Thumb amputation. Hyperbaric $O_2$ | All upper extremity arteries intact | Radial forearm flap | - | Thumb amputation at MCP joint. | |

TUD: Time under debris; DoA: Day of admission; AtF: Admission-to-flap time; TCT: Total closure time; Hosp: Duration of hospitalization; GS: Great saphenous; ES: Erythrocyte suspension; PLT: Platelet; FFP: Fresh frozen plasma; Alb: albumin. *Patient 13 is still hospitalized; complete soft tissue coverage has not yet been achieved.

drainage. Our findings align with the meta-analysis of Riot et. al, which demonstrated significantly reduced flap loss and fewer venous thromboses with two vein anastomoses.[8] These findings highlight the advantage of proximal inflow and dual venous outflow in improving flap success in limb crush injuries.

In our study, medical leech therapy was used as an adjunct treatment for flaps exhibiting signs of venous congestion. This approach was guided by evidence from the current literature, which supports the efficacy of leech therapy in improving venous outflow and enhancing flap survival in cases where surgical revision is limited.[9,10]

We primarily employed ALT and chimeric LD-SA flaps for large soft tissue defects. Notably, the LD-SA flap offers substantial coverage capacity but is prone to distal muscle necrosis, likely due to diminished capillary perfusion at its extremities. This observation aligns with the findings of Mahajan et al., who, in their series of 47 lower limb trauma cases, emphasized the flap's versatility but also acknowledged regional perfusion vulnerabilities.[11] These results underscore the need for careful flap design in complex reconstructions.

Adjuvant therapies played a crucial role in optimizing surgical outcomes. Preoperative vacuum-assisted closure (VAC) therapy and postoperative hyperbaric oxygen treatment significantly contributed to wound bed preparation, infection control, and improved flap survival. These findings are consistent with the current literature, which highlights that pre-flap VAC therapy enhances local perfusion, reduces edema, and lowers flap failure rates—particularly in complex extremity reconstructions.[12,13] Additionally, studies have shown that VAC therapy is associated with reduced reoperation rates and better overall wound healing in contaminated or high-risk cases.[14] When combined with meticulous debridement, these supportive treatments appear to enhance flap viability and surgical success in vulnerable patient populations, such as those with earthquake-related injuries.[15] However, persistent infection, particularly in contaminated fasciotomy wounds, led to flap loss in a small number of patients.

Upper extremity reconstructions had better outcomes than lower extremity cases, possibly due to higher local perfusion. However, the small number of upper extremity cases limits generalizability.

Despite the limitations of a small sample size and the absence of a control group, this study provides valuable insight into microsurgical reconstruction in disaster settings. These patients present unique surgical and systemic challenges that are often not reflected in standard flap literature.

## CONCLUSION

Microsurgical limb salvage is a viable treatment option for earthquake victims who refuse amputation, although it carries a higher risk of complications due to vascular fragility, infection, and delayed reconstruction. Successful outcomes

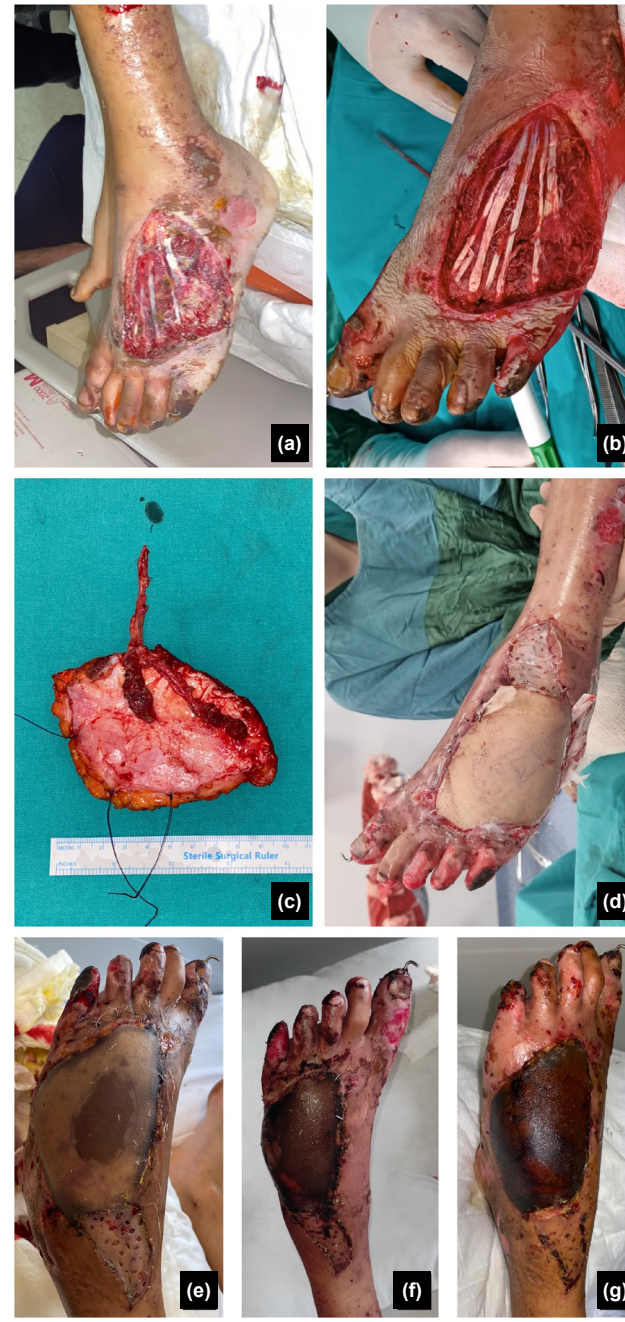


**Figure 2.** Progression of Patient 1 (12 year-old-boy) treated with an anterolateral thigh (ALT) flap. **a)** Admission — Left foot of patient 1 at admission, showing the initial defect on the dorsum. **b)** Debridement surgery — Photograph after debridement surgery, illustrating the exposed tendons. **c)** Flap anatomy — Photograph of the flap with its lateral circumflex femoral artery descending branch vessels. **d)** Completion of flap surgery — Photograph taken at the end of the procedure, demonstrating successful reconstruction. **e)** Postoperative week 1 — Photograph one week after surgery, showing early healing and tissue integration. **(f)** Postoperative week 2 — Photograph two weeks after surgery, revealing early superficial necrosis. **(g)** Postoperative week 3 — Photograph captured three weeks after surgery, showing superficial necrosis with a viable flap.

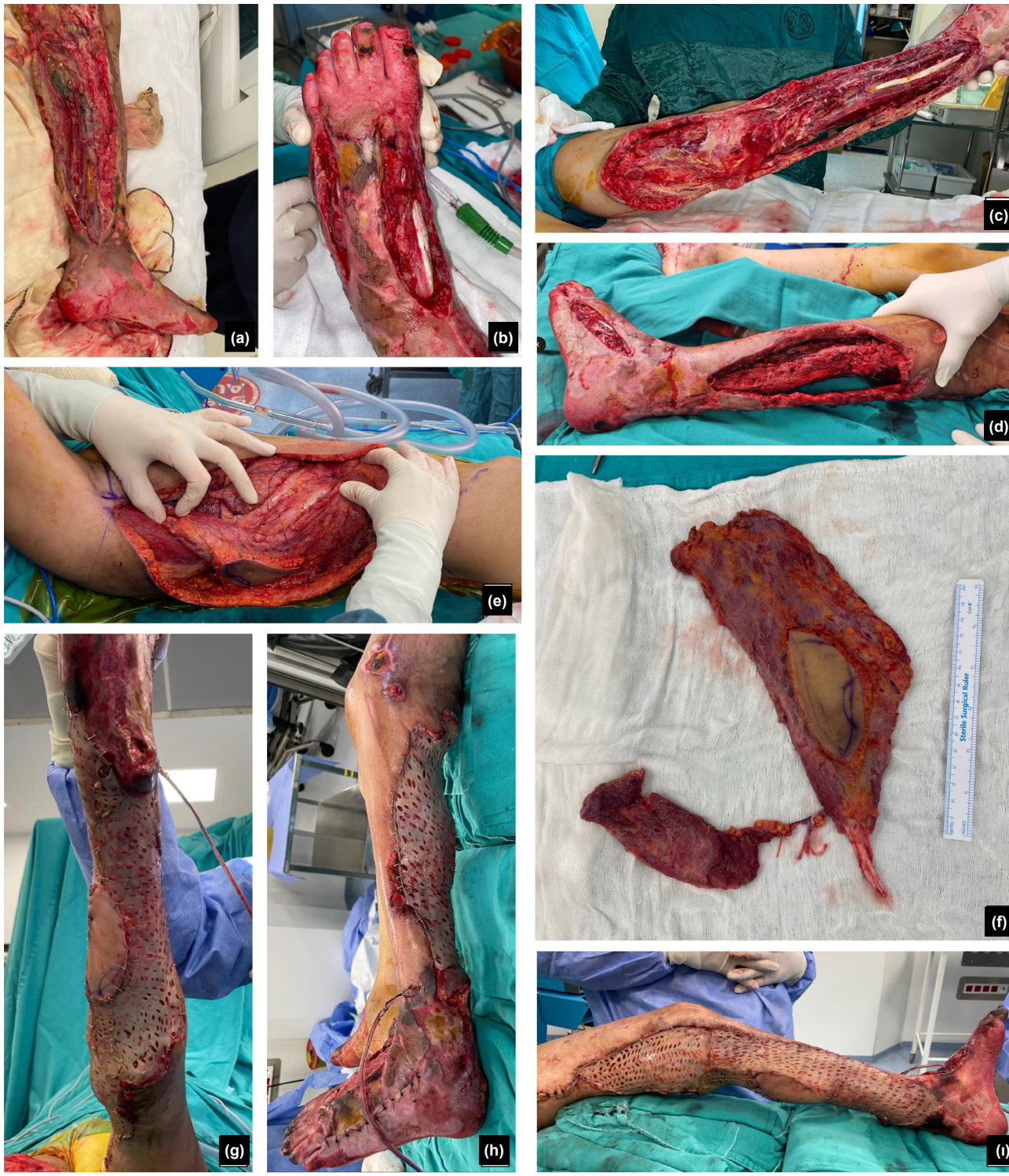


**Figure 3.** Progression of patient 4 (nine-year-old girl) treated with a latissimus dorsi-serratus anterior (LA-SA) chimeric flap. **(a,b)** Admission — Initial photographs of the patient 4's leg injury upon admission, illustrating the extent of the open wound and soft tissue defect. **(c,d)** Debridement surgery — Photographs taken during debridement surgery, illustrating the extent of the soft tissue defect in the lower leg. **(e)** Flap surgery — Image from flap surgery, showing the donor site with flap. **(f)** Flap anatomy — Image of the flap, showing the latissimus dorsi flap with skin island, the serratus anterior portion, and the thoracodorsal vessels. **(g,h,i)** Postoperative photos showing the reconstruction, with flap coverage and skin grafts applied over muscle tissue.

depend on proximal anastomosis, adequate debridement, dual venous outflow when possible, and the use of adjuvant therapies such as VAC and hyperbaric oxygen. These findings underscore the need for a meticulous orthoplastic approach

when managing complex soft tissue injuries in disaster settings.

**Ethics Committee Approval:** This study was approved by the Ankara University Ethics Committee (Date: 07.08.2023, Decision No: İ07-484-23).

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ORİJİNAL ÇALIŞMA - *ÖZ*

## Kahramanmaraş depremi: Ortopedik el cerrahisi birimi mikrocerrahi perspektifi

AMAÇ: Depremler, doğal afetlerin en yıkıcı türü olarak kabul edilir. Türkiye, fay hatları üzerinde bulunduğundan tarihinde birçok felaket deprem yaşamıştır. Ülkenin güneydoğu kesiminde 6 Şubat'ta meydana gelen şiddetli deprem, on bir şehri etkileyerek büyük zarara yol açmıştır. Bu çalışmanın amacı, başlangıçta amputasyon önerilen ancak bu işlemi reddeden belirli bir hasta grubunun tedavi yönetimini değerlendirmektir, bu hastalar rekonstrüksiyon amacıyla kliniğimize yönlendirilmiştir.

GEREÇ VE YÖNTEM: Bu tek merkezli retrospektif analiz, mikrocerrahi gerektirmeyen durumlar dışlanarak 15 hasta (8 kadın, 7 erkek) ve 17 flep içermektedir. Hastaların enkaz altında geçirdikleri süre, debridman cerrahileri, flep cerrahileri, anastomoz detayları, laboratuvar değerleri, anjiyografi, yeniden operasyonlar, yara kapanma süreleri, komplikasyonlar, flep sonuçları, hastanede kalış süresi, amputasyonlar veya ölümler gibi veriler toplandı.

BULGULAR: On beş hasta ortalama 30.67±18.51 yaşındaydı, bunların %33.33'ü pediyatrik hastalardı. Hastalar, ortalama 41.77±40.68 saat enkaz altında kalmış ve ortalama 11.40±5.80 gün gecikmeli olarak kabul edilmişlerdir. Flep cerrahisinden önce ortalama 4.41±3.02 debridman cerrahisi geçirmişler ve bu cerrahiler kabul sonrası ortalama 21.06±18.24 gün yapılmıştır. Ortalama yara kapanma süresi 37.93±37.58 gün olup, hastanede kalış süresi ortalama 77.33±36.67 gün olarak tespit edilmiştir. Hastaların %46'sı hiperbarik oksijen tedavisi almıştır. Çeşitli flep tipleri kullanılmış, anterolateral uyluk (ALT) veya sural arter fleplerinde başarısızlık görülmemiştir. Latissimus dorsi + serratus anterior kimerik flepler ise büyük defektlerde kullanılmış, daha fazla kan ürünü değişimi gerektirmiş ve zorluklarla karşılaşılmıştır. Toplamda, 4 flep başarısız olmuş, tüm çabalara rağmen 3 hastada amputasyon gerekliliği ortaya çıkmış ve 1 hasta hayatını kaybetmiştir.

SONUÇ: Vasküler ve enfeksiyon sorunları nedeniyle "göründüğünden kötü" durumda olan deprem mağdurları, dikkatli mikrocerrahiye ihtiyaç duyar. Proksimal anastomozlar, venöz komplikasyon izlemi, titiz debridman, VAC terapisi ve hiperbarik oksijen tedavisi gibi yardımcı tedaviler, bu karmaşık vakaların yönetiminde kritik öneme sahiptir.

Anahtar sözcükler: Deprem; ezilme yaralanması; flep; mikrocerrahi.

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ORIGINAL ARTICLE

# Incidentally detected nonspecific and unusual histopathological findings in childhood appendectomy specimens: A retrospective analysis of 2,633 cases

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## ABSTRACT

**BACKGROUND:** Acute appendicitis is an important clinical condition that usually occurs as a result of obstruction of the appendix lumen due to fecaloma or reactive lymphoid hyperplasia. However, in rare cases, various nonspecific and unusual pathologies can cause acute appendicitis or mimic this clinical condition. This study aimed to present patients who underwent surgery with a preliminary diagnosis of acute appendicitis and to determine the frequency of incidentally diagnosed nonspecific and unusual pathologies identified during histopathological examination of the specimens.

