ISSN 1306 - 696X

TURKISH JOURNAL of TRAUMA & EMERGENCY SURGERY

Ulusal Travma ve Acil Cerrahi Dergisi

Volume 32 | Number 5 | May 2026

www.tjtes.org

TURKISH JOURNAL of TRAUMA & EMERGENCY SURGERY

Ulusal Travma ve Acil Cerrahi Dergisi

ISSUED BY THE TURKISH ASSOCIATION OF TRAUMA AND EMERGENCY SURGERY

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

Publisher *(Yayımcı):* KARE Yayıncılık- KARE Medya (KARE Publishing) • www.kareyayincilik.com • Design *(Tasarım):* Ali Cangül • Graphics *(Grafikler):* Kare Publising • Linguistic Editor *(İngilizce Editörü):* Sinjore • Online Manuscript & Web Management *(Online Dergi & Web):* LookUs • Press *(Baskı):* Yıldırım Matbaacılık • Press date *(Basım tarihi):* May *(Mayıs)* 2026 • This publication is printed on paper that meets the international standard ISO 9706: 1994 *(Bu dergide kullanılan kağıt ISO 9706: 1994 standardına uygundur.)*

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

Examining the effectiveness of nintedanib in preventing post-laminectomy epidural fibrosis in rats

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ABSTRACT

BACKGROUND: In this rat model study, we examined the effects of topical and systemic nintedanib treatment on the development of post-laminectomy epidural fibrosis.

METHODS: Thirty-two rats were divided into four equal groups (n=8 per group). An L1–L2 laminectomy was performed using standard microsurgical procedures. The control group underwent laminectomy only; the sterile saline group underwent laminectomy followed by sterile saline irrigation; the topical nintedanib group underwent laminectomy followed by topical nintedanib application; and the systemic nintedanib group underwent laminectomy followed by oral nintedanib administration. The degree of fibrosis was evaluated by histological examination. Plasma levels of matrix metalloproteinase-9 (MMP-9), interleukin-6 (IL-6), vascular endothelial growth factor (VEGF), transforming growth factor beta-1 (TGF-β1), tumor necrosis factor-alpha (TNF-α), hydroxyproline (HYP), and myeloperoxidase (MPO) were compared among the groups.

RESULTS: In the control group, two rats developed grade 2 epidural fibrosis, while six animals developed grade 3 fibrosis. The sterile saline group demonstrated a similar degree of fibrosis to the control group. In the topical nintedanib group, three, four, and one rat developed grade 1, grade 2, and grade 3 epidural fibrosis, respectively. In the systemic nintedanib group, five rats had grade 1 epidural fibrosis, whereas three rats had grade 2 fibrosis. Groups 3 and 4 showed significantly decreased plasma levels of MMP-9, IL-6, VEGF, TGF-β1, TNF-α, and HYP compared to Groups 1 and 2 ($p<0.05$). Plasma levels of these markers were lower in Group 4 than in Group 3; however, the difference was not statistically significant ($p>0.05$). Plasma MPO activity in the study groups was not altered following nintedanib treatment ($p>0.05$).

CONCLUSION: The histological and biochemical findings of the present study indicate that nintedanib is a promising pharmacological agent for the prevention of post-laminectomy epidural fibrosis. Further studies with larger sample sizes and interval assessments are needed to clarify the effects of different dosages.

Keywords: Epidural fibrosis; nintedanib; inflammation; hydroxyproline; myeloperoxidase.

Cite this article as: Ocal O, Tas A, Yildirim Z, Cakir Gundogdu A, Selahi O, Aycan A. Examining the effectiveness of nintedanib in preventing post-laminectomy epidural fibrosis in rats. Ulus Travma Acil Cerrahi Derg 2026;32:519-526.

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Ulus Travma Acil Cerrahi Derg 2026;32(5):519-526 DOI: 10.14744/tjtes.2025.33789
Submitted: 21.07.2025 Revised: 15.08.2025 Accepted: 19.12.2025 Published: 05.05.2026

INTRODUCTION

Laminectomy may lead to failed back syndrome (FBS), a condition characterized by pain in the back and lower extremities, caused by epidural fibrosis (EF), a common postoperative complication.[1,2] As EF progresses after surgery, it causes the dura mater and nerve roots to adhere to the disc and vertebrae anteriorly, and to the spinal erector muscles posteriorly. FBS results from the compression and immobilization of nerve roots caused by the formation of this scar tissue.[3] Postoperative pain, which is frequently observed in many surgeries involving the epidural region, may occur as a result of this complication. By decreasing the availability of cerebrospinal fluid and obstructing regional vascular support, this fibrosis can cause hypoxia, which in turn intensifies pain.[4] Reoperation in regions with substantial fibrosis presents considerable technical challenges and carries inherent risks that must be carefully considered.

In recent years, several studies have investigated two main strategies to reduce the development of EF. Although antifibrotic medications have been studied, EF is still not always preventable. Decreased tissue cellularity and increased deposition of extracellular matrix components are two characteristics contributing to the etiopathogenesis of EF.[5,6] Previously, barriers composed of polyethylene oxide and carboxymethylcellulose were examined to limit the formation of epidural adhesions in rabbit laminotomy and laminectomy models, and these barriers were found to reduce epidural fibrosis.[5] Despite the use of medications such as anti-inflammatory agents, steroids, and hyaluronan, there is currently no effective preventive method for EF.[7,8]

Nintedanib is a potent second-generation intracellular tyrosine kinase inhibitor that effectively targets a specific group of growth factor receptors, including fibroblast growth factor receptors, platelet-derived growth factor receptors, and vascular endothelial growth factor receptors.[9] Nintedanib inhibits the proliferation and migration of lung fibroblasts and the growth of endothelial cells within tumor tissue. It helps reduce the ongoing fibrotic process and delays the onset of permanent damage.[10] In vitro studies have demonstrated that nintedanib exerts antifibrotic effects on primary lung fibroblasts, muscle fibroblasts from patients with Duchenne muscular dystrophy, and skin fibroblasts from individuals with systemic sclerosis. Additionally, its antifibrotic properties have been confirmed in vivo using animal models of various fibrotic diseases.[11-14]

In preclinical disease models, nintedanib has demonstrated remarkable antifibrotic effects in animal studies of pulmonary fibrosis. This has been evidenced by significant reductions in total lung collagen and a marked decrease in fibrosis observed in histological analyses. Additionally, nintedanib exhibited potent anti-inflammatory properties, as illustrated by substantial reductions in lymphocyte and neutrophil counts in bronchoalveolar lavage fluid. Furthermore, it led to decreased levels of inflammatory cytokines and a notable reduction in inflammation and granuloma formation in histological examinations of lung tissue. These findings underscore nintedanib's potential as a promising treatment for pulmonary fibrosis.[11,15]

The importance of early treatment and prevention of epidural scar adhesions is evident, as many patients remain dissatisfied with clinical outcomes. Given the clinical consequences associated with epidural fibrosis, adopting a preventive approach may significantly improve the success of lumbar surgery. Therefore, this study aimed to investigate the effects of nintedanib, administered both topically and systemically, on the formation of epidural fibrosis in a rat model following laminectomy.

MATERIALS AND METHODS

Study Design

This experimental study was conducted in accordance with the highest ethical standards and received approval from the Local Animal Ethics Committee at Van Yüzüncü Yıl University (Decision Number: 2021/07-06; Decision Date: 29/07/2021). All experimental procedures were performed in accordance with the guidelines of the National Institutes of Health (NIH) for the Care and Use of Laboratory Animals, ensuring the humane and responsible treatment of all animals. The principles of the Declaration of Helsinki were also adhered to in this study.

The study included 32 Wistar albino rats weighing between 250-350 g and aged over six months, selected without regard to sex. The animals were housed under controlled environmental conditions with temperatures maintained at 20-24°C, humidity of 50±10%, and a 12-hour light/dark cycle. The rats were randomly divided into four equal groups (n=8 per group) and were provided unrestricted access to food and water throughout the study.

Experimental Groups

Laminectomy Group (Group 1) (n=8): L1-L2 laminectomy was performed without any topical or systemic treatment.

Sterile Saline Group (Group 2) (n=8): L1-L2 laminectomy was performed followed by irrigation with sterile saline.

Topical Nintedanib Group (Group 3) (n=8): L1-L2 laminectomy was performed followed by perioperative topical administration of nintedanib[11] (30 mg/kg dose diluted with 2 cc sterile saline).

Systemic Nintedanib Group (Group 4) (n=8): L1-L2 laminectomy was performed followed by a single systemic dose of nintedanib[11] (1/6 of a 30 mg/kg dose).

All animals were sacrificed 30 days after the procedure according to the protocols described below.

Surgical Procedure

Anesthesia was induced using ketamine (60–100 mg/kg, Keta-

sol, Richter Pharma, Austria) and xylazine (5 mg/kg, BIOVETA PLC, Czech Republic), administered intravenously. To prevent surgical site infections, an intramuscular injection of cefazolin (20 mg/kg) was administered prior to the procedure. Body temperature was maintained at 37°C using a heating pad and a rectal probe. The rats were positioned prone on the surgical table. After shaving the lower back region, the surgical area was disinfected with povidone. Following sterile preparation, a longitudinal midline skin incision was made between the L1 and L3 levels. The lumbosacral fascia was incised to expose the L2 laminae, and the paravertebral muscles were dissected subperiosteally. A laminectomy was performed at the L2 level to expose the dura mater and epidural space. Subsequently, the ligamentum flavum and epidural fat tissue were removed from the surgical site. Bipolar cautery, bone wax, and other hemostatic agents were intentionally not used during the procedure. Following topical drug administration in the local therapy group, the wounds were closed anatomically using 4-0 Prolene polypropylene sutures. No topical treatment was administered in either the laminectomy or systemic therapy groups. All procedures were performed under a surgical microscope to protect neurological structures.

In the second group, after laminectomy, the dura mater was irrigated with 10 mL of 0.9% sodium chloride, and the surgical site was closed in anatomical layers using 4-0 polypropylene sutures. In the third group, following laminectomy, a cotton pad soaked with nintedanib at a dose of 30 mg/kg diluted in 2 cc of sterile saline was placed on the exposed dura mater. After 10 minutes, the pad was removed and the area was irrigated with 10 mL of saline before closure. In the fourth group, a single oral dose of nintedanib, corresponding to one-sixth of the 30 mg/kg dose, was administered, after which the incision was closed in anatomical layers to promote healing and reduce complications.

The rats were euthanized by cardiac exsanguination under deep anesthesia with ketamine (80 mg/kg) and xylazine (20 mg/kg). All animals were ambulatory at the time of euthanasia. No infections, hematomas, or cerebrospinal fluid leakage were observed at the surgical site. The entire lumbar vertebral column, including the surgical region, was carefully removed and fixed in 10% neutral formaldehyde for 48 hours to preserve tissue integrity. Subsequently, the specimens were decalcified in 10% formic acid for three days to enable histological evaluation. Following standard tissue processing procedures, the samples were embedded in paraffin for further examination.

Biochemical Evaluation

Blood samples were collected into ethylenediaminetetraacetic acid (EDTA) tubes and centrifuged at 3,000 × g for 10 minutes at 4°C to obtain plasma. The separated plasma samples were stored at -80°C until analysis.

Plasma levels of several biomarkers were measured using solid-phase sandwich enzyme-linked immunosorbent assay (ELISA) methods, ensuring precise and reliable results that underscore their significance in clinical assessments. The evaluated biomarkers included matrix metalloproteinase-9 (MMP-9) (Sunred Rat Immunoassay Kit, Cat. No: 201-11-0322), interleukin-6 (IL-6) (Sunred Rat Immunoassay Kit, Cat. No: 201-11-0136), vascular endothelial growth factor (VEGF) (Sunred Rat Immunoassay Kit, Cat. No: 201-11-0660), transforming growth factor beta-1 (TGF-β1) (Sunred Rat Immunoassay Kit, Cat. No: 201-11-0780), tumor necrosis factor-alpha (TNF-α) (Sunred Rat Immunoassay Kit, Cat. No: 201-11-0765), hydroxyproline (HYP) (Sunred Rat Immunoassay Kit, Cat. No: 201-11-0512), and myeloperoxidase (MPO) (Sunred Rat Immunoassay Kit, Cat. No: 201-11-0575). This rigorous approach underscores the significance of these biomarkers in understanding underlying physiological processes and their potential implications for research.

Histopathological Examination

Four-micron-thick sections were cut from the paraffin blocks using a microtome (Thermo-Fisher Scientific, Germany) and stained with hematoxylin and eosin (H&E). The stained slides were examined blindly by a histopathologist using a Nikon Eclipse 80i light microscope (Nikon, Germany) at 10× magnification and evaluated for fibrosis intensity and dural thickness. ImageJ analysis software (version 1.52; National Institutes of Health, MD, USA) was used for morphometric analysis.

According to the definition of He et al.,[8] histological epidural fibrosis was graded as follows:

• Grade 0: No scar tissue is present on the dura mater.

• Grade 1: Only thin fibrous bands are present between the dura mater and scar tissue.

• Grade 2: Continuous adhesion involving less than two-thirds of the laminectomy defect.

• Grade 3: Extensive scar tissue adhesion covering more than two-thirds of the laminectomy defect or extending to the nerve roots.

The thickness of the dura mater was measured at the midpoint of the laminectomy defect, as well as 2 mm to both the right and left sides of the midline. These measurements were analyzed to obtain mean values for statistical evaluation.[16] Additionally, fibroblast density within the scar tissue was assessed at the same locations. Cells were counted in three distinct regions (the two borders and the central point of the laminectomy defect) to calculate an average value.

The histopathological density of epidural fibrosis was graded based on the fibroblast predominance according to the criteria described by Hinton et al.[17] In this classification, grade 1 corresponds to fewer than 100 fibroblasts, grade 2 to 100–150 fibroblasts, and grade 3 to more than 150 fibroblasts. Fibroblasts were counted in three regions using a light microscope at 40× magnification to obtain the mean value (Fig. 1). This approach highlights the significance of our findings for

understanding epidural fibrosis and its implications.

Statistical Analysis

Statistical analysis was performed using IBM SPSS version 27 (Statistical Package for the Social Sciences, New York, USA) to ensure a rigorous and reliable interpretation of the data. Frequency tables and descriptive statistics were used to summarize the data. For measurement data that followed a normal distribution, parametric methods were applied. Specifically, the analysis of variance (ANOVA) test (F value) was used to compare measurement values among three or more independent groups. For measurement data that did not follow a normal distribution, non-parametric methods were used. The Kruskal-Wallis H test (χ^2) was applied to compare three or more independent groups, reinforcing the integrity and depth of our analysis. When the analysis of variance showed statistical significance, the Mann-Whitney U test with Bonferroni correction was used to determine group differences. Data are expressed as mean±standard deviation, and a p value <0.05 was considered statistically significant.

RESULTS

Biochemical Evaluation

Plasma MMP-9, IL-6, VEGF, TGF-β1, TNF-α, and HYP levels were significantly lower in Group 3 and Group 4 compared to Group 1 and Group 2 (p<0.05) (Table 1). Plasma MMP-9, IL-6, VEGF, TGF-β1, TNF-α, and HYP levels were lower in Group 4 compared to Group 3; however, this difference was not statistically significant (p>0.05) (Table 1). Plasma MPO activity remained unchanged in the study groups following nintedanib treatment (p>0.05) (Table 1).

Histopathological Evaluation

In the laminectomy group, two rats exhibited grade 2 fibrosis (25%), while six rats showed grade 3 fibrosis (75%). Extensive epidural fibrotic tissue, marked dural thickening, and fibrotic tissue adhesion were observed. Numerous irregular blood vessels adhered to the dura on the laminectomy side, resulting in spinal cord compression (Figs. 1, 2). The level of fibrosis in Group 2 (sterile saline [SF] group) was similar to that observed in Group 1, with two rats presenting grade 2 fibrosis and six rats exhibiting grade 3 fibrosis. In the topical nintedanib group, three rats showed grade 1 fibrosis, four rats showed grade 2 fibrosis, and one rat showed grade 3 epidural fibrosis. In the oral nintedanib group, five rats exhibited grade 1 fibrosis and three rats showed grade 2 fibrosis. Notably, no rats in this group displayed grade 3 fibrosis.

In both the control and SF groups, the majority of the rats displayed grade 3 epidural fibrosis. The laminectomy defects were entirely covered by fibrotic tissue adherent to the dura mater (indicated by an arrow), affecting nearly two-thirds of each defect. In contrast, rats treated with topical nintedanib frequently developed grade 2 fibrosis, with less than two-thirds of the laminectomy defect showing continuous adhesion of the dura mater (arrow) to the fibrous tissue. Only thin fibrous bands between the loose fibrous tissue and the underlying dura mater (arrow) were indicative of grade 1 epidural fibrosis, which was present in the majority of animals in the oral nintedanib group (scale bar: 100 μm).

The differences in epidural fibrosis levels among the groups were statistically significant ($\chi2=19.871$; p<0.001). Bonferroni-corrected pairwise comparisons were conducted to identify the groups responsible for this significant difference. The epidural fibrosis values in Group 1 were found to be significantly greater than those of Groups 3 and 4. Similarly, Group 2 also showed significantly higher epidural fibrosis values compared to Groups 3 and 4. A striking disparity was identified between animals in Group 2 and those in Groups 3 and 4, with Group 2 demonstrating significantly higher levels

Table 1. Plasma levels of matrix metalloproteinase-9 (MMP-9), interleukin-6 (IL-6), vascular endothelial growth factor, transforming growth factor beta-1, tumor necrosis factor-alpha, hydroxyproline), and myeloperoxidase in all groups (mean±standard deviation)

Parameters	Group 1 (n=8)	Group 2 (n=8)	Group 3 (n=8)	Group 4 (n=8)
MMP-9 (ng/mL)	1.43±0.23	1.41±0.13	1.40±0.13	1.28±0.22
IL-6 (pg/mL)	2.84±1.11	2.86±0.53	1.13±0.12	1.01±0.25
VEGF (ng/mL)	3.04±0.21	2.91±0.38	1.16±0.43	1.13±0.05
TGF-β1 (ng/L)	2.20±0.51	1.98±0.23	1.04±0.22	1.03±0.16
TNF-α (ng/L)	2.14±0.28	2.23±0.27	1.45±0.13	1.37±0.38
HYP (ng/mL)	3.13±0.63	3.16±0.54	0.93±0.13	0.92±0.14
MPO(ng/mL)	2.98±0.96	3.18± 0.64	1.21±0.33	1.32±0.23

MMP-9: Matrix metalloproteinase-9; IL-6: Interleukin-6; VEGF: Vascular endothelial growth factor; TGF-β1: Transforming growth factor beta-1; TNF-α1: Tumor necrosis factor-alpha; MPO: Myeloperoxidase; HYP: Hydroxyproline.

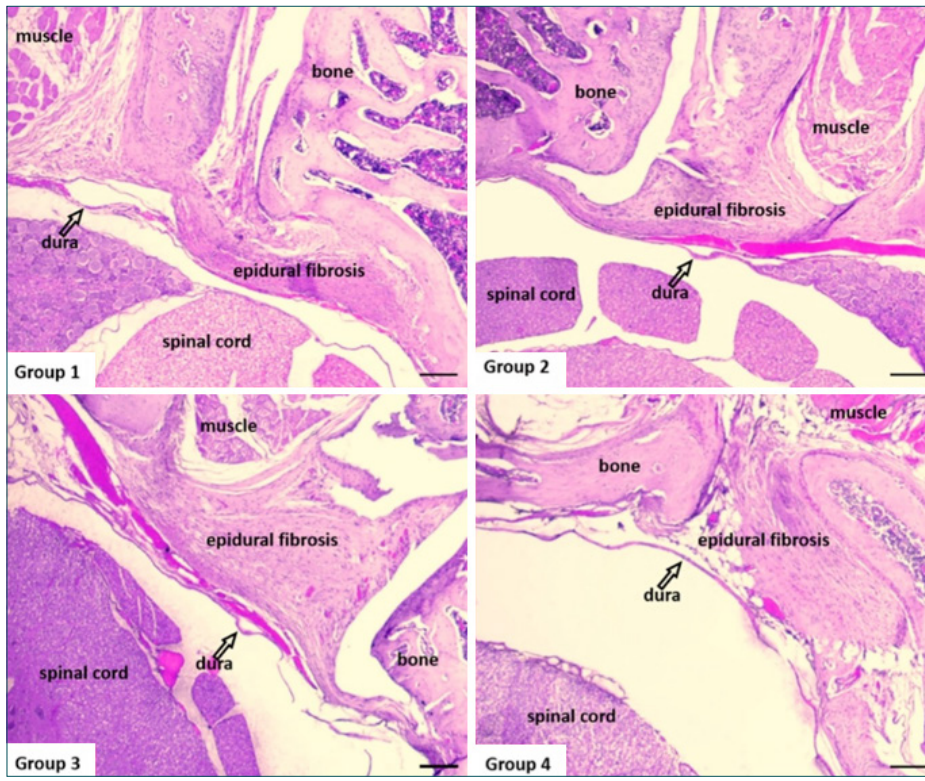

Figure 1. Photomicrographs of hematoxylin and eosin (H&E)-stained epidural adhesions on the laminectomy sides.

of epidural fibrosis compared to its counterparts.

Moreover, analysis of dural thickness at the midpoint revealed significant differences among the groups (F=106.686; p<0.001). Tukey pairwise tests conducted to evaluate variance homogeneity revealed a notable difference between Group 1 and Groups 3 and 4. Group 1 exhibited substantially greater midpoint dural thickness values, indicating a significant difference among the groups. Similarly, a significant difference was observed between animals in Group 2 and those in Groups 3 and 4 (Fig. 3, Table 2).

A statistically significant difference was also detected in right-sided dural thickness values among the groups (F=73.911; p<0.001). As a result of Tukey pairwise comparisons performed by considering the homogeneity of variances to determine which group the significant difference originated from, a significant difference was detected between animals in Group 1 and those in Groups 3 and 4. It was determined that the dural thickness (right-sided) values of Group 1 were

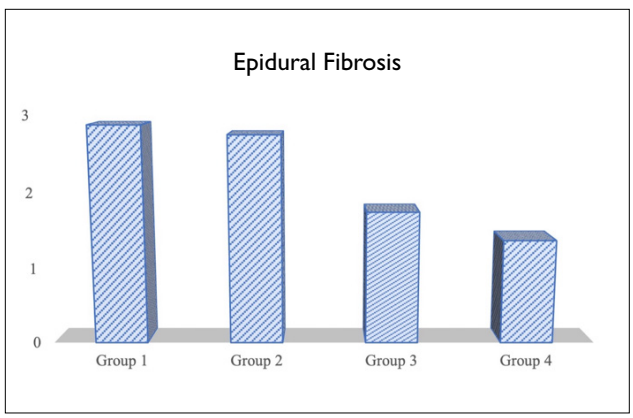

Figure 2. A line graph illustrating the distribution of epidural fibrosis across the study groups.

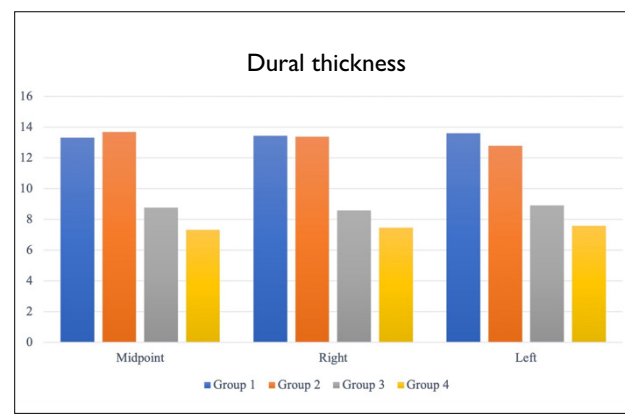

Figure 3. Line chart depicting dural thickness in all groups measured at the laminectomy areas—right side, midpoint, and left side.

Table 2. Comparison of epidural fibrosis and dural thickness values among the groups

Variable	Group 1 (n=8) (1)		Group 2 (n=8) (2)		Group 3 (n=8) (3)		Group 4 (n=8) (4)	Statistical analysis* Probability
	$\bar{X}$±S.S.	Median [IQR]	$\bar{X}$±S.S.	Median [IQR]	$\bar{X}$±S.S.	Median [IQR]	$\bar{X}$±S.S.	Median [IQR]
Epidural fibrosis	2.87±0.35	3.0 [1.0]	2.75±0.46	3.0 [0.8]	1.75±0.71	2.0 [1.0]	1.38±0.51	1.0 [1.0] χ^2=19.874 p<0.001 [1-3,4] [2-3,4]
Dural thickness (midpoint)	13.32±0.78	13.6 [1.6]	13.69±0.89	13.4 [1.2]	8.77±0.94	8.8 [1.3]	7.32±0.89	7.2 [1.5] F=106.686 p<0.001 [1-3,4] [2-3,4] [3-4]
Dural thickness (right)	13.45±1.19	13.6 [1.9]	13.39±1.27	13.5 [1.6]	8.59±0.79	8.4 [1.4]	7.47±0.77	7.5 [1.4] F=73.911 p<0.001 [1-3,4] [2-3,4] [3-4]
Dural thickness (left)	13.62±0.94	13.6 [0.8]	12.79±0.88	12.7 [1.7]	8.91±1.02	9.1 [1.1]	7.59±1.15	7.7 [2.3] F=67.816 p<0.001 [1-3,4] [2-3,4]

*The analysis of variance (ANOVA) test (F value) was used to compare measurement values among three or more independent groups when the data followed a normal distribution. The Kruskal-Wallis H test (χ^2 value) was used to compare measurement values among three or more independent groups when the data did not follow a normal distribution.

significantly higher than those of Groups 3 and 4. Likewise, a significant difference was detected between animals in Group 2 and those in Groups 3 and 4. The results indicated that the epidural fibrosis values in Group 1 were significantly higher than those in Groups 3 and 4. Similarly, a notable difference was found between Group 2 and both Groups 3 and 4, with the epidural fibrosis values in Group 2 also being significantly higher than those in Groups 3 and 4.

DISCUSSION

In this study, both local and systemic therapy with nintedanib resulted in a reduction of EF. Previous studies have demonstrated a strong correlation between epidural fibrosis and both collagen overproduction and fibroblast activation.[18,19] Various materials and drugs have been investigated to prevent epidural fibrosis, including adipose tissue, hydrogel membranes, polytetrafluoroethylene membranes, polyvinyl alcohol, polylactic acid membranes, pentoxifylline, and Vicryl mesh, all of which act as physical barriers.[8,16,17]

This study investigates the protective effects of nintedanib on epidural fibrosis using both histological and biochemical analyses. The findings demonstrate that nintedanib significantly reduces fibrosis formation in the epidural area, as shown in Figures 1-3. Notably, the midpoint dural thickness values in Group 2 were significantly greater than those in Groups 3 and 4, highlighting the detrimental impact of fibrosis. Furthermore, a significant difference in dural thickness was observed between Groups 3 and 4, with Group 3 exhibiting greater thickness than Group 4. These results underscore the efficacy of nintedanib. Additionally, treatment led to an increase in bone regeneration areas in both Groups 3 and 4. These findings support the potential role of nintedanib as a therapeutic agent in the management of epidural fibrosis.

TGF-β plays a crucial role in fibrosis by stimulating the synthesis of collagen and fibronectin through fibroblasts.[20-22] Additionally, TGF-β significantly influences the production of the extracellular matrix (ECM) by fibroblasts and inhibits the biosynthesis of proteases responsible for ECM degradation.[20,22] According to several studies, TGF-β1 levels increase in fibrosis, and inhibition of TGF-β1 can prevent the production of fibrous tissue.[23] Upon tissue injury, cellular proliferative and migratory factors are activated, leading to increased secretion of matrix metalloproteinases (MMPs), which facilitate remodeling. Growth factors and cytokines such as TGF-β1, IL-6, and TNF-α further stimulate this process.[24] MMPs degrade basement membrane matrices, enabling cell proliferation and migration.[25] While most cytokines are pro-inflammatory, IL-6 also possesses strong anti-inflammatory effects, inhibit-

ing TNF-α-induced upregulation of endothelial adhesion molecules.[26] Some studies have also shown that TNF-α's role in collagen synthesis and fibrosis can be mitigated by specific agents.[27]

In the current investigation, we found that Groups 3 and 4 had considerably lower plasma levels of MMP-9, IL-6, VEGF, TGF-β1, and TNF-α than Groups 1 and 2. Furthermore, compared to Group 3, the plasma levels of these markers in Group 4 were lower; however, this difference was not statistically significant.

In preclinical models of systemic sclerosis (SSc), an immune-mediated rheumatic disease of uncertain etiology characterized by vasculopathy and fibrosis of the skin and internal organs, nintedanib has demonstrated antifibrotic properties.[28] Nintedanib showed potent antifibrotic effects and significantly reduced fibroblast activation in two preclinical mouse models of SSc. Additionally, nintedanib improved the histological features of pulmonary arterial hypertension, destructive microangiopathy, and pulmonary and cutaneous fibrosis in another mouse model.[13,29]

In the present study, nintedanib may improve fibrosis not only through its direct effects but also by reducing the levels of MMP-9, IL-6, VEGF, TGF-β1, and TNF-α. Hydroxyproline rapidly accumulates in collagen during the wound-healing process. The degree of adhesion is negatively correlated with its concentration.[23]

According to the findings, Groups 3 and 4 had significantly lower plasma HYP levels than Groups 1 and 2. Furthermore, the plasma HYP levels in Group 4 were lower than those in Group 3; however, this difference was not statistically significant.

We suggest that the systemic administration of nintedanib has the potential to effectively target multiple stages of inflammation simultaneously, rather than being limited to a single phase. Significant effects on both the inflammation and proliferation phases are indicated by the observed decrease in HYP levels. Notably, fibroblasts modified by reduced levels of pro-inflammatory cytokines become more prominent during the proliferation phase of inflammation, suggesting that this phase may be indirectly affected.

Extensive research has demonstrated that lowering the levels of key inflammatory markers such as TNF-α, IL-6, and TGF-β1 can inhibit the proliferation and differentiation of fibroblasts and endothelial fibroblasts.[30,31] In our current study, both systemic and topical administration of nintedanib resulted in a marked reduction in MMP-9, IL-6, VEGF, TGF-β1, and TNF-α levels. These findings support the role of nintedanib as a powerful therapeutic option for managing complex inflammatory responses.