**METHODS:** Data from 2,633 patients who underwent appendectomy with a preliminary diagnosis of acute appendicitis in our clinic between January 2014 and June 2023 were retrospectively analyzed. Patients who underwent elective appendectomy in conjunction with other intra-abdominal operations were excluded. Specimens with unusual diagnoses were re-evaluated histopathologically. Data were analyzed statistically.

**RESULTS:** A total of 2,633 patients were included in the study, comprising 1,617 (61.4%) males and 1,016 (38.6%) females. The mean age was 11.32±3.66 years (range: 1-18). All patients underwent a standard appendectomy procedure. Histopathological examination revealed inflamed appendicitis in 2,150 cases (81.65%), perforated appendicitis in 162 cases (6.15%), fibrous obliteration in 104 cases (3.94%), and unusual histopathological findings in 57 cases (2.16%). Of the patients with unusual histopathological findings, 40 were female and 17 were male. Enterobius vermicularis was detected in 41 patients (1.55%), appendicular carcinoid tumor in 10 patients (0.4%), and serous appendicitis in six patients (0.2%). Microscopic findings of acute appendicitis were not observed in 35 of these patients.

**CONCLUSION:** Nonspecific and unusual histopathological findings are more common in childhood appendectomy specimens than in those from adults. Careful histopathological evaluation of appendix specimens allows early diagnosis and treatment of these rarely encountered pathologies.

**Keywords:** Appendicitis; fibrous obliteration; enterobiasis; carcinoid tumor; serous appendicitis.

## INTRODUCTION

The appendix vermiformis is a blind-ended tubular structure originating from the cecum, and inflammation of this organ is called appendicitis. Acute appendicitis (AA) is one of the most common causes of acute abdominal pain in adults and children, with a lifetime risk of 8.6% in men and 6.7% in women.[1] While AA accounts for 25% of acute abdomen cases requiring emergency abdominal surgery in adults, this rate increases to 32% in children.[2]

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Acute appendicitis, the most common surgical emergency in pediatrics, develops as a result of ischemic damage and bacterial proliferation caused by increased intraluminal and intramural pressure, microvascular and/or lymphatic stasis, and obstruction of the appendix lumen by fecaliths or diffuse lymphoid hyperplasia.[3] Appendix perforation rates in children are reported to be approximately 30% (typically ranging from 20% to 74%) when diagnosis and treatment are delayed, and the risk of perforation increases with age.[4] In addition, fibrous obliteration, which develops as a result of nonspecific changes in the appendix wall, is another factor contributing to the clinical picture of appendicitis.[5]

However, some unusual causes can also lead to AA or mimic this clinical presentation. These include parasitosis agents such as Enterobius vermicularis, benign tumors (e.g., mucinous tumors), malignant tumors (e.g., adenocarcinoma and neuroendocrine tumors), and certain infectious processes referred to as serous appendicitis.[6] In previous studies, histopathological examination of specimens obtained from patients who underwent surgery with a preliminary diagnosis of AA revealed unusual findings at a rate of 1% in adults and 1.91% in children.[7] If careful histopathological evaluation of appendectomy specimens is not performed, serious morbidity and mortality risks may arise due to misdiagnosis or delayed diagnosis.

In this retrospective study, we aimed to present cases operated on with a preliminary diagnosis of AA and to evaluate nonspecific and unusual findings, as well as their incidence, based on histopathological examination of the specimens.

## MATERIALS AND METHODS

A total of 2,633 patients under the age of 18 who underwent surgery with a preliminary diagnosis of AA between January 2014 and June 2023 were retrospectively analyzed. Patients who underwent elective appendectomy in conjunction with other intra-abdominal operations were excluded from the study. The authors attempted to mitigate possible problems such as missing data or loss to follow-up by reviewing available records and contacting patients for follow-up. Age, gender, preoperative clinical findings, surgical data, histopathological results, and follow-up records were collected.

Appendectomy materials were examined by eight experienced histopathologists with similar training during the study period. Specimens stained with hematoxylin and eosin (H&E) were evaluated, and ischemic changes and/or necrosis characterized by a predominance of polymorphonuclear leukocytes, inflammatory cellular reactions in the appendix wall, and partial or complete involvement of the appendix wall were accepted as the usual microscopic findings of AA. Original pathology samples with nonspecific and unusual findings were re-evaluated by an experienced pathologist using H&E staining, and specimens diagnosed with carcinoid tumors were re-evaluated using immunohistochemical (IHC) staining. The current study was approved by the local institutional ethics committee (ESH/GOEK 2023/47, 25/08/2023). This study was conducted in accordance with the Declaration of Helsinki.

### Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) for Windows, version 22.0 (IBM, Armonk, NY). Descriptive analyses summarized patient data as mean ± standard deviation (SD) for each demographic or histopathological feature. The frequency of occurrence of specific findings was calculated as a percentage of the total study population.

## RESULTS

A total of 2,633 patients (1,617 (61.4%) male and 1,016 (38.6%) female) who underwent appendectomy with a preliminary diagnosis of AA were included in the study. The mean age was 11.32±3.66 years (range: 1-17). Tenderness, defense, and rebound in the right lower quadrant were common physical examination findings in patients presenting with abdominal pain. All patients underwent a standard appendectomy procedure.

Histopathological examination revealed 2,150 cases of AA (81.65%), 162 cases of perforated appendicitis (6.15%), 112 cases of lymphoid hyperplasia (4.25%), 48 cases with normal appendices (1.82%), and 104 cases of fibrous obliteration (3.94%) (Table 1). Incidental unusual histopathological findings were identified in 57 patients (2.16%) of all appendectomies (Table 2), with microscopic features of AA present in only 22 of these specimens. Among these, 40 patients were female and 17 were male. Histopathological evaluation revealed 41 cases of Enterobius vermicularis (1.55%), 10 cases of carcinoid tumor (0.38%), and six cases of serous appendicitis (0.02%).

Fibrous obliteration was identified as a nonspecific histopathological finding in 104 appendectomy specimens (3.94%). The mean age of these patients was 12.22±3.16 years (range: 8-15), and 30 were female. Clinically, these patients presented with gastrointestinal symptoms such as chronic right quadrant pain, prolonged anorexia, and failure to gain weight, differing from the typical acute appendicitis presentation. Preopera-

**Table 1.** Histopathological findings in appendectomy specimens (n=2,633)

| Histopathological Findings | Number | Percent |
|---|---|---|
| Normal appendix vermiformis | 48 | 1.82 |
| Lymphoid hyperplasia | 112 | 4.25 |
| Acute appendicitis | 2,150 | 81.65 |
| Perforated appendicitis | 162 | 6.15 |
| Fibrous obliteration | 104 | 3.94 |
| Unusual appendicitis | 57 | 2.16 |

**Table 2.** Distribution of unusual histopathological findings in all appendectomy specimens

| Histopathological Findings | Number (%) | Negative Laparotomy | Acute Appendicitis |
|---|---|---|---|
| Enterobius vermicularis | 41 (1.55%) | 23 | 18 |
| Carcinoid tumor | 10 (0.04%) | 6 | 4 |
| Serous appendicitis | 6 (0.02%) | 6 | 0 |
| Total | 57 | 35 | 22 |

tive radiological evaluations did not reveal any specific imaging findings suggestive of fibrous obliteration. Intraoperatively, no edema was observed in the appendix, but the appendix tissue had a firm, string-like consistency. Histopathological examination demonstrated disappearance of the appendix lumen, with the mucosa, crypts, and lymphoid follicles replaced by increased fibrocollagen tissue, adipose tissue, hypertrophic nerve fibers, neuroendocrine cells, and chronic inflammatory cell reaction (Fig. 1).

Enterobius vermicularis was identified in 41 appendectomy specimens (1.56%). Acute inflammation was detected in only 18 of these cases. The mean age of affected patients was 12.34±4.24 years (range: 8-17), and 30 were female. In addition to chronic abdominal pain, these patients presented with nonspecific symptoms such as prolonged anorexia and failure to gain weight. The diagnosis was made histopathologically, based on the presence of parasite eggs and/or parasites in the appendix lumen. Various inflammatory patterns, including mucosal ulceration, lymphoid hyperplasia, eosinophilic infiltration, neutrophilic infiltration, and plasma cells were observed in the appendix wall (Fig. 2). Postoperatively, patients diagnosed with enterobiasis received mebendazole treatment (a single dose of 200 mg in children weighing less than 20 kg and a single dose of 400 mg in children weighing more than 20 kg). A single dose was repeated two weeks later.

Ten patients (0.4%) were diagnosed with appendicular carcinoid tumors, with a mean age of 12.6±3.09 years (range: 8-17), and a male-to-female ratio of 2:3. Microscopically, the diagnosis was established by observing tumoral growths composed of regular round cells with fine chromatin networks arranged in acini, lines, trabeculae, and nests (Fig. 3). None of the patients exhibited features of carcinoid syndrome. The tumor was located at the tip of the appendix in nine patients. Seven tumors were smaller than 1 cm, while three were between 1 and 2 cm. The depth of tumor penetration reached the subserosa in eight cases and the mesoappendix in two cases. Surgical margins were intact in all patients, and no additional surgery was performed. Demographic and histopathological features of patients with carcinoid tumors are summarized in Table 3. Postoperatively, patients diagnosed

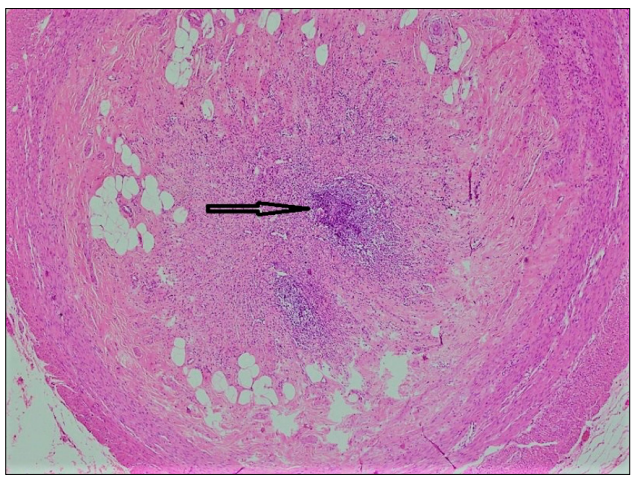

**Figure 1.** Fibrous obliteration of the appendix lumen by fibromyxoid tissue composed of spindle cells, adipose tissue proliferation, nerve bundles, and neuroendocrine cells (H&E, ×400).

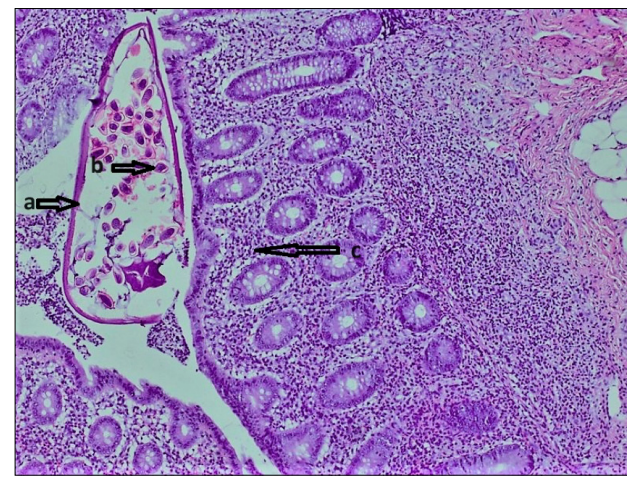


**Figure 2.** Histological spectrum of appendicitis associated with Enterobius vermicularis infection (H&E, ×100). **a)** Adult Enterobius vermicularis in the appendix lumen. **b)** Enterobius eggs within the parasite. **c)** Edema and thickening due to eosinophilic inflammatory cell infiltration in all layers of the appendix wall.

**Table 3.** Detailed characteristics of the 10 patients with appendicular carcinoid tumors

| Patient No | Age (y) | Gender | Localization | Depth of Invasion | Size (mm) | Ki-67 | Follow-up (mo) |
|---|---|---|---|---|---|---|---|
| 1 | 10 | M | Tip | Submucosa | 10 | <2% | 84 |
| 2 | 14 | F | Tip | Submucosa | 3 | <2% | 32 |
| 3 | 14 | F | Tip | Submucosa | 2 | <2% | 54 |
| 4 | 14 | M | Tip | Submucosa | 3 | <2% | 72 |
| 5 | 17 | F | Middle | Mesoappendix | 11 | <2% | 12 |
| 6 | 10 | M | Tip | Submucosa | 5 | <2% | 44 |
| 7 | 10 | F | Tip | Mesoappendix | 12 | 4% | 24 |
| 8 | 12 | F | Tip | Submucosa | 5 | <2% | 32 |
| 9 | 8 | F | Tip | Submucosa | 1 | <2% | 42 |
| 10 | 17 | M | Tip | Submucosa | 6 | <2% | 28 |

y: Year; mm: Millimeters; mo: Month; M: Male; F: Female.

with carcinoid tumors were followed with annual abdominal ultrasonography (US) and positron emission tomography/computed tomography (PET/CT) with 68Ga-DOTATATE uptake. Follow-up was calculated from the date of diagnosis. Patients were monitored for an average of 42.4 months, and no recurrences were detected.

The mean age of the six patients (0.2%) diagnosed with serous appendicitis was 8.66±2.60 years (range: 8-15), and four were female. All patients presented with right lower quadrant abdominal pain. Preoperative evaluation revealed leukocytosis in four of six patients relative to age, while all patients had increased C-reactive protein (CRP) levels (normal range: 0-6 U/L). Midstream urine sample microscopy performed before surgery showed more than 2 leukocytes per field in all patients, and Escherichia coli grew in two urine cultures. Abdominal US revealed findings suspicious for appendicitis in only two of six patients. All patients received intravenous cephalosporin/cefuroxime (100 mg/kg) at 12-hour intervals starting in the perioperative period and underwent standard appendectomy. Serosal appendicitis of known cause was identified in two patients, both of whom had severe urinary tract infections. Microscopically, neutrophilic inflammatory reaction and fibrinous material accumulation were observed on the serosal surface of the appendix; the inflammatory reaction extended into the muscle layer, while the mucosa was preserved (Fig. 4). No early or late postoperative complications developed in serous appendicitis, whether with or without a known cause.

## DISCUSSION

Acute appendicitis, the most common surgical emergency in pediatrics, usually develops as an inflammatory process

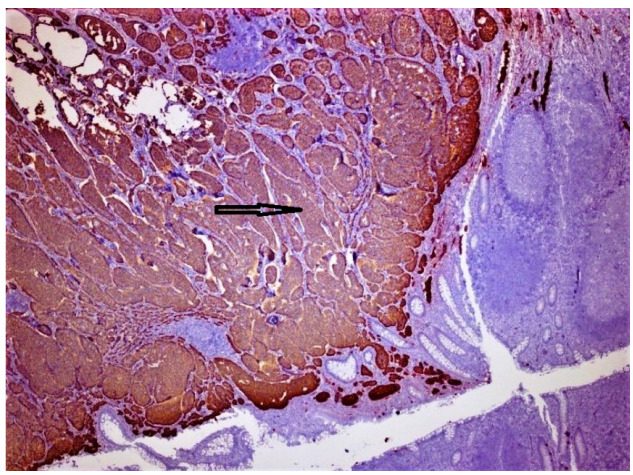

**Figure 3.** Immunohistochemical study showing diffuse, strong positivity for the neuroendocrine cell component marker synaptophysin in tumor cells (IHC, ×100).

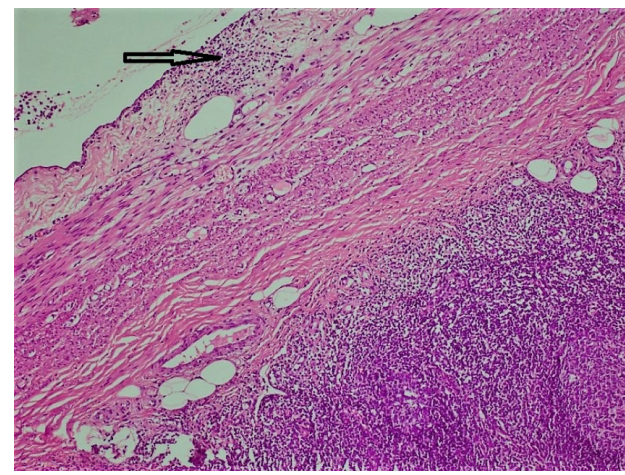

**Figure 4.** Edematous fibrinous accumulation and neutrophilic cellular reaction on the serosal surface of the appendix (H&E, ×100).

following complete obstruction of the appendix lumen due to fecaloma or lymphoid hyperplasia.[8] When diagnosis and treatment are delayed, increased intraluminal pressure can lead to perforation of the appendix, thereby increasing morbidity and mortality.[9] Examination of specimens from patients who underwent surgery with a preliminary diagnosis of AA revealed inflamed appendicitis in 89.3% of children and 94.5% of adults, with perforation rates of 22.2% and 16.4%, respectively.[10] In recent years, the more widespread use of imaging modalities such as abdominal US and CT in suspicious cases has facilitated earlier preoperative diagnosis.[9] In our study, acute inflamed appendicitis was detected in 81.65% of cases, while perforated appendicitis was identified in 6.15% of all appendectomies. We believe that the reason for the low rate of perforated appendicitis in our study is the use of abdominal US and abdominal CT in suspicious cases.

Fibrous obliteration of the appendix is defined as nonspecific changes associated with clinical symptoms resembling AA but lacking the histopathological features of classical acute inflammation in appendectomy specimens.[5] According to PubMed data, fibrous obliteration has not yet been classified as an unusual histopathological finding. It has also been described as neurogenic appendicitis (NA), with an incidence of 4.8% in children.[11] The pathogenesis of NA, i.e. the mechanisms underlying acute abdominal pain, fibrosis, and hyperplasia of nerve fibers, remains unclear. It was reported that the changes associated with NA result from increased density of neuroendocrine ganglia and neuronal hypertrophy.[12] The fibroproliferative process resulting from the release of fibrogenic mediators leads to partial or complete obliteration of the appendix lumen.[13] Although the mechanisms underlying pain in NA are not well understood, it has been suggested that neuroinflammation, together with increased levels of neuropeptides, is effective in this process.[14] An appendix with NA does not appear enlarged, swollen, or purulent at the time of surgery.[5] In our study, the rate of fibrous obliteration was 3.94%. An appendix presenting with clinical features of AA but no apparent signs intraoperatively should suggest the possibility of NA.

Parasitic diseases are rare in developed countries but more common in developing countries. Parasitic infections in the lumen of the appendix can cause acute appendicitis or mimic this clinical picture, and the most common agent is Enterobius vermicularis.[15] It can obstruct the appendix lumen and lead to the development of acute appendicitis. It has been reported in 0.2-4.18% of appendectomy specimens[16] and is more common in females.[17] Patients may present with nonspecific symptoms such as long-term abdominal pain and loss of appetite. It can also lead to other pathological changes ranging from lymphoid hyperplasia to life-threatening complications.[18] No preoperative clinical feature or diagnostic laboratory test distinguishes between helminthic appendicitis and bacterial appendicitis. Studies have reported that acute inflammation is absent in 25% to 85.7% of appendectomy specimens with parasitic agents.[19] In our study, the most common unusual finding in appendectomy materials was E. vermicularis. In our study, the enterobiasis rate was 1.55%, with 73.17% of these patients being female. In 43.90% of these cases, no signs of inflammation were found.

Appendiceal carcinoid tumors are rare in children and are usually detected incidentally during histopathological examination after appendectomy. Their incidence has been reported as 0.2%–0.5% of all appendectomy specimens.[20] The mean age of children with appendiceal carcinoid tumors is 12-13 years, and the condition is more common in females.[21] Appendiceal carcinoid tumors lack specific clinical findings. Enterochromaffin cell neuroendocrine tumors (NETs) are well-differentiated epithelial neoplasms of the appendix.[22,23] In our study, the frequency of appendiceal carcinoid tumors was 0.4%, consistent with the literature. Similarly, the mean age was 12.64 years, and females were slightly more predominant in our cohort.

In children, most carcinoid tumors are less than 2 cm in size and located at the tip of the appendix, accounting for approximately 75% of cases.[22,24] This distribution helps explain the nonspecific clinical presentation and the difficulty of radiological detection. In the present case series, all tumors were smaller than 2 cm, and nine of ten were located at the tip of the organ. Simple appendectomy has been reported as curative in most patients with carcinoid tumors.[23] However, some authors advocate a more aggressive approach, recommending right hemicolectomy, particularly for tumors located proximally in the appendix, high-grade malignant carcinoids, or those with a high mitotic index.[25,26] In our study, all tumors were small, none were located at the base of the appendix, and the resection margins were reported as free of cancer cells on histopathological analysis. Additionally, no findings requiring further surgical procedures were observed during postoperative follow-up of our cases.

Cell proliferative rate is an important factor in determining the prognosis of neuroendocrine tumors.[27] Therefore, proliferation markers, particularly the Ki-67 labeling index and high mitotic activity, have become increasingly important in NET assessment.[28] The World Health Organization (WHO) and the European Neuroendocrine Tumor Society (ENETS) classify NETs into three groups according to grade, Ki-67 proliferation index, and mitotic count. NET, low grade (Class 1) is defined as fewer than two mitoses per 10 HPF and a Ki-67 proliferation index below 2%. NET, intermediate grade (Class 2) is defined as 2-20 mitoses per 10 HPF and a Ki-67 index of 3%-20%. NET, high grade (Class 3) is defined as more than 20 mitoses and a Ki-67 index greater than 20%.[29] In nine of our cases, there were fewer than two mitoses per 10 HPF and a Ki-67 proliferation index below 2%. In one patient, there were two mitoses per 10 HPF and a Ki-67 proliferation index of 4%. This patient was followed for 24 months with annual abdominal ultrasonography and gallium 68 PET-CT, and no recurrence was detected. Across all cases, no synchronous

tumors, recurrences, or metastases were observed during follow-up, and no mortality occurred.

Serous appendicitis is an inflammatory reaction on the serosal surface of the appendix caused by an inflammation source outside the appendix and is also called periappendicitis.[30] Previous publications have reported serous appendicitis in 0.1%-0.5% of resected appendectomy specimens.[31] It is a rare and benign pathology. Since no specific diagnostic method exists, diagnosis is difficult. Abdominal CT and/or transvaginal US in adult patients can be helpful in suspicious findings on USG. The cause is mostly unknown, and in only 1%-5% of cases can an intra-abdominal pathology responsible for serous appendicitis be identified.[31] Various intra-abdominal conditions, primarily urogynecological (e.g., ovarian torsion, tubo-ovarian abscess, renal abscess) and intestinal diseases (e.g., diverticulitis, Crohn's disease), can lead to this clinical picture.[30] Appendectomy combined with perioperative antibiotic therapy is curative for serous appendicitis. In serous appendicitis where the cause is identified, it is important to treat the accompanying pathology. In our study, periappendicitis was detected in six patients, two of whom had severe urinary tract infections with Escherichia coli growth in urine cultures. No postoperative complications were observed in any of our patients.

### Limitations

The main limitation of this study is its retrospective design. All procedures were performed at a single institution, and because the number of patients was limited, descriptive rather than comparative analyses were included. Specimens were examined by a team of academic staff in the pathology department with similar experience and educational background. The relatively specific and easily detectable microscopic features on histopathological examination minimized potential pathologist-dependent variability in diagnostic accuracy. This enabled appropriate further investigation and treatment of patients with unusual diagnoses.

## CONCLUSION

Unusual pathological findings are more common in children than in adults. Careful histopathological evaluation of appendix specimens enables detection and treatment planning for unusual malignant and infectious causes that clinically mimic AA.

**Ethics Committee Approval:** This study was approved by the Eskişehir City Hospital Ethics Committee (Date: 25.08.2023, Decision No: ESH/GOEK 2023/47).

**Peer-review:** Externally peer-reviewed.

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

**Conflict of Interest:** None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

## Çocukluk çağı apendektomi örneklerinde tesadüfen saptanan nonspesifik ve olağandışı histopatolojik bulgular: 2633 vakanın retrospektif analizi

AMAÇ: Akut apandisit, genellikle fekaloma veya reaktif lenfoid hiperplazi nedeniyle apendiks lümeninin tıkanması sonucu ortaya çıkan önemli bir klinik durumdur. Bununla birlikte, nadiren çeşitli nonspesifik ve olağandışı patolojiler akut apandisite neden olabilir veya bu klinik durumu taklit edebilir. Bu çalışmanın amacı, akut apandisit ön tanısıyla ameliyat edilen hastaları sunmak ve örneklerin histopatolojik incelemesi sırasında tesadüfen saptanan nonspesifik ve olağandışı patolojilerin insidansını belirlemektir.
GEREÇ VE YÖNTEM: Ocak 2014 ile Haziran 2023 tarihleri arasında kliniğimizde akut apandisit ön tanısı ile apendektomi yapılan 2633 hastanın verileri retrospektif olarak analiz edildi. Diğer intraabdominal operasyonlara ek olarak elektif apendektomi yapılan hastalar hariç tutuldu. Olağandışı tanıları olan örnekler histopatolojik olarak yeniden değerlendirildi. Veriler istatistiksel olarak analiz edilmiştir.
BULGULAR: Çalışmaya 1617'si (%61.4) erkek ve 1016'sı (%38.6) kadın olmak üzere toplam 2633 hasta dahil edildi. Ortalama yaş 11.32±3.66 (dağılım: 1-18) yıldı. Tüm hastalara standart apendektomi prosedürü uygulandı. Histopatolojik inceleme sonrasında, örneklerin 2150 olguda (%81.65) inflame apandisit, 162 olguda (%6.15) perfore apandisit, 104 olguda (%3.94) fibröz obliterasyon ve 57 olguda (%2.16) olağandışı histopatolojik bulgular gösterdiği tespit edildi. Olağandışı histopatolojik bulguları olan hastaların 40'ı kadın, 17'si erkekti. Enterobius vermicularis 41 hastada (%1.55), apendiküler karsinoid tümör 10 hastada (%0.4) ve seröz apandisit 6 hastada (%0.2) tespit edildi. Bu hastaların 35'inde akut apandisitin mikroskopik bulguları gözlenmedi.
SONUÇ: Nonspesifik ve olağandışı histopatolojik bulgular çocukluk çağı apendektomi örneklerinde yetişkinlerden alınan örneklere göre daha yaygındır. Apendiks örneklerinin dikkatli histopatolojik değerlendirmesi, nadir görülen bu patolojilerin erken tanı ve tedavisine olanak sağlayacaktır.

Anahtar sözcükler: Akut apandisit; enterobiyazis; fibröz obliterasyon; karsinoid tümör; seröz apandisit.

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CASE REPORT

# Fourteen-year outcome of unilateral leg replantation after bilateral lower leg and unilateral upper extremity amputation following traumatic injury

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## ABSTRACT

In cases of traumatic major extremity amputations, particularly ofthe lower extremity, every stage—from decision-making to implementation and outcomes—remains a matterof debate. Managing such cases, which carry high mortality rates, is extremely challenging both at the time of injury and throughout treatment. We present a rare and severe case of a 30-year-old patient who sustained injuries from a concrete machine, resulting in bilateral lower extremity amputations and a unilateral proximal arm amputation. A replantation was successfully performed at the proximal ankle level on one side. Our patient has been followed for 14 years, during which we achieved a satisfactory outcome through meticulous surgical intervention, evaluated using the American Orthopaedic Foot & Ankle Society (AOFAS) and Maryland foot scores. We attained a limb with intact plantar sensation and near-complete range of motion in the ankle and toe joints. Although the clinical application of the Mangled Extremity Severity Score (MESS) score has established criteria for replantation in traumatic amputation cases, we believe there maybe relative indications for limb salvage, particularly in cases of multiple traumatic amputations, especially bilateral lower extremity amputations. In such injuries, the patient's life should be prioritized. Subsequently, at least one amputated extremity and its stump should be thoroughly evaluated. Rather than opting for stump closure, we advocate attempting replantation.

**Keywords:** Multiple traumatic amputation; lower extremity; replantation.

## INTRODUCTION

Limb replantation has been practiced worldwide for more than fifty years. The majority of cases, however, have involved the upper limb, with far fewer performed on the lower limb. Unlike upper limb replantation, lower limb replantation is rarely reported due to its comparatively low incidence and higher rate of postoperative complications. While current concepts regarding major upper extremity amputations indicate that every effort should be made for replantation, the case for lower extremity replantation is less clear.[1] In lower limb replantation, high-level amputations often have disappointing success rates, and complications such as infection, sepsis, renal failure—which are very difficult to manage—can occur, sometimes resulting in death.[2]

Due to advances in prosthetics for below-knee amputations, along with mixed functional outcomes following lower limb replantation and the costs associated with reconstruction, amputation may be favored over limb salvage despite the technical feasibility of the procedure. Consequently, the literature on lower extremity replantation is limited to case reports and small case series. Most reports of replantation involving lower limb amputations pertain to children and individuals in

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developmental stages. The vast majority of these case reports pertain to single-limb amputations.

Here, we present a case report involving an adult patient with major traumatic amputations of three different extremities at various levels. In such cases, where the patient's life is the priority, it is crucial to make appropriate decisions and evaluate amputation versus replantation for each limb separately. We report the successful outcomes of both amputation and replantation in a patient who suffered bilateral traumatic lower extremity amputations (right below-knee and left at the hind foot level) as well as a multilevel subtotal amputation of the left upper extremity due to a crush injury.

## CASE REPORT

On July 8, 2011, a 30-year-old male patient was evaluated in the emergency room after sustaining an injury from a concrete machine. According to the patient's history, he had entered the machine for cleaning when it was accidentally activated by someone else pressing the start button. He arrived at the hospital within two hours of the injury. On admission, the patient was transiently hypotensive, unstable, and semiconscious, but he responded to crystalloid fluids and blood products.

On physical examination, complete amputations of both lower extremities were noted: below the knee on the right and at the hindfoot level on the left. Additionally, a multi-level crush injury of the left upper extremity extended from the shoulder joint to the distal forearm (Fig. 1). The amputated part of the right lower limb was wrapped in saline-soaked gauze, placed in a bag, and transported in a bucket of water and ice. No abdominal, chest, or head trauma was observed. The Mangled Extremity Severity Score was 8 (skeletal/soft tissue=3; ischemia=3; shock=1; age=1).