The results demonstrate that rats treated systemically with nintedanib exhibited significantly lower grades of epidural fibrosis compared to those in the other groups. Moreover, systemic nintedanib proved to be more effective in preventing epidural fibrosis than topical administration. This study highlights nintedanib's potent antifibrotic mechanisms, which not only directly inhibit TNF-α but also substantially reduce the levels of MMP-9, IL-6, VEGF, TGF-β1, and HYP. These findings underscore the potential of systemic nintedanib as an effective approach to combating epidural fibrosis.

CONCLUSION

In conclusion, our study clearly demonstrates that the systemic administration of nintedanib significantly reduces the formation of epidural fibrosis in a rat model of laminectomy. Moreover, nintedanib shows promise as an effective intervention at various stages of inflammation, highlighting its potential as a powerful therapeutic agent for preventing epidural fibrosis. To fully harness its benefits, further research is needed to establish the optimal dosage and method of administration of nintedanib.

Ethics Committee Approval: This study was approved by Local Animal Ethics Committee at Van Yüzüncü Yıl University (Date: 29.07.2021, Decision No: 2021/07-06).

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

Financial Disclosure: This work has been supported by Van Yuzuncu Yil University Scientific Research Projects Coordination Unit under grant number: TSA-2022-9958

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DENEYSEL ÇALIŞMA - *ÖZ*

Sıçanlarda laminektomi sonrası oluşan epidural fibrozisi önlemede nintedanibin etkinliğini araştırma

AMAÇ: Nintedanibin topikal ve sistemik uygulanmasının, bir sıçan modelinde post-laminektomi epidural fibrozis gelişimi üzerindeki etkisini araştırmak.
GEREÇ VE YÖNTEM: Otuz iki sıçan, dört eşit gruba ayrıldı. L1–L2 laminektomi, standart mikrocerrahi tekniği kullanılarak gerçekleştirildi. Kontrol grubuna yalnızca laminektomi yapıldı; steril salin grubuna laminektomi sonrası steril salin ile yıkama yapıldı; topikal nintedanib grubuna laminektomi sonrası topikal nintedanib uygulandı; sistemik nintedanib grubuna laminektomi sonrası oral nintedanib verildi.
BULGULAR: Kontrol grubundaki iki sıçanda 2. derece ve altı sıçanda 3. derece epidural fibrozis gelişti. Steril salin grubundaki fibrozis seviyesi kontrol grubuna benzerdi. Topikal nintedanib grubunda üç, dört ve bir sıçan sırasıyla 1., 2. ve 3. derece epidural fibrozis geliştirdi. Sistemik nintedanib grubunda beş sıçanda 1. derece ve üç sıçanda 2. derece epidural fibrozis gözlemlendi. Plazma matriks metalloproteinaz-9 (MMP-9), interlökin-6 (IL-6), vasküler endotelyal büyüme faktörü (VEGF), transformasyon büyüme faktörü beta-1 (TGF-β1), tümör nekroz faktörü-alfa (TNF-α) ve hidroksiprolin (HYP) seviyeleri grup 3 ve grup 4'te, grup 1 ve grup 2 ile karşılaştırıldığında önemli ölçüde daha düşüktü ($p<0.05$). Çalışma gruplarında plazma miyeloperoksidaz (MPO) aktivitelerinin nintedanib tedavisinden sonra değişmediği gösterilmiştir ($p>0.05$).
SONUÇ: Mevcut çalışmada histolojik ve biyokimyasal sonuçlar, nintedanibin post-laminektomi epidural fibrozisin tedavisi için potansiyel bir farmakolojik ajan olduğunu göstermektedir. Doz etkinliğini belirlemek için geniş popülasyon üzerinde ve aralıklı değerlendirme yapılan çalışmalara ihtiyaç vardır.

Anahtar sözcükler: Epidural fibrozis; nintedanib; inflamasyon; hidroksiprolin; miyeloperoksidaz.

Ulus Travma Acil Cerrahi Derg 2026;32(5):519-526 DOI: 10.14744/tjtes.2025.33789

EXPERIMENTAL STUDY

Relationship between serum β-catenin mRNA expression and femoral fracture healing after head trauma: an experimental rat study

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ABSTRACT

BACKGROUND: Fracture healing may be influenced by concomitant traumatic brain injury (TBI). Both clinical and experimental studies have reported accelerated union and enhanced callus formation in the presence of TBI. The Wnt/β-catenin signaling pathway is thought to play a role in this process; however, the relationship between serum β-catenin mRNA relative expression and fracture healing in the context of TBI remains unclear.

METHODS: Thirty-six female Wistar albino rats were randomly assigned to four groups: control, TBI only, femoral fracture only, and combined TBI + femoral fracture. Radiographic healing was evaluated using the Radiographic Union Scale for Tibial fractures (RUST) at weeks 3 and 6. Serum β-catenin mRNA relative expression was quantified by real-time polymerase chain reaction at baseline (week 0) and during follow-up (weeks 3 and 6). Histological analysis was performed at week 6.

RESULTS: Radiographic evaluation demonstrated progressive healing in all fracture groups, with significantly higher RUST scores in the TBI + fracture group compared to the fracture-only group at both time points ($p<0.05$). Serum β-catenin mRNA relative expression decreased significantly over time in both fracture groups, whereas no significant temporal changes were observed in the control or isolated TBI groups. Because this decline occurred in both fracture groups, it did not indicate a TBI-specific molecular effect. Histological analysis showed a tendency toward more mature osseous callus formation in the TBI + fracture group; however, these differences were not statistically significant.

CONCLUSION: Concomitant TBI was associated with enhanced radiographic fracture healing and showed a non-significant trend toward more advanced osseous callus formation. The observed decline in serum β-catenin mRNA relative expression in the fracture groups suggests phase-dependent regulation of Wnt/β-catenin–related activity during repair. However, serum β-catenin mRNA represents an indirect systemic marker and does not establish a mechanistic, TBI-specific pathway. These findings highlight the complex systemic influence of TBI on skeletal repair and support further mechanistic studies—particularly those incorporating fracture-site (local) analyses—to clarify the biological pathways underlying the observed radiographic association.

Keywords: Callus formation; experimental rat model; fracture healing; traumatic brain injury; Wnt/β-catenin signaling.

Cite this article as: Gümüşoğlu E, Öztuna V, Asfuroğlu ZM, Oruç Demirbağ H, Aktaş S, Kızıltuğ MT, Erdal ME. Relationship between serum β-catenin mRNA expression and femoral fracture healing after head trauma: An experimental rat study. Ulus Travma Acil Cerrahi Derg 2026;32:527-534.

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Ulus Travma Acil Cerrahi Derg 2026;32(5):527-534 DOI: 10.14744/tjtes.2026.23177
Submitted: 03.11.2025 Revised: 15.02.2026 Accepted: 20.02.2026 Published: 05.05.2026

INTRODUCTION

Fracture healing is a complex biological process involving a highly coordinated cascade of cellular and molecular events that restore bone integrity and mechanical strength.[1,2] This intricate repair mechanism is central to orthopedic traumatology given the high global incidence of bone fractures and the clinical challenges that arise in cases of delayed union or nonunion.[3] A striking clinical observation that has attracted increasing attention is the phenomenon of accelerated fracture healing in patients who sustain traumatic brain injury (TBI).[4] Evidence from both clinical and preclinical studies supports this association, demonstrating enhanced callus formation, earlier bridging, and a shorter time to union in the presence of concomitant head trauma.[5,6] This accelerated healing response, often described as "TBI-induced osteogenesis," has been reported across different fracture types and injury severities, suggesting a systemic influence of head injury on skeletal repair.[7] For example, studies of femoral shaft fractures indicate that more than one-third of patients present with associated head or neck injuries, underscoring the clinical relevance of this phenomenon.[8] Proposed mechanisms include neuroendocrine alterations, the release of specific humoral factors, and the systemic dissemination of extracellular vesicles following TBI.[5-7,9]

Accumulating evidence implicates the Wnt/β-catenin signaling pathway as a key pathway that may contribute to this enhanced osteogenic response.[10-14] β-catenin, the central effector of this pathway, plays a crucial role in multiple phases of fracture healing, including the early differentiation of mesenchymal stem cells into osteoblasts and chondrocytes, subsequent bone formation, and the later remodeling of the callus.[10,12] Although the role of β-catenin in bone metabolism and fracture repair is well established, studies directly examining the relationship between serum β-catenin mRNA relative expression and fracture healing outcomes in the context of TBI remain scarce. This gap represents a critical area of investigation because clarifying the dynamics of serum β-catenin mRNA relative expression could provide valuable insight into the systemic regulation of bone repair after TBI. Therefore, the present experimental rat study aimed to investigate this relationship in greater depth by examining femoral fracture healing in the presence of concomitant head trauma. To achieve this, we conducted a comprehensive evaluation integrating radiological, histological, and serum-based molecular analyses.

We hypothesized that concomitant traumatic brain injury would accelerate femoral fracture healing radiographically, promote more mature osseous callus formation histologically, and alter systemic β-catenin dynamics, as reflected by temporal changes in serum β-catenin mRNA relative expression.

The primary research question was whether fracture healing differs between isolated femoral fracture and combined femoral fracture with TBI. Secondary questions addressed whether serum β-catenin mRNA relative expression changes over time within each group and whether these changes correspond with radiological and histological findings.

MATERIALS AND METHODS

This prospective, randomized, controlled experimental animal study was conducted at the Mersin University Experimental Animal Research Laboratory and was approved by the Mersin University Rectorate Animal Experiments Local Ethics Committee (Date: 25.03.2019, Decision no: 15). A preliminary pilot study was performed to identify potential challenges, including the feasibility of the surgical procedures, the adequacy of the instruments, potential issues related to animal housing, and expected animal survival throughout the study period.

Animals

The study included 36 female Wistar albino rats, 24 weeks old and weighing 200–250 g. The animals were acclimatized for two weeks before the experiment. During this period, they were maintained on standard rodent chow and tap water at a constant room temperature of 22°C under a 12-hour light/dark cycle. Each rat was housed individually in a cage until sacrifice.

Experimental Design

The rats were randomly assigned to four groups. Group 1 served as the control group (no trauma), Group 2 was subjected to head trauma only, Group 3 underwent surgically induced femoral fracture, and Group 4 was subjected to both head trauma and surgically induced femoral fracture. In Groups 3 and 4, standardized anteroposterior and lateral radiographs of the fractured femurs were obtained during follow-up, and femoral specimens were harvested for histological evaluation at the end of the study. Blood samples for serum β-catenin mRNA analysis were collected at baseline (week 0), week 3, and week 6. All animals were sacrificed at the end of week 6.

Of the initial 36 rats, four were excluded from the final analysis. In Group 3 (femoral fracture), one rat developed pseudoarthrosis. In Group 4 (head trauma + femoral fracture), one rat died during the induction of head trauma and two developed pseudoarthrosis. Consequently, the final analysis included 32 rats (Group 1: n=6; Group 2: n=10; Group 3: n=9; Group 4: n=7).

Anesthesia and Surgical Procedure

All animals were anesthetized via intraperitoneal injection of xylazine 2% (10 mg/kg; Xylazin Bio®, Bioveta, Czech Republic) and ketamine 10% (80 mg/kg; Ketasol®, Richter Pharma, Austria). Adequate anesthesia was confirmed by the absence of whisker and pedal withdrawal reflexes.

Femoral fractures were created using a modified version of the method described by Bonnarens and Einhorn.[15] A medial

parapatellar approach was performed, and the intramedullary canal was reamed using a 20-gauge needle. A 0.45-mm Kirschner wire was inserted for stabilization, after which a fracture was created at the mid-diaphysis using bone scissors. The fracture configuration was standardized as a simple mid-diaphyseal fracture produced under direct visualization. Using bone scissors, fractures were consistently created as transverse or short oblique patterns. Fracture alignment and configuration were confirmed intraoperatively by macroscopic inspection; comminution was not intended in this model.

Head trauma was induced using a modified experimental mild TBI model.[16] To prevent depressed fractures, a steel disc (2 cm in diameter and 2 mm thick) was fixed between the coronal and lambdoid sutures. A 300-g weight was then dropped from a height of 1 m onto the disc to produce closed head trauma.

For postoperative analgesia, paracetamol (Calpol™ Suspension 120 mg/5 mL; GlaxoSmithKline, Türkiye) was added to the drinking water during the first postoperative day. Wounds were treated with topical oxytetracycline HCl (Neo-Caf® Aerosol Spray; Intervet, Türkiye). All rats were monitored daily for feeding behavior, mobility, and signs of pain.

Radiographic Evaluation

At weeks 3 and 6, anteroposterior and lateral radiographs of the fractured femurs (Groups 3 and 4) were obtained. Radiographs were acquired using a standardized protocol with consistent limb positioning (true anteroposterior and lateral views) and fixed imaging parameters throughout the study. Fracture healing was assessed independently by two blinded orthopedic surgeons using the RUST (Radiographic Union Score for Tibial fractures) scoring system.[17] This system evaluates healing at four cortices—medial and lateral cortices on one projection, and anterior and posterior cortices on the other. Each cortex is scored from 1 to 3 points: 1 indicates a visible fracture line without callus, 2 indicates a visible fracture line with callus formation, and 3 indicates bridging callus with no visible fracture line. The total score ranges from 4 to 12. The mean score of the two observers was calculated and recorded as the final score. To minimize bias, radiographs were anonymized and coded, and images were evaluated independently in randomized order without access to group allocation or time-point information. Scoring was repeated in separate sessions to reduce recall bias. Pseudoarthrosis was defined radiographically as persistence of a visible fracture line without bridging callus and absence of interval progression between weeks 3 and 6 on both anteroposterior and lateral views, despite intramedullary stabilization.

Serum β-Catenin mRNA Relative Expression

Blood samples were collected from the jugular vein at predefined time points and processed to obtain serum. For RNA isolation, approximately 200–300 µL of serum was transferred into 1.5-mL microcentrifuge tubes, mixed with 500 µL Ribozol, vortexed, and incubated for 15 minutes. Subsequently, 200 µL chloroform:isoamyl alcohol (24:1), pre-cooled to 4°C, was added, and the samples were centrifuged at 14,000 rpm for 10 minutes at 4°C. The aqueous phase was transferred to new tubes, and RNA was precipitated with 500 µL isopropanol for 10 minutes at room temperature, followed by centrifugation at 14,000 rpm for 10 minutes at 4°C. The RNA pellet was washed with 1 mL of cold 80% ethanol and centrifuged again at 14,000 rpm for 10 minutes at 4°C. After air-drying for 10–15 minutes, the pellets were resuspended in 50 µL RNase/DNase-free water, briefly vortexed, incubated for 10 minutes at room temperature, and stored at −20°C until complementary DNA (cDNA) synthesis. Complementary DNA was synthesized using RevertAid RT reagents with oligo d(T)18 primers (37°C for 60 minutes, followed by 95°C for 5 minutes and a hold at 4°C). For each sample, 5 µL RNA was added to 50 µL of the prepared RT reaction mixture, resulting in a final volume of 100 µL. A pooled RNA sample from control rats served as the calibrator. Quantitative real-time polymerase chain reaction (PCR) was performed on an ABI Prism 7500 platform using the comparative Ct (ΔΔCt) method to estimate relative serum-derived Ctnnb1 (β-catenin) mRNA expression normalized to Actb. Primer and hydrolysis probe sets were designed from rat reference sequences (Actb: NM_031144.3; Ctnnb1: NM_053357.2) and synthesized commercially; the sequences are provided in the manuscript. Each reaction contained 12.5 µL 2× master mix, primers at a final concentration of 900 nM, probes at 200 nM, 2.5 µL cDNA (~30 ng), and 5 µL distilled water. Cycling conditions consisted of 50°C for two minutes and 95°C for 12 minutes, followed by 50 cycles of 95°C for 15 seconds and 60°C for one minute. Data acquisition and analysis were performed using ABI 7500 system software (SDS v2.0.6; Applied Biosystems). Actb was selected as the reference gene based on its common use in rat quantitative polymerase chain reaction (qPCR) assays; however, its stability in serum was not formally validated in the present study. Therefore, the reverse transcription quantitative polymerase chain reaction (RT-qPCR) results should be interpreted as reflecting relative transcript dynamics rather than absolute quantification of circulating β-catenin protein.

Histological Analysis

At the end of week 6, fractured femurs were harvested following sacrifice. The specimens were fixed in 10% formaldehyde solution and decalcified in ethylenediaminetetraacetic acid. After decalcification, the tissues were embedded in paraffin, sectioned, and stained with hematoxylin–eosin and Masson's trichrome for histological evaluation. Histological assessment and histomorphometric measurements were performed by an assessor blinded to group allocation. For each specimen, representative sections through the fracture region were analyzed using a standardized region-of-interest approach. The proportions of osseous, cartilaginous, and fibrous tissue were quantified using predefined measurement criteria applied consistently across all samples. Final values were recorded for each specimen prior to statistical analy-

sis. Fracture healing was further graded using the histological scoring system described by Huo et al.[18]

Statistical Analysis

All data were analyzed using SPSS software version 25.0 (IBM Corp., Armonk, NY, USA). No a priori sample size or power analysis was performed. Descriptive statistics were expressed as mean ± standard deviation for normally distributed data and as median (interquartile range) for non-normally distributed data. The Shapiro–Wilk test was used to assess data normality. For comparisons among more than two groups, one-way analysis of variance (ANOVA) was applied to parametric data, followed by Tukey's post hoc test. For non-parametric data, the Kruskal–Wallis test was used, with Dunn's test for pairwise comparisons. Within-group comparisons over time were performed using repeated-measures ANOVA or the Friedman test, as appropriate. Interobserver reliability for radiographic scoring was assessed using intraclass correlation coefficients (ICC). A p-value <0.05 was considered statistically significant.

RESULTS

Radiological Findings

Interobserver reliability analysis demonstrated excellent agreement for RUST scoring in both groups at weeks 3 and 6 (ICC=0.904–0.937). According to the RUST system, both groups exhibited progressive fracture healing from week 3 to week 6. At week 3, the median union score in Group 3 (isolated femoral fracture) was 7.5 (range, 4.0–8.5), whereas Group 4 (concomitant head trauma + femoral fracture) showed a significantly higher median score of 8.0 (range, 8.0–11.5) (p=0.008). By week 6, Group 3 reached a median score of 9.0 (range, 7.0–10.5), while Group 4 demonstrated more advanced healing with a median score of 11.0 (range, 9.0–11.5) (p=0.006). Within-group analyses also showed significant temporal progression. Group 3 improved from week 3 to week 6 (p=0.012), and Group 4 demonstrated a significant increase over the same period (p=0.047). Overall, these findings indicate that radiographic fracture healing was more advanced in the presence of concomitant head trauma.

Table 1. Relative serum β-catenin mRNA expression measured by reverse transcription quantitative polymerase chain reaction (RT-qPCR) and temporal changes within groups

Group	Week 0 (Mean±SD)	Week 3 (Mean±SD)	Week 6 (Mean±SD)	p (within group)
Group 1 (n=6)	1.34±0.13	1.34±0.13	1.18±0.08	0.144
Group 2 (n=10)	1.33±0.12	1.28±0.20	1.19±0.20	0.089
Group 3 (n=9)	1.37±0.18	1.17±0.19	1.09±0.09	0.005
Group 4 (n=7)	1.36±0.13	1.16±0.13	1.11±0.11	<0.001

SD: Standard deviation. Overall comparison (group × time interaction): p=0.261.

Table 2. Histomorphometric analysis of callus composition and Huo scores in Group 3 (femoral fracture) and Group 4 (head trauma + femoral fracture)

Parameter	Group 3 (n=9) Median (Min–Max)	Group 4 (n=7) Median (Min–Max)	p-value
Histology – Bone callus			
Callus area (mm²)	0.48 (0.29–0.83)	0.72 (0.26–0.83)	0.347
Callus area (%)	37.03 (22.59–64.6)	55.9 (20.11–62.19)	0.347
Histology – Cartilaginous callus			
Callus area (mm²)	0.041 (0–0.35)	0.024 (0–0.36)	0.670
Callus area (%)	3.18 (0–27.17)	1.86 (0–27.8)	0.670
Histology – Fibrous callus			
Callus area (mm²)	0.015 (0–0.19)	0 (0–0.59)	0.639
Callus area (%)	1.16 (0–14.36)	0 (0–45.89)	0.639
Histology – Huo score	8 (6–9)	9 (6–9)	0.999

Serum β-Catenin mRNA Relative Expression (RT-qPCR Findings)

RT-qPCR results of serum β-catenin mRNA relative expression are summarized in Table 1. No significant temporal changes were observed in Group 1 (control) or Group 2 (head trauma) ($p>0.05$). In contrast, both Group 3 (femoral fracture) and Group 4 (head trauma + femoral fracture) exhibited a significant decline in serum β-catenin mRNA relative expression from baseline to week 6 ($p=0.005$ and $p<0.001$, respectively). The group × time interaction was not statistically significant ($p=0.261$). Overall, these findings indicate that serum β-catenin mRNA relative expression decreased over time, particularly in groups with fractures.

Histological Findings

Histomorphometric evaluation revealed no statistically significant differences between the isolated femoral fracture group and the concomitant head trauma + femoral fracture group (Table 2). Although the head trauma group showed a tendency toward a greater proportion of osseous callus and slightly higher Huo scores compared with the isolated fracture group, these differences did not reach statistical significance ($p>0.05$). Similarly, the proportions of cartilage and fibrous tissue within the callus were comparable between the groups. Overall, the histological analyses suggested a trend toward enhanced bone formation in the presence of concomitant head trauma, although the differences were not statistically significant (Figs. 1, 2).

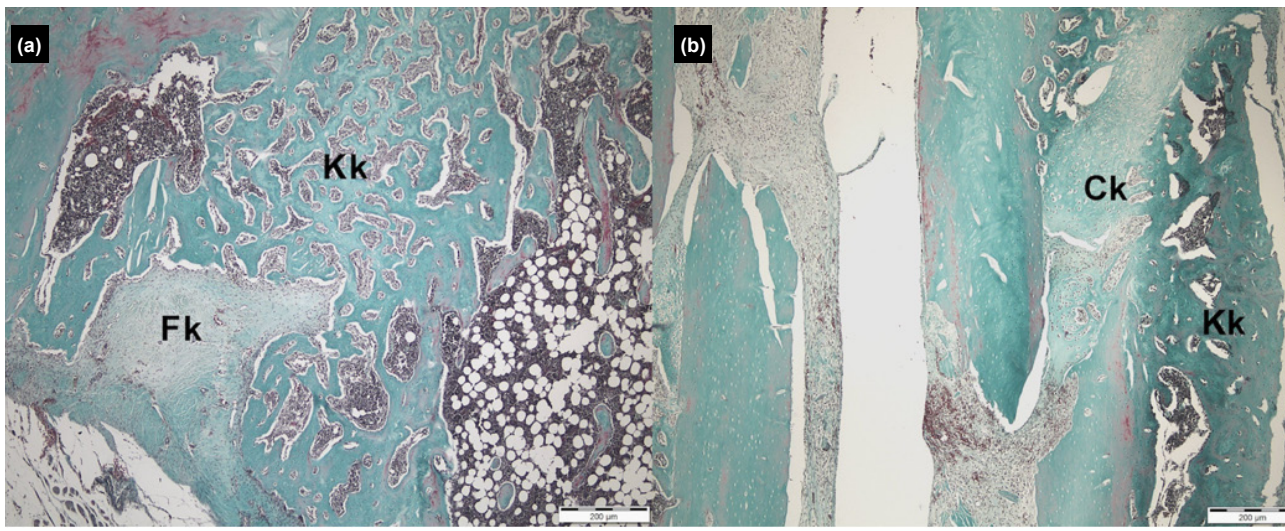

Figure 1. Histological sections stained with Masson's trichrome (magnification ×40). **(a)** Representative section from Group 3 demonstrating abundant bone callus (Kk) formation with a smaller proportion of fibrous callus (Fk). **(b)** Representative section from Group 4 showing prominent bone callus (Kk) together with a lesser amount of cartilaginous callus (Ck).

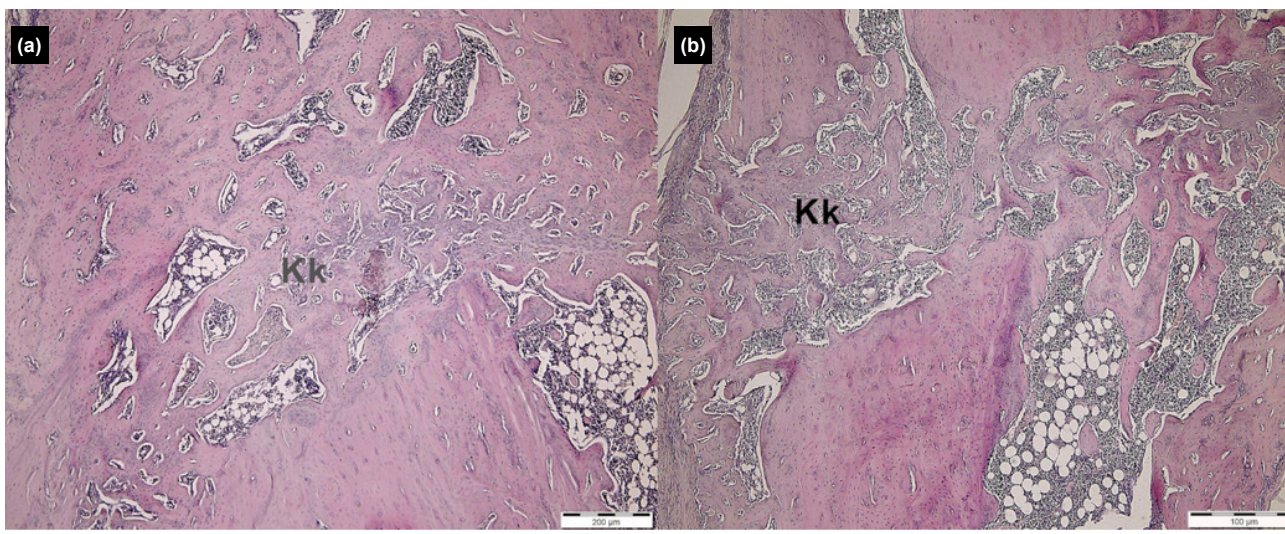

Figure 2. Histological sections stained with hematoxylin and eosin (magnification ×40). **(a)** Representative section from Group 3 showing bone callus (Kk). **(b)** Representative section from Group 4 also demonstrating bone callus (Kk).

DISCUSSION

In this experimental study, we examined the impact of concomitant head trauma on femoral fracture healing using radiological, histological, and serum-based molecular assessments. Our primary endpoint was radiographic healing, and RUST scores were consistently higher in the fracture + TBI group than in the fracture-only group at weeks 3 and 6, supporting an association between concomitant TBI and accelerated radiographic healing in this model. Secondary endpoints provided more limited support. Histological evaluation demonstrated only a non-significant trend toward more mature osseous callus formation at a single terminal time point, while serum β-catenin mRNA relative expression declined over time in the fracture groups without a significant group × time interaction. Accordingly, these serum transcript dynamics should be interpreted as an indirect systemic readout and do not establish a TBI-specific mechanistic pathway. Taken together, these findings support a clear radiographic association while underscoring the need for future studies incorporating longitudinal tissue-level and fracture-site molecular analyses to clarify the underlying biological mechanisms.

Radiological evaluation showed that the concomitant TBI group demonstrated significantly higher RUST scores at both weeks 3 and 6 compared with the isolated fracture group, consistent with the well-documented phenomenon of "TBI-induced osteogenesis." Although the RUST scoring system was originally developed for tibial fractures, its validity has also been demonstrated for femoral fractures in clinical studies, where it provides reliable predictive value for union.[19] Our findings are consistent with previous clinical reports describing more exuberant callus formation and accelerated radiographic healing in patients with concomitant TBI.[5,20,21] Similarly, a recent comprehensive review reported that, across both clinical and experimental studies, TBI consistently shortens the radiological time to union.[7] Collectively, these observations reinforce the concept that TBI significantly accelerates early radiographic fracture healing, in agreement with our findings.

β-catenin functions primarily as an intracellular effector of canonical Wnt signaling; therefore, serum-based mRNA measurements should be interpreted as an indirect systemic readout rather than as a circulating signaling mediator. At the molecular level, our study demonstrated that serum β-catenin mRNA relative expression declined significantly over time in the fracture groups, whereas no significant temporal changes were observed in the control or isolated TBI groups. Importantly, the group × time interaction between the fracture-only and fracture + TBI groups was not significant, suggesting that this decline was primarily associated with the presence of fracture rather than with concomitant brain injury (Table 1). These findings are consistent with previous reports highlighting the phase-dependent regulation of Wnt/β-catenin signaling during bone repair. Chen et al.[12] demonstrated that excessive β-catenin activity may impair early chondrogenesis, whereas appropriate levels are required for ossification; sustained activation may also hinder the remodeling phase. Consistent with these findings, Bao et al.[10] reported that optimal—rather than excessive—β-catenin activity during the remodeling phase is essential for maintaining bone quality and mechanical stability. Reviews have further emphasized that Wnt/β-catenin must remain within a physiological range, as both insufficient and excessive signaling may compromise repair.[11,13] Human tissue studies have likewise demonstrated strong Wnt activation in fracture callus but reduced or dysregulated signaling in nonunion tissue.[14] Taken together, these observations suggest that the temporal downregulation of β-catenin observed in our fracture groups may represent a physiological adaptation that supports appropriate callus maturation. At the same time, they highlight that systemic serum β-catenin mRNA relative expression may not fully reflect the localized regulatory activity occurring within fracture tissue.

In the present study, Group 4 (head trauma + femoral fracture) demonstrated a greater proportion and volume of osseous (mature) callus than Group 3 (femoral fracture alone), although this difference did not reach statistical significance (Table 2). In contrast, several experimental studies have reported significant histological differences indicating enhanced callus formation in the presence of TBI.[22-24] The absence of statistical significance in our data may be attributable to factors such as the relatively small sample size, the assessment of histology at a single time point (week 6), and the inherent biological variability of fracture healing in animal models. Despite these limitations, the observed trend toward more mature callus in the TBI group is biologically plausible and consistent with recent studies. For example, Yang et al.[22] reported that exosomes released following TBI stimulate osteoblast proliferation and differentiation, while Xia et al.[25] identified neuron-derived, miRNA-enriched vesicles that enhance osteogenesis, both of which may represent potential mechanisms underlying increased callus ossification. Taken together, although not statistically significant, our findings are consistent with the broader body of evidence suggesting that concomitant TBI may promote the formation of more mature callus during fracture repair.