Immediately after informed consent for amputation and replantation was obtained from the patient's relatives and the necessary preoperative examinations were completed, the patient was transferred to the operating room. The surgery began with three teams, three hours after the injury. One team worked on the right lower limb, another on the left lower limb, and a third on the left upper limb. Initially, the

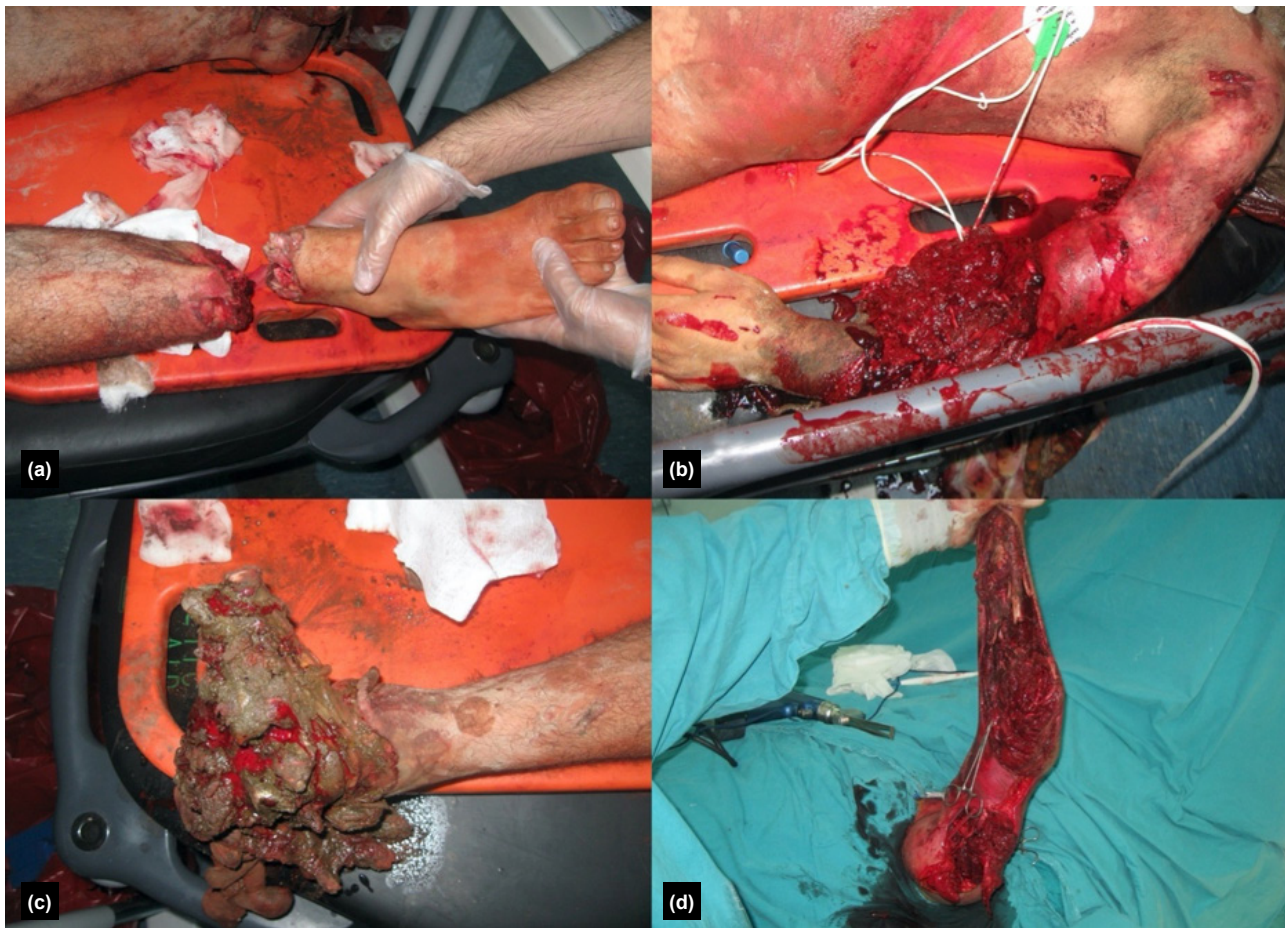


**Figure 1. (a)** Injury to the right lower leg withamputation at the proximal right ankle joint, **(b)** multi-level crush injury of the left upper extremity extending from the shoulder joint to the distal forearm, **(c)** injury to the left lower leg, showing more severe crushingthan the right, **(d)** intraoperative images of the left upper extremity.

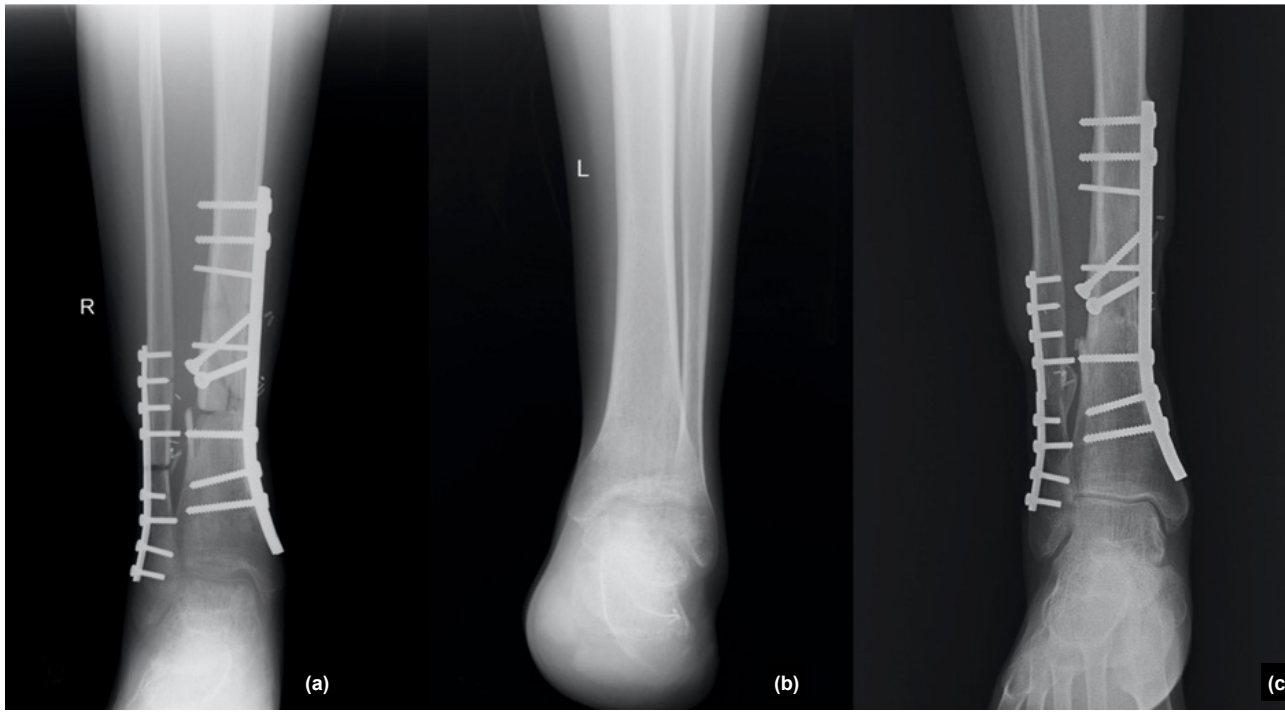


**Figure 2. (a)** Postoperative anteroposterior view of the replanted right lower extremity, **(b)** postoperative anteroposterior view of the amputated left lower extremity, and **(c)** anteroposterior view of the replanted right lower extremity 14 years later.

lower extremities and the left upper extremity were thoroughly cleaned, and debridement of severely damaged soft and bony tissues was performed. Intraoperative evaluation of the left upper extremity revealed multi-level injury with associated arterial disruption, and the crush injury had caused extensive soft tissue disruption. Therefore, amputation was performed. The left lower extremity was shortened to the Chopart joint, and the stump was closed after the necessary soft tissue and bone debridement.

The amputation at the proximal right ankle exhibited clean-cut margins, and a decision for replantation was made. Since amputation was indicated for the left upper extremity, two separate teams were formed to handle the procedures on the right lower extremity, with participation from the replantation surgery team allocated for this purpose. This was followed by preparation of the proximal stump and the amputated part.

First, the vessels, nerves, and tendons were meticulously dissected and marked as quickly as possible. The tibia and fibula were shortened by approximately 3 cm to facilitate soft tissue approximation. Rigid osteosynthesis of the tibia and fibula was achieved with plates and screws. The Achilles tendon, tibialis anterior, tibialis posterior, flexor hallucis longus, flexor digitorum longus, extensor digitorum longus, extensor hallucis longus, and peroneal muscles were repaired at their tendinous or musculotendinous junctions.

The anterior and posterior tibial arteries were anastomosed using 8-0 nylon with a microsurgical technique. The tibialis posterior and peroneal nerves were repaired using the epineural method. After tourniquet deflation, adequate arterial flow was established. With venous filling observed, the great saphenous vein, the accompanying vein of the posterior tibial artery, and two superficial veins were repaired. Replantation was completed six hours after the injury.

Following skin closure and draping, the patient was transferred to the postoperative intensive care unit. Once hemodynamically stable, the patient underwent close wound monitoring, and kidney function was assessed with laboratory parameters for crush syndrome. The patient was discharged approximately 11 days after hospitalization without developing any clinical complications commonly associated with replantation, such as circulatory disorders or kidney function impairment.

During the follow-up period, radiographs were obtained and evaluated (Fig. 2).As the patient did not require any additional surgical intervention, he was fitted with a left lower-leg prosthesis six months after the operation, and gait training was subsequently initiated. He attended outpatient clinic visits at two weeks, six weeks, and three months postoperatively (Fig. 3). Thereafter, yearly follow-ups were planned.

After 14 years of follow-up, the physical examination findings recorded during the most recent assessment were as follows: At the ankle joint, the active and passive range of motion measured with a goniometer showed active plantar flexion of

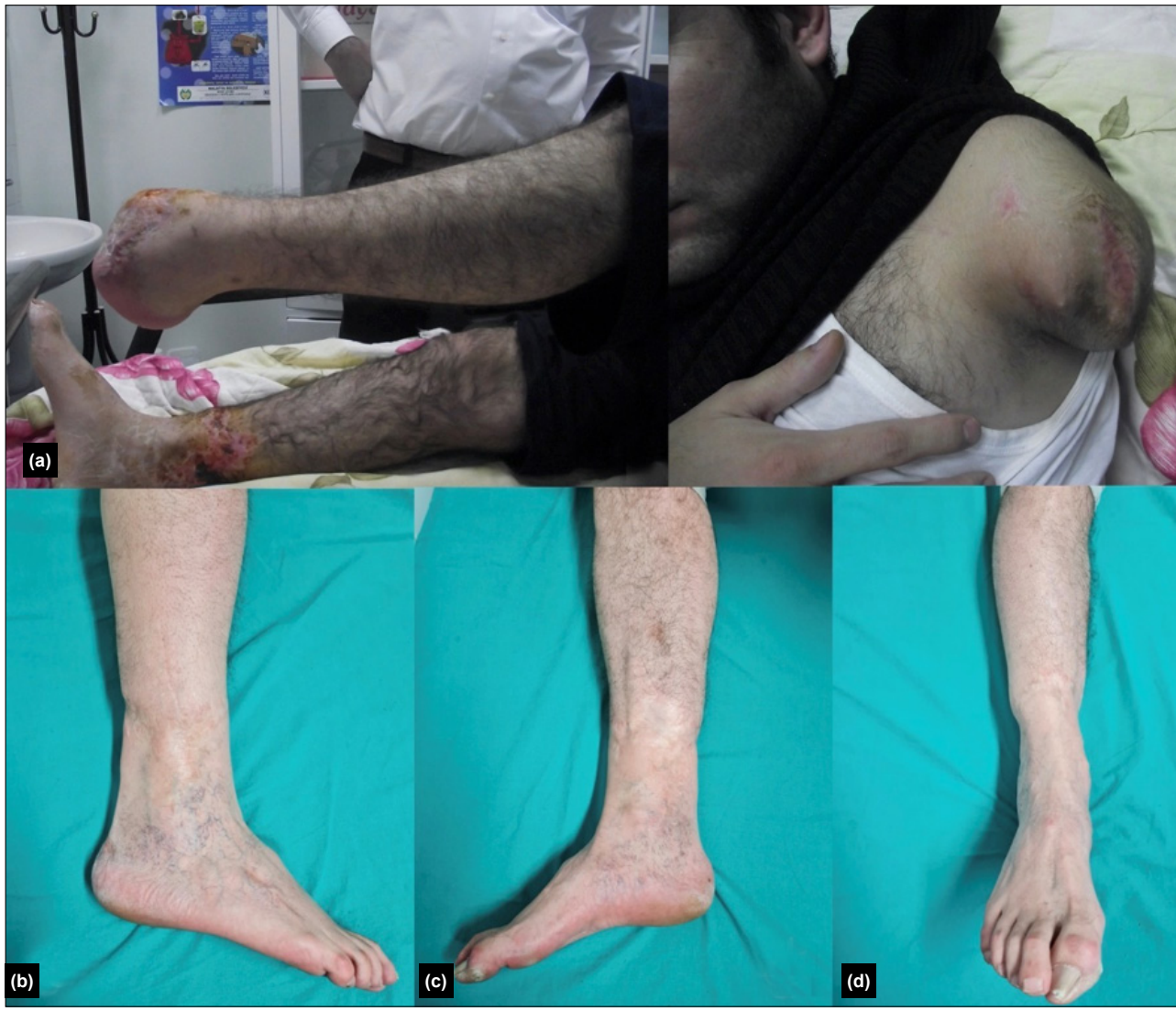


**Figure 3. (a)** Appearance of both lower extremities three months after the operation, **(b)** amputated left upper extremity, **(c)** lateral view, **(d)** medial view, €anterior view at the final follow-up.

20 degrees (muscle strength 5/5) and active dorsiflexion of 15 degrees (muscle strength 5/5). Active foot inversion was 15 degrees (muscle strength 5/5) and eversion was 20 degrees (muscle strength 5/5).

Subtalar joint inversion measured 15 degrees, while eversion was 5 degrees. Toe flexion and extension (both hallux and other toes) demonstrated muscle strength of 4/5. Despite the presence of sensory loss and paresthesia in the dermatomes of the deep peroneal, superficial peroneal, sural, and saphenous nerves, there was no sensory loss in the plantar region, corresponding to the dermatome of the posterior tibial nerve. The dorsalis pedis and posterior tibial pulses at the ankle were palpable and recorded as intact with a handheld Doppler device, and there was no cold intolerance.

The patient, who uses a prosthesis on his right lower extremity, reported difficulties particularly when climbing stairs and walking on uneven terrain. His left leg is 2.5 cm shorter; however, he compensates for this difference with high-heeled orthopedic shoes. When evaluating functional outcomes, the AOFAS[3] score was 64, and the Maryland[4] foot score was 73.