In our study, serum β-catenin mRNA relative expression did not increase over time; instead, a significant decline was observed in the fracture groups. This finding may reflect phase-specific regulation of the Wnt/β-catenin pathway and underscores that systemic serum measurements may not fully capture local activity within the fracture callus. Accordingly, the serum β-catenin mRNA expression findings should be interpreted as associative and cannot be considered evidence that systemic β-catenin signaling mediates the enhanced radiographic healing observed with concomitant TBI. Previous studies have demonstrated that β-catenin plays a central role in fracture repair at the tissue level, exerting stage-dependent effects on chondrogenesis, ossification, and remodeling.[10,12,14] Therefore, the decrease in serum β-catenin mRNA

relative expression observed in this study does not preclude the biological importance of local β-catenin signaling within the callus. Clinical observations similarly indicate that long bone fractures accompanied by TBI are associated with faster union and more exuberant callus formation.[5,20] These findings support the translational relevance of the radiographic association observed in our study and suggest that Wnt/β-catenin signaling warrants further mechanistic investigation in the context of TBI-associated fracture repair. However, our data do not establish a mediating role for systemic serum β-catenin mRNA. Experimental studies have shown that interventions such as glycogen synthase kinase-3β (GSK-3β) inhibition, antisclerostin antibody therapy, and other pharmacological modulators of Wnt/β-catenin signaling can enhance callus formation and improve bone quality, although their efficacy is critically dependent on timing and dosage.[11,26] Importantly, these findings are not specific to TBI-associated fracture healing and should not be interpreted as implying therapeutic applicability based on our serum mRNA findings alone. Taken together, our results highlight the complex, phase-dependent regulation of β-catenin during fracture repair and reinforce the need for further mechanistic and translational studies, particularly those incorporating local (fracture-site) pathway analyses.

This study has several limitations that should be acknowledged. First, the sample size was relatively small, which may have reduced the statistical power to detect subtle differences, particularly in the histological analyses. Consequently, modest between-group differences in secondary tissue-level outcomes may have been missed. In addition, group sizes became unequal after exclusions, which may have further reduced statistical power and increased the likelihood of overlooking modest between-group differences. No a priori power calculation was performed; therefore, the study may have been underpowered to detect small histological effects. Second, biomechanical testing (e.g., torsional or bending strength) was not performed, and thus the mechanical competence of the healed femur could not be directly assessed. Third, histological and molecular assessments were conducted at a single time point (week 6), which does not capture the full dynamics of fracture healing across different phases. As a result, subtle or phase-dependent tissue-level differences between the fracture-only and TBI + fracture groups may have gone undetected, and the study may have been underpowered to detect modest histological effects. Fourth, serum β-catenin mRNA relative expression was evaluated only in serum and may not accurately reflect local signaling activity within the fracture callus. Moreover, pre-analytical serum handling variables (e.g., serum separation conditions and storage history) were not independently standardized or recorded, which could influence serum-based RT-qPCR measurements. Because β-catenin is predominantly intracellular, circulating measurements are inherently indirect and may not adequately capture callus-level pathway activation. Finally, as this was an experimental animal study, caution is warranted when extrapolating the findings directly to clinical practice. Future studies with larger cohorts, multiple time-point analyses, and combined systemic and local molecular evaluations will be needed to better define the role of Wnt/β-catenin signaling in TBI-associated fracture repair.

CONCLUSION

In this rat model, concomitant TBI was associated with higher radiographic RUST scores at weeks 3 and 6, indicating accelerated radiographic healing as the primary study finding. Histological evaluation at week 6 demonstrated only a non-significant trend toward greater osseous callus formation, and serum β-catenin (Ctnnb1) mRNA relative expression did not reveal a TBI-specific systemic signal. Thus, the serum RT-qPCR findings represent an indirect systemic readout and do not establish a mechanistic TBI-specific β-catenin pathway.

Ethics Committee Approval: This study was approved by the Mersin University Rectorate Animal Experiments Local Ethics Committee (Date: 25.03.2019, Decision No: 15).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: V.Ö., E.G.; Design: V.Ö., E.G.; Supervision: V.Ö.; Data collection and/or processing: H.O.D., S.A., M.T.K., M.E.E.; Analysis and/or interpretation: H.O.D., S.A., M.T.K., M.E.E.; Literature review: V.Ö., Z.M.A., H.O.D., S.A., M.T.K., M.E.E.; Writing: V.Ö., E.G., Z.M.A.; Critical review: E.G., V.Ö.

Conflict of Interest: None declared.

Financial Disclosure: This study was financially supported by the Turkish Orthopaedic Research Council (TOAK).

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DENEYSEL ÇALIŞMA - *ÖZ*

Kafa travması ile ilişkili femur kırıklarının iyileşmesi ile serum β-katenin mRNA ekspresyonu arasındaki ilişki: Deneysel bir sıçan çalışması

AMAÇ: Kırık iyileşmesi eşlik eden travmatik beyin hasarından (TBH) etkilenebilir; klinik ve deneysel çalışmalar hızlanmış kaynama ve artmış kallus oluşumunu düşündürmektedir. Wnt/β-katenin sinyal yolunun bu süreçte rol oynayabileceği düşünülmektedir. Ancak, TBH varlığında serum β-katenin mRNA ekspresyonu ile kırık iyileşmesi arasındaki ilişki belirsizliğini korumaktadır.
GEREÇ VE YÖNTEM: Otuz altı dişi Wistar albino sıçanı dört gruba rastgele atanmıştır: Kontrol, yalnız TBH, yalnız femur kırığı ve kombine TBH ve femur kırığı. Radyografik iyileşme 3. ve 6. haftalarda RUST puanlama sistemi kullanılarak değerlendirilmiştir. Serum β-katenin mRNA göreli ekspresyonu gerçek zamanlı polimeraz zincir reaksiyonu ile yapılmış ve histolojik analiz 6. haftada gerçekleştirilmiştir.
BULGULAR: Radyografik değerlendirme tüm kırık gruplarında ilerleyici iyileşme göstermiş, TBH + kırık grubunda RUST puanları her iki zamanda da ($p<0.05$) yalnız kırık grubuna göre anlamlı olarak daha yüksek bulunmuştur. Serum β-katenin mRNA ekspresyonu kırık gruplarında zaman içinde anlamlı olarak azalmış, kontrol grubunda veya izole TBH grubunda ise anlamlı zamana bağlı değişiklik gözlenmemiştir. Serum β-katenin mRNA ekspresyonundaki düşüş her iki kırık grubunda da gözlenmiş olup, bu bulgu TBH'ye özgü moleküler bir etkiyi doğrulamamaktadır. Histolojik analiz, TBH + kırık grubunda daha olgun osseöz kallus oluşumuna yönelik bir eğilimi düşündürmüş, ancak farklar istatistiksel olarak anlamlı bulunmamıştır.
SONUÇ: Eşlik eden TBH, radyografik kırık iyileşmesinde artış ile ilişkili bulunmuş ve daha büyük osseöz kallus oluşumuna yönelik istatistiksel olarak anlamlı olmayan bir eğilim göstermiştir. Kırık gruplarında gözlenen serum β-katenin mRNA ekspresyonundaki düşüş, onarım sürecinde Wnt/β-katenin ile ilişkili aktivitenin faz-bağımlı düzenlenmesini düşündürmekle birlikte, serum β-katenin mRNA göreli ekspresyonu indirekt bir sistemik göstergedir ve TBH'ye özgü mekanistik bir yolu kanıtlamaz. Bu bulgular, TBH'nın iskelet onarımı üzerindeki karmaşık sistemik etkisini vurgulamakta ve gözlenen radyografik ilişkinin biyolojik alt yapısını aydınlatmak için, tercihen kırık sahası (lokal) analizlerini içeren daha ileri mekanistik çalışmaları desteklemektedir.

Anahtar sözcükler: Deneysel sıçan modeli; kallus formasyonu; kırık iyileşmesi; travmatik beyin hasarı; Wnt/β-katenin yolağı.

Ulus Travma Acil Cerrahi Derg 2026;32(5):527-534 DOI: 10.14744/tjtes.2026.23177

ORIGINAL ARTICLE

Developing and validating the Earthquake-Related Crush Syndrome Knowledge Scale using tetrachoric and Rasch analyses

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ABSTRACT

BACKGROUND: A substantial proportion of earthquake-related fatalities result from severe trauma at the time of the event and entrapment under debris. Prolonged compression significantly increases the risk of developing crush syndrome, which is considered a critical determinant of mortality and morbidity. This study aimed to develop and evaluate a scale designed to assess pediatric surgical nurses' knowledge of earthquake-related crush syndrome.

METHODS: This methodological study was conducted between August and September 2023. The sample consisted of 77 pediatric surgical nurses working in pediatric surgery units of a city hospital who voluntarily participated in the study. Data were collected using a data collection form and a draft 30-item version of the scale. Content and construct validity were assessed to validate the instrument. Tetrachoric factor analysis was used to examine construct validity. Reliability was evaluated using the Kuder–Richardson Formula 20 coefficient and the person reliability coefficient. Rasch analysis was performed to assess item difficulty and discrimination.

RESULTS: The Content Validity Index for the Earthquake-Related Crush Syndrome Knowledge Scale was 0.99. Tetrachoric factor analysis revealed two subdimensions comprising nine items. Goodness-of-fit indices for the confirmatory two-factor model indicated an acceptable to excellent fit. The Kuder–Richardson Formula 20 reliability coefficients were 0.90 for Factor 1 and 0.88 for Factor 2. According to Rasch analysis, the scale demonstrated a two-subdimension structure comprising seven items, with factor loadings ranging from 0.59 to 0.90; the factors were interrelated. In the Rasch model, the person reliability coefficient was 0.433, indicating low reliability. The mean absolute deviation of Q3 residual correlations (MADaQ3), used to assess model fit, was 0.116, while the information-weighted fit (infit) and outlier-sensitive fit (outfit) statistics were within the acceptable range (0.5–1.5).

CONCLUSION: Preliminary findings suggest that the scale demonstrates acceptable validity and reliability for assessing pediatric surgical nurses' knowledge of earthquake-related crush syndrome.

Keywords: Crush syndrome; earthquake injuries; knowledge scale; nurse; trauma.

INTRODUCTION

Earthquakes are devastating natural disasters that cause extensive injuries and high mortality due to their sudden and unpredictable nature.[1] A substantial proportion of earthquake-related deaths result from severe trauma at the time of the event or from entrapment under debris. The risk of developing earthquake-related crush syndrome (ECS) increases significantly in individuals exposed to prolonged compression, which is a key determinant of mortality and morbidity.[2] The

Cite this article as: Suluhan D, Koyun E, Yildiz D, Şenel E. Developing and validating the earthquake-related Crush syndrome knowledge scale using tetrachoric and Rasch analyses. Ulus Travma Acil Cerrahi Derg 2026;32:535-543.

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Ulus Travma Acil Cerrahi Derg 2026;32(5):535-543 DOI: 10.14744/tjtes.2025.37646
Submitted: 11.07.2025 Revised: 10.11.2025 Accepted: 18.12.2025 Published: 05.05.2026

Kahramanmaraş earthquakes, among the most destructive in recent Turkish history, resulted in at least 56,000 deaths and caused severe trauma in a large number of patients.[3] A study by Kulakoğlu et al.[4] reported that 33.1% of 957 trauma patients admitted after the earthquake were aged 0 to 20 years, and ECS developed in 7.7% of these patients.

Crush syndrome is a severe clinical condition caused by prolonged compression of the extremities or other body parts, leading to muscle edema, rhabdomyolysis, and subsequent systemic complications.[5] The major life-threatening manifestations of crush syndrome (CS) include acute renal failure, hyperkalemia, hypocalcemia, metabolic acidosis, and compartment syndrome. These complications primarily result from the release of nephrotoxic substances from damaged muscle cells, hypovolemia, and metabolic disturbances.[6] Early fluid resuscitation and timely medical intervention, particularly within the first six hours following injury, are essential to reduce crush syndrome–related mortality and morbidity.[7]

Children who survive earthquakes require care from healthcare professionals with expertise in pediatric practice.[8,9] According to the American Pediatric Surgical Nurses Association, pediatric surgical nurses provide evidence-based, patient- and family-centered care aimed at promoting, protecting, and optimizing the health of children with surgical conditions from infancy through young adulthood.[10] Their advanced clinical expertise and leadership competencies enable them to provide comprehensive care across the pre-crisis, crisis, and post-crisis phases.[11]

The Disaster Nursing Competencies framework published by the International Council of Nurses defines the competencies required of nurses in disaster situations and outlines the essential knowledge, skills, and attitudes they are expected to possess.[12] One key competency is the ability to effectively manage disaster-related conditions such as multiple trauma and CS. Therefore, assessing the clinical manifestations of ECS and implementing evidence-based nursing interventions for pediatric earthquake survivors are critical responsibilities of pediatric surgical nurses.[13] However, evidence suggests that nurses are still insufficiently prepared to manage disaster situations and often lack clarity regarding their roles during such events.[14] Studies by Guner and Oncu[13] and Özpulat et al.[15] reported that nurses possess insufficient knowledge of ECS. Similarly, Moghaddam et al.[16] found that nurses emphasized the need for additional training in clinical skills, including the provision of emotional support and care for survivors affected by ECS.

The use of valid and reliable measurement instruments to assess healthcare professionals' knowledge, skills, and attitudes provides valuable evidence for both the literature and clinical practice.[16] Although several tools exist to evaluate nurses' preparedness and awareness in disaster contexts,[17-21] no valid and reliable instrument specific to ECS—a condition frequently observed in patients with post-earthquake trauma—has been identified in the literature.

The aim of this study is to develop a measurement tool, the Earthquake-Related Crush Syndrome Knowledge Scale (ECSKS), to assess pediatric surgical nurses' knowledge of ECS and to evaluate its validity and reliability. Additionally, the study seeks to determine nurses' knowledge levels regarding ECS management and to contribute to the development of targeted training programs.

MATERIALS AND METHODS

Study Design and Settings

This methodological study was conducted to assess pediatric surgical nurses' knowledge of ECS. The research took place between August and September 2023 in a city hospital that served as a referral center for pediatric survivors following the Kahramanmaraş earthquakes. The study was carried out in the pediatric surgical intensive care unit, two pediatric surgical wards, and a pediatric burn center of a hospital located in Ankara, the capital of Türkiye and home to the country's second-largest city hospital.

Sample Size and Study Population

The study population consisted of 77 pediatric surgical nurses working in the aforementioned units, all of whom were included in the study. In scale development research, it is generally recommended that the sample size be at least five to ten times the number of items in the draft scale.[16] However, this study was conducted in a tertiary city hospital that functioned as a referral and disaster response center following the Kahramanmaraş earthquakes. Therefore, the sample comprised all eligible pediatric surgical nurses who voluntarily agreed to participate (n=77). Due to the limited number of pediatric surgical nurses employed in earthquake-prone tertiary care settings, it was not feasible to increase the sample size beyond the available population. This limitation should be considered when interpreting the findings, as it reflects the specialized nature and restricted workforce distribution of this nursing group.

Instrument Development

The ECSKS was developed in nine stages, following the scale development framework proposed by Comrey and Lee.[22]

Stage I: Identification of Basic Concepts and Stage 2: Item Pool Generation

The researchers (D.S., E.K.) conducted a literature review to define the scope of the draft scale. Three electronic databases, PubMED, Google Scholar, and ScienceDirect, were searched. The following English keywords were used: earthquake, crush syndrome, children, nurse, knowledge, practice, tool, and scale. This search yielded 92 articles published between 2013 and 2023. After reviewing studies related to ECS,[2,5,13,23–28] an initial pool of 30 items was generated.

Stage III: Content Validity

Expert opinions were obtained to assess the content validity

of the items in the pool. The expert panel consisted of five academicians in pediatric nursing, three specialist physicians in pediatric surgery, and two specialist nurses working in a pediatric surgery clinic at a different hospital. Using the "Expert Evaluation Form," the experts evaluated the extent to which each item represented the intended construct and its clarity for the target population. Items were rated according to the Davis technique as follows: 1=not appropriate, 2=requires major revision, 3= appropriate but requires minor revision, and 4=appropriate. The Content Validity Ratio (CVR) for each item was calculated by dividing the number of experts who rated the item as 3 or 4 by the total number of experts.[29] The Content Validity Index (CVI) was then computed as the average of the CVR values across all items.[23]

Stage IV: Pilot Study

A pilot study was conducted to evaluate the face validity of the scale. The 30-item draft scale was administered to 15 nurses working in pediatric urology surgery clinics. The results indicated that the items were comprehensible, and no revisions were required. The 15 nurses who participated in the pilot study were excluded from the main data collection.

Stage V: Application of the Study

Data were collected using the Descriptive Data Collection Form and the draft version of the ECSKS. The Descriptive Data Collection Form, developed by the researchers based on a literature review, consisted of six items assessing participants' age, sex, educational level, years of professional experience, experience providing care to patients with crush syndrome, and prior training on crush syndrome.[2,5,13,24-28]

The draft ECSKS was a 30-item instrument designed to assess pediatric surgical nurses' knowledge and practices related to crush syndrome. The items were formatted as binary Likert-type responses ("true"/"false"). Each correct response was scored as 1 point, while incorrect or unanswered items were scored as 0. The ECSKS comprised two domains: "general knowledge" and "evaluation." Following the literature review, the theoretical framework and key problem areas were identified, and items aligned with the study objectives were developed for each domain. Each was constructed based on predefined content areas and related variables. The preliminary version of the scale was reviewed in detail by the researchers and approved for suitability. A total of 30 items were retained for subsequent face and content validity analyses.

Stage VI: Retest Application

As only five nurses agreed to participate in the retest procedure, statistical analysis could not be performed.

Stage VII: Validity Assessment of the ECSKS

The construct validity of ECSKS was evaluated, with findings presented in the Results and Discussion sections.

Stage VIII: Reliability Assessment of the ECSKS

The consistency of the ECSKS was assessed by calculating Kuder–Richardson Formula 20 (KR-20) coefficients and person reliability values; the findings are reported in the Results and Discussion sections.

Stage IX: Final ECSKS

The overall validity and reliability of the ECSKS are discussed in the Conclusion section.

Ethical Considerations

The study protocol was approved by the Ethics Committee No. II of Ankara Bilkent City Hospital (approval number: E2-23-4738). Informed consent was obtained from all participants prior to data collection. The study was conducted in accordance with the principles of the Declaration of Helsinki. All healthcare professionals were informed about the study, and written informed consent was obtained before participation.

Data Collection

Data were collected under the supervision of the researchers after participants were informed about the purpose of the study. The data collection form was administered in a quiet and private setting. Participants were instructed to select the responses that best reflected their views and completed the forms independently, without guidance. Completion of the data collection form required approximately 20 minutes.

Data Analysis

The research data were analyzed using Statistical Package for the Social Sciences (SPSS) version 23.0 (IBM Corp., Armonk, NY, USA), Factor version 12.04.04 for Windows, and Jamovi version 2.6.13. Descriptive statistics for numerical variables were expressed as mean±standard deviation, as well as median, minimum, and maximum values. Categorical variables were summarized using numbers and percentages. The validity of the scale was evaluated in terms of content, face, and construct validity. Expert opinions on the draft ECSKS were assessed using Davis's technique to calculate the content validity index, along with Kendall's coefficient of concordance. Construct validity was examined using tetrachoric factor analysis. When analyzing dichotomous data, tetrachoric correlations are required to ensure that factor analysis appropriately reflects the nature of the data, allowing for a more accurate representation of the underlying structure. For reliability analysis, internal consistency was assessed using Kuder–Richardson Formula 20 coefficient.

The Rasch model was applied to determine item difficulty levels and participants' ability levels. The Mann–Whitney U test was used to compare non-normally distributed scores between lower and upper groups. Statistical significance was set at $p<0.05$.

RESULTS

Characteristics of the Participants

The mean age of the participants was 28.09±3.11 years. Of the participants, 68.8% (n=53) were female, and 87% (n=67)

held a bachelor's degree. Additionally, 75.3% (n=58) had 1–5 years of professional experience. While 70.1% (n=54) had previously cared for a patient with crush syndrome, 74% (n=57) had not received any formal education on the condition. The participants' characteristics are presented in Table 1.

Validity Results

Content and construct validity were assessed as part of validity analyses. The findings indicated that the developed measurement instrument demonstrated a high level of validity.

Content Validity

The content validity of the scale was evaluated based on the opinions of 10 experts. The CVI was calculated as 0.99. Since all experts agreed on the 30 items included in the draft scale and the CVI value of the Earthquake-Related Crush Syndrome Knowledge Scale exceeded 0.80, all items were retained in the draft form. Furthermore, Kendall's coefficient of concordance indicated a high level of agreement among experts (W=0.78), which was statistically significant (p=0.001).

Construct Validity

The draft form of the instrument was first administered to assess construct validity. Bartlett's test of sphericity was statistically significant (χ^2=201.3, sd=21, p<0.001), and the Kaiser–Meyer–Olkin (KMO) value was 0.61.

Based on the multicollinearity assessment, items 18 and 19 were excluded from the analysis. Subsequently, construct validity analysis was conducted using the remaining items.

Tetrachoric factor analysis was performed to determine the underlying factor structure of the scale. The results indicated that 21 items (items 1, 3, 4, 5, 9, 10, 11, 13, 14, 15, 16, 20, 21, 23, 24, 25, 26, 27, 28, 29, and 30) were excluded due to factor loadings below 0.32. The final scale consisted of seven items across two sub-dimensions, labeled "Knowledge" and "Evaluation" (Table 2). Fit indices obtained from the tetrachoric factor analysis indicated an acceptable fit for the chi-square to degrees of freedom ratio (χ^2/df), and excellent fit levels for the Adjusted Goodness-of-Fit Index (AGFI), Comparative Fit Index (CFI), Goodness-of-Fit Index (GFI), and Root Mean Square Error of Approximation (RMSEA) (Table 3).

Results of Reliability

Following factor analysis, the Kuder–Richardson Formula 20 reliability coefficients were calculated as 0.90 for Factor 1 and 0.88 for Factor 2 (Table 2).

Item Difficulty and Discrimination

According to the Rasch analysis, the person reliability coefficient of the scale was 0.433. The Mean Absolute Deviation of adjusted Q3 (MADaQ3) value, calculated to assess model fit, was 0.116, with a p-value of 0.062 (Table 4).

The proportion of correct responses ranged from 42.3% (Item M22) to 85.9% (Item M8). Rasch measures varied between -2.258 and 0.401, where negative values indicate easier

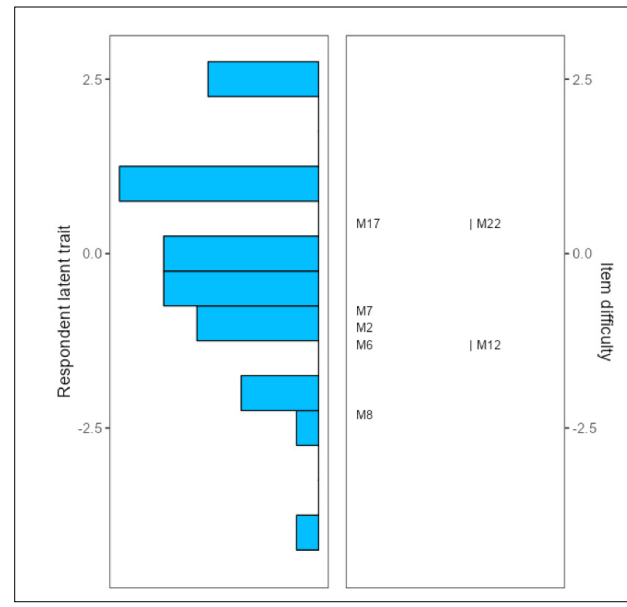

Figure 1. Wright map of the scale.

Table 1. Descriptive characteristics of participants (n=77)

Variables	n	%
Mean age, years (range)	28.09±3.11	(24-44)
Sex		
Female	53	68.8
Male	24	31.2
Educational level		
Associate degree	1	1.3
Bachelor's degree	67	87
Master's degree	8	10.4
Doctoral degree	1	1.3
Professional experience (years)		
<1 year	4	5.2
1-5 years	58	75.3
6-10 years	7	9.1
11-15 years	4	5.2
16-20 years	4	5.2
Experience caring for patients with crush syndrome		
Yes	54	70.1
No	23	29.9
Received training on crush syndrome		
Yes	20	26
No	57	74
Total	77	100

*n: Number of participants; %: Percentage.

Table 2. Eigenvalues, variance, and factor loadings from tetrachoric factor analysis

Factor	Items	Eigenvalue	Cumulative variance (%)	KR-20 reliability	Factor Determinacy Index	Interfactor correlation
Factor 1	M2, M6, M8, M12	1.48	0.43	0.90	0.949	0.216
Factor 2	M7, M17, M22	3.03	0.64	0.88	0.936	

	Items	Factor 1	Factor 2
M8	In most cases of crush syndrome, early initiation of appropriate fluid therapy can prevent the development of acute kidney injury.	0.850	–
M6	Clinical signs of crush syndrome are primarily due to systemic effects of muscle tissue damage, with rhabdomyolysis being a common cause of acute kidney injury.	0.846	–
M12	Compartment syndrome is characterized by increased intracompartmental pressure caused by hypoxia and neuromuscular and microvascular changes due to muscle edema.	0.703	–
M2	Earthquakes, as natural disasters, are the most common cause of crush syndrome.	0.662	
M17	Since cardiac function is generally preserved in patients with crush syndrome, monitoring with pulse oximetry alone is sufficient.	–	0.909
M7	Clinical signs and symptoms of acute kidney injury should be carefully evaluated in all patients with crush syndrome.	–	0.796
M22	Due to the risk of hyperkalemia, patients with crush syndrome should be provided with a potassium-restricted diet.	–	0.594

*KR-20: Kuder–Richardson Formula 20.

Table 3. Goodness-of-fit indices from tetrachoric factor analysis

Fit index	Criteria for excellent fit	Criteria for acceptable fit	Calculated value	Fit level
χ^2/df	$0 \leq \chi^2/df \leq 2$	$2 \leq \chi^2/df \leq 3$	2.480	Acceptable fit
GFI	$0.95 \leq GFI \leq 1$	$0.90 \leq GFI \leq 0.95$	0.988	Excellent fit
AGFI	$0.90 \leq AGFI \leq 1.00$	$0.85 \leq AGFI \leq 0.90$	0.968	Excellent fit
CFI	$0.95 \leq CFI \leq 1.00$	$0.90 \leq CFI \leq 0.95$	0.999	Excellent fit
RMSEA	$0.00 \leq RMSEA \leq 0.05$	$0.90 \leq GFI \leq 0.95$	0.001	Excellent fit

*AGFI: Adjusted Goodness-of-Fit Index; CFI: Comparative Fit Index; df: Degrees of freedom; GFI: Goodness-of-Fit Index; RMSEA: Root Mean Square Error of Approximation; χ^2: Chi-square.

Table 4. Rasch model fit statistics

	Min–Max	Mean±SD	Median	Person reliability	MADaQ3	p
Scale	0–7	4.53±1.78	5.00	0.433	0.116	0.062

*MADaQ3: Mean absolute deviation of centered Q_3 residual correlations; P indicates model fit to the Rasch model.

items and positive values indicate more difficult items. Accordingly, Item M8 (Measure=-2.258) was the easiest, while Item M22 (Measure=0.401) was the most difficult (Fig. 1, Table 5). Item information-weighted fit (infit) statistics ranged from 0.947 (Item M8) to 1.082 (Item M22), all within the acceptable range of 0.7–1.3. Similarly, outlier-sensitive fit (outfit) values ranged from 0.921 (Item M2) to 1.116 (Item M22), also indicating acceptable fit (Table 5).

The Wright map (person-item map) presented in Figure 1 illustrates, based on Rasch analysis, participants' latent trait

Table 5. Item statistics in Rash analysis

	Proportion (%)	Item difficulty	SE	Infit	Outfit
M2	0.679	-0.961	0.273	0.957	0.921
M6	0.744	-1.355	0.289	0.968	0.946
M7	0.654	-0.815	0.269	1.014	0.992
M8	0.859	-2.258	0.354	0.947	0.969
M12	0.731	-1.272	0.286	1.012	1.034
M17	0.436	0.334	0.259	0.992	1.015
M22	0.423	0.401	0.260	1.082	1.116

*Infit: Information-weighted mean square; Outfit: Outlier-sensitive mean square, SE: Standard error.

Table 6. Comparison of the lowest- and highest-scoring 27% groups

Group	Median	Min	Max	Mean±SD	Test statistic	p
Lowest-scoring 27% group	2.00	0.00	3.00	2.19±0.98	231.000	<0.001
Highest-scoring 27% group	6.00	6.00	7.00	6.48±0.51		

*n: Number of participants; %: Percentage; Mean±SD: Mean±standard deviation.

levels (left panel) and item difficulty levels (right panel) on the same logit scale. The distribution on the left side of the map, represented by blue bars, reflects participants' trait levels. Item difficulty levels are displayed on the right panel. Item M8 has the lowest difficulty level, whereas Items M22 and M17 are the most difficult. Additionally, Items M6, M12, M2, and M7 are relatively easier and are positioned closer to the center of the scale.

Total scores on the scale ranged from 0 to 7, with a mean of 4.53±1.78 and a median of 5.00. A significant difference was observed between the median scores of the lower and upper groups (p<0.001). The median score was 2.00 for the lower group and 6.00 for the upper group (Table 6).

DISCUSSION

The present study employed the dichotomous Rasch model to evaluate the psychometric properties, namely structural validity, internal consistency, and measurement characteristics, of the seven-item Earthquake-Related Crush Syndrome Knowledge Scale, developed to assess pediatric surgical nurses' knowledge of ECS. Adequate knowledge of ECS is essential for nurses, as it is one of the most common conditions observed in patients hospitalized following earthquakes. Competency in this area directly influences the effectiveness of post-disaster interventions and improves patient outcomes.[12,14,28,30] The ECSKS is the first instrument in the literature specifically designed to measure ECS knowledge among pediatric surgical nurses caring for child earthquake survivors in hospital settings.

Validity of the Scale

Content validity refers to the extent to which a scale and its subscales adequately represent the construct being measured, ensuring semantic clarity and conceptual consistency across items.[31,32] This method is commonly used to evaluate content validity, and items with low CVI values may be revised.[32] A CVI of at least 0.80 is generally considered acceptable for content validity.[33,34] In this study, the CVI value was high, indicating that the ECSKS draft demonstrated adequate content validity. A Kendall's W value exceeding 0.70 indicates a strong level of agreement among experts,[35] reflecting consistency in their evaluations of item relevance and clarity. In this study, the statistically significant result suggests that the observed agreement was unlikely to have occurred by chance, thereby supporting the content validity and conceptual representativeness of the scale items.

In the literature, it is recommended that sample size in scale development be at least five to ten times the number of items.[23] In the present study, the sample consisted of nurses with highly specific characteristics who met the inclusion criteria and were working in a city hospital that served as a referral and disaster response center following the Kahramanmaraş earthquake. Therefore, the entire accessible population meeting these criteria was included. However, the number of participants did not meet the recommended item-to-sample ratio. Accordingly, the suitability of the dataset for factor

analysis and construct validity was assessed using the KMO measure and Bartlett's test of sphericity.[36] The KMO value indicated that the sample was moderately adequate, suggesting that the dataset was acceptable for factor analysis. However, this value also implies that the sample size or the intercorrelations among variables were not particularly strong.[36]

Construct validity analysis was conducted to determine whether the scale items work were consistent with the intended theoretical structure.[37] In this study, the measurement model was evaluated using tetrachoric factor analysis. The presence of multicollinearity can lead to unstable parameter estimates and inflated standard errors, thereby reducing the precision of confidence intervals and the validity of hypothesis testing. To address this issue, it is recommended to remove one of the highly correlated variables.[38,39] Accordingly, items 18 and 19 were excluded due to multicollinearity. An item–total correlation coefficient of 0.30 or higher is generally considered indicative of consistency between an item and the overall scale, as well as with other items within the same factor.[40] Following factor analysis item–total evaluation, 21 items with low factor loadings were removed. Consequently, seven items that met the psychometric and theoretical adequacy criteria were retained. Although the number of items was reduced, this process ensured that the final version of the scale maintained statistical validity and conceptual coherence.

Tetrachoric factor analysis is appropriate for measurement instruments with dichotomous variables (e.g., yes/no or true/false).[41] The tetrachoric factor analysis conducted in this study showed that all items in the "Knowledge" and "Evaluation" subdimensions had factor loadings above 0.40. Additionally, the fit indices indicated an excellent fit.[42,43] All goodness-of-fit indices for the confirmatory two-factor model met acceptable threshold values. Specifically, the CFI (0.99>0.95), RMSEA (0.001<0.05), and AGFI (0.968>0.90) demonstrated excellent fit. Accordingly, the two-factor structure was confirmed.[42,43] Following tetrachoric factor analysis, the ECSKS was found to consist of two subdimensions with seven items.

Reliability of the Scale

The Kuder–Richardson Formula 20 coefficient is a widely used reliability measure of internal consistency for instruments with dichotomous (true/false) response formats, with values ranging from 0 to 1.[44,45] In this study, the KR-20 results indicated that the scale demonstrated excellent internal consistency.

The Rasch model findings further supported the reliability of the scale.[46] This model enables the ordering of items from easiest to most difficult, identifying those that participants are least and most likely to answer correctly.[47,48]

According to the Rasch analysis, the person reliability coefficient (0.433) indicated a limited ability of the scale to differentiate individuals across varying levels of the measured construct.[49] The MADaQ3 value confirmed that the assumption of local independence among items was met, and the model–data fit indices indicated an acceptable overall fit. Although the scale demonstrated adequate model fit, the low person reliability suggests that individuals could not be sufficiently distinguished along the latent trait continuum. To improve measurement precision, future studies should include a more heterogeneous sample (e.g., participants from different clinical units, with varying levels of experience, and those without prior experience in caring for child earthquake survivors). Additionally, adding items at both the lower and higher ends of the difficulty spectrum may improve the scale's targeting capacity.

In this study, Item 8 was identified as the easiest item, indicating that participants had adequate knowledge of the administration and clinical importance of intravenous fluid therapy in child earthquake survivors.[1] In contrast, Item 22 was the most difficult, as it required an understanding of the pathophysiology of earthquake-related crush syndrome. Consistent with these findings, previous studies have reported that nurses often lack sufficient knowledge of ECS and its management.[13,14,16] The identification of this item as the most challenging highlights the need for targeted educational interventions to strengthen evidence-based knowledge and address misconceptions about ECS among pediatric surgical nurses. Moreover, the difference in scale scores between the highest- and lowest-performing groups provides additional evidence of the discriminative validity of the scale items.

Limitations

The primary limitation of this study is that the sample size was limited to 77 pediatric surgical nurses working in a city hospital in Türkiye that provided centralized care for pediatric earthquake survivors following the Kahramanmaraş earthquake. In scale development studies, it is generally recommended that the sample size be at least 5-10 times the number of items in the draft scale.[23] However, because this hospital was designated by the Ministry of Health as a primary referral center for children affected by the earthquake, all eligible nurses working in this setting were included in the study. Consequently, the recommended sample size could not be achieved. The limited sample size may have reduced the ability of some items to adequately discriminate between different levels of knowledge. Nevertheless, the excellent fit statistics obtained from the Rasch analysis suggest that the instrument demonstrates validity and reliability, supporting its use in future research. Therefore, further studies with larger and more heterogeneous samples are recommended to more accurately assess individual discrimination.

CONCLUSION

Based on the preliminary findings of this study, the 7-item ECSKS demonstrates acceptable validity and reliability for assessing pediatric surgical nurses' knowledge of ECS. The results indicate that the scale shows adequate fit to the Rasch

model. Furthermore, the instrument may be used to evaluate the effectiveness of educational intervention aimed at improving pediatric surgical nurses' knowledge of ECS. Future studies should examine the applicability and validity of the ECSKS across different cultural contexts.

Acknowledgements: We would like to thank all the participating health professionals.

Ethics Committee Approval: This study was approved by the Ankara Bilkent City Hospital Ethics Committee (Date: 09.08.2023, Decision No: E2-23-4738).

Informed Consent: Written informed consent was obtained.

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: D.S., E.K.; Design: D.S.; Supervision: D.S., D.Y., E.Ş.; Resource: E.K.; Materials: E.K.; Data collection and/or pro cessing: D.S., E.K., D.Y.; Analysis and/or interpretation: D.S., E.K., D.Y., E.Ş.; Literature review: D.S., E.K.; Writing: D.S., E.K.; Critical review: D.S., D.Y., E.Ş.

Conflict of Interest: None declared.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Tetrachoric ve Rasch analizleri kullanarak Depremle İlgili Ezilme Sendromu Bilgi Ölçeğinin geliştirilmesi ve geçerliğinin doğrulanması

AMAÇ: Depremle ilişkili ölümlerin önemli bir kısmı, olay anında meydana gelen ciddi travma ve enkaz altında kalmaya bağlıdır. Uzun süreli basıya maruz kalan hastalarda ezilme sendromu gelişme riski riski belirgin şekilde artmakta olup, bu durum mortalite ve morbiditeyi etkileyen kritik faktörlerden biri olarak kabul edilmektedir. Bu çalışmanın amacı, çocuk cerrahisi hemşirelerinin depremle ilişkili ezilme sendromu hakkındaki bilgi düzeylerini değerlendirmeye yönelik bir ölçme aracı geliştirmek ve bu aracın psikometrik özelliklerini incelemektir.
GEREÇ VE YÖNTEM: Bu metodolojik çalışma Ağustos ve Eylül 2023 tarihleri arasında gerçekleştirilmiştir. Örneklem, bir şehir hastanesinin çocuk cerrahisi birimlerinde görev yapan ve çalışmaya gönüllü olarak katılan 77 hemşireden oluşmuştur. Veriler, bir veri toplama formu ve 30 maddeden oluşan ölçeğin taslak versiyonu ile toplanmıştır. Ölçeğin geçerliliğini doğrulamak için içerik ve yapı geçerliliği testleri uygulanmıştır. Ölçeğin yapı geçerliliğini belirlemek için Tetrachoric Faktör Analizi kullanılmıştır. Ölçeğin güvenirliğini belirlemek için Kuder–Richardson (KR) 20 katsayısı ve kişi güvenirlik katsayısı hesaplanmıştır. Madde güçlük ve ayırt edicilik indekslerini incelemek üzere Rasch analizi gerçekleştirilmiştir.
BULGULAR: Depremle İlgili Ezilme Sendromu Bilgi Ölçeği için Kapsam Geçerlilik Endeksi 0.99 olarak hesaplanmıştır. Tetrahorik faktör analizi sonucunda, dokuz maddeden oluşan iki alt boyutlu bir yapı ortaya çıkmıştır. İki faktörlü doğrulayıcı model için incelenen uyum indeksleri kabul edilebilir ve mükemmel uyum düzeyleri göstermiştir. KR-20 güvenirlik katsayıları faktör 1 için 0.90, faktör 2 için 0.88 olarak hesaplanmıştır. Rasch analizi sonuçları, ölçeğin yedi maddeden oluşan iki alt boyutlu bir yapıya sahip olduğunu; madde yüklerinin 0.59 ile 0.90 arasında değiştiğini ve faktörlerin birbiriyle ilişkili olduğunu göstermiştir. Rasch modelinde kişi güvenirlik katsayısı 0.433 olup düşük düzeydedir. Model uyumunu değerlendirmek amacıyla hesaplanan MADaQ3 değeri 0.116 olup kabul edilebilir düzeydedir; infit ve outfit istatistikleri ise 0.5–1.5 aralığında bulunarak uygun uyum göstermiştir.
SONUÇ: Ön bulgular, ölçeğin pediatrik cerrahi hemşirelerinin depremle ilişkili ezilme sendromuna ilişkin bilgi düzeylerini ölçmede kabul edilebilir geçerlik ve güvenirlik gösterdiğini ortaya koymaktadır.

Anahtar sözcükler: Bilgi ölçeği; deprem yaralanmaları; ezilme sendromu; hemşire; travma.

Ulus Travma Acil Cerrahi Derg 2026;32(5):535-543 DOI: 10.14744/tjtes.2025.37646

ORIGINAL ARTICLE

Postoperative ileus as a surgical challenge: comparative outcomes of end-to-end and side-to-side ileal anastomosis in radical cystectomy

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ABSTRACT

BACKGROUND: This study aimed to compare the incidence of postoperative ileus (POI) between end-to-end hand-sewn and side-to-side stapled ileo-ileal anastomoses and to identify independent risk factors associated with POI.

METHODS: We conducted a retrospective analysis of patients who underwent radical cystectomy with urinary diversion at Ankara Etlik City Hospital between October 2022 and October 2024. Patients were categorized according to the anastomosis technique used: end-to-end hand-sewn or side-to-side stapled. Perioperative data, including demographic characteristics, comorbidities, preoperative laboratory parameters, operative variables, and postoperative outcomes, were collected. POI was defined as intolerance to oral intake accompanied by abdominal distension and absence of flatus or stool beyond postoperative day five, requiring medical or surgical management. Univariable and multivariable logistic regression analyses were performed to identify risk factors for POI.

RESULTS: A total of 71 patients were included in the analysis. POI occurred in nine patients (23.7%) in the hand-sewn group and in four patients (12.1%) in the stapled group, indicating a significantly lower incidence in the stapled group. Multivariable analysis identified side-to-side stapled anastomosis as an independent protective factor against POI. Additional independent predictors included age ≥65 years, abnormal body mass index (BMI), preoperative constipation, hypoalbuminemia, and prolonged operative time. Receiver operating characteristic (ROC) curve analysis demonstrated good predictive performance of the model.

CONCLUSION: Side-to-side stapled ileo-ileal anastomosis is associated with a lower risk of POI compared to end-to-end hand-sewn anastomosis in patients undergoing radical cystectomy with urinary diversion.

Keywords: Hand-sewn anastomosis; ileal anastomosis; postoperative ileus; radical cystectomy; risk factors; stapled anastomosis; urinary diversion.

INTRODUCTION

Radical cystectomy with urinary diversion is widely accepted as the standard surgical treatment for muscle-invasive bladder cancer (MIBC).[1,2] Despite being performed routinely for several decades, it remains one of the most complex procedures in urologic oncology.[3] Postoperative ileus (POI) is among the most common complications following radical cystectomy and may lead to prolonged hospitalization.[4,5] One of the factors that may contribute to the development of this complication is the technique used for bowel anastomosis during neobladder or ileal conduit construction. Following urinary diversion reconstruction (ileal loop or neobladder), bowel continuity can be restored using end-to-end, side-to-side, or end-to-side anastomosis techniques.[6] These techniques may be performed either manually or with the assistance of a stapling

Cite this article as: Sandıkçı F, Aydın MY, Doğan AE, Yavuz A, Hasdemir AO, İmamoğlu MA. Postoperative ileus as a surgical challenge: comparative outcomes of end-to-end and side-to-side ileal anastomosis in radical cystectomy. Ulus Travma Acil Cerrahi Derg 2026;32:544-551.

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Ulus Travma Acil Cerrahi Derg 2026;32(5):544-551 DOI: 10.14744/tjtes.2026.79776
Submitted: 30.09.2025 Revised: 25.11.2025 Accepted: 12.12.2025 Published: 05.05.2026

device.[7] Some studies have suggested that stapled anastomosis reduces operative time and postoperative complications; however, other studies have reported fewer bowel-related complications with the manual technique.[8-12] Consequently, there is no clear consensus in the current literature regarding the optimal method of bowel anastomosis. Moreover, studies comparing different techniques and their technical approaches are limited. Determining whether one technique offers a safer profile in terms of postoperative bowel recovery may help optimize perioperative management.

We aimed to compare the incidence of postoperative ileus between patients undergoing end-to-end hand-sewn and side-to-side stapled ileal anastomoses during radical cystectomy with urinary diversion.

MATERIALS AND METHODS

This retrospective study was conducted in the Department of Urology at Ankara Etlik City Hospital and included all patients who underwent open radical cystectomy with urinary diversion between October 20, 2022 and October 20, 2024. Patient data were obtained from the hospital's electronic medical record system. The study protocol was approved by the Ankara Etlik City Hospital Scientific Research Evaluation and Ethics Committee (Approval Number: AEŞH-BADEK-2024-1123, Date: 27.11.2024). All procedures were performed in accordance with the ethical standards of the Declaration of Helsinki, and informed consent was obtained from all participants.

Inclusion and Exclusion Criteria

Eligible participants were adult patients who underwent open radical cystectomy with urinary diversion via either ileal conduit or orthotopic neobladder reconstruction, regardless of age, sex, or comorbid conditions, provided that the pathological tumor stage ranged from T1 to T4a. Patients were excluded if they underwent ureterocutaneostomy, experienced perioperative mortality, required postoperative intensive care unit admission, presented with ileus prior to surgery, or had non-muscle-invasive bladder cancer with a pathological stage below T1 or above T4a.

Group Design

Standard bowel preparation was not performed prior to surgery. Patients followed a restricted diet for one day before the procedure, and oral intake was discontinued 8 hours preoperatively. Prophylactic cefazolin and metronidazole were administered one hour before surgery. Fluid replacement was individualized according to the patient's clinical condition, fluid deficit, and electrolyte balance. Patients were stratified into two groups according to the ileo-ileal anastomosis technique used. Group 1 consisted of patients who underwent end-to-end hand-sewn ileo-ileal anastomosis, whereas Group 2 included patients who underwent side-to-side stapled ileo-ileal anastomosis. The choice of surgical technique and type of urinary diversion was determined based on surgeon preference and patient-specific factors. Manual anastomoses were performed using absorbable sutures, whereas stapled anastomoses were constructed using standardized stapling devices.

Data Collection and Parameters

Demographic and clinical data collected included sex, age, body mass index (BMI), smoking history, and the presence of comorbidities such as hypertension (HT), diabetes mellitus, and hyperlipidemia (HL). Additional clinical variables included preoperative constipation, history of prior abdominal surgery, and chemotherapy details, including treatment regimen. Preoperative laboratory parameters recorded were hemoglobin, albumin, urea, creatinine, electrolytes, glycated hemoglobin (HbA1c), and lipid profile. Bladder cancer history was documented, including the number and cumulative duration of previous transurethral resections of bladder tumor (TURBT), the largest tumor size, pathological findings from TURBT and radical cystectomy specimens, lymph node dissection status, and nodal pathology.

Perioperative variables included the type of urinary diversion, anastomosis technique and duration, stapler size and manufacturer (when applicable), total operative time, estimated intraoperative blood loss, requirement for blood transfusion, and adherence to Enhanced Recovery After Surgery (ERAS) protocols. Postoperative outcomes assessed included the occurrence of postoperative ileus, intestinal complications, need for reoperation, time to first mobilization, and time to first passage of flatus or stool.

Outcome Measures

The primary outcome was the incidence of postoperative ileus in each anastomosis group. POI was defined as intolerance to oral intake accompanied by abdominal distension and absence of flatus or bowel movements beyond postoperative day five, requiring medical or surgical management. Postoperative complications were classified according to the Clavien-Dindo classification system.[13] Secondary outcomes included the identification of risk factors associated with POI based on perioperative variables and patient demographic characteristics.

Statistical Analysis

Statistical analyses were performed using SPSS Statistics version 22.0 (IBM, New York, USA). Continuous variables were presented as mean±standard deviation or median with interquartile range, depending on the distribution of the data. Comparisons between groups were performed using the Student's t-test or Mann-Whitney U test, as appropriate. Categorical variables were expressed as frequencies and percentages and compared using the chi-square test or Fisher's exact test. Comparative analyses were conducted between the two independent groups (end-to-end versus side-to-side anastomosis). A two-tailed t-test was used for normally distributed continuous variables, whereas the Mann-Whitney U test was applied for nonparametric data. Sample size calculation was performed assuming an effect size of 0.5, α=0.05, and a power

of 80%, resulting in a required sample size of 29 patients per group (58 patients in total). Receiver operating characteristic (ROC) curve analysis was performed to evaluate the discriminative ability of significant variables for predicting POI, and the area under the curve (AUC) with 95% confidence intervals was calculated. Logistic regression analyses were used to

Table 1. Baseline demographic, clinical, and perioperative characteristics of patients undergoing radical cystectomy with urinary diversion

Variable	Group 1: End-to-end hand-sewn (n=38)	Group 2: Side-to-side stapled (n=33)	p-value
Sex		0.75	
Male	35 (92.1%)	30 (90.9%)	
Female	3 (7.9%)	3 (9.1%)	
Age (mean±SD)	66.5±7.4	66.0±7.2	0.84
Smoking	29 (76.3%)	26 (78.8%)	0.82
Hypertension	23 (60.5%)	20 (60.6%)	0.99
Diabetes mellitus	14 (36.8%)	13 (39.4%)	0.82
BMI (kg/m²)			0.95
<18.5	3 (7.9%)	2 (6.1%)	
18.5–30	29 (76.3%)	26 (78.8%)	
>30	6 (15.8%)	5 (15.1%)	
Constipation	8 (21.1%)	7 (21.2%)	0.99
Prior TURBT	17 (44.7%)	14 (42.4%)	0.85
Prior abdominal surgery	5 (13.2%)	4 (12.1%)	0.88
Chemotherapy	14 (36.8%)	13 (39.4%)	0.82
Anemia	6 (15.8%)	5 (15.2%)	0.95
Hypoalbuminemia	5 (13.2%)	5 (15.2%)	0.82
Renal insufficiency	3 (7.9%)	3 (9.1%)	0.85
Surgical approach			—
Open radical cystectomy	38 (100%)	33 (100%)	
Urinary diversion			0.98
Ileal conduit	29 (76.3%)	25 (75.8%)	
Orthotopic neobladder	9 (23.7%)	8 (24.2%)	
PLND	34 (89.5%)	30 (90.9%)	0.89
Operative time (hours, mean±SD)	4.7±0.9	4.8±0.8	0.74
Intestinal reconstruction time (minutes, mean±SD)	49.5±5.3	35.0±5.0	0.01
Blood loss (mL, mean±SD)	370±320	360±290	0.89
Blood transfusion	15 (39.5%)	12 (36.4%)	0.79
Pathological stage			0.88
T1	2 (5.3%)	3 (9.1%)	
T2	24 (63.2%)	21 (63.6%)	
T3	9 (23.7%)	8 (24.2%)	
T4	3 (7.9%)	1 (3.0%)	
Postoperative time to first flatus (days, mean±SD)	4.08±0.26	3.88±0.29	0.629
Postoperative time to first bowel movement (days, mean±SD)	6.00±0.33	6.30±0.43	0.930
Postoperative time to first mobilization (days, mean±SD)	1.95±0.15	3.88±0.28	0.651

PLND: Pelvic lymph node dissection; TURBT: Transurethral resection of bladder tumor; BMI: Body mass index

identify predictors of POI. Variables with a p-value <0.1 in univariate analysis were included in the multivariate model. A p value <0.05 was considered statistically significant.

RESULTS

A total of 71 patients who underwent open radical cystectomy with urinary diversion were included in the study. All procedures were performed using an open surgical approach. Of these, 38 patients (53.5%) underwent end-to-end hand-sewn ileo-ileal anastomosis (Group 1), whereas 33 patients (46.5%) received side-to-side stapled anastomosis (Group 2). Baseline demographic and clinical characteristics were similar between the two groups (Table 1).

Postoperative ileus occurred in nine patients (23.7%) in the end-to-end hand-sewn anastomosis group and in four patients (12.1%) in the side-to-side stapled anastomosis group, indicating a significantly lower incidence in the stapled group compared to the hand-sewn group (p=0.001). Univariate logistic regression identified several variables associated with an increased risk of POI. Patients aged ≥65 years had a significantly higher likelihood of developing POI (odds ratio [OR]: 2.10, 95% confidence interval [CI]: 1.32–3.30; p=0.002). Both underweight (BMI <18.5; OR: 2.50, 95% CI: 1.07–5.85; p=0.038) and obese patients (BMI >30; OR: 3.00, 95% CI: 1.70–5.20; p=0.001) demonstrated an increased risk of POI. Preoperative constipation was also identified as a significant predictor (OR: 1.84, 95% CI: 1.10–3.10; p=0.023), as was hypoalbuminemia (OR: 2.63, 95% CI: 1.51–4.60; p=0.001). Operative time was strongly associated with POI, with each additional 30 minutes of surgery increasing the odds of POI approximately threefold (OR: 3.02, 95% CI: 2.29–3.99; p=0.001).

Multivariate logistic regression analysis confirmed that side-to-side stapled anastomosis significantly reduced the risk of POI (OR: 0.30, 95% CI: 0.13–0.72; p=0.001), independent of other variables. Additionally, age ≥65 years (OR: 2.00, 95% CI: 1.20–3.30; p=0.004), abnormal BMI categories (underweight: OR: 3.00, 95% CI: 1.70–5.20; p=0.001; obese: OR: 1.58, 95% CI: 1.04–2.42; p=0.034), constipation (OR: 1.85, 95% CI: 1.10–3.10; p=0.020), hypoalbuminemia (OR: 2.75, 95% CI: 1.56–4.86; p=0.001), and prolonged operative time (OR: 3.00, 95% CI: 2.28–3.99; p=0.001) remained independent predictors of POI.

No significant associations were observed between POI and other variables, including sex, smoking status, hypertension, diabetes mellitus, anemia, prior abdominal surgery, pathological tumor stage, or type of urinary diversion (Table 2).

Receiver operating characteristic curve analysis demonstrated that the multivariate model predicting POI had strong discriminative ability, with an AUC of 0.87 (95% CI: 0.79–0.94, p<0.001) (Fig. 1). Among individual predictors, operative time showed the highest predictive accuracy for POI (AUC: 0.82, 95% CI: 0.73–0.91), followed by serum albumin level (AUC: 0.79, 95% CI: 0.70–0.88) and anastomosis technique (stapled vs. hand-sewn) (AUC: 0.76, 95% CI: 0.66–0.86; p=0.001). The optimal cut-off values, determined using the Youden index, were >310 minutes for operative time and <3.5 g/dL for serum albumin.

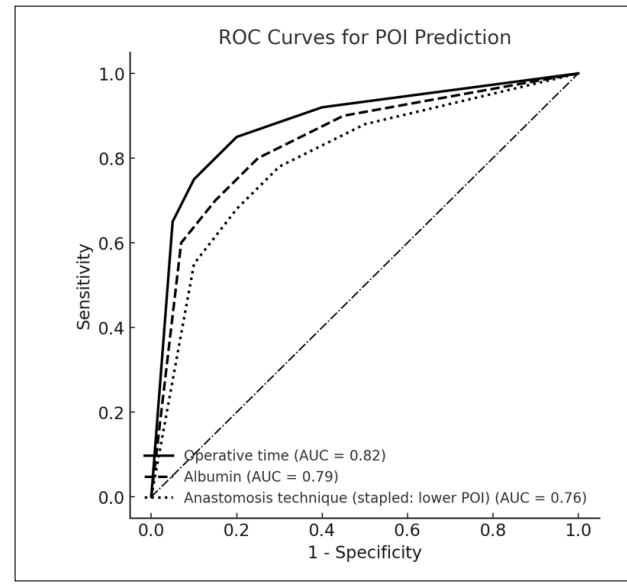

Figure 1. Receiver operating characteristic (ROC) curve of the multivariable model predicting postoperative ileus.

DISCUSSION

In this retrospective study evaluating postoperative ileus in patients undergoing radical cystectomy with urinary diversion, we found that side-to-side stapled ileo-ileal anastomosis was associated with a significantly lower incidence of POI compared to the end-to-end hand-sewn technique. Additionally, several independent risk factors for POI were identified, including advanced age (≥65 years), abnormal body mass index (both underweight and obesity), preoperative constipation, hypoalbuminemia, and prolonged operative time. Other variables such as sex, smoking status, hypertension, diabetes mellitus, anemia, prior abdominal surgery, pathological tumor stage, and type of urinary diversion were not significantly associated with POI.

Abnormal BMI is associated with an increased risk of postoperative ileus. Hinojosa-Gonzalez et al.[14] reported that the incidence of major complications increases with the severity of malnutrition in patients with low BMI, cachexia, and hypoalbuminemia. In their study, the need for blood transfusion and mortality rates were approximately doubled, and patients with low BMI experienced longer hospital stays.

Our findings are consistent with those reported by Schineis et al.[13] in their retrospective study, in which stapled anastomosis was associated with reduced operative time and lower postoperative complication rates, including POI. Similarly, in our cohort of 71 patients undergoing radical cystectomy with urinary diversion, the incidence of POI was significantly lower

Table 2. Logistic regression analysis of risk factors for postoperative ileus

Variable	Univariable OR (95% CI)	p-value	Multivariable OR (95% CI)	p-value
Sex				
Male	1.17 (0.65–2.10)	0.65	–	–
Female	Ref	Ref	Ref	Ref
Smoking				
Yes	1.34 (0.85–2.11)	0.21	–	–
No	Ref	Ref	Ref	Ref
Hypertension				
Yes	0.92 (0.54–1.55)	0.79	–	–
No	Ref	Ref	Ref	Ref
Diabetes mellitus				
Yes	0.85 (0.46–1.56)	0.65	–	–
No	Ref	Ref	Ref	Ref
Anemia				
Yes	1.07 (0.58–1.97)	0.88	–	–
No	Ref	Ref	Ref	Ref
Prior TURBT				
Yes	1.10 (0.70–1.73)	0.73	–	–
No	Ref	Ref	Ref	Ref
Chemotherapy				
Yes	1.17 (0.74–1.85)	0.55	–	–
No	Ref	Ref	Ref	Ref
Surgical approach				
End-to-end (hand-sewn)	Ref	Ref	Ref	Ref
Side-to-side (stapled)	0.35 (0.15–0.80)	0.012*	0.30 (0.13–0.72)	0.001*
Estimated blood loss				
Per 100 mL increase	1.05 (0.88–1.24)	0.62	–	–
Pathological stage				
T1	Ref	Ref	Ref	Ref
T2	2.55 (0.75–8.60)	0.15	–	–
T3	2.45 (0.68–8.80)	0.16	–	–
T4	2.50 (0.58–10.80)	0.30	–	–
Intestinal reconstruction time	Per 5 min. increase	1.20 (0.95–1.52)	0.10	–
Age				
<65 years	Ref	Ref	Ref	Ref
≥65 years	2.10 (1.32–3.30)	0.002*	2.00 (1.20–3.30)	0.004*
BMI				
<18.5	2.50 (1.07–5.85)	0.038*	3.00 (1.70–5.20)	0.001*
18.5–30	Ref	Ref	Ref	Ref
>30	3.00 (1.70–5.20)	0.001*	1.58 (1.04–2.42)	0.034*
Constipation				
Yes	1.84 (1.10–3.10)	0.023*	1.85 (1.10–3.10)	0.020*
No	Ref	Ref	Ref	Ref
Renal insufficiency				
Yes	1.74 (0.85–3.58)	0.15	1.70 (0.85–3.58)	0.13
No	Ref	Ref	Ref	Ref
Prior abdominal surgery				

Yes	1.77 (0.97–3.25)	0.086	2.08 (1.01–4.31)	0.073
No	Ref	Ref	Ref	Ref
Hypoalbuminemia				
Yes	2.63 (1.51–4.60)	0.001*	2.75 (1.56–4.86)	0.001*
No	Ref	Ref	Ref	Ref
Urinary diversion				
Ileal conduit	Ref	Ref	Ref	Ref
Ileal neobladder	1.49 (0.90–2.47)	0.14	1.58 (0.94–2.65)	0.08
PLND				
Yes	1.95 (0.46–1.14)	0.17	0.70 (0.44–1.12)	0.14
No	Ref	Ref	Ref	Ref
Blood transfusion				
Yes	1.47 (0.93–2.32)	0.10	1.47 (0.93–2.32)	0.097
No	Ref	Ref	Ref	Ref
Operative time	Per 30 min. increase	3.02 (2.29–3.99)	0.001*	3.00 (2.28–3.99)

POI incidence: 23.7% (9/38) in the hand-sewn group vs. 12.1% (4/33) in the stapled group (p=0.001). PLND: Pelvic lymph node dissection; TURBT: Transurethral resection of bladder tumor; BMI: Body mass index.

in the side-to-side stapled group (p=0.001), supporting the beneficial impact of stapled anastomosis on postoperative bowel recovery. In a prospective study of elective gastrointestinal surgeries, stapled anastomosis was shown to reduce operative time, accelerate the return of bowel function, shorten hospital stay, and decrease anastomotic leak rates compared to hand-sewn techniques. Additionally, the stapled group demonstrated a lower rate of surgical site infections, while pain scores and the relationship between albumin levels and leak rates did not differ significantly between the groups.[15] However, not all studies support this finding. Lahes et al.,[16] in a study including 339 patients, found no significant difference in POI rates between hand-sewn and stapled anastomosis. The authors suggested that outcomes may be more strongly influenced by surgeon experience and perioperative management protocols rather than by the anastomotic technique itself. Furthermore, the meta-analysis by Feng et al.[17] highlighted considerable heterogeneity among studies and emphasized the limited number of large randomized controlled trials, underscoring the need for more reliable data to establish definitive conclusions.