## DISCUSSION

In the management of major traumatic lower extremity amputations, treatment should be individualized. The surgeon must first decide between prioritizing the patient's life and the viability of the limb. When the patient's life is at risk, replantation should not be attempted, and stump closure should be performed. The threat to the patient's life can be categorized into early and late periods. Early-period management or algorithms include supportive treatments, active bleeding control, and emergency surgery, with decisions be-

ing relatively straightforward. However, death can also occur in the late period following limb replantation, with the incidence of mortality as a complication of replantation reported at 11.7%.[5] Conditions such as crush syndrome, sepsis, and ischemia-reperfusion syndrome can also develop after major replantation, and the surgeon must consider these factors when formulating a treatment plan before making a decision regarding replantation.

In the second stage, the potential success of replantation must be evaluated. The success of replantation is influenced by several factors, including the type of injury, an ischemia duration of less than six hours, the extent of tissue damage, and the contamination status of both the amputated part and the replantation site.[5] Re-amputation of the replanted limb is also not uncommon. Ultimately, after a successful replantation, the surgeon aims to achieve a favorable clinical outcome for the patient. Maintaining plantar sensation following major lower extremity replantation is particularly important, and careful repair of the posterior tibial nerve is essential.[6] In a study investigating patient satisfaction, replantation was preferred over amputation and prosthesis use by all patients who underwent replantation.[7] Although the presence of a limb resembling a prosthesis may be acceptable to patients from a psychosocial and cosmetic perspective, the ultimate goal should be to achieve a functional extremity. Attaining this objective requires clinical experience and a skilled multidisciplinary team.

Recently, with the increased use of the Mangled Extremity Severity Score[8] in clinical settings, attempts at replantation in cases of traumatic amputation have likely decreased. Recent studies have explored the predictive value of the MESS score across different types of lower extremity injuries, including in pediatric patients, indicating an open field for further research on its safety and efficacy.[9-11] Our patient presented with a MESS score of 8 at the time of injury and sustained injuries to three extremities, not just one. In this case, the injuries to the left lower extremity and left upper extremity were unsuitable for replantation due to their crush and multilevel nature; however, the right lower extremity amputation was deemed suitable for replantation.

For a patient with a MESS score of 8, replantation carries inherent risks. Significant controversy remains regarding the indications for replantation, and while various scoring systems exist to assist in decision-making, it is important to emphasize that statistics cannot replace clinical judgment. The presentations of replantation interventions in cases of major traumatic amputations have predominantly been documented as case reports within pediatric cohorts, largely due to the high recovery capacity of children and the dependence of replantation indications on multiple factors such as timing and injury type.[12-14] In adults, these procedures are considerably less common due to high complication rates and the frequency of repeat surgeries associated with limited functional outcomes.

One study reported unilateral replantation in two patients with bilateral lower extremity amputation.[15] Additionally, cross-replantations have been performed in cases of bilateral lower extremity amputation where anatomical replantation was not feasible.[16,17] In adults, replantations involving the ankle and leg are indeed rare and have primarily been documented through case reports, with no established series.

Regaining at least one limb in cases of bilateral amputation encourages surgeons to attempt replantation. Although the literature includes reports of successful ankle and foot replantations, the details are often sparse. While tissue damage varies across replantation surgeries, our case demonstrates preserved range of motion (ROM) in the tibiotalar and subtalar joints, as well as preserved muscle strength. Toe extension and flexion strengths were nearly complete, and there was good protective sensation on the plantar aspect of the foot after a 13-year follow-up period. Functional outcomes were assessed using the AOFAS and Maryland ankle scores, yielding highly satisfactory results.

In conclusion, we present not only a successful case of major replantation but also insights into the outcome and management of a rare and devastating traumatic injury involving the loss of three extremities. Although contraindications for replantation have been established based on specific rules regarding injury type, time elapsed, and patient characteristics, the indications remain controversial. In particular, in cases of bilateral traumatic amputation at the proximal ankle, we believe that at least unilateral replantation should be considered, or the criteria reevaluated. In circumstances where the priority is the patient's life, very successful results can be achieved with timely decision-making and meticulous surgical intervention.

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**Conflict of Interest:** None declared.

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OLGU SUNUMU - *ÖZ*

## Travmatik yaralanmayı takiben iki taraflı alt bacak ve tek taraflı üst ekstremite amputasyonu sonrası tek taraflı bacak replantasyonunun on dört yıllık sonuçları

Travmatik majör ekstremite amputasyonlarıyla sonuçlanan yaralanmalarda, özellikle alt ekstremitede, karar verme aşamasından uygulama ve sonuçlara kadar her aşama tartışma konusu olmaya devam etmektedir. Yüksek mortalite oranına sahip majör amputasyon vakalarını yönetmek hem yaralanma hem de tedavi sürecinde son derece zordur. Bu yazıda, beton makinesiyle yaralanma sonrası, iki taraflı alt ekstremite ve tek taraflı proksimal kol amputasyonu ile sonuçlanan 30 yaşında nadir ve ciddi bir vaka sunulmuştur. Proksimal kol seviyesinden ve bir taraf alt ekstremitede travmatik amputasyon sonrası güdük kapatma işlemi yapılsa da , diğer tarafta proksimal ayak bileği seviyesinde başarılı bir replantasyon gerçekleştirdik. On dört yıllık takip süresi olan hastamızda, AOFAS ve Maryland ayak skorları kullanılarak değerlendirilen titiz bir cerrahi ile tatmin edici bir sonuç elde ettik. Sağlam plantar duyusu olan ve ayak bileği ile ayak parmağı eklemlerinde neredeyse tam hareket açıklığına sahip bir uzuv elde ettik. MESS skorunun klinik uygulaması travmatik amputasyon vakalarında replantasyon endikasyonlarının sınırlarını belirlemiş olsa da, özellikle bilateral alt ekstremite amputasyonları da olmak üzere çoklu travmatik amputasyon vakalarında uzuv kurtarma için göreceli bir endikasyonun düşünülebileceğine inanıyoruz. Bu nedenle, bu tür yaralanmalarda öncelikle hastanın yaşamı ön planda tutulmalı, daha sonra ampute edilen en az bir ekstremite ve güdük iyi değerlendirilmelidir. Güdük kapatılması yerine replantasyon denenmelidir.

Anahtar sözcükler: Alt ekstremite; çoklu travmatik amputasyon; replantasyon.

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# A giant popliteal artery pseudoaneurysm 24 years after gunshot trauma: A rare delayed vascular complication

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## ABSTRACT

Popliteal artery pseudoaneurysms are uncommon and can present as delayed complications of trauma, with clinical symptoms that may not appear until many years after the initial injury. This report describes a remarkable case of a giant popliteal artery pseudoaneurysm diagnosed 24 years following a gunshot wound. The patient, a 71-year-old male, presented with a palpable swelling and restricted movement in the left popliteal region. Notably, he had sustained a gunshot injury to the same limb more than two decades earlier, during which no immediate vascular complications were identified. Diagnostic imaging played a crucial role in this case. Doppler ultrasonography and computed tomography (CT) angiography revealed a large pseudoaneurysm measuring 12 cm in diameter, accompanied by erosion of the adjacent tibial bone. Surgical exploration confirmed the diagnosis of a popliteal artery pseudoaneurysm. The patient underwent successful vascular reconstruction using an autologous saphenous vein graft, which restored arterial continuity and limb function. This case highlights the diagnostic challenges posed by late-presenting popliteal artery pseudoaneurysms. Because symptoms can remain latent for years, these vascular abnormalities may be overlooked or misdiagnosed, particularly when there is a long interval since the initial trauma. The findings underscore the importance of prolonged and vigilant follow-up in patients who have sustained penetrating limb injuries, as pseudoaneurysms can develop decades later. Early diagnosis, facilitated by appropriate imaging modalities such as Doppler ultrasound and CT angiography, is essential for effective management. Prompt surgical intervention can prevent serious complications, including rupture, limb ischemia, and chronic pain, ultimately improving patient outcomes.

**Keywords:** chronic traumatic aneurysm; delayed vascular complication; gunshot wound sequelae; popliteal artery pseudoaneurysm; saphenous vein graft.

## INTRODUCTION

Pseudoaneurysms are pulsatile masses caused by arterial wall disruption, creating a communication between the vessel lumen and a surrounding fibrous capsule. Popliteal artery injuries—particularly from penetrating trauma such as gunshot wounds—pose a significant risk of morbidity and limb loss. Following popliteal artery trauma, pseudoaneurysms may develop acutely or present as delayed complications, with onset reported from hours to decades post-injury.[1]

Most of the knowledge about popliteal artery pseudoaneurysms comes from 20th-century military conflicts involving high-velocity projectiles. Although the incidence may increase due to rising terrorist attacks and advances in trauma care, chronic traumatic popliteal pseudoaneurysms remain rare in civilian practice.[2,3] Notably, in military settings, approximately 50% of trauma-related pseudoaneurysms present more than 30 days after injury.[4]

This case report describes a 71-year-old male diagnosed with a left popliteal artery pseudoaneurysm 24 years after sustaining a gunshot wound in a military zone. This case is notable for the exceptionally delayed presentation of a giant popliteal

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artery pseudoaneurysm, which occurred 24 years after the initial gunshot injury—an extremely rare phenomenon. It underscores the importance of lifelong vascular surveillance in trauma patients, as pseudoaneurysms—such as this giant popliteal artery pseudoaneurysm—can manifest decades after the initial injury. It also highlights the surgical challenges and management strategies associated with delayed diagnosis.

## CASE REPORT

A 71-year-old retired military officer had a history of gunshot wounds to both lower extremities, including the left lower extremity popliteal region, approximately 24 years earlier. Initial assessment at the time revealed no evidence of bone or vascular injury.

In 2017, 17 years after the initial injury, the patient presented to the dermatology outpatient clinic with a two-year history of pruritus and discoloration localized to the left popliteal area. However, no vascular examination was performed at that time. Subsequently, a gradual decrease in the range of motion of the left knee joint was noted.

In May 2024, the patient was admitted to the Cardiovascular Surgery Clinic for further evaluation. Physical examination revealed weak but pulsatile distal pulses in the left leg. The patient exhibited a limited range of motion in the left knee and ankle joints, resulting in a characteristic limping gait with the left knee fixed at approximately 30 degrees of flexion. A noticeable decrease in skin temperature was observed in the left foot compared to the right, indicating potential chronic ischemia. Additionally, there was a significant discrepancy in

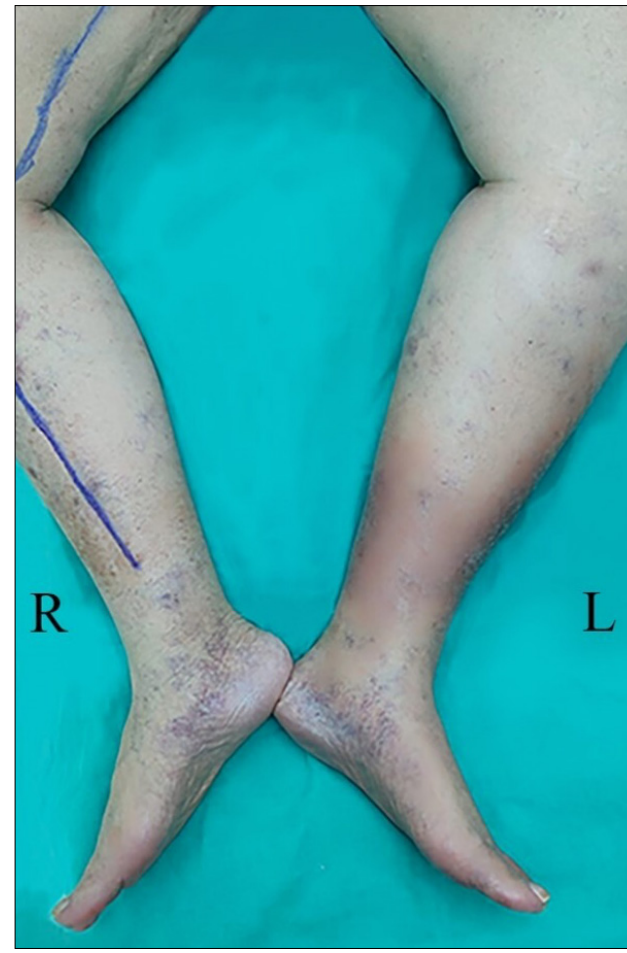


**Figure 1.** Preoperative clinical image of the patient.

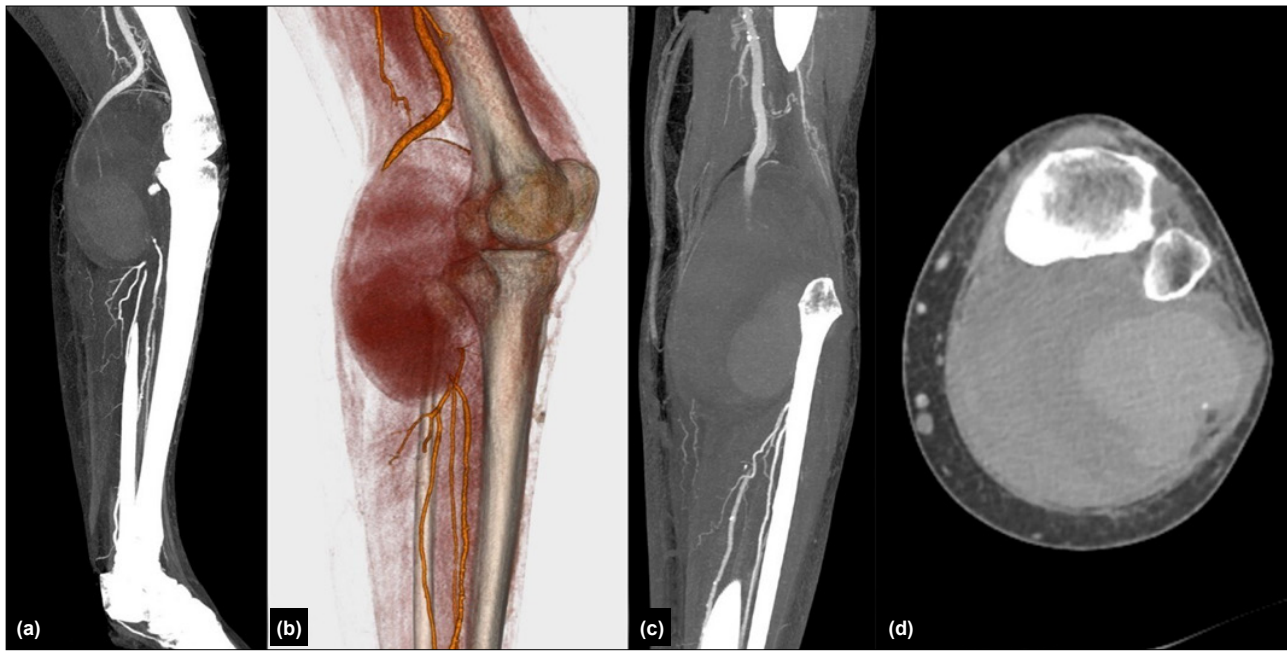


**Figure 2.** Computed tomography (CT) angiography of the patient. **(a,c)** Sagittal and coronal plane CT angiography images of the left lower extremity, respectively. **(b)** Three-dimensional CT angiography image of the left lower extremity. **(d)** Transverse plane CT angiography image of the left lower extremity. This image shows that the aneurysm is very close to rupturing by eroding the skin.