The role of preoperative constipation as a risk factor for POI, observed in approximately 21% of patients in both groups, is supported by evidence from the colorectal surgery literature. Xue et al.,[18] in their retrospective study, reported that baseline bowel dysmotility increases susceptibility to prolonged postoperative ileus. Hypoalbuminemia was detected in 13.2% and 15.2% of patients in Groups 1 and 2, respectively, and significantly increased the risk of postoperative ileus in our study (OR: 2.75, 95% CI: 1.56–4.86; p=0.001). Similarly, Sun et al.[19] retrospectively analyzed 452 patients with bladder cancer undergoing radical cystectomy and identified hypoalbuminemia as an independent risk factor for POI, subsequently incorporating this variable into a nomogram designed to predict POI occurrence. Unlike the study by Sun et al.,[19] our analysis additionally evaluated the impact of anastomosis technique on POI incidence and demonstrated that side-to-side stapled anastomosis significantly reduced the risk of POI. Although operative times were similar between the two groups (mean 4.7±0.9 hours in the hand-sewn group vs. 4.8±0.8 hours in the stapled group; p=0.74), prolonged operative duration independently increased the risk of POI (OR: 3.00, 95% CI: 2.28–3.99; p=0.001). This finding is consistent with previous surgical literature emphasizing that longer operative times lead to greater tissue trauma and inflammatory responses, thereby delaying the recovery of bowel function.[20] Other variables, including sex, smoking status, hypertension, diabetes, anemia, prior abdominal surgery, tumor stage, and type of urinary diversion, were not significantly associated with POI.

This study has several strengths that support the reliability of its findings. First, the analysis included a relatively homogeneous cohort of patients who underwent open radical cystectomy with either ileal conduit or orthotopic neobladder, ensuring consistency in the surgical approach. This homogeneity allowed for a clearer assessment of the impact of anastomosis technique on POI. Additionally, the availability of detailed perioperative data enabled the use of multivariable logistic regression to adjust for confounders such as age, BMI, nutritional status, and operative time, thereby strengthening the reliability of the risk factor analysis.

However, several limitations should be acknowledged. Since this was a retrospective study, there is a potential risk of selection bias and the presence of unmeasured confounding factors. Surgeon preference may have influenced the choice of anastomosis technique, which could have affected the results independently of the technique itself. Additionally, the total

number of patients (n=71) was relatively small, limiting the ability to perform detailed subgroup analyses or generalize the results to a wider population. Furthermore, perioperative care was not standardized; for example, ERAS protocols were not implemented, which may have influenced POI rates and makes comparisons with other centers more difficult. Finally, the follow-up period was not clearly defined, limiting the assessment of long-term bowel function.

Our findings suggest that side-to-side stapled ileo-ileal anastomosis may reduce the risk of POI after radical cystectomy with urinary diversion. Surgeons should also consider patient-related factors such as advanced age, abnormal BMI, preoperative constipation, and low albumin levels when planning surgical management. Optimization of nutritional status and management of constipation before surgery may help improve postoperative recovery. Additionally, operative duration appears to be an important factor, as longer procedures were associated with an approximately threefold increase in POI risk in our cohort. These findings highlight the importance of careful surgical planning and strategies aimed at reducing operative time, including the potential use of minimally invasive approaches.

Future prospective randomized studies are needed to provide clearer comparisons between anastomosis techniques and to standardize perioperative care, including ERAS protocols.

CONCLUSION

In conclusion, this retrospective study of 71 patients demonstrated that side-to-side stapled ileo-ileal anastomosis was associated with a lower risk of postoperative ileus compared to end-to-end hand-sewn anastomosis. These findings highlight the importance of surgical technique and patient preparation in postoperative recovery. Larger prospective studies with standardized care protocols are needed to confirm these results and guide clinical practice.

Ethics Committee Approval: Ethics committee approval was obtained from the Ankara Etlik City Hospital Scientific Research Evaluation Ethics Committee (Date: 27.11.2024, Decision No: AEŞH-BADEK-2024-1123).

Informed Consent: Written informed consent was obtained from all patients.

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: F.S., M.Y.A.; Design: F.S., M.Y.A., A.E.D.; Supervision: M.A.İ.; Resource: F.S., A.Y., A.O.H.; Materials: F.S., M.Y.A.; Data Collection and/or Processing: F.S., M.Y.A., A.E.D.; Analysis and/or Interpretation: F.S., M.Y.A., M.A.İ.; Literature Review: F.S., A.E.D.; Writing: F.S., M.Y.A., M.A.İ.; Critical Review: M.A.İ.

Conflict of Interest: The authors have no conflicts of interest to declare.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Cerrahi bir zorluk olarak ameliyat sonrası ileus: Radikal sistektomide uç-uç ve yan-yan ileal anastomozun karşılaştırmalı sonuçları

AMAÇ: Bu çalışmanın amacı, uç uca elle dikilmiş ve yan yana zımbalanmış ileoileal anastomozlar arasında ameliyat sonrası ileus (POI) sıklığını karşılaştırmak ve POI ile ilişkili bağımsız risk faktörlerini belirlemektir.

GEREÇ VE YÖNTEM: Ekim 2022 ile Ekim 2024 tarihleri arasında Ankara Etlik Şehir Hastanesi'nde radikal sistektomi ve idrar diversiyonu uygulanan hastaları geriye dönük olarak analiz ettik. Hastalar anastomoz tekniğine göre gruplandırıldı: Uç uca elle dikilmiş veya yan yana zımbalanmış. Demografik bilgiler, komorbiditeler, ameliyat öncesi laboratuvar değerleri, ameliyat detayları ve ameliyat sonrası sonuçlar dahil olmak üzere perioperatif veriler toplandı. POI, ameliyat sonrası beşinci günden sonra karın distansiyonu, gaz veya dışkı olmaması ve tıbbi veya cerrahi müdahale gerektiren oral alımı tolere edememe olarak tanımlanmıştır. POI için risk faktörlerini belirlemek amacıyla tek değişkenli ve çok değişkenli lojistik regresyon analizleri kullanılmıştır.

BULGULAR: Toplam 71 hasta dahil edildi. El dikişli grupta 9 hastada (%23.7) ve zımbalı grupta 4 hastada (%12.1) ameliyat sonrası ileus (POI) görülmüş olup, bu da zımbalı grupta anlamlı derecede daha düşük bir insidansı gösterdi. Çok değişkenli analiz, yan yana stapler anastomozunun POI riskini bağımsız olarak azalttığını belirledi. Diğer bağımsız öngörücüler arasında yaş ≥65, anormal BMI, ameliyat öncesi kabızlık, hipoalbüminemi ve uzamış ameliyat süresi yer alıyordu. ROC eğrisi analizi, modelin iyi bir öngörücü performans gösterdiğini ortaya koydu.

SONUÇ: Üriner diversiyonlu radikal sistektomide yan yana zımbalı ileo-ileal anastomoz, uç uca el dikişli anastomozla karşılaştırıldığında ameliyat sonrası ileus riskinin daha düşük olmasıyla ilişkilidir.

Anahtar sözcükler: Elle dikilmiş anastomoz; ileal anastomoz; ameliyat sonrası ileus; radikal sistektomi; risk faktörleri; zımbalı anastomoz; üriner diversiyon.

Ulus Travma Acil Cerrahi Derg 2026;32(5):544-551 DOI: 10.14744/tjtes.2026.79776

ORIGINAL ARTICLE

The role of the HALP score and inflammatory biomarkers in differentiating complicated and uncomplicated acute appendicitis: a retrospective cohort study

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ABSTRACT

BACKGROUND: This study aimed to investigate the role of the HALP (hemoglobin, albumin, lymphocyte, platelet) score and inflammatory biomarkers C-reactive protein (CRP), neutrophil-to-lymphocyte ratio (NLR), and platelet-to-lymphocyte ratio (PLR) in distinguishing between complicated and uncomplicated acute appendicitis.

METHODS: This retrospective study was conducted between May and August 2024 at Ankara Etlik State Hospital and included patients diagnosed with acute appendicitis who were treated surgically. HALP score, CRP, NLR, and PLR were calculated using preoperative laboratory results. Patients were categorized into complicated and uncomplicated appendicitis groups based on intraoperative and histopathological findings. Statistical analyses included the independent samples t-test, Mann–Whitney U test, and chi-square test. A p-value <0.05 was considered statistically significant.

RESULTS: A total of 208 patients were analyzed. HALP scores were significantly lower in the complicated appendicitis group (4.6 vs. 5.8, p=0.002), while CRP levels were significantly higher (84.9 vs. 38.7 mg/L, p<0.001). NLR (7.0 vs. 6.9, p=0.091) and PLR (165 vs. 170, p=0.767) did not differ significantly between the groups.

CONCLUSION: CRP and HALP score are useful parameters for predicting complicated appendicitis. The HALP score, reflecting both systemic inflammation and nutritional status, may serve as a novel and cost-effective tool in clinical assessment.

Keywords: Acute appendicitis; HALP score; inflammatory markers.

INTRODUCTION

Acute appendicitis remains one of the most frequent causes of acute abdomen worldwide. Although its diagnosis is often straightforward, distinguishing between uncomplicated and complicated appendicitis is critical, as it influences treatment planning and prognosis. Complicated appendicitis, which includes perforation, gangrene, or periappendiceal abscess, is associated with higher morbidity, longer hospital stays, and an increased risk of sepsis. In contrast, uncomplicated cases may sometimes be managed conservatively with antibiotic therapy in selected patients.[1,2]

Current diagnostic tools include imaging techniques such as ultrasonography and computed tomography (CT), along with clinical and laboratory findings. Among laboratory markers, white blood cell (WBC) count and C-reactive protein (CRP) levels are routinely used. Composite inflammatory indices such as the neutrophil-to-lymphocyte ratio (NLR) and platelet-to-lymphocyte ratio (PLR) have also been explored as predictors of disease severity.[3,4] However, their sensitivity and specificity vary considerably across studies and populations.[5]

The hemoglobin, albumin, lymphocyte, and platelet (HALP) score is a novel index initially developed by Chen et al.[6] to

Cite this article as: Çanakçı MH, Değirmencioğlu G, Kütük D, Süer MS, Sucu GN. The role of the HALP score and inflammatory biomarkers in differentiating complicated and uncomplicated acute appendicitis: a retrospective cohort study. Ulus Travma Acil Cerrahi Derg 2026;32:552-557.

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Ulus Travma Acil Cerrahi Derg 2026;32(5):552-557 DOI: 10.14744/tjtes.2025.72585

Submitted: 09.07.2025 Revised: 29.11.2025 Accepted: 11.12.2025 Published: 05.05.2026

predict prognosis in gastric cancer. Since then, its prognostic value has been demonstrated in stroke, malignancy, and cardiovascular disease.[7,9] HALP integrates four routine laboratory parameters reflecting systemic inflammation, immune competence, and nutritional status. Despite its growing use in various diseases, its utility in acute surgical inflammatory conditions such as appendicitis has not been well characterized.

This study aimed to investigate whether the HALP score, alongside CRP, NLR, and PLR, could differentiate complicated from uncomplicated acute appendicitis and thereby serve as a valuable preoperative prognostic tool.

MATERIALS AND METHODS

Study Design and Setting

This retrospective cohort study was conducted at Ankara Etlik City Hospital between May and August 2024. Ethical approval was obtained from the hospital's Clinical Research Ethics Committee Ankara Etlik State Hospital (Date: 25.12.2024, Decision no: AEŞH-BADEK-2024-1080).

Patient Selection

Inclusion Criteria:

• Adults (≥18 years) who underwent appendectomy for acute appendicitis.

• Availability of complete preoperative laboratory and pathology data.

Exclusion Criteria:

• Incomplete or missing laboratory records.

• Chronic inflammatory or hematologic diseases.

• Patients receiving immunosuppressive therapy or with a history of malignancy.

Definitions and Grouping

Patients were categorized into complicated appendicitis (perforation, abscess, or gangrene confirmed intraoperatively or histopathologically) and uncomplicated appendicitis groups.

The severity of complications was graded using the Clavien–Dindo classification system. Postoperative outcomes, including length of hospital stay (LOS) and the need for intensive care unit (ICU) admission, were also recorded.

Data Collection and Calculations

Preoperative laboratory values obtained within 24 hours before surgery were extracted.

• HALP score=(Hemoglobin (g/L) × Albumin (g/L) × Lymphocyte (10^9/L)) / Platelet (10^9/L)

• NLR=Neutrophil (10^9/L) / Lymphocyte (10^9/L)

• PLR=Platelet (10^9/L) / Lymphocyte (10^9/L)

Additionally, demographic data, including body mass index (BMI), American Society of Anesthesiologists (ASA) physical status scores, and history of chronic illnesses (e.g., diabetes mellitus, hypertension, and chronic obstructive pulmonary disease [COPD]) were extracted from hospital records.

Surgical Approach and Management

All patients diagnosed with acute appendicitis underwent surgical treatment. The decision between laparoscopic and open appendectomy was made by the attending surgical team based on the clinical presentation and surgeon preference. For patients with complicated appendicitis (i.e., perforation, abscess, or gangrenous changes), intravenous broad-spectrum antibiotics (e.g., ceftriaxone and metronidazole) were administered upon diagnosis. Emergency surgery was performed after initial stabilization. Intraoperative findings such as abscesses or perforation were managed with drainage and peritoneal lavage when necessary. Postoperative antibiotic regimens were adjusted based on intraoperative findings and culture results. No patients required reoperation during their hospital stay.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 22.0 (IBM Corporation, Armonk, NY, USA). The independent samples t-test was used for comparisons of continuous variables, while the Mann-Whitney U test was used for continuous variables that did not follow a normal distribution. The chi-square test was applied for comparisons of categorical variables. A p value <0.05 was considered statistically significant.

RESULTS

Demographic Characteristics

A total of 208 patients were included in the study: 71 in the complicated appendicitis group and 137 in the uncomplicated appendicitis group. The mean age was 37.7 years in the complicated group and 36.4 years in the uncomplicated group. However, no statistically significant difference was observed between the two groups with respect to age (p=0.414). Regarding gender distribution, the female-to-male ratios were similar in both groups (complicated: F:M=0.73; uncomplicated: F:M=0.81), and no significant difference was found (p=0.457). These findings indicate that demographic factors do not play a significant role in the development of complications (Table 1).

Further analysis revealed no significant difference between the groups in terms of BMI (complicated: 26.1 vs. uncomplicated: 25.8, p=0.317). Similarly, ASA scores did not differ significantly between groups (ASA ≥III: 21.1% in the complicated group vs. 19.7% in the uncomplicated group, p=0.448). The prevalence of chronic comorbidities was also comparable (complicated: 28.2% vs. uncomplicated: 26.3%, p=0.509), indicating that baseline health status did not significantly influence the development of complications.

Table 1. Comparison of demographic characteristics between complicated and uncomplicated appendicitis groups

Variable	Complicated appendicitis (n=71)	Uncomplicated appendicitis (n=137)	p-value
Age	37.7	36.4	0.414
Gender (F/M)	F:M=0.73	F:M=0.81	0.457
BMI (kg/m²)	26.1	25.8	0.317
ASA ≥III (%)	21.1%	19.7%	0.448
Chronic comorbidities (%)	28.2%	26.3%	0.509

F: Female; M: Male.

Comparison of Laboratory Values

Laboratory data from the complicated and uncomplicated appendicitis groups were analyzed comprehensively. No statistically significant differences were observed between the groups in white blood cell count, neutrophil (NEU), lymphocyte (LYM), platelet (PLT), hemoglobin (HGB), or platelet-to-lymphocyte ratio values (p>0.05). These parameters did not demonstrate a distinguishing role in predicting the development of complications (Table 2).

However, significant differences were observed in certain laboratory parameters:

• C-reactive protein levels were significantly higher in the complicated appendicitis group (84.9 vs. 38.7; p<0.001). CRP is a well-known marker of inflammatory processes and, in this study, emerged as an important biomarker for identifying the presence of complications.

• HALP score was significantly lower in the complicated group (5.8 vs. 4.6; p=0.002). A lower HALP score may reflect increased inflammation in patients with complicated appendicitis.

• Albumin levels tended to be higher in the uncomplicated group (45.0 vs. 43.6), although the difference did not reach statistical significance (p=0.066). This finding suggests that lower albumin levels in patients with complicated appendicitis may be associated with the inflammatory response.

Operative Details

Of the total 208 patients, 123 (59.1%) underwent laparoscopic appendectomy and 85 (40.9%) underwent open appendectomy. The proportion of open surgeries was significantly higher in complicated cases (61.9%) compared to uncomplicated cases (29.2%) (p<0.001). The mean operative time was 58.4±12.6 minutes for complicated appendicitis and 41.2±10.7 minutes for uncomplicated cases (p<0.001). Additional intraoperative interventions, such as localized abscess drainage, were required in 18.3% of patients in the complicated group (Table 3).

Table 2. Laboratory data comparison between complicated and uncomplicated appendicitis groups

Parameter	Complicated appendicitis (n=71)	Uncomplicated appendicitis (n=137)	p-value
WBC	14.5	13.3	0.833
NEU	11.4	10.0	0.320
LYM	2.20	1.98	0.178
PLT	272	271	0.960
HGB	14.5	13.8	0.949
ALB	43.6	45.0	0.066
CRP	84.9	38.7	<0.001
NLR	7.0	6.9	0.091
PLR	165	170	0.767
HALP	4.6	5.8	0.002

WBC: White blood cell count; NEU: Neutrophil count; LYM: Lymphocyte count; PLT: Platelet count; HGB: Hemoglobin; ALB: Albumin; CRP: C-reactive protein; NLR: Neutrophil-to-lymphocyte ratio; PLR: Platelet-to-lymphocyte ratio; HALP: Hemoglobin, albumin, lymphocyte, and platelet score.

Table 3. Operative characteristics

Variable	Complicated appendicitis (n=71)	Uncomplicated appendicitis (n=137)	p-value
Laparoscopic surgery (%)	27 (38.0%)	96 (70.1%)	<0.001
Open surgery (%)	44 (61.9%)	41 (29.9%)	<0.001
Mean operative time (min)	58.4±12.6	41.2±10.7	<0.001
Abscess drainage performed	13 (18.3%)	–	–

Table 4. Postoperative outcomes

Outcome	Complicated appendicitis (n=71)	Uncomplicated appendicitis (n=137)	p-value
Mean length of stay (days)	5.4±3.2	2.1±1.4	<0.001
ICU admission (%)	9 (12.7%)	0 (0%)	<0.001
Clavien–Dindo Grade I–II	40 (56.3%)	–	–
Clavien–Dindo Grade III	23 (32.4%)	–	–
Clavien–Dindo Grade IV	8 (11.3%)	–	–

Postoperative Complications and Outcomes

Among the 71 patients with complicated appendicitis, 27 (38.0%) had perforation, 17 (23.9%) had gangrenous appendicitis, and 10 (14.1%) developed periappendiceal abscesses. The remaining 17 patients (23.9%) exhibited mixed or non-specific intraoperative findings. According to the Clavien–Dindo classification, Grade I–II complications were observed in 40 patients (56.3%), Grade III in 23 patients (32.4%), and Grade IV in eight patients (11.3%).

The mean length of hospital stay was significantly longer in complicated cases (5.4±3.2 days) compared to uncomplicated cases (2.1±1.4 days) ($p<0.001$). ICU admission was required in nine patients (12.7%) in the complicated group, whereas no ICU admissions occurred in the uncomplicated group ($p<0.001$) (Table 4).

Among the complicated cases, intraoperative abscess drainage was performed in 13 patients (18.3%). No patient required reoperation. Postoperative recovery was uneventful in the majority of patients.

DISCUSSION

Acute appendicitis remains one of the most common causes of acute abdominal pain requiring emergency surgery. It is classically categorized into uncomplicated (non-perforated) and complicated (perforated, gangrenous, or associated with periappendiceal abscess) forms, with the latter associated with higher morbidity, prolonged hospital stays, and an increased risk of postoperative complications.[10,11] Early and accurate differentiation between these subtypes is essential to guide appropriate surgical and perioperative management. While imaging modalities such as ultrasonography and CT play a critical role in diagnosis, laboratory parameters and scoring systems are frequently used to aid risk stratification.[12]

In our clinical setting, all patients with complicated appendicitis received prompt intravenous antibiotic therapy upon diagnosis, followed by urgent surgical intervention. Perioperative management included peritoneal lavage and abscess drainage when necessary. Broad-spectrum antibiotics were continued postoperatively and adjusted based on intraoperative culture results. This approach was successful in preventing the need for reoperation or prolonged ICU support in most patients. These findings underscore the importance of a standardized management protocol in improving outcomes for patients with complicated appendicitis.

This study demonstrates a statistically significant relationship between lower HALP scores and the presence of complicated acute appendicitis. Among the evaluated parameters, only CRP and HALP showed significant differences between complicated and uncomplicated cases. While CRP's acute-phase dynamics are well established in inflammatory conditions and are particularly useful for early risk stratification ($p<0.001$),[13,14] the HALP score, a composite marker reflecting hemoglobin, albumin, lymphocyte, and platelet levels, pro-

vides a broader systemic perspective that incorporates nutritional and immune status.

Initially introduced by Chen et al.[6] for prognostic assessment in gastric cancer, the HALP score has since been validated across various chronic and malignant conditions, including colorectal,[15] pancreatic,[16] and hepatocellular cancers.[17] Beyond its oncologic applications, recent studies have also explored its role in acute inflammatory conditions such as pancreatitis[18] and intestinal obstruction,[19] where it has shown potential as a prognostic marker. Consistent with these findings, our study observed significantly lower HALP scores in patients with complicated appendicitis (p=0.002), supporting earlier evidence by Benli et al.,[20] who reported a similar association between reduced HALP values and higher rates of postoperative morbidity in acute appendicitis.

Nevertheless, the clinical utility of HALP in acute surgical settings must be interpreted with nuance. Its components, particularly albumin and hemoglobin, respond slowly to acute inflammatory stimuli and are more reflective of a patient's baseline physiological reserve than of immediate disease activity.[21] Given that the majority of appendicitis patients undergo surgery shortly after diagnosis and are discharged within 1-2 days, the delayed kinetics of HALP components limit its usefulness for real-time clinical decision-making. Although statistically significant, its contribution to immediate clinical management appears limited when compared to CRP or white blood cell count.

Moreover, while the expanding interest in HALP has led to its application in diverse clinical settings, there is concern that its inclusion in acute care research may sometimes reflect trend-driven investigation rather than a grounded clinical rationale. In this study, although HALP scores correlated with disease severity, they did not provide additional predictive value beyond CRP. Therefore, HALP may be better conceptualized as a supplementary risk stratification tool, particularly for patients with chronic illnesses, poor nutritional status, or equivocal clinical presentations, rather than as a first-line prognostic marker in acutely evolving surgical emergencies.

Similarly, although the neutrophil-to-lymphocyte ratio and platelet-to-lymphocyte ratio have gained popularity as accessible markers of systemic inflammation and prognosis, their diagnostic and prognostic performance in appendicitis remains variable. Several studies suggest that elevated NLR values (commonly >4.7 or >8.8) may correlate with complicated appendicitis or perforation,[22,23] and PLR has also been investigated as a marker of disease severity.[24,25] However, in our study, neither NLR nor PLR showed significant differences between the groups (NLR p=0.091; PLR p=0.767). These findings align with certain meta-analyses that question the consistency of these ratios, possibly due to differences in the timing of blood sampling, disease stage, or inter-individual variability.[26]

In summary, while HALP demonstrates statistical relevance in distinguishing complicated from uncomplicated appendicitis, its clinical applicability is limited by its non-acute kinetic profile. In most cases of acute appendicitis, particularly those managed promptly with surgery, HALP provides minimal additional prognostic value beyond CRP. It may have adjunctive value in selected clinical scenarios but should not be overemphasized in acute decision-making algorithms. Future studies may further clarify its role, especially in complex or comorbid patient populations.

CONCLUSION

In this study, HALP and CRP were significantly associated with complicated appendicitis. The HALP score, as a novel and accessible biomarker, may assist clinicians in early risk stratification and operative decision-making. Larger, prospective trials are warranted to validate its clinical utility.

Ethics Committee Approval: This study was approved by the Clinical Research Ethics Committee Ankara Etlik State Hospital (Date: 25.12.2024, Decision No: AEŞH-BADEK-2024-1080).

Informed Consent: Retrospective study.

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Komplike ve komplike olmayan akut apandisitlerin ayırımında HALP skoru ve enflamatuvar biyobelirteçlerin rolü: Retrospektif kohort çalışması

AMAÇ: HALP (Hemoglobin, Albümin, Lenfosit, Trombosit) skoru ve enflamatuvar biyobelirteçler C-reaktif protein (CRP), nötrofil-lenfosit oranı (NLR) ve trombosit-lenfosit oranının (PLR) komplike ve komplike olmayan akut apandisit arasındaki ayrımı yapmadaki rolünü araştırmak.
GEREÇ VE YÖNTEM: Bu retrospektif çalışma Mayıs ve Ağustos 2024 tarihleri arasında Ankara Etlik Şehir Hastanesi'nde yürütülmüş olup akut apandisit tanısı konulan ve cerrahi olarak tedavi edilen hastaları kapsamıştır. HALP skoru, CRP, NLR ve PLR ameliyat öncesi laboratuvar sonuçları kullanılarak hesaplanmıştır. Hastalar intraoperatif ve histopatolojik verilere göre komplike ve komplike olmayan apandisit olarak gruplandırılmıştır. İstatistiksel analizler Bağımsız Örneklem t-testi, Mann-Whitney U ve ki-kare testlerini içermektedir. p-değeri <0.05 anlamlı kabul edilmiştir.
BULGULAR: Toplam 208 hasta analiz edilmiştir. HALP skorları komplike grupta önemli ölçüde daha düşüktü (4.6'ya karşı 5.8, p=0.002) ve CRP seviyeleri önemli ölçüde daha yüksekti (84.9'a karşı 38.7 mg/L, p<0.001). NLR (7.0'a karşı 6.9, p=0.091) ve PLR (165'e karşı 170, p=0.767) gruplar arasında önemli ölçüde farklılık göstermedi.
SONUÇ: CRP (C-reaktif protein) ve HALP (Hemoglobin, Albümin, Lenfosit, Trombosit) skoru komplike apandisiti tahmin etmede yararlı parametrelerdir. Hem sistemik inflamasyonu hem de beslenme durumunu yansıtan HALP (Hemoglobin, Albümin, Lenfosit, Trombosit) skoru, klinik değerlendirmede yeni ve maliyet etkin bir araç olarak hizmet edebilir.

Anahtar sözcükler: Akut apandisit; HALP skoru; enflamatuvar belirteç.

Ulus Travma Acil Cerrahi Derg 2026;32(5):552-557 DOI: 10.14744/tjtes.2025.72585

ORIGINAL ARTICLE

A different perspective in trauma patients: can pan-immune-inflammation value (PIV) predict mortality?

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ABSTRACT

BACKGROUND: Trauma is a leading cause of mortality worldwide. Accurate prognostic assessment in emergency departments and intensive care units is essential for effective triage and management. Consequently, various prognostic markers have been explored in trauma populations. The pan-immune-inflammation (PIV) is a biomarker derived from a complete blood count (CBC) and can be rapidly obtained in clinical settings. This study aimed to evaluate the role of PIV in predicting the prognosis of trauma patients.

METHODS: This study examined patients admitted to a tertiary-level intensive care unit due to trauma at a training and research hospital. Established prognostic parameters, including the Revised Trauma Score (RTS), Glasgow Coma Scale (GCS), and Acute Physiology and Chronic Health Evaluation II (APACHE II) scores, were evaluated. PIV values were calculated from laboratory data. Mortality, morbidity, and length of hospital stay were retrospectively analyzed. The predictive value of PIV for mortality was assessed using statistical methods.

RESULTS: A total of 74 patients were included. The survivor group comprised seven females (11.5%) and 54 males (88.5%), while the non-survivor group included one female (7.7%) and 12 males (92.3%). PIV, RTS, GCS, and APACHE II scores were effective in predicting mortality ($p<0.001$). The cut-off value for PIV was 6367.5; patients with PIV values below this threshold had a higher risk of mortality compared to those with higher values.

CONCLUSION: Rapid and reliable prognostication is essential in emergency settings. PIV demonstrates predictive performance comparable to established prognostic scoring systems. Early assessment of PIV in trauma patients may support more effective triage and treatment planning.

Keywords: Mortality; pan-immune-inflammation value; prognosis; trauma.

INTRODUCTION

Trauma represents a major global health challenge due to its potential to cause long-term complications, permanent disability, and substantial healthcare costs. According to the World Health Organization (WHO), trauma accounts for 5.8 million deaths annually, representing 10% of all deaths and 16% of disabilities worldwide.[1] It is also one of the leading causes of mortality among young individuals, with nearly 80% of deaths in those aged 15–24 years attributed to trauma.[2] Although trauma-related mortality has declined in recent years due to advances in hemorrhage control and the management of coagulopathy, secondary immunological complications, such as hospital-acquired infections, sepsis, and multiple organ failure, remain a significant concern in this patient population. With the rising incidence of traffic accidents and interpersonal violence, trauma patients constitute a substantial proportion of intensive care unit (ICU) admissions,

Cite this article as: Güneri G, Andıç KD, İnan FÇ, Çorbacı K. A different perspective in trauma patients: can pan-immune-inflammation value (PIV) predict mortality? Ulus Travma Acil Cerrahi Derg 2026;32:558-566.

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Ulus Travma Acil Cerrahi Derg 2026;32(5):558-566 DOI: 10.14744/tjtes.2026.33746
Submitted: 23.12.2025 Revised: 13.03.2026 Accepted: 23.03.2026 Published: 05.05.2026

accounting for an estimated 10–15% of all ICU cases.[3] In low- and middle-income countries, emergency departments and ICUs are often overburdened, and the availability of advanced trauma centers is limited.[4] Therefore, reliable scoring systems are essential to ensure the efficient use of ICU resources, which are characterized by limited bed capacity and high treatment costs.

In high-acuity settings such as emergency departments, rapid assessment of large patient volumes is critical to identify life-threatening conditions and ensure timely transfer to the ICU or operating room when necessary. The ICU period represents a critical phase in trauma care, during which much of the early management is undertaken. Because the clinical status of patients with multiple trauma can change rapidly, continuous assessment of organ dysfunction, which predicts morbidity, and the use of prognostic scoring systems, which assess disease severity and predict mortality, are essential in this patient population. Early warning scores play an important role in guiding clinical monitoring and treatment.

Risk stratification at the time of admission is crucial in trauma patients, as it directly influences prognosis by supporting accurate clinical decision-making, enabling early intervention, and facilitating appropriate supportive care. Scoring systems based on physiological and anatomical parameters, such as the Acute Physiology and Chronic Health Evaluation II (APACHE II), Revised Trauma Score (RTS), Injury Severity Score (ISS), and Trauma and Injury Severity Score (TRISS), are widely used in trauma care.[5] Among these, RTS, ISS, and TRISS have been in use for more than three decades.[5] Anatomical scores (e.g., ISS and New Injury Severity Score [NISS]) are more effective in predicting ICU admission, whereas physiological scores (RTS, Glasgow Coma Scale [GCS], and APACHE II) are more closely associated with mortality prediction. The TRISS, a combined anatomo-physiological scoring system, has been shown to better predict ICU length of stay and duration of mechanical ventilation.[6] Various quantitative trauma scoring systems have been developed to support clinical decision-making in trauma management, and numerous studies have evaluated their performance. Jiang et al.[7] emphasize that the ideal scoring tool for trauma patients should be easy to use, accurately identify critically ill patients, and provide rapid and reliable mortality prediction to improve outcomes.

A complex physiological cascade is initiated within seconds of trauma, involving hemodynamic, metabolic, hemostatic, neuroendocrine, and immunological systems.[8] A systemic inflammatory response is typically triggered within approximately 30 minutes following severe injury or multiple trauma.[9] Although this response is essential for tissue repair, dysregulation of the balance between pro- and anti-inflammatory processes may lead to immune dysfunction in severe trauma, resulting in complications such as sepsis and multiple organ failure. The systemic response to trauma has long been a major focus of research; however, the underlying mechanisms are not yet fully understood. Although various markers have been investigated to assess the systemic response to trauma, none has been established as part of trauma scoring systems.[10]

Proinflammatory mediators released from damaged tissues following trauma and elevated in the circulation further exacerbate endothelial injury and inflammation.[11,12] At this stage, understanding the role of blood cell components used in calculating the pan-immune-inflammation value (PIV) is essential for elucidating trauma pathophysiology.[13,14] Neutrophils, the most abundant leukocytes in humans and key regulators of immune homeostasis, are the first cells to arrive at the site of injury.[15] They are activated by endogenous signals released from damaged and/or necrotic cells following tissue damage. These mediators stimulate neutrophil production and activation, resulting in the release of substances such as proteases and oxygen radicals that damage healthy tissues. Following major trauma, neutrophils may accumulate and injure not only damaged tissues but also healthy organs, such as the lungs and liver, potentially leading to severe complications such as acute respiratory distress syndrome (ARDS).

The pan-immune-inflammation value is a novel biomarker used to estimate the inflammatory status of patients, based on neutrophil, platelet, monocyte, and lymphocyte counts (calculated as neutrophils × platelets × monocytes / lymphocytes).[16] Derived from routine whole-blood parameters that can be rapidly and easily obtained in most clinical settings, PIV has been increasingly investigated in recent years for its association with inflammation and patient outcomes, including mortality and survival. Its advantages include low cost, wide availability, and ease of calculation, which contribute to its growing popularity. PIV was first identified as a prognostic factor in patients with metastatic colorectal cancer receiving chemotherapy by Fucà et al.[15] in 2020. Subsequently, its prognostic role has been explored in various malignancies, including esophageal, gastric, pancreatic, hepatocellular, breast, lung, melanoma, glioblastoma (GBM), prostate, and renal cancers, as well as in a range of non-malignant conditions such as multiple sclerosis, deep vein thrombosis, pulmonary embolism, cerebrovascular disease, chronic obstructive pulmonary disease (COPD), coronavirus disease 2019 (COVID-19), psoriasis, geriatric frailty, and burns. In recent years, studies have examined PIV in various immune and inflammatory diseases and specific patient populations, including hypertension, ST-elevation myocardial infarction, dyslipidemia, anti-neutrophil cytoplasmic antibody-associated (ANCA-associated) vasculitis, sepsis, and septic shock, demonstrating its association with prognosis.[17-23]

A review of the literature in scientific databases reveals a lack of studies evaluating the relationship between PIV and trauma severity, organ failure, or mortality. This gap underscores the need for simple, cost-effective biomarkers that enable rapid assessment of the systemic inflammatory response following trauma. Investigating the potential predictive role of PIV, particularly in relation to post-traumatic organ failure, sepsis, and mortality, may support clinical decision-making and con-

tribute to improved management strategies. Therefore, the evaluation of PIV in trauma patients represents an important and clinically relevant gap in the literature.

MATERIALS AND METHODS

This retrospective study was conducted at a tertiary care center in accordance with the Declaration of Helsinki and was approved by the Bilecik Şeyh Edebali University Non-Interventional Clinical Research Ethics Committee (Date: 29.11.2023, Decision no: E-10333602-050.04.01-218622). Patients who presented to the emergency department due to trauma and subsequently required intensive care unit admission within the past two years were included.

Inclusion Criteria:

1. Age ≥18 years

2. Admission to the ICU following trauma.

Exclusion Criteria:

1. Age <18 years.

Demographic characteristics (age, sex), comorbidities, mechanisms of trauma, length of hospital stay, laboratory parameters, surgical interventions during hospitalization, and mortality outcomes were recorded. Laboratory data were obtained from routine tests performed during the patients' stay in the intensive care unit. The mean transfer time from the emergency department to the ICU was 3 hours 30 minutes (209.8 minutes), with a median of 2 hours 55 minutes (174.5 minutes). Based on laboratory data, the glucose-to-potassium ratio and the PIV were calculated. Additionally, the RTS, GCS, and APACHE II scores were retrospectively assessed. Clinical outcomes, including mortality, length of hospital stay, and need for endotracheal intubation, were obtained from hospital records, and patients were analyzed according to outcome groups. Supplemantery Appendix: https://jag.journalagent.com/travma/abs_files/UTD-47646/UTD-47646_(2)_Screen_Shot_2026-04-16_at_16.42.57.png

Using appropriate statistical methods, the predictive performance of PIV for mortality in trauma patients was evaluated and compared with established prognostic parameters.

Patients aged ≥18 years who were admitted to the ICU due

Table 1. Distribution of demographic characteristics and vital signs in survivor and non-survivor patients

	Survivor n (%)	Non-survivor n (%)	Test value	p-value
Sex				
Female	7 (11.5)	1 (7.7)	0.159	0.690
Male	54 (88.5)	12 (92.3)		
Age*	36.26	43.31	321.0	0.283
Type of trauma				
Blunt	57 (93.4)	11 (84.6)	1.121	0.290
Sharp force	4 (6.6)	2 (15.4)		
Total hospital stay*	41.91	16.81	127.5	<0.001
Diagnosis at admission				
Thoracic trauma	7 (11.5)	1 (7.7)		
Head trauma	36 (59.0)	8 (61.5)		
Extremity trauma	9 (14.8)	0 (0)	3.636	0.304
Abdominal trauma	9 (14.8)	4 (30.8)		
Concomitant injury				
Yes	41 (67.2)	9 (69.2)		
No	20 (32.8)	4 (30.8)	0.020	0.888
Intubation				
Yes	19 (31.1)	13 (100)		
No	42 (68.9)	0 (0)	20.699	<0.001
Surgical intervention				
Yes	28 (45.9)	8 (61.5)		
No	33 (54.1)	5 (38.5)	1.049	0.306

Chi-square test; *Mann–Whitney U test (mean rank).

to trauma were included in the study. Exclusion criteria were age <18 years and transfer to another hospital for any reason. A total of 81 trauma patients were screened, and seven were excluded based on these criteria.

Statistical Analysis

All data were analyzed using SPSS version 26.00 (SPSS Inc., Chicago, USA). The normality of continuous variables was assessed using the Kolmogorov–Smirnov test. Categorical variables were compared using the Pearson chi-square test. Differences between two groups with non-normally distributed continuous variables were analyzed using the Mann–Whitney U test. Continuous variables were expressed as median (first and third quartiles). Optimal cut-off values for PIV, RTS, GCS, glucose-to-potassium ratio, and APACHE scores were determined using receiver operating characteristic (ROC) curve analysis. A p value <0.05 was considered statistically significant.

RESULTS

Sample size estimation was performed using G*Power based on α=0.05, power=0.8, and an effect size of 0.7. The minimum sample size required to achieve statistical power was calculated as 70 patients. A total of 74 patients were included in the study, of whom 13 (17.6%) were non-survivors and 67 (82.4%) were survivors. In the survivor group, there were seven females (11.5%) and 54 males (88.5%), while the non-survivor group included one female (7.7%) and 12 males (92.3%). The mean age was 50.23±22.03 years in non-survivors and 44.67±20.57 years in survivors. The mean length of hospital stay was 7.85±14.37 days in non-survivors and 12.44±7.78 days in survivors. Table 1 presents the distribution of demographic characteristics and vital signs among survivor and non-survivor groups. There were statistically significant differences between the groups in terms of intubation status and length of hospital stay (p<0.001).

Table 2 shows the comparison of laboratory parameters and trauma scores between the groups. Comparative analysis of laboratory parameters and trauma scores revealed significantly higher values of PIV, RTS, GCS, hematocrit, hemoglobin, platelet count, and diastolic and systolic blood pressure in survivors. In contrast, APACHE II scores, lactate, glucose, potassium, glucose-to-potassium ratio, and lymphocyte count were higher in non-survivors. There was no statistically significant difference in PIV values between females and males (p=0.095). Similarly, no significant difference was observed between blunt and sharp-force injuries (p=0.984).

ROC analysis showed that the area under the curve (AUC) for PIV, RTS, GCS, and APACHE II was statistically significant (p<0.001) (Fig. 1). The AUC values for PIV, RTS, GCS, and APACHE II were 0.702, 0.871, 0.805, and 0.115, respectively (Table 3), demonstrating that these parameters have predictive value for mortality.[24] The optimal cut-off values for PIV, RTS, GCS, and APACHE II were 6367.5, 3.5, 14.5, and

Table 2. Comparison of laboratory parameters and trauma scores between survivor and non-survivor patients

	Survivor Median (first and third quartiles)	Non-survivor Median (first and third quartiles)	Test value	p-value
PIV 1875.0 (1078.5-4367.5)	484.2 (73.68-4145.5)	236.0	0.023	
RTS8.0 (6.5-8.0)	4.0 (3.0-5.0)	102.5	<0.001	
APACHE II	13.0 (8.0-17.0)	28.0 (22.5-39.5)	91.0	<0.001
GCS	14.0 (9.0-15.0)	3.0 (1.0-6.0)	155.0	<0.001
Lactate	1.8 (1.20-2.55)	4.6 (2.71-10.95)	130.5	<0.001
Glucose	135.0 (119.0-163.0)	210.0 (122.0-240.0)	249.0	0.036
Potassium	4.10 (3.81-4.39)	4.64 (3.68-5.21)	271.0	0.075
G/P	33.0 (29.1-39.5)	43.7 (25.9-54.4)	311.5	0.227
Hematocrit (Hct)	36.8 (33.3-40.7)	31.2 (16.8-35.75)	195.0	0.004
Hemoglobin (Hb)	12.5 (11.3-13.8)	10.7 (5.45-12.1)	184.5	0.002
Neutrophils	11.07 (8.72-15.86)	7.6 (3.63-20.4)	327.0	0.324
Monocytes	0.73 (0.55-1.02)	0.7 (0.18-1.28)	325.0	0.310
Platelets	190.0 (161.5-232.0)	155.0 (110.5-204.0)	232.5	0.020
Lymphocytes	0.87 (0.5-1.14)	1.3 (0.85-2.08)	204.5	0.006
Diastolic blood pressure	75.0 (70.0-81.0)	52.0 (34.5-62.5)	83.5	<0.001
Systolic blood pressure	124.0 (113.0-137.0)	86.0 (66.0-112.0)	123.5	<0.001

PIV: Pan-immune-inflammation value; RTS: Revised trauma score; GCS: Glasgow coma scale; APACHE II: Acute Physiology and Chronic Health Evaluation I.

Table 3. Areas under the curve, cut-off values, sensitivity, and specificity of the, Acute Physiology and Chronic Health Evaluation II, Glasgow Coma Scale, and glucose-to-potassium ratio for predicting mortality

Variable	Area	Asymptotic sig.	Asymptotic 95% CI		Cut-off	Sensitivity (%)	Specificity (%)
			Lower	Upper			
PIV	0.702	0.046	0.504	0.901	6367.5	0.846	0.148
RTS	0.871	<0.001	0.758	0.981	3.5	0.462	0.984
GCS	0.805	<0.001	0.676	0.933	14.5	0.923	0.361
G/P	0.393	0.335	0.175	0.611	25.3	0.077	0.918
APACHE II	0.115	<0.001	0.028	0.201	4.5	0	0.934

PIV: Pan-immune-inflammation value; RTS: Revised Trauma Score; GCS: Glasgow Coma Scale; APACHE II: Acute Physiology and Chronic Health Evaluation I.

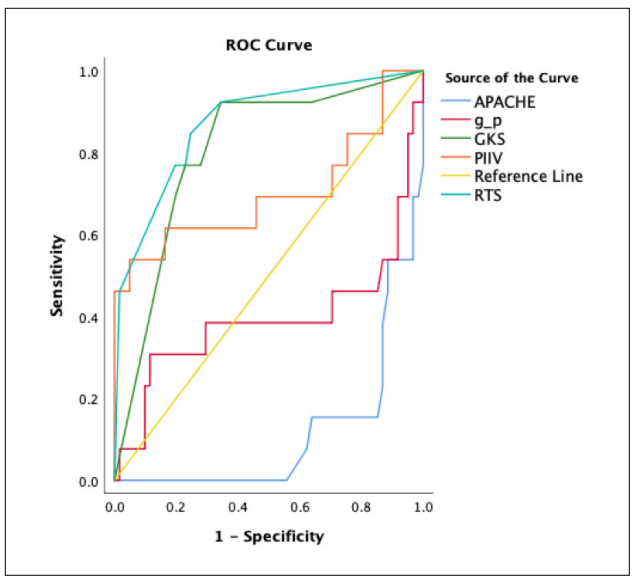

Figure 1. Receiver operating characteristic (ROC) curves of Acute Physiology and Chronic Health Evaluation II (APACHE II), glucose-to-potassium ratio, Glasgow Coma Scale (GCS), pan-immune-inflammation value (PIV), and Revised Trauma Score (RTS) for predicting mortality.

4.5, respectively, demonstrating their diagnostic value for mortality. At these thresholds, the sensitivity values for PIV, RTS, GCS, and APACHE II were 0.846, 0.462, 0.923, and 0, respectively, while the corresponding specificity values were 0.148, 0.984, 0.361, and 0.934.

DISCUSSION

When demographic and clinical characteristics were compared between survivor and non-survivor groups, no significant differences were observed in terms of sex, age, trauma mechanism, primary diagnosis at admission, or the presence of additional injuries. The length of hospital stay was significantly longer among survivors, which is consistent with the expected course of recovery. A marked difference was observed in intubation status, as all patients in the non-survivor group were intubated, compared with only a minority of survivors. Surgical intervention rates did not differ significantly between the groups. Overall, these findings suggest that demographic factors did not have a significant impact on mortality in our study.

In the present study, PIV was found to be associated with mortality in trauma patients. In addition to supporting the predictive value of established prognostic markers reported in the literature, our study strengthens the evidence linking PIV to trauma outcomes and highlights the need for further research in this area.[25,26] There are no published studies in the literature evaluating the prognostic value of PIV in polytrauma patients. However, a limited number of recent studies in conditions such as burn injuries and earthquake-related injuries—both of which involve trauma-like inflammatory responses—suggest its potential relevance, although direct evidence remains limited. Agan et al.[14] evaluated 76 patients with earthquake-related crush injuries and reported that higher PIV values were associated with increased rates of ICU admission and dialysis requirement. These findings suggest that PIV may serve as an early indicator to guide triage and treatment planning. Similarly, in a retrospective study including 140 patients with earthquake-induced crush injuries and 200 control patients, Yasar et al.[27] evaluated PIV alongside other inflammatory biomarkers, such as neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), monocyte-to-lymphocyte ratio (MLR), systemic immune-inflammation index (SII), and systemic inflammation response index (SIRI), and assessed clinical outcomes, including length of hospital stay, dialysis requirement, and blood product transfusion. PIV values were significantly higher in the earthquake group; however, no significant associations were observed with dialysis requirement, blood transfusion, or length of hospital stay. Nevertheless, elevated PIV levels were suggested to be associated with poorer overall outcomes. Furthermore, two recent studies have evaluated PIV values in burn patients.[25,26] Dincer et al.[25] reported significantly higher PIV values in a cohort of 100 burn patients who died, suggesting that PIV

may serve as a reliable biomarker for predicting in-hospital mortality. Similarly, Xi et al.,[26] in a study of 367 patients with facial burns, found that higher PIV values were associated with increased scar formation. In contrast to these studies, our study examined the relationship between PIV and key clinical outcomes in polytrauma patients, including injury severity, development of organ failure, need for and duration of intubation, length of intensive care and hospital stay, and mortality. These aspects underscore the novelty and clinical relevance of our study.

In the present study, elevated lactate levels and reduced systolic and diastolic blood pressure were identified as significant predictors of mortality. These parameters reflect tissue hypoxia, inadequate perfusion, and shock—well-established biochemical and clinical markers strongly associated with early mortality.[27] Additionally, the glucose-to-potassium (Glu/K) ratio was significantly higher in non-survivors. Consistent with our findings, Katipoglu et al.,[28] in a study of 99 patients with blunt abdominal trauma, also reported higher Glu/K ratios among non-survivors. Following trauma, sympathetic activation and catecholamine release increase serum glucose levels while reducing potassium levels. Moreover, post-traumatic hyperglycemia and insulin resistance are recognized contributors to increased mortality.

Numerous studies have compared the prognostic performance of established trauma scoring systems, such as RTS, GCS, and ISS.[29-31] Consistent with the literature, RTS and GCS were strong predictors of mortality in our study. The lack of an association between APACHE II scores and mortality may be attributable to the relatively small sample size. Furthermore, APACHE II requires assessment of the worst values within the first 24 hours, limiting its utility in emergency settings. GCS and RTS also have certain limitations, particularly the influence of endotracheal intubation and patient age, as respiratory rate is not standardized in intubated patients or younger individuals.[32] Additionally, the use of GCS alone has limited sensitivity for detecting traumatic brain injury in polytrauma patients.[33]

In recent years, inflammatory biomarkers derived from complete blood count parameters have attracted increasing interest for predicting clinical outcomes.[20,34,35] The PIV is a novel biomarker incorporating four immune cell types—neutrophils, monocytes, platelets, and lymphocytes—reflecting the systemic immune-inflammatory response. Numerous studies in oncology, cardiology, and critical care have demonstrated strong associations between PIV, disease severity, and mortality.[16] Although PIV has been linked to clinical outcomes in conditions such as malignancy, sepsis, acute burns, stroke, and heart failure, its prognostic utility in trauma patients—particularly those with polytrauma—remains insufficiently explored. Given that trauma-induced physiological and inflammatory responses are closely associated with mortality, investigating PIV in this population is of particular importance.

In our study, lower PIV values were significantly associated with mortality. ROC analysis confirmed that PIV had significant predictive ability for mortality, suggesting its potential role as a prognostic biomarker in trauma patients. Across the literature, PIV values vary substantially among different disease groups, suggesting that their clinical interpretation may differ between acute inflammatory states, such as trauma, and chronic conditions, such as cancer or cardiometabolic diseases.

For example, Lin et al.[36] demonstrated improved overall survival in breast cancer patients with lower PIV values in a cohort of 1,312 patients. Baş et al.[34] reported that higher PIV levels were associated with frailty in 450 geriatric patients. In patients with hypertension, Wu et al.[30] found that elevated PIV values were linked to increased mortality.[30] Furthermore, a meta-analysis by Hai-Jing et al.,[37] including 8,799 cancer patients across 30 studies, concluded that high PIV values were significantly associated with reduced overall survival.

The differences observed in trauma may be related to the distinct nature and temporal dynamics of the inflammatory response. In chronic conditions such as cancer or cardiovascular disease, inflammation is persistent, low-grade, and prolonged, leading to elevation of immune cell counts and, consequently, higher PIV values. In contrast, trauma induces a sudden hyperinflammatory response that may rapidly transition into a state of immune suppression. Previous studies have demonstrated that cellular reserves and functions decline rapidly following severe trauma. Therefore, PIV should not be interpreted in isolation but rather in the context of the underlying disease process and its temporal course.

Given the variables influencing PIV, the potential effects of blood transfusions and therapeutic interventions on hematological parameters should be considered. To minimize confounding, PIV in our study was calculated using laboratory values obtained at initial presentation. In a study involving 82 patients with septic shock, PIV did not reliably predict mortality, likely due to treatment-related fluctuations in immune cell counts.[35] Nevertheless, even in that study, patients with lower PIV values demonstrated better survival compared with those with higher values.

In our cohort, in contrast to studies involving burns or earthquake-related crush injuries—where elevated PIV has been associated with poorer outcomes—we found that lower PIV values were associated with mortality. This discrepancy may be explained by the heterogeneity of trauma mechanisms, compared with the more homogeneous populations observed in burn or crush injury studies.

Several mechanisms may account for this inverse relationship:

1. Early post-traumatic immune exhaustion: Severe trauma may lead to rapid depletion or functional impairment of neutrophils, monocytes, and platelets, resulting in reduced cell counts and lower PIV values.[38]

2. Failure of lymphocyte recovery: Persistent lymphopenia has been associated with increased mortality in trauma, independent of leukocytosis patterns.[39]

3. Functional, not just numerical, immune deficits: Trauma impairs neutrophil chemotaxis, phagocytosis, receptor expression, and T-cell function, leading to inadequate antigen presentation and dysregulated cytokine response.[40]

Taken together, the association between high PIV and poor outcomes described in chronic inflammatory or more homogeneous acute conditions may not apply to severe trauma. In this context, low PIV may reflect immune exhaustion, dysfunction, or impending immunosuppression, factors closely associated with increased mortality. Therefore, the clinical interpretation of PIV should consider trauma type, timing, and the phase of the immune response (early hyperinflammation vs. late immunosuppression). Future studies should evaluate serial PIV measurements (e.g., at 0–24 hours, 48 hours, and day 7) to better characterize the dynamic relationship between PIV, immune dysfunction, and mortality.

In the context of major trauma and mass-casualty scenarios, incorporating PIV into simplified scoring systems may enhance triage accuracy during the "golden hours." Moreover, real-time digital or mobile tools for calculating PIV could support rapid clinical decision-making in emergency settings.

Limitations

The primary limitations of this study include its retrospective and single-center design. Although the sample size was relatively small compared with other studies, it exceeded the minimum required based on G*Power analysis. Another limitation is the inability to precisely determine the time interval between the trauma event and laboratory evaluation. Only the time between emergency department admission and intensive care unit admission could be obtained from the hospital system. Additionally, due to the limited sample size, subgroup analyses based on trauma type could not be performed. Larger, multicenter prospective studies are needed to further clarify the relationship between PIV and trauma outcomes.

CONCLUSION

In this trauma cohort, RTS, GCS, APACHE II scores, intubation status and duration, length of hospital stay, serum lactate levels, glucose-to-potassium ratio, and systolic and diastolic blood pressures differed significantly between survivors and non-survivors. Notably, this study is the first to evaluate the early prognostic value of PIV at initial presentation in trauma patients, demonstrating a significant association between PIV and mortality.

Rapid and reliable prognostication is essential in emergency settings. Early inflammatory responses following trauma are closely linked to subsequent organ failure. Given that PIV is simple to calculate, cost-effective, and based on widely available laboratory parameters, it may serve as a valuable adjunct for triage and treatment planning in trauma care. In particular, low PIV values may warrant increased clinical vigilance.

Acknowledgments: We would like to thank our valued family members for their understanding and support during the time devoted to this work.

Ethics Committee Approval: This study was approved by the Bilecik Şeyh Edebali University Non-Interventional Clinical Research Ethics Committee (Date: 29.11.2023, Decision No: E-10333602-050.04.01-218622).

Informed Consent: Informed consent was waived by the institutional review board due to the retrospective nature of the study.

Authorship Contributions: Concept: G.G., K.Ç.; Design: K.Ç., K.D.A.; Supervision: K.Ç.; Resource: K.D.A., G.G.; Materials: K.D.A., F.Ç.I.; Data collection and/or processing: F.Ç.I., K.Ç.; Analysis and/or interpretation: F.Ç.I., K.Ç.; Literature review: G.G., K.D.A.; Writing: G.G., K.Ç., K.D.A., F.Ç.I.; Critical review: K.D.A., K.Ç.

Conflict of Interest: None declared.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Travma hastalarında farklı bir bakış açısı kohortu: PIV ölüm oranını öngörebilir mi?

AMAÇ: Travma, dünya genelinde ölümlerin önemli bir bölümünü oluşturmaktadır. Acil servislerde ve yoğun bakım ünitelerinde bu hastaların prognozunu tahmin etmek, etkili triyaj ve takip planlaması için çok önemlidir. Bu nedenle, travma hastalarında çok sayıda prognostik belirteç araştırılmaktadır. Panimmün-inflamasyon (PIV), tam kan sayımından (CBC) hesaplanabilen ve tıbbi ünitede hızlı bir şekilde uygulanabilen bir biyobelirteçtir. Bu çalışma, PIV değerinin travma hastalarının prognozunda rol oynayıp oynamadığını değerlendirmeyi amaçlamıştır.

GEREÇ VE YÖNTEM: Bu çalışma, üçüncü basamak yoğun bakım olanaklarına sahip bir eğitim ve araştırma hastanesinde travma nedeniyle yoğun bakım ünitesine yatırılan hastaları incelemiştir. Bilinen prognostik parametreler (RTS, GCS ve APACHE II gibi) değerlendirilmiş, PIV değerleri hesaplanmış ve mortalite, morbidite ve hastanede kalış süresi retrospektif olarak analiz edilmiştir. PIV değerinin mortaliteyi tahmin etme değeri istatistiksel olarak analiz edilmiştir.

BULGULAR: Çalışmaya toplam 74 hasta dahil edilmiştir. Hayatta kalanlar grubunda 7 kadın (%11.5) ve 54 erkek (%88.5) bulunurken, ölenler grubunda 1 kadın (%7.7) ve 12 erkek (%92.3) vardı. PIV, RTS, GKS ve APACHE skorlarının mortaliteyi tahmin etmede etkili olduğu bulundu ($p<0.001$). PIV değeri için eşik değer 6367.5 olarak bulundu ve bu değerin altında PIV değerine sahip hastaların, daha yüksek değerlere sahip olanlara göre ölme olasılığı daha yüksekti.

SONUÇ: Acil durumlarda hızlı ve güvenilir prognoz çok önemlidir. PIV değeri, diğer bilinen prognoz skorlama sistemlerine benzer bir mortalite tahmin etkisi yaratma potansiyeline sahiptir. Travma hastalarında PIV değerinin hızlı değerlendirilmesi, daha etkili triyaj ve tedavi planlamasını kolaylaştırabilir.

Anahtar sözcükler: Mortalite; panimmün-enflamasyon değeri; prognoz; travma.

Ulus Travma Acil Cerrahi Derg 2026;32(5):558-566 DOI: 10.14744/tjtes.2026.33746

ORIGINAL ARTICLE

Ultrasonographic evaluation of tendon injuries in hand trauma: a crucial tool for emergency care

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ABSTRACT

BACKGROUND: Hand injuries, particularly tendon injuries, are a common reason for emergency department visits and may significantly impact daily functioning. Traditional diagnostic approaches may fail to detect partial tendon injuries, highlighting the need for alternative imaging techniques. Ultrasonography (USG) has emerged as a rapid, non-invasive, and effective diagnostic tool for tendon injuries, particularly in emergency settings where magnetic resonance imaging (MRI) may not be readily available. This study evaluates the diagnostic effectiveness of ultrasonography in assessing tendon injuries among patients presenting with hand trauma in the emergency department (ED). Ultrasonography findings were compared with clinical evaluations to determine its role in diagnosing tendon injuries and guiding surgical management. This prospective observational study was conducted in the ED of a single tertiary-care hospital over a one-year period and included adult patients presenting with hand injuries.

METHODS: Patients who met the inclusion criteria underwent both clinical evaluation and ultrasonographic examination. A total of 68 patients were included in the study. All assessments were performed by an experienced emergency medicine physician using a Philips Affinity S70 ultrasonography system (Philips Healthcare, Bothell, WA, USA). Collected data included patient demographics, injury characteristics, ultrasonographic findings, and the need for surgical intervention. Statistical analyses were performed using the chi-square test and binary logistic regression to compare the diagnostic performance of the two methods.

RESULTS: Ultrasonography demonstrated a sensitivity of 82.6% (95% confidence interval [CI]: 0.69–0.91), specificity of 90.9% (95% CI: 0.70–0.98), and an overall accuracy of 85.3% (95% CI: 0.75–0.92) in predicting the need for tendon repair. Clinical evaluation showed slightly lower diagnostic performance, with a sensitivity of 80.4% (95% CI: 0.67–0.89) and an accuracy of 80.9% (95% CI: 0.70–0.89).

CONCLUSION: Regression analysis indicated that ultrasonography increased the likelihood of accurately diagnosing tendon injuries by 21.8 times compared to clinical assessment. Together, clinical evaluation and ultrasonography predicted 61% of all cases requiring tendon repair.

Keywords: Dynamic ultrasonography; emergency care; hand injuries; imaging techniques; prospective study; tendon injuries.

INTRODUCTION

Hand injuries are frequently encountered in the emergency department (ED) and are often straightforward, requiring only basic medical management.[1] However, some injuries require surgical repair and may result in significant morbidity if not treated promptly.[2] Among hand injuries that may necessitate emergency surgical intervention, tendon lacerations can sometimes be overlooked.[3] Tendon injuries are primarily diagnosed through clinical evaluation. However, clinical examination may be inadequate when patients are unable to cooperate because of severe pain or when assessment is limited

Cite this article as: Yurtsever G, Acar H, Saylav Bora E, Arıkan C. Ultrasonographic evaluation of tendon injuries in hand trauma: a crucial tool for emergency care. Ulus Travma Acil Cerrahi Derg 2026;32:567-573.

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Ulus Travma Acil Cerrahi Derg 2026;32(5):567-573 DOI: 10.14744/tjtes.2025.20351
Submitted: 02.09.2025 Revised: 03.12.2025 Accepted: 29.12.2025 Published: 05.05.2026

by impaired consciousness.[4] In such situations, physicians require a rapid and reliable diagnostic method. These limitations may lead to unnecessary surgical recommendations or inappropriate treatment plans.