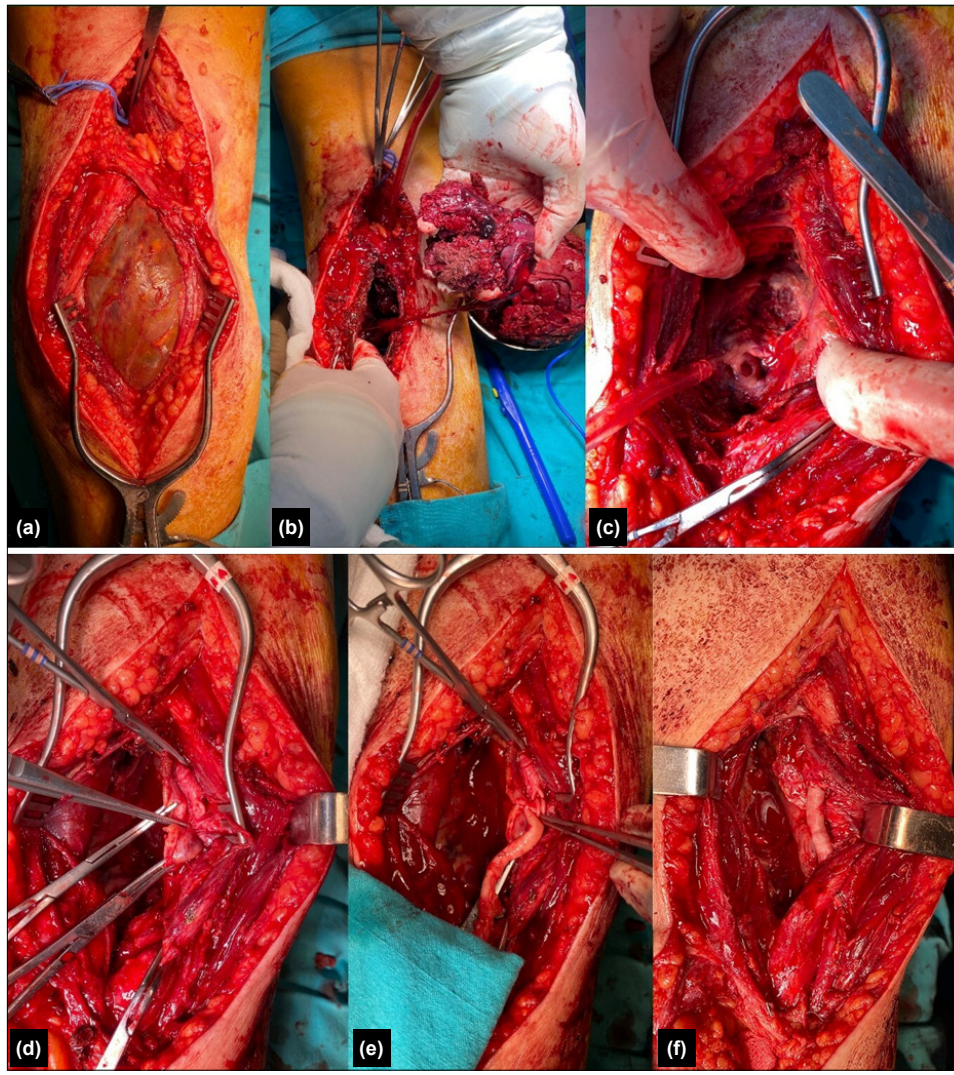


**Figure 3.** Surgical view. **(a)** As the first step of the surgery, a vascular clamp was placed on the proximal popliteal artery, and the aneurysm was inspected. The distal part could not be observed. **(b)** Organized and locally fibrosed material that had accumulated in the aneurysm sac for many years. **(c)** Erosion observed in the posterior tibia after the aneurysm sac was cleaned. **(d)** Identification of the proximal and distal ends of the popliteal artery. **(e,f)** Bypass with a saphenous vein and postoperative view.

limb circumference, with the left lower extremity measuring 10 cm greater in diameter than the right below the knee. Venous stasis dermatitis was also diagnosed in the left ankle region (Fig. 1).

Vascular Doppler ultrasound demonstrated patency of the left common femoral artery, deep femoral artery, and superficial femoral artery, with no critical stenosis or occlusion. The left dorsalis pedis and anterior tibial arteries exhibited a monophasic flow pattern, while the left posterior tibial and popliteal arteries showed biphasic flow. An aneurysmal dilation was noted in the left popliteal artery.

Computed tomography angiography (CTA) of the lower extremities revealed a hypodense, well-circumscribed lesion measuring approximately 12 cm in diameter in the left popliteal fossa. The lesion exhibited a lamellar peripheral appearance and contained a 67×56 mm hyperdense component. The adjacent popliteal artery appeared compressed by the lesion. The differential diagnosis included a peripherally thrombosed pseudoaneurysm or a hemorrhagic mass. Additionally, heterogeneous striations were observed in the surrounding adipose tissue, along with cortical destruction and remodeling of the posterior tibial bone (Fig. 2).

The patient underwent open surgical repair under general anesthesia. Using a posterior approach, careful dissection allowed for excision of the pseudoaneurysm sac. Approximately 1.5 liters of organized thrombus were evacuated from the aneurysm cavity. Notably, cortical erosion of the posterior aspect of the tibia adjacent to the aneurysm was observed. Arterial continuity was re-established by interposing a re-

versed autologous great saphenous vein graft between the proximal and distal segments of the popliteal artery (Fig. 3).

The patient's postoperative course was uneventful, and he was discharged on the fifth postoperative day. At the control examination on postoperative day 5, cyanosis in the left lower extremity had improved. Range of motion in the left knee improved by approximately 50%, while ankle joint mobility improved by 100%. A physiotherapy program was initiated to further enhance functional recovery.

## DISCUSSION

Vascular complications following gunshot wounds may manifest long after the initial injury.[5] Pseudoaneurysms are a well-documented complication of popliteal artery trauma and can develop years after the inciting event.[4,6,7] Clinically, a popliteal artery pseudoaneurysm typically presents as a pulsatile swelling in the popliteal fossa, often accompanied by localized pain or discomfort.[8] Accurate diagnosis relies heavily on imaging modalities such as duplex ultrasound, CTA, and magnetic resonance angiography, which are essential for treatment planning.[9]

In this case, the pseudoaneurysm presented after a notably long asymptomatic interval of approximately 17 years post-injury. The lesion was localized precisely at the site of the prior trauma, with no intervening vascular insults to suggest a degenerative origin. Intraoperative findings importantly included cortical erosion of the adjacent tibia caused by the mass effect of the aneurysmal sac, a feature more indicative of chronic mechanical compression than acute pathology. The absence of atherosclerotic changes in the femoropopliteal artery, coupled with the patient's lack of systemic risk factors, effectively excludes atherosclerotic true aneurysm or other degenerative causes. Furthermore, the large volume of organized thrombus within the sac suggests a prolonged pathological process, aligning more with the history of trauma than with a recent rupture. Surgical exploration confirmed the diagnosis of a popliteal artery pseudoaneurysm. While it is acknowledged that chronic traumatic pseudoaneurysms may remain silent for decades, the onset of symptoms in this case reflects the natural progression of such lesions rather than an acute event.

To our knowledge, this is one of the most delayed presentations of traumatic popliteal artery pseudoaneurysm reported in the literature. Although the 24-year latency period is unusually long, it is consistent with known mechanisms of delayed pseudoaneurysm development, where initially contained vascular injuries may gradually deteriorate under persistent hemodynamic stress on weakened arterial walls. This case highlights the importance of considering pseudoaneurysms in the differential diagnosis of patients with remote penetrating trauma, regardless of the time elapsed since injury, as these lesions can present with subtle and insidious symptoms that may first be evaluated by non-vascular specialists. Such a delayed diagnosis may predispose patients to complications, including knee contracture and neurovascular compromise. Notably, the patient's initial presentation to dermatology with nonspecific symptoms of redness and itching preceded the vascular diagnosis by seven years, underscoring the importance of a multidisciplinary approach and comprehensive evaluation in patients with a history of trauma.

Surgical repair remains the gold standard for managing popliteal artery pseudoaneurysms.[10] Given the patient's advanced age, the aneurysm's large size, associated tibial bone erosion, and extensive tissue adhesions, open surgical repair was preferred over endovascular approaches. The choice of an autologous saphenous vein graft was guided by its lower infection risk, superior biocompatibility, and better long-term patency compared to synthetic grafts.[11]

## CONCLUSION

This case underscores the importance of considering delayed popliteal artery pseudoaneurysm in patients with a remote history of trauma. Prompt recognition and vascular evaluation are essential to prevent serious complications, ensuring timely management that improves patient outcomes, preserves limb function, and enhances quality of life.

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**Peer-review:** Externally peer-reviewed.

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OLGU SUNUMU - *ÖZ*

## Ateşli silah yaralanmasından 24 yıl sonra gelişen dev popliteal arter psödoanevrizması: Nadir bir gecikmiş vasküler komplikasyon

Popliteal arter psödoanevrizmaları nadir görülen ve travma sonrası gecikmiş bir komplikasyon olarak ortaya çıkabilen durumlardır. Klinik semptomlar bazen başlangıç yaralanmadan yıllar sonra bile görülebilir. Bu olguda, 24 yıl önce ateşli silah yaralanması sonrası gelişen dev popliteal arter psödoanevrizması olan dikkat çekici bir vaka sunulmaktadır. 71 yaşındaki erkek hasta, sol popliteal bölgede şişlik ve hareket kısıtlılığı şikayetiyle başvurmuştu. Hastanın aynı bacağına 24 yıl önce kurşun yarası aldığı, ancak o dönemde herhangi bir vasküler komplikasyon tespit edilmediği öğrenildi. Tanısal görüntüleme bu olguda kritik rol oynadı. Doppler ultrasonografi ve bilgisayarlı tomografi (BT) anjiyografi, 12 cm çapında dev bir psödoanevrizma ve komşu tibia kemiğinde erozyon olduğunu gösterdi. Cerrahi eksplorasyon ile popliteal arter psödoanevrizması tanısı doğrulandı. Hasta, otolog safen ven grefti kullanılarak başarılı bir vasküler rekonstrüksiyon geçirdi ve arteriyel devamlılık ile ekstremite fonksiyonu sağlandı. Bu olgu, geç başvuran popliteal arter psödoanevrizmalarının tanısal zorluklarını vurgulamaktadır. Semptomlar yıllarca gizli kalabileceğinden, özellikle travma üzerinden uzun zaman geçmişse bu vasküler anomaliler gözden kaçabilir veya yanlış tanı alabilir. Bu bulgular, penetran ekstremite yaralanması olan hastalarda uzun süreli ve dikkatli takibin önemini ortaya koymaktadır. Doppler ultrasonografi ve BT anjiyografi gibi uygun görüntüleme yöntemleri erken tanı, etkin tedavi için hayati öneme sahiptir. Zamanında cerrahi müdahale, rüptür, ekstremite iskemisi veya kronik ağrı gibi ciddi komplikasyonları önleyerek hasta sonuçlarını iyileştirebilir.

Anahtar sözcükler: Ateşli silah yaralanması sekeli; gecikmiş vasküler komplikasyon; kronik travmatik anevrizma; popliteal arter psödoanevrizması; safen ven grefti.

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ORIGINAL ARTICLE

# Massive simple renal cyst causing colonic obstruction: The largest documented case in the literature

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## ABSTRACT

Simple renal cysts are often asymptomatic; however, they can sometimes cause clinical symptoms when they reach a large size. In this report, we present the case of a 78-year-old male patient who visited the emergency department with symptoms of nausea, vomiting, and abdominal swelling near the belly button. The patient had diabetes mellitus controlled with metformin. Physical examination revealed a 5×5 cm umbilical swelling, abdominal asymmetry, and palpable fluctuation on the left side of the abdomen. Laboratory tests showed elevated white blood cell count and creatinine levels. Abdominal computed tomography revealed herniated segments of the small intestine emerging from the umbilical area and partial obstruction of the sigmoid colon, caused by a 28×30 cm cyst in the left kidney and a 15×12 cm cyst in the right kidney, with progressive narrowing in the diameter. The patient underwent a surgical procedure involving unroofing of the bilateral cyst walls, aspiration of 15 liters of fluid, and mesh repair of the umbilical hernia. He was discharged on postoperative day six without complications. This case highlights the potential of giant renal cysts to cause intestinal obstruction and underscores the importance of considering this etiology in patients presenting with abdominal symptoms. Imaging methods such as computed tomography, ultrasonography, and magnetic resonance imaging are vital for identifying and assessing renal cysts and their potential complications. Therapeutic approaches include percutaneous aspiration, sclerotherapy, laparoscopic deroofing, and surgical intervention in cases of significant complications or large cysts.

**Keywords:** Cyst; emergency surgery; kidney; obstruction.

## INTRODUCTION

Renal cysts, although frequently benign and asymptomatic, can occasionally result in complications such as intestinal obstruction due to their size or location, which may exert pressure on adjacent structures. This pressure can lead to symptoms including abdominal pain, bloating, and alterations in bowel habits, necessitating vigilant monitoring and potential intervention to alleviate obstruction. In severe cases, surgical intervention may be required to excise the cyst or relieve pressure on the intestine. This report describes a case of intestinal obstruction caused by giant, bilateral renal cysts.