In recent years, the evaluation of tendon injuries has become an important application area for ultrasonography (USG). Radiological techniques, such as magnetic resonance imaging (MRI) and ultrasound are valuable tools for diagnosing tendon injuries.[5] Although MRI provides high-quality images, its use is limited by high cost, restricted availability, and the need to transport the patient to the imaging unit.[6] USG, in contrast, is a low-cost imaging modality that can be performed quickly at the bedside.[7] Because of these advantages, ultrasonography is increasingly used as a diagnostic tool in the ED.[8] It is anticipated that USG will become an essential diagnostic modality for emergency physicians when evaluating patients presenting with hand and wrist injuries involving potential tendon damage.

The aim of this study was to evaluate the effectiveness of ultrasonography in detecting tendon injuries in patients presenting to the ED with hand and wrist trauma.

MATERIALS AND METHODS

Study Design

This prospective observational study was conducted at a single center and included patients who presented to the emergency department with hand injuries between October 1, 2022 and October 1, 2023. The study was performed in accordance with the principles of the Declaration of Helsinki (1964) and its subsequent amendments. This study was approved by the İzmir Local Clinical Research Ethics Committee (Date: 15.09.2022, Decision no: 57). Written informed consent was obtained from all participants. The study was designed and reported in compliance with the Standards for Reporting Diagnostic Accuracy Studies (STARD) 2015 guidelines for diagnostic accuracy studies.

Study Setting

The study was conducted in the ED of a tertiary-care hospital with an annual patient volume of approximately 400,000 visits. A hand surgeon is available on duty at this hospital every day. Consequently, patients from other hospitals who are suspected of requiring hand surgery are frequently referred to this center. Patients presenting to the ED are initially evaluated by an emergency medicine resident and an emergency medicine specialist. During this evaluation, patients suspected of requiring hand surgery are referred for consultation with the hand surgeon. The hand surgeon evaluates the patient in the emergency department and determines whether surgical intervention is required. Patients deemed to require surgery undergo either urgent or elective operative treatment, which is performed by the hand surgeon. This workflow reflects the routine clinical practice at our hospital. In this study, the routine workflow was maintained; however, all patients for whom a hand surgery consultation was requested additionally underwent tendon ultrasonography performed by a single emergency medicine physician involved in the research. All corresponding images and data were systematically recorded. The emergency physicians evaluating the patients were blinded to the ultrasound findings. Likewise, the physician performing the ultrasound examination was blinded to the clinical assessment and consultation decision prior to the examination.

Patient Selection

Patients presenting to the ED with hand injuries were screened according to the following inclusion and exclusion criteria to establish the study population.

Inclusion Criteria

1. Age ≥18 years

2. Voluntary participation in the study with written informed consent

3. Glasgow Coma Scale (GCS) score of 14 or 15.

Exclusion Criteria

1. Age <18 years

2. Presence of additional injuries that could negatively affect tendon examination

3. GCS score <14

4. Intoxication with drugs or alcohol, or withdrawal states that could adversely affect the patient's consciousness and cooperation

5. Requirement for cardiopulmonary resuscitation during ED evaluation

6. Abrasions and superficial skin cuts without deep incisions.

Ultrasonographic Evaluation

Following the initial evaluation, all patients for whom a hand surgery consultation was requested underwent tendon ultrasonography performed by a designated emergency medicine physician with four years of experience and training in ultrasonography. This examination assessed whether the tendon had a complete or partial rupture. The assessment was performed using the linear probe of a Philips Affinity S70 ultrasonography system (Philips Healthcare, Bothell, WA, USA) with the "superficial tissue" preset. Ultrasonographic evaluation was conducted in B-mode grayscale, and all acquired images were recorded. During the ultrasound examination, the affected extremity was positioned on a table with the area of interest facing upward. If the skin surface was intact, the procedure was performed directly over the area of interest. In cases where an open wound was present, the wound edges were temporarily approximated using sterile adhesive strips (Steri-Strips) before imaging. The ultrasound examination was then performed under these standardized conditions.

Data Collection

The collected data included patient age, sex, mechanism of injury, anatomical location of the injury, past medical history, medication usage, alcohol or drug use status, ultrasonographic findings, and the need for hand surgery consultation. These data were recorded using a predesigned data collection form. The primary outcome of the study was the requirement for hand surgery. This outcome included both patients who did not require surgery after evaluation by the hand surgeon and patients who underwent surgery but were found to have no tendon injury.

Imaging

In this study, imaging was performed to identify tendon injuries and to evaluate potential damage to the muscle, tendon, and vascular structures. The imaging findings were classified as follows: (Fig. 1).

1. Normal Appearance

o Imaging demonstrated an intact and healthy tendon with no pathological findings (Fig. 2).

2. Muscle Rupture

o Disruption of muscle tissue continuity was observed (Fig. 3).

3. Partial Tendon Laceration

o In cases of partial tendon laceration, the tendon retained partial structural integrity, while a localized area showed disruption (Fig. 4). This finding suggests the possibility of partial functional impairment.

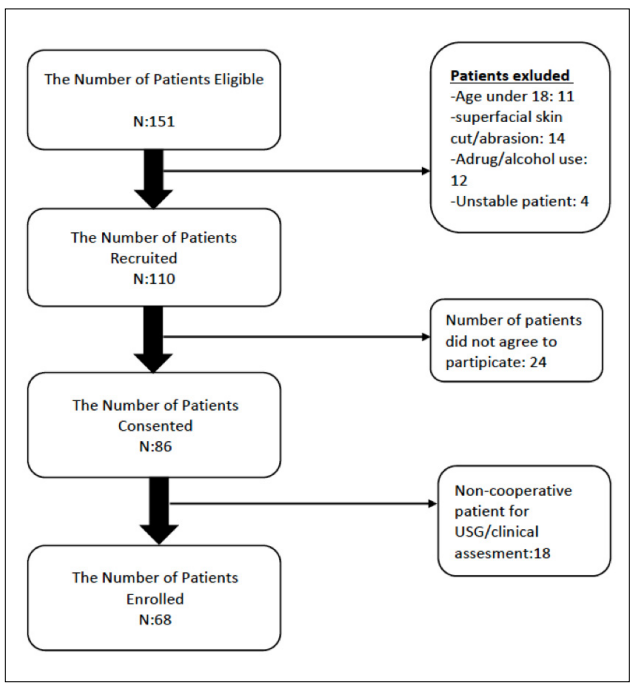

Figure 1. Study flowchart.

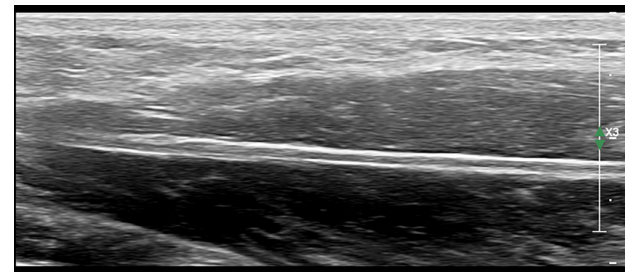

Figure 2. Normal appearance showing intact tendon and muscle structures.

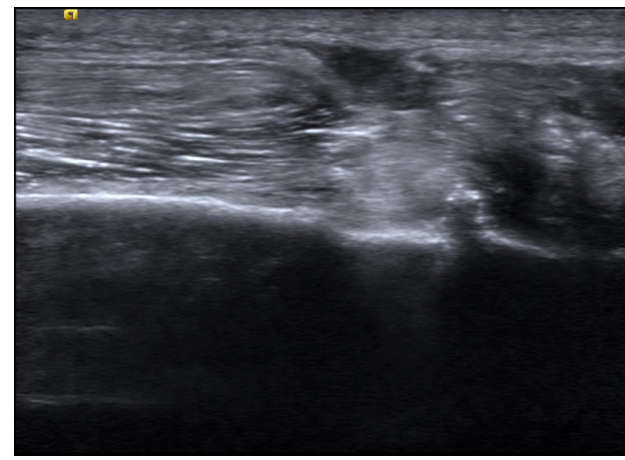

Figure 3. Muscle rupture demonstrating disruption of muscle tissue continuity.

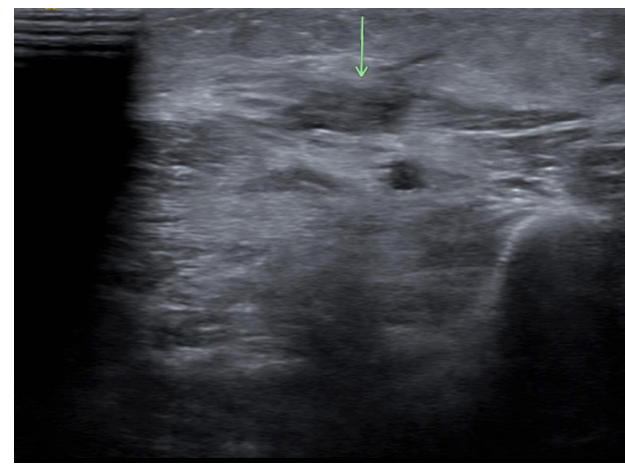

Figure 4. Partial tendon laceration showing localized disruption of the tendon structure.

4. Full-Thickness Tendon Rupture

o Full-thickness tendon rupture was characterized by complete discontinuity of the tendon, resulting in significant functional loss (Fig. 5).

5. Intact Digital Artery and Tendon

o No evidence of vascular or tendon injury was detected (Fig. 6).

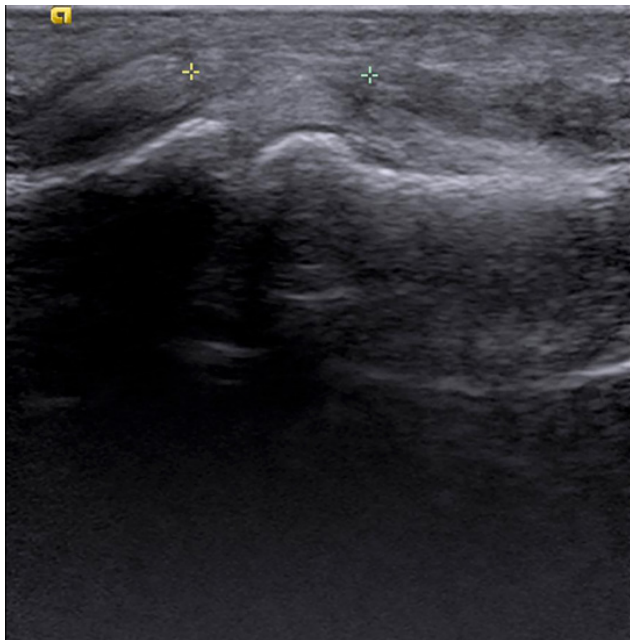

Figure 5. Full-thickness tendon rupture with complete discontinuity of the tendon.

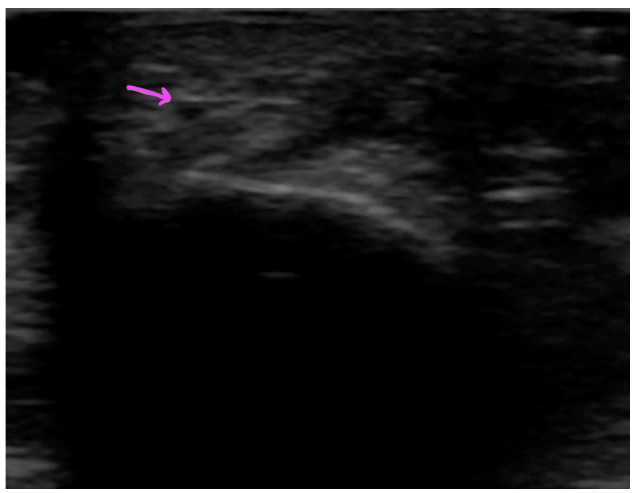

Figure 6. Intact digital artery and tendon with no evidence of vascular or tendon injury.

Note: The figures presented illustrate representative diagnostic images obtained during the study and correspond directly to the findings described above.

Statistical Analysis

Data were analyzed using SPSS (Statistical Package for the Social Sciences) version 26.0. Numerical data were presented as numbers, percentages, and means. The chi-square test was used to evaluate associations between categorical variables when comparing ultrasonographic and clinical evaluation methods. Sensitivity, specificity, positive predictive value, and negative predictive value were calculated for both diagnostic approaches. Binary logistic regression analysis was performed to compare the effectiveness of the two methods in determining the need for hand surgery.

Additionally, a logistic regression model was developed to assess the combined effectiveness of both methods. The results of this model were presented using the Cox & Snell R2 and Nagelkerke R2 parameters. These measures illustrate the predictive capability of clinical and ultrasonographic evaluations in determining the need for hand surgery. All analyses were reported with a 95% confidence interval, and a p-value of <0.05 was considered statistically significant.

Post-Hoc Power Analysis

A post-hoc power analysis was performed based on the primary outcome of diagnostic accuracy between ultrasonographic and clinical evaluations. Using the observed effect size derived from the difference in accuracy (0.85 vs. 0.81), a sample size of 68 subjects, and a significance level (α) of 0.05, the calculated statistical power of the study was 0.88 (88%). This indicates that the study had adequate power to detect a clinically meaningful difference between the two diagnostic methods.

Table 1. General characteristics of the patients

	Number (n)	Percentage (%)
Sex		
Male	58	85%
Female	10	15%
Side of injury		
Right	40	59%
Left	28	41%
Type of injury		
Flexor	35	52%
Extensor	33	48%
Mechanism of injury		
Cutting tool	63	93%
Crush injury	5	7%
Tendon injury on clinical examination		
No	27	40%
Yes	41	60%
Tendon injury on ultrasonography		
No	40	59%
Yes	28	41%
Need for hand surgery		
No	22	32%
Yes	46	68%
Alcohol use		
No alcohol use	57	84%
Alcohol use	11	16%

RESULTS

A total of 151 patients were evaluated for the need for hand surgery during the study period. After applying the exclusion criteria, 68 patients were included in the final analysis. The mean age of the included patients was 34±15 years, and 58 (85%) were male. It was determined that 68% of the patients required hand surgery, highlighting the severity of the condition in a substantial proportion of the study population. The general characteristics of the study population are presented in Table 1.

According to the chi-square analysis, both clinical evaluation and high-frequency linear transducer ultrasonography were statistically significant in determining the need for tendon repair (p<0.001 for both) (Table 2). When the diagnostic performance of ultrasonography in predicting the need for tendon repair was evaluated, the sensitivity was 82.6% (95% confidence interval [CI]: 0.69–0.91), specificity 90.9% (95% CI: 0.70–0.98), positive predictive value (PPV) 95.0% (95% CI: 0.83–0.99), negative predictive value (NPV) 71.4% (95% CI: 0.53–0.85), and overall accuracy 85.3% (95% CI: 0.75–0.92). For clinical examination, sensitivity was 80.4% (95% CI: 0.67–0.89), specificity 81.8% (95% CI: 0.60–0.94), PPV 90.2% (95% CI: 0.77–0.97), NPV 66.7% (95% CI: 0.48–0.82), and overall accuracy 80.9% (95% CI: 0.70–0.89) (Table 3).

When the effectiveness of clinical evaluation and high-frequency linear transducer ultrasonography in determining the need for tendon repair was assessed using binary logistic regression analysis, each unit increase in the clinical evaluation score increased the likelihood of requiring tendon repair by 4.419 times, whereas each unit increase in the ultrasonography score increased it by 21.809 times (Table 4). This finding underscores the importance of ultrasonography as a complementary tool to clinical examination. According to the Nagelkerke value, the model including clinical examination and ultrasonography explained 61.4% of the need for tendon repair (Table 5).

Table 2. Chi-square analysis

	Need for tendon repair			p
	No	Yes	Total	
Tendon injury on USG				
Yes	2	38	40	<0.001
	5.0%	95.0%	100.0%	
No	20	8	28	
	71.4%	28.6%	100.0%	
Total	22	46	68	
	32.4%	67.6%	100.0%	
Tendon injury on clinical examination				
Yes	4	37	41	<0.001
	9.8%	90.2%	100.0%	
No	18	9	27	
	66.7%	33.3%	100.0%	
Total	22	46	68	
	32.4%	67.6%	100.0%	

USG: Ultrasonography.

Table 3. Diagnostic accuracy analysis

	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	Overall accuracy (95% CI)
USG	83% (0.69–0.91)	91% (0.70–0.98)	95% (0.83–0.99)	71% (0.53–0.85)	0.86 (0.75–0.92)
Clinical examination	80% (0.67–0.89)	82% (0.60–0.94)	90% (0.77–0.97)	67% (0.48–0.82)	0.81 (0.70–0.89)

PPV: Positive predictive value; NPV: Negative predictive value.

Table 4. Binary logistic regression analysis

	B	Sig.	Exp(B)	95% CI for Exp(B)	
				Lower	Upper
Clinical evaluation	1.486	0.071	4.419	0.879	22.232
USG evaluation	3.082	0.001	21.809	3.650	130.301
Constant	-1.298	0.009	0.273		

USG: Ultrasonography.

DISCUSSION

This study highlights the importance of using ultrasonography to evaluate hand tendon injuries in the emergency department. The findings demonstrate that high-frequency linear transducer ultrasonography is effective in determining the need for tendon repair, with a sensitivity of 83% and a specificity of 91%, indicating that it is a reliable diagnostic method. These results emphasize the importance of rapid intervention in the ED and demonstrate how ultrasonography can contribute to this process.

The literature presents conflicting results regarding the effectiveness of ultrasonography in diagnosing upper extremity tendon injuries. For example, Meisami et al.[9] reported that ultrasound evaluation, when compared to surgical outcomes, was not a reliable method for diagnosing tendon injuries. In contrast, Mohammadrezaei et al.[10] evaluated tendon injuries in penetrating extremity traumas using ultrasonography and reported that ultrasound showed high accuracy in distinguishing injured tendons from normal tendons. However, in that study, the reference standard was clinical evaluation performed by a team consisting of orthopedic and emergency medicine residents, and the performance of ultrasonography was assessed accordingly. In the present study, surgical outcomes were used as the reference standard, and clinical decisions were compared with ultrasonographic evaluations performed by an emergency physician. According to our findings, both clinical examination and ultrasonographic evaluation were effective in distinguishing injured tendons from normal tendons. However, when the two methods were compared, ultrasonography demonstrated higher sensitivity and specificity. Moreover, because our hospital functions as a referral center for hand surgery, the PPV (95%) observed in our study may be higher than that reported in the literature due to the higher prevalence of injuries in the study population.

In the emergency department, clinical evaluation is the primary method used to diagnose tendon injuries; however, some patients may undergo unnecessary surgical exploration. Therefore, diagnostic methods that can more accurately confirm the diagnosis are being investigated. In one such study, Wu et al. reported that ultrasound was superior to clinical evaluation in diagnosing lower and upper extremity tendon ruptures in the emergency department.[8] In the present study, consistent with previous literature, ultrasonographic evaluation demonstrated better diagnostic performance than clinical examination, with higher sensitivity and specificity. Moreover, according to the binary logistic regression analysis performed to evaluate the relationship between tendon injuries in hand and wrist trauma and both clinical and ultrasonographic assessments, a one-unit increase in the clinical evaluation score was associated with a 4.419-fold increase in the probability of tendon injury, whereas a one-unit increase in the ultrasonographic evaluation score was associated with a 21.809-fold increase in the likelihood of tendon injury. When both methods were used together, the model explained approximately 61% of all tendon injuries in hand and wrist trauma according to Nagelkerke R2 value.

Table 5. Regression model summary

	Model Summary		
Step	-2 Log likelihood	Cox&Snell R^2	Nagelkerke R^2
1	46.246[a]	0.439	0.614

This study has certain limitations. First, it did not evaluate whether the use of ultrasound influenced the time to diagnosis or the time to surgical intervention. Because bedside ultrasound has the potential to reduce both diagnostic and operative delays, future studies should investigate this aspect. Second, tendon injuries of the hand and wrist were analyzed collectively by anatomical region, flexor or extensor function, or specific tendon involvement. Future studies with larger sample sizes should include subgroup analyses comparing flexor and extensor tendon injuries separately, which may provide more detailed insights into the diagnostic performance and clinical utility of ultrasonography across different tendon types. Additionally, surgical exploration was not performed in patients who were clinically determined not to require hand surgery. This represents a limitation of the study, as the absence of confirmatory surgery in this group may have led to an overestimation of the NPV. Finally, because 68% of the patients in this study required surgical intervention, the positive predictive value may have been influenced by the high prevalence of tendon injury in the study population.

CONCLUSION

Bedside ultrasonography is a practical, safe, and reliable diagnostic tool for identifying partial or complete tendon ruptures in hand and wrist injuries. It supports clinical decision-making regarding the need for emergency surgical intervention, particularly in cases where the physical examination is inconclusive. Nevertheless, further large-scale studies are required to validate these findings and to establish standardized diagnostic protocols.

Ethics Committee Approval: This study was approved by the İzmir Local Clinical Research Ethics Committee (Date: 15.09.2022, Decision No: 57).

Informed Consent: Written informed consent was obtained from all participants.

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

El travmalarında tendon yaralanmalarının ultrasonografik değerlendirilmesi: Acil bakımda kritik bir araç

AMAÇ: El yaralanmaları, özellikle tendon yaralanmaları, acil servise başvuruların önemli bir nedenidir ve günlük yaşam aktivitelerini ciddi şekilde etkileyebilir. Geleneksel tanı yöntemleri kısmi tendon yaralanmalarını sıklıkla gözden kaçırmakta, bu da alternatif görüntüleme yöntemlerinin gerekliliğini ortaya koymaktadır. Ultrasonografi (USG), özellikle manyetik rezonans görüntüleme (MRG) imkânının olmadığı acil durumlarda, hızlı, non-invaziv ve etkili bir tanı aracı olarak öne çıkmaktadır.

GEREÇ VE YÖNTEM: Bu çalışma, acil servise el travması ile başvuran hastalarda tendon yaralanmalarının değerlendirilmesinde ultrasonografinin tanısal etkinliğini incelemeyi amaçlamaktadır. Ayrıca USG'nin klinik değerlendirme ile karşılaştırılarak tendon yaralanmalarının tanısındaki rolü ve cerrahi müdahale planlamasındaki katkısı araştırılmıştır. Bu prospektif gözlemsel çalışma, üçüncü basamak tek merkezli bir hastanenin acil servisinde bir yıl boyunca yürütülmüştür. Çalışmaya el yaralanması ile başvuran erişkin hastalar dahil edilmiştir. Dahil edilme kriterlerini karşılayan hastalara klinik değerlendirme ve ultrasonografi uygulanmıştır. Çalışmaya toplam 68 hasta alınmış, değerlendirmeler deneyimli bir acil tıp uzmanı tarafından Philips Affinity S70 ultrasonografi cihazı (Philips Healthcare, Bothell, WA, ABD) kullanılarak yapılmıştır. Demografik veriler, yaralanma özellikleri, ultrasonografik bulgular ve cerrahi müdahale gereksinimleri kaydedilmiştir. İstatistiksel analizlerde ki-kare testi ve ikili lojistik regresyon kullanılmıştır.

BULGULAR: Tendon onarımı gerekliliğinin belirlenmesinde ultrasonografinin duyarlılığı %83, özgüllüğü %91, pozitif prediktif değeri %95 ve negatif prediktif değeri %71 olarak bulunmuştur. Yalnızca klinik değerlendirme ise daha düşük prediktif değerlere sahipti.

SONUÇ: Regresyon analizi, ultrasonografinin klinik değerlendirmeye kıyasla tendon yaralanmalarını doğru tanılama olasılığını 21.8 kat artırdığını göstermiştir. Hem klinik değerlendirme hem de ultrasonografi birlikte tüm tendon onarımı gereksinimlerinin %61'ini öngörebilmiştir.

Anahtar sözcükler: Acil bakım; dinamik ultrasonografi; el yaralanmaları, görüntüleme teknikleri; prospektif çalışma; tendon yaralanmaları.

Ulus Travma Acil Cerrahi Derg 2026;32(5):567-573 DOI: 10.14744/tjtes.2025.20351

ORIGINAL ARTICLE

Safety and effectiveness of nonoperative management in liver lacerations: a retrospective cohort study

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ABSTRACT

BACKGROUND: Liver trauma remains a major contributor to morbidity in patients with abdominal injuries. Although nonoperative management (NOM) is widely accepted in hemodynamically stable patients, the relationship between American Association for the Surgery of Trauma (AAST) injury grade, laboratory parameters, transfusion requirements, and the need for surgical intervention remains unclear.

METHODS: This retrospective observational study included 53 patients with radiologically or intraoperatively confirmed liver lacerations treated at a tertiary surgical center between October 2024 and May 2025. Data collected included demographics, vital signs, AAST injury grade, laboratory values, transfusion requirements, imaging use, and clinical outcomes. Statistical analyses were performed using analysis of variance (ANOVA), chi-square/Fisher's exact tests, and logistic regression.

RESULTS: The mean age was 41.4 years, with 67.9% of patients being male. The most common mechanism of injury was motor vehicle accidents (56.6%). On admission, 64.2% of patients had AAST grade I–II injuries, while 7.5% had grade IV injuries. NOM was successful in 81.1% of cases, with 18.9% requiring operative intervention. No in-hospital mortality was observed. Changes in hemoglobin and hematocrit levels were not significantly associated with injury grade or the need for surgery. However, transfusion requirements increased with injury severity, including erythrocyte suspension ($p=0.006$) and fresh frozen plasma ($p<0.001$). Follow-up imaging (n=25) demonstrated stable or improved findings in 96% of patients. Logistic regression analysis did not identify independent predictors of surgical intervention.

CONCLUSION: NOM of liver lacerations is safe and effective, with excellent outcomes and no mortality observed in this cohort. Although AAST injury grade alone did not predict the need for surgery, transfusion requirements correlated with injury severity, highlighting their value as practical indicators in clinical decision-making.

Keywords: American Association for the Surgery of Trauma (AAST) grade; Liver trauma; nonoperative management; transfusion.

INTRODUCTION

Traumatic liver injury remains a significant contributor to morbidity and mortality in patients with abdominal trauma and continues to present a common challenge in emergency surgical practice. Historically, operative management was considered the standard approach; however, over the past two decades, nonoperative management (NOM) has emerged as the preferred strategy for hemodynamically stable patients, including those with high-grade injuries. This shift has been driven by advances in imaging, critical care, and interventional radiology.[1]

Success rates for NOM in blunt hepatic trauma now exceed

Cite this article as: Değirmencioğlu G, Kütük D, Çanakçı MH, Yıldırım M, Kurt MH. Safety and effectiveness of nonoperative management in liver lacerations: a retrospective cohort study. Ulus Travma Acil Cerrahi Derg 2026;32:574-581.

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Ulus Travma Acil Cerrahi Derg 2026;32(5):574-581 DOI: 10.14744/tjtes.2026.73965
Submitted: 13.01.2026 Revised: 19.01.2026 Accepted: 19.02.2026 Published: 05.05.2026

90% in many large series, with corresponding reductions in morbidity and mortality as patient selection and institutional protocols have evolved.[2] However, NOM failure, requiring delayed surgical or interventional procedures, remains clinically important, and predictors of such outcomes are not yet well established.

The American Association for the Surgery of Trauma (AAST) liver injury scale is widely used for grading injury severity and guiding management decisions. However, previous studies have reported inconsistent associations between AAST grade and clinical outcomes, including transfusion requirements, radiologic progression, and the need for surgical intervention.[3] Furthermore, only a limited number of studies have evaluated radiologic grading alongside serial imaging changes and laboratory parameters, such as transfusion requirements, within an integrated framework.

In this context, we conducted a retrospective analysis of patients with liver lacerations treated at a tertiary surgical center. The aim of this study was to evaluate the relationship between AAST grade, laboratory parameters, transfusion requirements, imaging findings, and clinical outcomes. Specifically, we sought to identify potential predictors of NOM failure or the need for surgical intervention, thereby contributing to more nuanced management strategies, particularly in settings with variable access to advanced imaging or interventional radiology.

MATERIALS AND METHODS

Study Design and Setting

This study was designed as a retrospective observational cohort study and conducted at a tertiary care surgical center. All patients diagnosed with liver lacerations and managed between October 2024 and May 2025 were evaluated. This study was approved by the Local Ethics Committee of Ankara Etlik City Hospital Ethics Committee (Date: 02/09/2025, Decision No: AEŞH-BADEK2-2025-365) and was carried out in accordance with the principles of the Declaration of Helsinki.

Study Population

A total of 53 consecutive patients with radiologically or intraoperatively confirmed liver lacerations were included. Patients with incomplete medical records, missing laboratory or imaging data, or concomitant injuries that precluded reliable assessment of liver trauma severity were excluded.

Data Collection

Data were obtained from electronic medical records and operative reports. Baseline demographic and clinical characteristics included age, sex, mechanism of injury, and vital signs on admission (systolic and diastolic blood pressure, heart rate), as well as findings from abdominal examination. All data were cross-verified using electronic medical records, operative notes, and radiology reports to ensure completeness and accuracy.

Injury severity was assessed using the AAST liver injury scale at presentation and, when available, reassessed on follow-up imaging. Laboratory parameters included hemoglobin, hematocrit, and prothrombin time/international normalized ratio (PT/INR), measured at both admission and discharge. The decline in hemoglobin and hematocrit during hospitalization was calculated as the difference between admission and discharge values. Blood product utilization was recorded as the total number of erythrocyte suspension and fresh frozen plasma (FFP) units administered.

Imaging utilization was evaluated based on the number and modality of studies performed, including ultrasonography, computed tomography, or both. Progression in AAST grade was assessed in patients who underwent at least one follow-up imaging study.

Clinical outcomes included length of hospital stay, occurrence of complications, requirement for surgical intervention, and in-hospital mortality.

Statistical Analysis

Continuous variables are presented as mean ± standard deviation (SD) with ranges, while categorical variables are expressed as counts and percentages. Comparisons across AAST grades were performed using one-way analysis of variance (ANOVA) or the Kruskal–Wallis test for continuous variables, and the chi-square test or Fisher's exact test for categorical variables, as appropriate. Logistic regression analysis was used to identify factors associated with the need for surgical intervention, with results reported as odds ratios (ORs) and 95% confidence intervals (CIs). A p-value <0.05 was considered statistically significant.

All statistical analyses were conducted using IBM SPSS Statistics, version 27 (IBM Corp., Armonk, NY, USA).

RESULTS

A total of 53 patients with liver lacerations were included in the study. The mean age was 41.4±16.5 years (range: 20–92 years). Most patients were male (67.9%), while females accounted for 32.1% of the cohort (Fig. 1). Demographic characteristics are summarized in Table 1.

Motor vehicle accidents were the most common mechanism of injury, accounting for 56.6% of cases. Among these, in-vehicle accidents were more frequent (37.7%) than incidents involving pedestrians or individuals outside the vehicle (18.9%). Falls and stab wounds each accounted for 17.0% of cases, while firearm injuries (5.7%) and physical assaults (3.8%) were less common (Table 1).