## CASE REPORT

A 78-year-old male patient was admitted to the emergency department with complaints of nausea, vomiting, and swelling of the umbilical region. His medical history indicated that he had been experiencing abdominal swelling for a decade, which he occasionally managed to manually reduce. The patient was receiving treatment for diabetes mellitus with oral antidiabetic medication, specifically metformin, at a dose of 2×1 g. The patient had no history of surgical procedures. Upon examination, his vital signs were as follows: blood pressure, 110/70 mm Hg; pulse rate, 125 bpm; and body temperature, 37°C. On physical examination, a swelling of approximately 5×5 cm was detected at the umbilicus, accompanied by notable abdominal asymmetry and palpable fluctuations on the left side of the abdomen. Laboratory analyses revealed a white blood cell count of 24.70×109/L, with neutrophils at 21.66×109/L, and a creatinine level of 1.56 mg/dL. Plain abdominal com-

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puted tomography revealed herniated segments of the small bowel emanating from the umbilical region. Furthermore, a partial obstruction of the sigmoid colon was identified, which was attributed to a 28×30 cm cyst likely originating from the left kidney and a 15×12 cm cyst likely originating from the right kidney. The patient was assessed for mechanical obstruction caused by an umbilical hernia and subsequently underwent surgery following nasogastric tube drainage. The segment of the small intestine distal to the herniated area exhibited dilation, necessitating the extension of the surgical incision. During laparotomy, the lumen of the sigmoid colon was markedly constricted due to adhesion of the cyst to the parietal peritoneum. Solid stool was detected in segments of the colon proximal to the site of construction. These findings suggest that the clinical manifestation resulted from luminal narrowing of the sigmoid colon due to extrinsic compression by the cyst. Bilateral cyst wall unroofing was performed, resulting in the aspiration of 15 liters of yellowish fluid, which exhibited normal protein and lactic dehydrogenase levels (Fig. 1). Cytological examination revealed no malignant cells, and mesh repair of the umbilical hernia was performed. The patient was discharged on the sixth postoperative day without

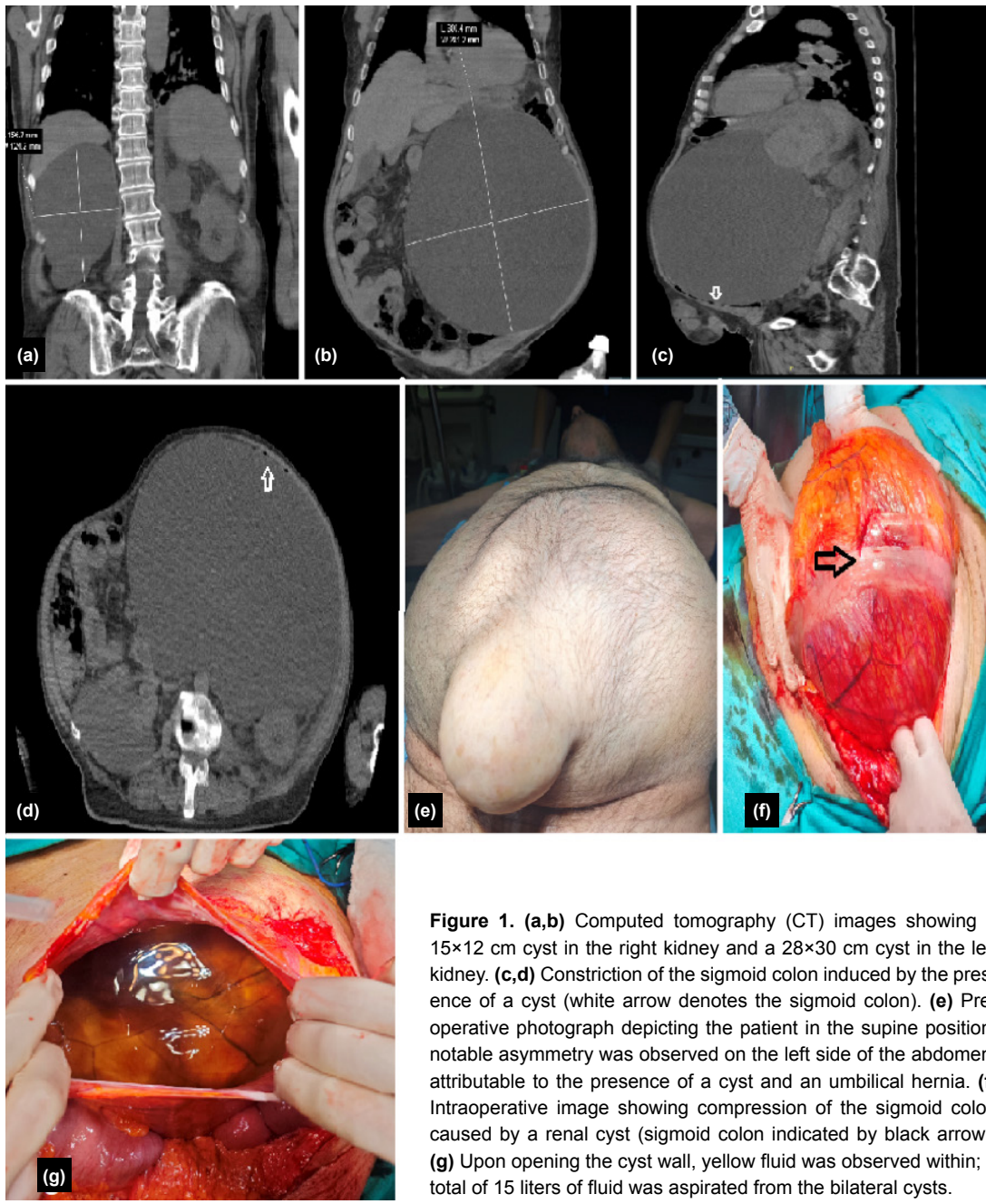


**Figure 1. (a,b)** Computed tomography (CT) images showing a 15×12 cm cyst in the right kidney and a 28×30 cm cyst in the left kidney. **(c,d)** Constriction of the sigmoid colon induced by the presence of a cyst (white arrow denotes the sigmoid colon). **(e)** Preoperative photograph depicting the patient in the supine position; notable asymmetry was observed on the left side of the abdomen, attributable to the presence of a cyst and an umbilical hernia. **(f)** Intraoperative image showing compression of the sigmoid colon caused by a renal cyst (sigmoid colon indicated by black arrow). **(g)** Upon opening the cyst wall, yellow fluid was observed within; a total of 15 liters of fluid was aspirated from the bilateral cysts.

complications. Written informed consent was obtained from the patient for the publication of this case report.

## DISCUSSION

Bilateral giant simple kidney cysts constitute an uncommon yet notable renal pathology that manifests with a diverse array of symptoms, complications, and diagnostic complexities. Patients frequently report symptoms such as abdominal distension, suprapubic discomfort, anorexia, and alterations in bowel habits. These clinical representations can potentially overlap with other conditions, including malignant ascites or obesity, thereby increasing the risk of misdiagnosis.[1] In certain instances, these factors may cause discomfort, vomiting, and the presence of blood in the vomit due to gastrointestinal tract constriction.[2] Abdominal pain and distension are common symptoms. A case study documented a patient with a 27 cm renal cyst who exhibited diffuse abdominal tenderness and pronounced distension.[3] Another investigation described a patient with a 22 cm cyst who experienced right flank pain and hyperkalemia.[4]

Intestinal obstruction is a major medical complication. Numerous cases of substantial renal cysts have been reported to induce partial or complete bowel obstruction (Table 1). For example, a 77-year-old male presenting with a 27 cm cyst experienced colonic obstruction that resolved after cyst drainage.[3] Similarly, a female patient with a 16 cm cyst developed large bowel obstruction attributable to compression of the descending colon.[5] In another case, a 42-year-old female patient with autosomal dominant polycystic kidney disease (ADPKD) experienced small bowel obstruction linked to the expansion of her renal anatomy.[6] Moreover, a 75-year-old woman with ADPKD developed strangulation necrosis of the intestine due to a massive cyst.[7] Upon reviewing the cases documented in the literature, the present case is characterized by the largest simple cyst reported to have resulted in intestinal obstruction.

Computed tomography (CT) is the leading diagnostic tool for detecting and assessing renal cysts. CT imaging facilitates a comprehensive evaluation of cyst size, anatomical location, and complexity, thereby aiding in the diagnosis of potential complications such as intestinal obstruction.[1,2] Ultrasound is commonly used for initial detection and monitoring, particularly because it is noninvasive.[11] Furthermore, the use of magnetic resonance imaging (MRI), endoscopic ultrasound (EUS), and technetium-99m diethylenetriamine pentaacetic acid (99mTc-DTPA) renal dynamic studies can provide additional diagnostic insights.

Therapeutic approaches include percutaneous aspiration, combined with sclerotherapy and laparoscopic deroofing. In cases involving significant complications or the presence of large cysts, surgical intervention may be indicated, as evidenced in the current case.[11,12,3] In some instances, unilateral nephrectomy alleviates partial intestinal obstruction caused by cyst compression.[13] In our case, the initial diagnosis sug-

**Table 1.** Reported cases of intestinal obstruction secondary to renal cysts in the literature

| Author (Year) | Symptoms | Diagnosis Method | Cyst Type<br>Cyst Size (cm) | Treatment or Outcome |
|---|---|---|---|---|
| (Ferraz de Arruda et al., 2011)[8] | Macroscopic hematuria, chronic abdominal pain | CT | ADPKD 43×19×16 (multicystic kidney size) | Nephrectomy |
| (Floyd et al., 2012)[1] | Suprapubic pain, abdominal distension, anorexia | CT | Simple 28×14×16 | Percutaneous drainage |
| Harrington et al., 2012)[3] | Abdominal pain, abdominal distension, poor appetite | CT | Simple 27 | Percutaneous drainage |
| (Kakinoki et al., 2002)[6] | Abdominal pain, vomiting | CT | ADPKD<br>25×20.5×12<br>25×15.5×11<br>Bilateral multicystic kidney | Percutaneous drainage |
| (Fernández-de la Varga et al., 2022)[5] | Abdominal pain, tenderness | CT | Simple 16 | Percutaneous drainage |
| (Vos & Laureys, 2009)[9] | Asthenia, anorexia, intermittent watery diarrhea | CT | Simple 15 | Percutaneous drainage |
| (Teparak & Tawanwongsri, 2022) [10] | Acute abdominal pain | CT | Simple<br>Multiple (3.5 to 13.0) | Referred for kidney transplantation due to chronic kidney disease |
| (Gonçalves et al., 2012)[13] | Fever (>39°C), abdominal distension | CT | ADPKD 11 | Nephrectomy |

ADPKD: Autosomal dominant polycystic kidney disease; CT: Computed tomography.

gested mechanical obstruction due to an umbilical hernia, leading us to pursue surgical intervention. In the absence of clinical signs of intestinal obstruction, percutaneous aspiration and sclerotherapy of the cyst could have been considered, with subsequent hernia repair.

Aspiration and sclerotherapy are associated with high success rates, ranging from 65% to 98.9%, and shorter procedure duration, although they carry higher recurrence rates.[14] Surgical unroofing offers certain advantages such as definitive treatment and prevention of recurrence but also presents disadvantages, including greater invasiveness and longer recovery periods.

## CONCLUSION

In conclusion, although renal cysts are frequently asymptomatic, they may require urgent surgical intervention when they reach substantial dimensions, as observed in this case. Clinicians should consider renal cysts as potential etiological factors for mechanical intestinal obstruction due to their compressive effects.

**Informed Consent:** Written informed consent was obtained from the patient for the publication of this case report.

**Peer-review:** Externally peer-reviewed.

**Authorship Contributions:** Concept: O.U.Ö.; Design: O.U.Ö.; Supervision: O.U.Ö.; Resource: O.U.Ö.; Materials: O.U.Ö.; Data collection and/or processing: O.U.Ö.; Analysis and/or interpretation: O.U.Ö.; Literature review: O.U.Ö.; Writing: O.U.Ö.; Critical review: O.U.Ö.

**Conflict of Interest:** None declared.

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OLGU SUNUMU - *ÖZ*

## Kolonik obstrüksiyona neden olan dev basit renal kist: literatürde bildirilen en büyük olgu

Böbrek kistleri çoğu zaman asemptomatik seyretse de bazen büyük boyutlara ulaşarak klinik bulgu verebilir. Bu olgu sunumunda, acil servise bulantı, kusma ve göbek deliği yakınında şişlik şikayetiyle gelen 78 yaşında bir erkek hasta sunulmaktadır. Hasta diyabetes mellitus nedeniyle oral antidiyabetik (Metformin) kullanmaktaydı. Fizik muayenede umblikal bölgede yaklaşık 5x5 santim boyutunda şişlik, abdominal asimetri ve batın sol yarısında palpasyonla fluktuasyon veren kitlesel görünüm mevcuttu.Laboratuar bulguları yükselmiş beyaz küre ve serum kreatinin dışında normaldi. Abdominal tomografi incelemesinde umblikal bölgede herni defekti ve bu defekt içerisine herniye olmuş ince barsak anslarının yanı sıra sol böbrekten kaynaklanan 28x30 santim, sağ böbrekten kaynaklanan 15x12 santim boyutunda kist mevcuttu. Sigmoid kolon çapı ileri derecede incelmişti. Hasta operasyona alınarak bilateral böbrek kistlerine deroofing uygulandı. Kistlerin içerisinden yaklaşık 15 litre sıvı aspire edildi. Herni defekti mesh ile onarıldı.Hasta postoperatif 6. gün komplikasyonsuz şekilde taburcu edildi. Bu vaka, dev böbrek kistlerinin bağırsak tıkanıklığını tetikleme potansiyelini ve abdominal semptomlarla başvuran hastalarda bu etiyolojinin göz önünde bulundurulması gerekliliğini vurgulamaktadır. Bilgisayarlı tomografi, ultrason muayenesi ve manyetik rezonans gibi görüntüleme yöntemleri böbrek kistlerini ve potansiyel komplikasyonlarını tanımak için büyük öneme sahiptir. Terapötik yaklaşımlar arasında perkütan aspirasyon, skleroterapi, laparoskopik deroofing ve önemli komplikasyonların veya büyük kistlerin olduğu durumlarda cerrahi müdahale yer almaktadır.

Anahtar sözcükler: Acil cerrahi; böbrek; kist; obstrüksiyon.

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ORIGINAL ARTICLE

# A rare case of abdominal gunshot trauma: Isolated common bile duct injury within the portal triad accompanied by liver and lung injury

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## ABSTRACT

Injuries to the common bile duct (CBD) have been reported in 0.4-0.5% of penetrating trauma cases across several series. Gunshot wounds pose unique challenges due to the thermal injury caused by the projectile, combined with the close anatomical proximity of the CBD, portal vein, and hepatic artery within the hepatoduodenal ligament. This proximity often results in combined injuries to these vital structures, which are associated with high perioperative morbidity or mortality. Isolated injuries to the CBD within the hepatoduodenal ligament are exceptionally rare, given the structure's protective location and the interconnected nature of its components. The management of isolated CBD injuries remains a topic of ongoing debate. Here, we present a rare case of a gunshot wound causing an isolated CBD injury within the portal triad, accompanied by concomitant injuries to other intra-abdominal and thoracic organs.We present a 41-year-old male patient with an isolated CBD injury within the portal triad, accompanied by liver and lung injury sustained from a gunshot. Emergency computed tomography (CT) imaging revealed a bullet trajectory of 14 cm extending from liver segment 6 to segment 4B, associated with laceration and contusion. Exploration revealed thermal damage to the gallbladder wall, and the integrity of the hepatoduodenal ligament was disrupted. A cholecystectomy was performed, and dissection of the hepatoduodenal ligament revealed that approximately 70% of the CBD wall was transected. Importantly, the portal vein and hepatic artery remained intact. The proximal CBD was clamped, and complete transection of the duct was performed. Reconstruction involved a Roux-en-Y hepaticojejunostomy after preparing the jejunal segment. The patient experienced an uneventful recovery and was discharged on postoperative day 7 following drain removal. At the 6-month follow-up, the patient remained asymptomatic with no evidence of late complications.We believe that dissection of the hepatoduodenal ligament is necessary in patients with penetrating injuries near the hepatoduodenal ligament after hemostasis. Hepaticojejunostomy is an effective surgical treatment for patients with full-thickness transection of the CBD and reduces the risk of postoperative complications.

**Keywords:** Abdominal trauma; common bile duct; gunshot trauma; hepaticojejunostomy.

## INTRODUCTION

In penetrating abdominal trauma, the most commonly injured organs are the liver and small intestine; however, injuries involving the hepatoduodenal ligament are relatively rare.[1] The hepatoduodenal ligament contains three critical anatomical structures: the hepatic artery, portal vein, and common bile duct (CBD).[2] Injuries to the CBD have been reported in 0.4-0.5% of penetrating trauma cases across several series.[3] Successful management of extrahepatic biliary tract injuries is crucial, as these injuries are associated with high morbidity rates, primarily due to the formation of biliary fistulas, strictures, and delays in diagnosis.[4]

Gunshot wounds pose unique challenges due to the thermal injury caused by the projectile, combined with the close anatomical proximity of the CBD, portal vein, and hepatic artery

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within the hepatoduodenal ligament. This proximity often results in combined injuries to these vital structures, which are associated with high perioperative morbidity or mortality.[5,6] Many patients either experience mortality before reaching the hospital or experience severe perioperative complications. Initial management strategies for these injuries typically involve damage control principles, such as abdominal packing and staged repair.[7] Immediate reconstruction is often unfeasible due to contamination and hemodynamic instability, necessitating the placement of abdominal drains and external biliary drainage. Isolated injuries to the CBD within the hepatoduodenal ligament are exceptionally rare, given the structure's protective location and the interconnected nature of its components. The management of isolated CBD injuries remains a topic of ongoing debate.[8,9]

Here, we present a rare case of a gunshot injury resulting in an isolated CBD injury without damage to other components of the hepatoduodenal ligament, accompanied by liver and lung injury. We aim to highlight our approach to managing this unique case, emphasizing the strategies employed in the treatment of extrahepatic biliary duct injuries caused by penetrating trauma.

## CASE REPORT

We present a 41-year-old male patient with an isolated CBD injury within the portal triad, accompanied by liver and lung injury sustained from a gunshot. The patient arrived at the emergency department approximately 1 hour post-injury. Upon admission, he was conscious and hemodynamically stable. Physical examination revealed a 1×1 cm bullet entry wound 1 cm below the right scapula posteriorly and a 1×2 cm exit wound 2 cm below the xiphoid process anteriorly. Abdominal examination identified findings consistent with generalized peritonitis.

Emergency computed tomography (CT) imaging revealed a bullet trajectory of 14 cm, extending from liver segment 6 to segment 4B, associated with laceration and contusion. The gallbladder and both intrahepatic and extrahepatic bile ducts appeared normal (Figure 1). Additionally, CT findings included intra-abdominal fluid of hemorrhagic density, lacerations in the right lung, a right hemothorax, and lacerations in the right kidney. Based on these findings, the patient underwent emergency surgery 20 minutes after admission. Informed consent was obtained from the patient and his relatives prior to the surgical procedure, including permission for the use and publication of related images and videos.

### Operative Findings and Management

The patient was positioned supine, and a median xiphoidopubic incision was performed. Exploration revealed 150-200 mL of hemorrhagic fluid within the abdominal cavity. A parenchymal injury was identified in the liver between segments 4 and 5, measuring approximately 1 cm in depth and 7–8 cm in length. There was no evidence of injury in the lesser sac. The bullet's trajectory caused thermal damage to the gallbladder wall, and the integrity of the hepatoduodenal ligament was disrupted.

Following a Pringle maneuver, hemostasis was achieved in the liver parenchymal injury using bipolar cautery. A cholecystectomy was performed, and dissection of the hepatoduodenal ligament revealed that approximately 70% of the CBD wall was transected. Importantly, the portal vein and hepatic artery remained intact. The proximal CBD was clamped, and complete transection of the duct was performed. Reconstruction involved a Roux-en-Y hepaticojejunostomy after preparing the jejunal segment (Figure 2).

### Postoperative Course and Follow-Up

The patient experienced an uneventful recovery and was discharged on postoperative day 7 following drain removal. The follow-up blood results obtained on postoperative day 20 were as follows: SGOT 12 U/L, SGPT 37 U/L, ALP 64 U/L, GGT 83 U/L, total bilirubin 0.25 mg/dL, direct bilirubin 0.11 mg/dL. At the 6-month follow-up, the patient remained asymptomatic with no evidence of late complications.

This case highlights the challenges and surgical management strategies in treating isolated CBD injuries within the portal triad resulting from penetrating trauma.

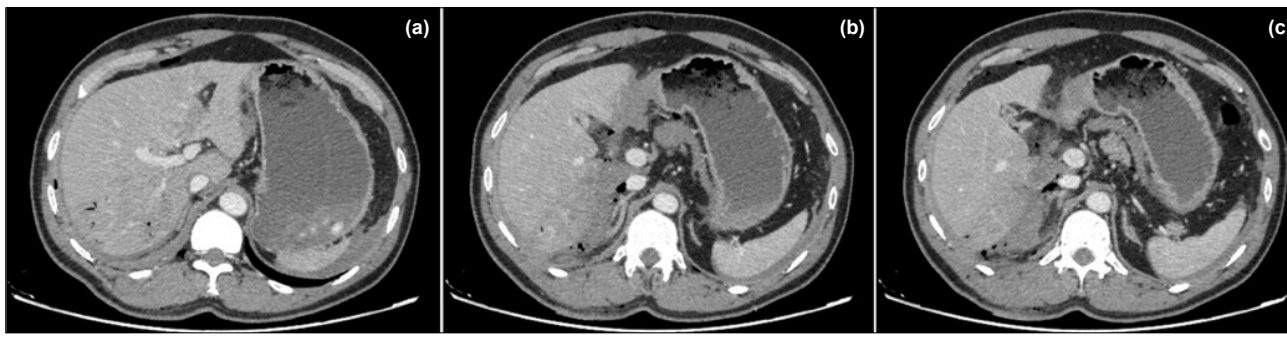


**Figure 1.** Laceration and contusion areas in the liver parenchyma **(a,b)** and free fluid with hemorrhagic density around the common bile duct **(c)**.

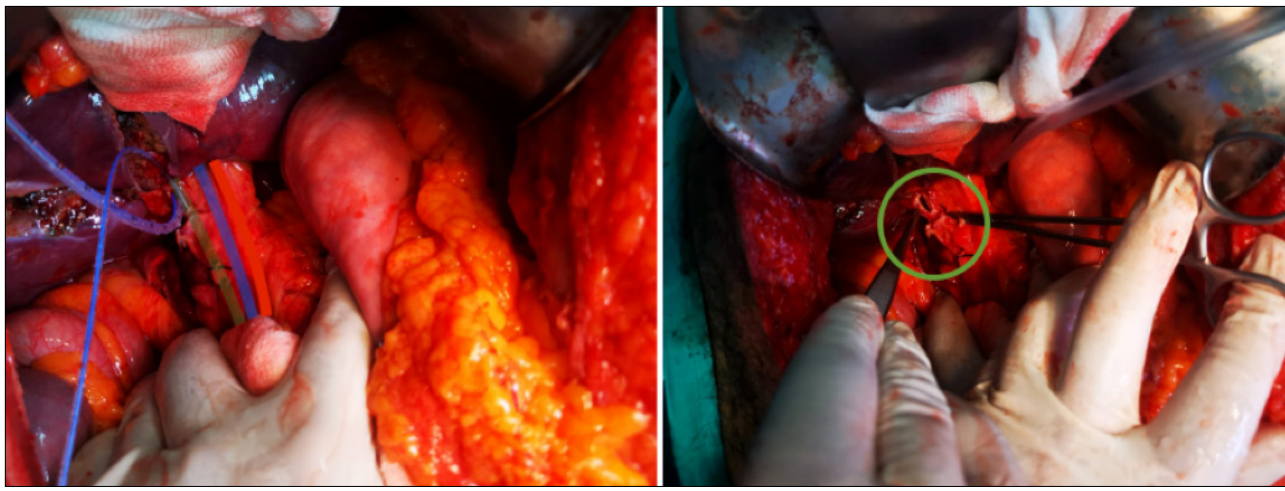

**Figure 2.** Identification of the common bile duct and the proximal duct after transection.

## DISCUSSION

Penetrating abdominal trauma due to gunshot is a critical and often life-threatening condition that requires prompt diagnosis and management. Among the structures affected in such injuries, the biliary system is rarely involved due to its deep location. Injury to the common bile duct is particularly uncommon and represents a difficult surgical challenge due to its anatomical position.[10,11] The limited number of patients and studies in the literature highlights that treatment modalities are often tailored specifically to the patient, and there is no established consensus.

In our case report, an exploratory laparotomy was performed on a patient with peritonitis and hemorrhagic fluid detected in the abdominal cavity on imaging, along with a liver injury. Following hemostasis, dissection of the hepatoduodenal ligament was carried out due to suspected injury in this area. The portal vein and hepatic artery were found to be intact, while an isolated CBD injury was identified.

In a meta-analysis conducted by Pereira et al.[12] in 2019, it was reported that deep liver laceration, intra-abdominal bile, hematoma of the porta hepatis, or bile-stained porta hepatis could be used as indicators for identifying bile duct injury in patients undergoing laparotomy. In the presence of these indicators, it was recommended that the surgeon suspect bile duct injury and consider diagnostic approaches such as intraoperative cholangiography, Kocher's maneuver, or extensive dissection of the porta hepatis. Due to the presence of an injury near the hepatic hilum in our patient and damage to the hepatoduodenal ligament, we deemed hepatoduodenal ligament dissection to be appropriate. This approach allowed us to identify the CBD injury effectively.

Following the identification of CBD injury, various repair approaches are available. In a case report from Taiwan presenting four cases of extrahepatic bile duct injury, it was reported that a patient with CBD injury due to penetrating abdominal trauma underwent primary repair with T-tube choledochostomy, and no additional complications were observed during follow-up. Additionally, the same study compiled results from studies conducted between 1985 and 1996 evaluating patients with bile duct injuries caused by trauma. Among a total of 75 patients, 35 underwent primary repair with T-tube choledochostomy, 18 underwent hepaticojejunostomy, 5 underwent liver resection, and 1 underwent the Whipple procedure. Among the patients treated with primary repair and T-tube choledochostomy, 7 experienced biliary morbidity, and 6 had mortality, whereas among those who underwent hepaticojejunostomy, 5 had biliary morbidity, and 1 had mortality. The study concluded that while no significant differences were found between treatment modalities, early diagnosis and injury-specific treatment selection were emphasized as crucial factors.[4] In our patient, following hepatoduodenal ligament dissection, near-complete transection of the CBD was observed, leading to complete transection being performed. The patient subsequently underwent Roux-en-Y hepaticojejunostomy.

While reviewing the literature, studies show that it is evident that the surgical technique for CBD injuries should be selected based on the type of injury. For incomplete transections, techniques such as primary repair, primary repair with T-tube placement, or end-to-end anastomosis with T-tube placement have been described. In cases of complete transections, surgical options include end-to-end anastomosis with T-tube placement, end-to-end anastomosis, or hepaticojejunostomy. Following T-tube applications, biliocutaneous fistula formation is a common complication, while stricture formation is frequently observed after primary repair and end-to-end anastomosis of the bile duct. For this reason, hepaticojejunostomy is recommended as the preferred surgical treatment for CBD injuries.[13-15]

Non-surgical treatment approaches for extrahepatic bile duct

injuries caused by penetrating trauma have been reported in the literature. Kleiner et al.[16] described a case in which a hemodynamically stable patient with a bile duct injury from a stabbing was successfully treated with endoscopic stenting. After duodenal repair and hemostasis during laparotomy, the patient developed bile leakage in the postoperative period, confirmed by a HIDA scan. The injury was managed with ERCP and intracholedochal stenting. The patient recovered without complications, with the stent removed two months later and the biliary system found to be intact.

In patients with penetrating right upper quadrant injuries managed with selective nonoperative observation, where bile duct injuries are detected during nonoperative follow-up, or in cases where bile duct injuries are not identified during laparotomy but biliary pathology is observed in the postoperative period, some studies have shown that endoscopic treatment methods are successful in 90-95% of cases.[17-19] Therefore, in these patients, diagnostic methods such as magnetic resonance cholangiography with gadoxetic acid disodium, HIDA scan, ERCP, or even diagnostic peritoneal lavage can be used to determine the nature of intra-abdominal fluid if present.[12,20] In patients treated with endoscopic stenting, the risks of complications such as bile leakage, stent migration, and the need for a second invasive intervention should be kept in mind.[21,22]

## CONCLUSION

We believe that dissection of the hepatoduodenal ligament is necessary in patients with penetrating injuries near the hepatoduodenal ligament after hemostasis. Hepaticojejunostomy is an effective surgical treatment for patients with full-thickness transection of the CBD and reduces the risk of postoperative complications.

**Informed Consent:** Informed consent was obtained from the patient and his relatives prior to the surgical procedure, including permission for the use and publication of related images and videos.

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ORİJİNAL ÇALIŞMA - *ÖZ*

# Ateşli silah yaralanmasına bağlı nadir bir olgu: Akciğer ve karaciğer yaralanmasıyla birlikte portal triad içerisinde izole koledok kanalı yaralanması

Koledok kanalı yaralanmaları, penetran batın travması vakalarının %0.4-0.5'inde görülmektedir. Ateşli silah yaralanmaları, merminin neden olduğu termal hasarın yanı sıra, koledok kanalı, portal ven ve hepatik arterin hepatoduodenal ligaman içerisindeki yakın anatomik komşuluğu nedeniyle tüm yapılarda hasar meydana getirebilir. Bu yakınlık, genellikle bu hayati yapıların bir arada yaralanmasına yol açarak yüksek perioperatif morbidite veya mortalite ile ilişkilidir. Hepatoduodenal ligaman içerisindeki izole koledok kanalı yaralanmaları son derece nadirdir. İzole koledok kanalı yaralanmalarının yönetimi halen tartışmalı bir konudur. Olgu raporumuzda, karaciğer ve akciğer yaralanmasına eşlik eden hepatoduodenal ligamanın diğer bileşenlerine zarar vermeden portal triad içerisinde yalnızca koledok kanalının yaralandığı nadir bir ateşli silah yaralanması vakasını sunmaktayız. 41 yaşında, ateşli silah yaralanmasına bağlı koledok kanalı yaralanması nedeniyle acil servise başvuran erkek hastayı sunuyoruz. Acil serviste çekilen bilgisayarlı tomografi (BT) görüntülemesinde, karaciğerin 6. segmentinden 4B segmentine kadar uzanan 14 cm'lik bir mermi yolunu ve buna bağlı laserasyon ve kontüzyonu olduğu saptandı. Eksplorasyonda safra kesesi duvarında termal hasar tespit edildi ve hepatoduodenal ligamanın bütünlüğünün bozulmuş olduğu görüldü. Hastaya kolesistektomi uygulandı ve hepatoduodenal ligamanın diseksiyonu uygulanması ardından koledok duvarının yaklaşık %70 oranında açılmış olduğu tespit edildi. Portal ven ve hepatik arter salim izlendi. Proksimal koledok kanalı klemplendi ve tam transeksiyon uygulandı. Roux-en-Y hepatikojejunostomi ile rekonstrüksiyon uygulandı. Hasta postoperatif 7. günde taburcu edildi. Altı aylık takipte hastada komplikasyon saptanmadı. Hepatoduodenal ligaman yakınında penetran yaralanması olan hastalarda, hemostaz sağlandıktan sonra hepatoduodenal ligamanın diseksiyonunun gerekli olduğuna inanıyoruz. Tam kat koledok yaralanması olan hastalar için hepatikojejunostomi etkili bir cerrahi tedavi yöntemi olup, postoperatif komplikasyon riskini azaltmaktadır.

Anahtar sözcükler: Ateşli silah yaralanması; hepatikojejunostomi; koledok kanalı; penetran batın travması.

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