On initial assessment, the mean systolic blood pressure was 111.3±9.7 mmHg and the mean diastolic blood pressure was 72.5±6.3 mmHg, indicating relative hemodynamic stability in most patients. The mean heart rate was 86.9±7.8 beats per minute. Abdominal tenderness was present in 30 patients

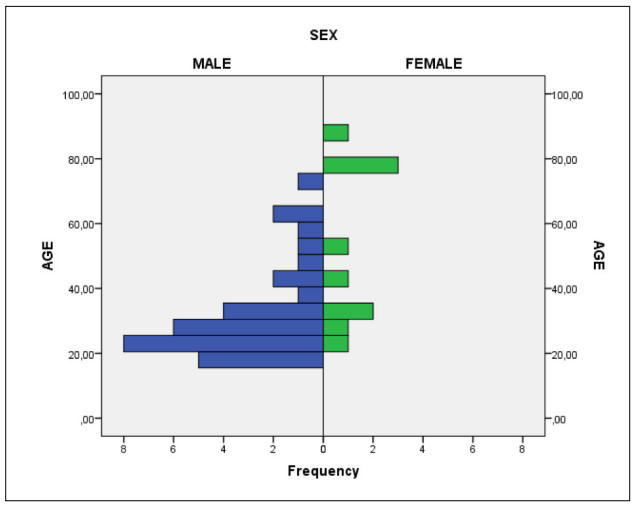

Figure 1. Population pyramid of the study cohort.

(56.6%), while 23 patients (43.4%) had no tenderness on examination.

Injury severity at presentation was distributed across the AAST grades I–IV. The most common grades were II (34.0%) and I (30.2%), followed by grade III (28.3%) and grade IV (7.5%). Injury grading at admission and follow-up according to the AAST classification is summarized in Table 2.

Among the 25 patients who underwent follow-up imaging, most demonstrated improvement. Eighteen patients (72.0%) were classified as grade I, six patients (24.0%) remained grade III, and one patient (4.0%) was classified as grade IV. Overall, 96.0% of patients showed stable or improved AAST grades, while only one patient (4.0%) experienced progression of injury severity on follow-up imaging (Table 2).

Laboratory analysis at admission showed a mean hemoglobin level of 13.9±2.3 g/dL (range: 8–18), which decreased to 12.1±2.5 g/dL (range: 8–17) at discharge. The mean decline in hemoglobin during hospitalization was 1.8±1.5 g/dL, ranging from a decrease of 3 g/dL to an increase of 6 g/dL. Similarly, hematocrit decreased from a mean of 41.9±6.6% at admission to 36.2±7.9% at discharge, with a mean reduction of 5.7±6.6% (range: −6 to 36).

Coagulation parameters were generally within normal limits, with a mean prothrombin time (PT/INR) of 10.3±3.1 seconds (range: 8–30). The mean erythrocyte suspension requirement was 0.41±0.88 units (maximum: 4 units), while fresh frozen plasma (FFP) use averaged 0.29±0.97 units (maximum: 6 units).

Patients underwent a mean of 1.86±1.34 imaging studies during hospitalization (range: 0–5). Ultrasonography was the most frequently used modality, performed in 40 patients

Table 1. Baseline demographic and clinical characteristics of patients with liver lacerations (n=53)

Variable	Overall (n=53)
Age, years	41.4±16.5 (20–92)
Sex, n (%)	
Male	36 (67.9%)
Female	17 (32.1%)
Mechanism of injury, n (%)	
Motor vehicle accident (occupant)	20 (37.7%)
Motor vehicle accident (pedestrian)	10 (18.9%)
Fall	9 (17.0%)
Stab wound	9 (17.0%)
Firearm injury	3 (5.7%)
Assault	2 (3.8%)
Systolic BP (mmHg)	111.3±9.7 (90–140)
Diastolic BP (mmHg)	72.5±6.3 (50–85)
Heart rate (bpm)	86.9±7.8 (70–105)
Abdominal tenderness, n (%)	
Yes	30 (56.6%)
No	23 (43.4%)

Values are presented as mean ± standard deviation (range) or number (percentage), as appropriate.

Table 2. Injury severity and laboratory findings of patients with liver lacerations (n=53)

Variable	Overall (n=53)
AAST grade at presentation, n (%)	
I	16 (30.2%)
II	18 (34.0%)
III	15 (28.3%)
IV	4 (7.5%)
AAST grade at follow-up (n=25)	
I	18 (72.0%)
III	6 (24.0%)
IV	1 (4.0%)
Initial hemoglobin (g/dL)	13.9±2.3 (8–18)
Discharge hemoglobin (g/dL)	12.1±2.5 (8–17)
Decrease in hemoglobin (g/dL)	1.8±1.5 (−3 to 6)
Initial hematocrit (%)	41.9±6.6 (24–53)
Discharge hematocrit (%)	36.2±7.9 (10–50)
Decrease in hematocrit (%)	5.7±6.6 (−6 to 36)
PT/INR (sec)	10.3±3.1 (8–30)
Erythrocyte suspension transfusion, mean units (range)	0.41±0.88 (0-4)
FFP transfusion, mean units (range)	0.29±0.97 (0-6)

Values are presented as mean ± standard deviation (range) or number (percentage), as appropriate. AAST: American Association for the Surgery of Trauma; n: Number of patients; g/dL: Grams per deciliter; PT/INR: Prothrombin Time / International Normalized Ratio; FFP: Fresh Frozen Plasma; sec: Seconds.

Table 3. Imaging utilization and American Association for the Surgery of Trauma (AAST) grade progression

Variable	Overall (n=53)
Number of imaging studies, mean±SD (range)	1.86±1.34 (0-5)
Imaging modality, n (%)	
Ultrasonography	40 (75.5%)
CT	2 (3.8%)
Both US and CT	11 (20.8%)
AAST grade at presentation, n (%)	
I	16 (30.2%)
II	18 (34.0%)
III	15 (28.3%)
IV	4 (7.5%)
AAST grade at follow-up (n=25)	
I	18 (72.0%)
III	6 (24.0%)
IV	1 (4.0%)
AAST progression, n (%)	
Stable or improved	24 (96.0%)
Worsened	1 (4.0%)

Values are presented as mean ± standard deviation (range) or number (percentage), as appropriate. AAST: American Association for the Surgery of Trauma; CT: Computed Tomography; n: Number of patients; SD: Standard Deviation; US: Ultrasonography.

Table 4. Clinical outcomes

Variable	Overall (n=53)
Complications, n (%)	
Yes	1 (1.9%)
No	52 (98.1%)
Surgical intervention, n (%)	
Yes	10 (18.9%)
No	43 (81.1%)
Length of hospital stay, days	5.4±4.0 (1–23)
In-hospital mortality, n (%)	0 (0%)

Values are presented as mean ± standard deviation (range) or number (percentage), as appropriate.

(75.5%), whereas computed tomography (CT) alone was used in two patients (3.8%). A combination of ultrasonography and CT was utilized in 11 patients (20.8%). Imaging modalities used during hospitalization are summarized in Table 3.

Injury grading at presentation showed that 30.2% of patients were classified as AAST grade I, 34.0% as grade II, 28.3% as grade III, and 7.5% as grade IV. Follow-up imaging was available for 25 patients, of whom 18 (72.0%) were classified as grade I, six (24.0%) as grade III, and one (4.0%) as grade IV.

Table 5. Association between American Association for the Surgery of Trauma (AAST) grade and surgical management

AAST Grade	No surgery, n (%)	Surgery, n (%)	Total, n (%)
I (n=16)	12 (75.0%)	4 (25.0%)	16 (30.2%)
II (n=18)	15 (83.3%)	3 (16.7%)	18 (34.0%)
III (n=15)	13 (86.7%)	2 (13.3%)	15 (28.3%)
IV (n=4)	3 (75.0%)	1 (25.0%)	4 (7.5%)
Total (n=53)	43 (81.1%)	10 (18.9%)	53 (100%)

Values are presented as number (percentage). AAST: American Association for the Surgery of Trauma.

Assessment of injury progression demonstrated that 96.0% of patients had stable or improved AAST grades on follow-up imaging, whereas only one patient (4.0%) exhibited worsening of injury severity.

Clinical outcomes were favorable overall. Complications occurred in only one patient (1.9%), while 52 patients (98.1%) had an uncomplicated hospital course.

Surgical intervention was required in 10 patients (18.9%), whereas 43 patients (81.1%) were managed nonoperatively. The mean length of hospital stay was 5.4±4.0 days (range: 1–23 days) (Table 4).

No in-hospital mortality was observed in the study cohort.

Comparisons between operative and nonoperative management according to AAST injury grade are presented in Table 5. Overall, 43 patients (81.1%) were treated nonoperatively, while 10 patients (18.9%) required surgery. In grade I injuries, 12 of 16 patients (75.0%) were managed nonoperatively and four (25.0%) underwent surgery. In grade II injuries, 15 of 18 patients (83.3%) were treated without surgery, whereas three patients (16.7%) required operative management. Among patients with grade III injuries, 13 of 15 patients (86.7%) were managed nonoperatively and two (13.3%) underwent surgery. Of the four patients with grade IV injuries, three (75.0%) were treated nonoperatively and one (25.0%) required surgical intervention (Table 5).

In contrast, transfusion requirements were significantly associated with injury severity. Erythrocyte suspension use increased progressively with higher AAST grades, reaching the highest levels in grade IV injuries ($p=0.006$). Similarly, fresh frozen plasma requirements were lowest in grade I and increased across higher grades, with the greatest use observed in grade IV patients ($p<0.001$). Transfusion requirements according to AAST grade are summarized in Table 6.

Table 6. Clinical implications of American Association for the Surgery of Trauma (AAST) injury grade in liver lacerations

Outcome	AAST I (n=16)	AAST II (n=18)	AAST III (n=15)	AAST IV (n=4)	p-value
Decrease in hemoglobin (g/dL)	–	–	–	–	0.854
Decrease in hematocrit (%)	–	–	–	–	0.924
Erythrocyte suspension transfusion (units)	↑ lowest	↑ low	↑ low	↑↑ highest	0.006
FFP transfusion (units)	↑ lowest	↑ low	↑ moderate	↑↑ highest	<0.001
Number of imaging studies	–	–	–	–	0.312
Length of hospital stay (days)	–	–	–	–	0.416
Surgical intervention (%)	–	–	–	–	0.850

Comparisons were performed across AAST grades I–IV. Values are expressed as means or proportions, as appropriate. AAST: American Association for the Surgery of Trauma; FFP: Fresh Frozen Plasma; g/dL: Grams per deciliter; n: Number of patients.

Table 7. Factors associated with surgical management in liver lacerations (n=51)

Variable	B	SE	Wald	p-value	OR (Exp[B])	95% CI for OR
Age (years)	–0.047	0.039	1.44	0.229	0.95	0.88–1.03
Initial hemoglobin (g/dL)	0.470	1.040	0.20	0.651	1.60	0.21–12.30
Initial hematocrit (%)	–0.285	0.362	0.62	0.431	0.75	0.37–1.53
PT (sec)	0.029	0.201	0.02	0.886	1.03	0.69–1.53
ES suspension (units)	–1.081	0.869	1.55	0.213	0.34	0.06–1.86
FFP (units)	–0.697	1.158	0.36	0.547	0.50	0.05–4.82
Systolic BP (mmHg)	–0.024	0.061	0.16	0.690	0.98	0.87–1.10
Diastolic BP (mmHg)	–0.226	0.144	2.47	0.116	0.80	0.60–1.06
Heart rate (bpm)	0.143	0.089	2.58	0.108	1.15	0.97–1.37
Abdominal tenderness	–0.891	1.285	0.48	0.488	0.41	0.03–5.09
Constant	12.665	11.852	1.14	0.285	3.2×10^5	–

Logistic regression analysis of factors associated with surgical management in patients with liver lacerations (n=51). OR: Odds ratio; CI: Confidence interval; SE: Standard error.

These findings indicate that, although most clinical parameters were not significantly influenced by AAST grade, transfusion requirements (both erythrocyte suspension and FFP) were significantly associated with increasing injury severity.

Logistic regression analysis was performed to identify factors associated with the need for surgical management in patients with liver lacerations (Table 7). None of the evaluated demographic, laboratory, or clinical variables emerged as statistically significant predictors of surgical intervention. Among the variables analyzed, transfusion requirement was the only parameter significantly correlated with higher AAST grades.

Specifically, age, initial hemoglobin, hematocrit, prothrombin time, erythrocyte suspension use, FFP use, systolic and diastolic blood pressure, heart rate, and the presence of abdominal tenderness all showed p-values >0.05. The corresponding odds ratios demonstrated wide confidence intervals, indicating a lack of consistent associations (Table 7).

Overall, no independent predictor of surgical requirement was identified in the multivariable model.

DISCUSSION

In this retrospective cohort of 53 patients with radiologically or intraoperatively confirmed liver lacerations, clinical outcomes were favorable. The majority of patients (81.1%) were managed nonoperatively, while 18.9% required surgical intervention, and no in-hospital mortality was observed. These findings are consistent with the current management paradigm, which increasingly favors nonoperative strategies for both blunt and selected penetrating liver injuries. Recent multicenter studies and contemporary trauma guidelines re-

port NOM success rates exceeding 90% in stable patients, reinforcing its role as the standard of care in modern trauma practice.[4-6]

Nonoperative Management and Clinical Outcomes

The NOM rate observed in our study (81.1%) is consistent with international evidence supporting NOM as the primary approach for blunt hepatic injuries in hemodynamically stable patients. The World Society of Emergency Surgery (WSES) 2020 guidelines report success rates above 90% in such cases.[5] While the Eastern Association for the Surgery of Trauma (EAST) guidelines similarly recommend NOM as the standard of care, reserving operative intervention for patients with persistent instability or evidence of ongoing hemorrhage.[6] The absence of in hospital mortality in our cohort is notable and aligns with recent reports from tertiary care centers, where structured monitoring, serial imaging, and comprehensive supportive care in nonoperative liver injury management have been associated with improved survival outcomes.[5]

AAST Grading and Surgical Requirement

We did not observe a statistically significant association between AAST grade and the need for surgical intervention, although patients with grade IV injuries demonstrated a trend toward higher transfusion requirements. This finding is consistent with previous evidence suggesting that anatomical injury grading alone may not reliably predict the need for operative management. While earlier studies reported correlations between higher AAST grades and increased rates of surgery or complications.[7] More recent literature emphasizes the importance of physiological parameters—such as hemodynamic instability, transfusion burden, and contrast extravasation—as more robust predictors of clinical course.[8,9] Our results support this perspective. Although changes in hemoglobin and hematocrit were not significantly associated with AAST grade, both erythrocyte suspension and FFP requirements increased significantly with injury severity, underscoring the clinical utility of transfusion patterns in injury stratification.

Laboratory Parameters and Transfusion

In our cohort, hemoglobin and hematocrit levels decreased modestly across all injury grades and were not associated with the need for surgical intervention. This finding contrasts with earlier literature, in which declining hemoglobin levels or ongoing transfusion requirements were considered early markers of nonoperative management failure.[10,11] However, our findings support a growing body of evidence that dynamic parameters—particularly transfusion volume—may better reflect clinical severity than baseline laboratory values. Notably, both erythrocyte suspension and fresh frozen plasma requirements increased significantly with AAST grade ($p=0.006$ and $p<0.001$, respectively), consistent with studies identifying transfusion needs as key indicators of bleeding severity and risk of clinical deterioration.[12] Recent series on solid organ trauma have similarly emphasized the prognostic value of blood product utilization in guiding management strategies, particularly in resource-limited or nonoperative settings.[13]

Imaging Utilization and AAST Progression

In our cohort, ultrasonography was the most frequently utilized imaging modality, while only 24% of patients underwent follow-up CT. This distribution likely reflects both institutional practice patterns and an emphasis on resource stewardship. Although contrast-enhanced CT is widely regarded as the preferred modality for evaluating hepatic injuries, particularly in higher AAST grades.[14] Our findings suggest that careful clinical monitoring combined with selective imaging is sufficient in most cases. Notably, 96% of patients demonstrated stable or improved injury grade on follow-up, with only one case of radiological progression. These results support existing literature indicating that low- to moderate-grade liver injuries typically resolve without complication under NOM, and that routine serial imaging may be unnecessary in the absence of clinical signs of deterioration.[15]

Predictors of Surgery

In our analysis, logistic regression did not identify any demographic, clinical, or laboratory variable as an independent predictor of surgical intervention. This likely reflects the complex and multifactorial nature of decision-making in liver trauma, where real-time dynamic clinical parameters often outweigh baseline measurements. In a prospective study of severe hepatic trauma, Leppaniemi et al.[16] identified admission shock as the only independent predictor of early laparotomy, despite evaluating multiple anatomical and physiological variables. Similarly, Rouy et al.,[8] in a multicenter study of 494 patients, demonstrated that high-grade injuries (AAST IV–V), hemoperitoneum, and contrast extravasation significantly increased the risk of NOM failure, particularly when present in combination. These findings are further reinforced by the WSES 2020 guidelines, which advocate for integrating imaging markers, such as contrast blush, hemodynamic instability, and the need for adjunctive interventions, into operative decision-making pathways, rather than relying solely on anatomical grade.[9] Consistent with this contemporary evidence, our results suggest that surgical escalation is best guided by dynamic clinical judgment incorporating multiple parameters, rather than by isolated predictors.

In addition to the overall favorable outcomes observed in this cohort, a focused subgroup analysis of patients with high-grade liver injuries (AAST Grade III–IV) further supports the efficacy of nonoperative management. Despite the increased injury severity, 84.2% of these patients were successfully managed without surgery, and only three required operative intervention. Furthermore, no significant decrease in hemoglobin or hematocrit levels was observed in this group; however, transfusion requirements, particularly for erythrocyte suspension and fresh frozen plasma, were higher and reached statistical significance ($p=0.006$ and $p<0.001$, respectively). Importantly, among high-grade patients who underwent

follow-up imaging, only one case demonstrated radiological progression. These findings are consistent with recent studies suggesting that hemodynamically stable patients with high-grade liver injuries may benefit from conservative management, provided that close monitoring, early recognition of clinical deterioration, and adequate institutional resources are available.[10] This study contributes to the existing literature by reporting transfusion-stratified NOM outcomes specifically in high-grade liver injury cases, supported by follow-up imaging in a substantial proportion of patients.

Study Limitations

This study contributes to the existing trauma literature by providing detailed insight into transfusion patterns, imaging follow-up, and clinical outcomes in a real-world tertiary care setting. The absence of in-hospital mortality and the exceptionally low complication rate underscore the safety and efficacy of a protocol-driven nonoperative approach to liver trauma. However, several limitations should be acknowledged. The retrospective, single-center design limits external validity, and the relatively small sample size may have reduced the statistical power to identify independent predictors of operative intervention. Although the sample size was relatively small (n=53), it reflects consecutive real-world experience at a tertiary trauma center and includes a substantial proportion of high-grade liver injuries, enabling meaningful subgroup analysis. Additionally, interventional radiology (IR) was not systematically utilized in our cohort, which may have influenced management decisions, particularly in patients with high-grade injuries or radiologic evidence of active bleeding. Despite these limitations, our findings provide valuable clinical context supporting selective imaging and transfusion-guided NOM strategies.

CONCLUSION

In this retrospective study of 53 patients with liver lacerations, nonoperative management was demonstrated to be safe and effective across all injury grades, including high-grade (AAST III–IV) injuries. The absence of in-hospital mortality, low complication rates, and high success rates of conservative treatment reinforce the role of protocol-based NOM in hemodynamically stable patients. These findings offer practical guidance, particularly for centers with limited access to interventional radiology, and underscore the importance of transfusion monitoring and the use of follow-up imaging in guiding management decisions.

Ethics Committee Approval: This study was approved by the Local Ethics Committee of Ankara Etlik City Hospital Ethics Committee (Date: 02.09.2025, Decision No: AEŞH-BADEK2-2025-365).

Peer-review: Externally peer-reviewed.

Informed Consent: The requirement for informed consent was waived by the ethics committee due to the retrospective nature of the study and the use of anonymized clinical data.

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

Conflict of Interest: None declared.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Karaciğer laserasyonlarında nonoperatif tedavinin güvenliği ve etkinliği: Retrospektif kohort çalışması

AMAÇ: Karaciğer travması, abdominal yaralanmalarda morbiditenin önde gelen nedenlerinden biri olmaya devam etmektedir. Hemodinamik olarak stabil hastalarda nonoperatif tedavi (NOM) yaygın olarak kabul görse de American Association for the Surgery of Trauma (AAST) yaralanma derecesi, laboratuvar parametreleri, transfüzyon gereksinimleri ve cerrahi ihtiyacı arasındaki ilişki hâlâ tartışmalıdır.

GEREÇ VE YÖNTEM: Bu retrospektif gözlemsel çalışmaya, üçüncü basamak bir cerrahi merkezde Ekim 2024-Mayıs 2025 tarihleri arasında yönetilen, radyolojik veya intraoperatif olarak doğrulanmış karaciğer laserasyonu olan 53 hasta dâhil edildi. Demografik veriler, vital bulgular, AAST derecesi, laboratuvar değerleri, transfüzyon gereksinimleri, görüntüleme kullanımı ve klinik sonuçlar kaydedildi. İstatistiksel analizlerde ANOVA, ki-kare/Fisher testleri ve lojistik regresyon kullanıldı.

BULGULAR: Hastaların ortalama yaşı 41.4 yıl olup, %67.9'u erkekti. Yaralanma mekanizması çoğunlukla trafik kazalarıydı (%56.6). Başvuru sırasında hastaların %64.2'sinde AAST derece I-II, %7.5'inde derece IV yaralanma saptandı. NOM başarısı %81.1 iken, %18.9 hastada cerrahi gereksinimi oldu. Hastane içi mortalite gözlenmedi. Hemoglobin ve hematokrit düşüşü, yaralanma derecesi veya cerrahi gereksinimi ile anlamlı ilişki göstermedi. Buna karşın, transfüzyon gereksinimleri şiddetle birlikte arttı: eritrosit süspansiyonu ($p=0.006$) ve taze donmuş plazma ($p<0.001$). Takip görüntülemelerinde (n=25) olguların %96'sında yaralanma derecesinin stabil veya iyileşmiş olduğu görüldü. Lojistik regresyon analizinde cerrahi için bağımsız bir prodüktör belirlenmedi.

SONUÇ: Karaciğer laserasyonlarında NOM, güvenli ve etkili bir tedavi seçeneğidir; bu kohortta mükemmel sonuçlar ve mortalite olmamasıyla dikkat çekmektedir. AAST derecesi tek başına cerrahi gereksinimini öngörmemiş olsa da, transfüzyon gereksinimleri yaralanma şiddeti ile korelasyon göstermiştir; bu da klinik karar verme sürecinde pratik göstergeler olarak değerlerini ortaya koymaktadır.

Anahtar sözcükler: de American Association for the Surgery of Trauma (AAST) derecesi, karaciğer travması, non-operative tedavi, transfüzyon

Ulus Travma Acil Cerrahi Derg 2026;32(5):574-581 DOI: 10.14744/tjtes.2026.73965

ORIGINAL ARTICLE

Short- and long-term outcomes of surgical techniques in gastrointestinal bezoar management

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ABSTRACT

BACKGROUND: Bezoars are masses formed by the accumulation of indigestible food or foreign materials within the gastrointestinal (GI) tract. This study aimed to compare the outcomes of fragmentation and milking (FM) versus enterotomy in patients with bezoar-induced GI obstruction and to evaluate these findings in the context of the literature.

METHODS: This retrospective study analyzed data from 44 patients who underwent surgery for mechanical intestinal obstruction between 2009 and 2021 at our institution, in whom bezoars were identified as the etiological factor during the perioperative period. Demographic characteristics, comorbidities, history of previous abdominal surgery, localization of the bezoar, postoperative complications, and follow-up outcomes were evaluated. Patients with bezoars were divided into two groups: those who underwent FM and those who underwent enterotomy. Categorical variables were analyzed using the chi-square tests and are presented as frequencies and percentages. A p value <0.05 was considered statistically significant.

RESULTS: Of the patients, 25 (54.3%) were male, and the median age was 65 years (range: 56–73). Thirty patients (65.2%) underwent FM, and 16 patients (34.8%) underwent enterotomy. Severe complications (Clavien–Dindo grade IIIb–V) were observed in the enterotomy group, whereas no such complications occurred in the FM group (p=0.034). Additionally, postoperative bridal intestinal obstruction developed in six patients (37.5%) in the enterotomy group after discharge (p=0.025).

CONCLUSION: Fragmentation and milking appears to be the preferred first-line surgical approach in patients undergoing emergency surgery for bezoar-induced gastrointestinal obstruction, as it is less invasive and associated with reduced postoperative morbidity. Furthermore, FM may decrease the risk of postoperative obstruction compared with the enterotomy technique.

Keywords: Bezoar; intestinal obstruction; surgery.

INTRODUCTION

Bezoars are masses formed by the accumulation of indigestible food or foreign bodies within the gastrointestinal (GI) tract. In 1854, Richard Quain, an Irish anatomist and surgeon at the University of London, described a mass found in the stomach during an autopsy and termed it a "bezoar."[1]

Bezoars may develop in any segment of the GI tract. They are identified in fewer than 0.5% of individuals undergoing esophagogastroduodenoscopy and account for 0.4-4.8% of cases presenting with mechanical intestinal obstruction.[2] The stomach is the most commonly affected organ. Diagnosis is typically established using endoscopic or radiological methods, and treatment approaches vary depending on clinical presentation.[2,3]

Cite this article as: Kocaaslan H, Usta S, Ceylan C, Gül MO, Kocaaslan Z, Sumer Fatih. Short- and long-term outcomes of surgical techniques in gastrointestinal bezoar management. Ulus Travma Acil Cerrahi Derg 2026;32:582-587.

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Ulus Travma Acil Cerrahi Derg 2026;32(5):582-587 DOI: 10.14744/tjtes.2026.29130
Submitted: 28.10.2025 Revised: 027.03.2026 Accepted: 30.03.2026 Published: 05.05.2026

Depending on their location within the GI tract, bezoars may present with uncommon clinical manifestations such as ulceration, bleeding, or gastric outlet obstruction; however, they most frequently cause obstruction, presenting as an acute abdominal syndrome. In patients with clinical signs of mechanical intestinal obstruction, prompt surgical planning is required following advanced imaging studies.[4,5]

Although bezoar-induced obstruction can rarely be managed conservatively with proteolytic enzymes, most patients require emergency surgical intervention.[2] Management depends on the location and mobility of the bezoar, with either endoscopic or surgical approaches employed. When feasible, endoscopic methods are preferred as first-line treatment. In surgical management, fragmentation and milking (FM) should initially be attempted. If the bezoar is impacted, immobile, or cannot be fragmented, it should be removed via enterotomy or gastrotomy. Partial bowel resection is indicated in cases where bowel circulation or integrity is compromised.[6,7]

In this study, we aimed to compare the outcomes of FM and enterotomy techniques in patients with bezoar-induced GI obstruction and to evaluate these results in the context of the literature.

MATERIALS AND METHODS

Patient Selection

Data from 44 patients who underwent surgery for mechanical gastrointestinal obstruction at our clinic between June 2009 and January 2021, and in whom a bezoar was identified as the perioperative cause, were retrospectively analyzed. Demographic characteristics (age, sex), comorbidities (diabetes mellitus [DM], hypertension [HT], coronary artery disease [CAD], chronic obstructive pulmonary disease [COPD]), history of previous abdominal surgery, bezoar location within the GI tract, postoperative complications (classified according to the Clavien–Dindo system), and follow-up duration were evaluated,[8] Patients with bezoars were divided into two groups based on the surgical technique used: FM and enterotomy. The mean follow-up period was 70.96±7.79 months. Episodes of mechanical bowel obstruction during postoperative follow-up were also reviewed.

Patient Management

In patients with bezoars identified on preoperative computed tomography of the GI tract, oral intake was discontinued and intravenous hydration was initiated. Decompression of proximal segments was achieved using a nasogastric tube. Endoscopic intervention with fragmentation was attempted in patients without signs of acute abdomen when the bezoar was located proximal to the second part of the duodenum or within colonic segments. Laparotomy was performed in cases of failed endoscopic treatment, development of complications, or when the bezoar was located in the ileum or jejunum.

During surgical exploration, bowel segments showing signs of necrosis were resected along with bezoar removal. In the absence of necrosis, bezoars were managed using either FM or enterotomy. Patients were categorized as follows: (1) bezoars suitable for fragmentation were fragmented and milked distally; (2) bezoars that could not be fragmented or were impacted underwent enterotomy.

Statistical Analysis

Normality of the data was assessed using the Shapiro–Wilk test. Nonparametric tests, specifically the Mann–Whitney U test, were applied where appropriate. Descriptive statistics were reported as medians and interquartile ranges (IQR). Categorical variables were analyzed using the chi-square test and are presented as frequencies and percentages. Statistical significance was set at $p<0.05$.

Multivariate logistic regression analysis was performed to identify independent predictors of enterotomy and postoperative complications, including postoperative mechanical bowel obstruction (MBO) and Clavien–Dindo (CD) grade. Odds ratios (OR) and 95% confidence intervals (CI) were calculated for each predictor. A p value <0.05 was considered statistically significant.

A post hoc power analysis was conducted for the primary outcome (postoperative MBO). Based on observed MBO rates (10% in the fragmentation group vs. 31% in the enterotomy group), sample sizes (n=30 and n=16), and a two-sided alpha of 0.05, the statistical power was estimated at approximately 65-70%, indicating moderate power to detect significant difference. Larger sample sizes would be required for more robust statistical power.

This study was approved by the Inonu University Health Sciences Non-Interventional Clinical Research Ethics Committee (Date: 26-07-2022, Decision no: 2022/3417) and was conducted in accordance with the principles of the Declaration of Helsinki.

RESULTS

Of the patients included in the study, 25 (54.3%) were male, and the median age was 65 (56–73) years. Twenty-five patients (56.8%) were in the geriatric age group (>65 years). The most common comorbidities were HT (25%) and CAD (15.9%), followed by DM (9.1%) and COPD (9.1%). The prevalence of DM in the geriatric subgroup was 12% (Table 1). A history of previous abdominal surgery was present in 30

Table 1. Prevalence of diabetes mellitus by age group

	Age <65 years	Age >65 years
	n (%)	n (%)
DM	1 (5.3%)	3 (12%)

DM: Diabetes mellitus.

Table 1. Demographic characteristics of patients

Variables	Median (Q1–Q3)	n (%)
Age, years	65 (56-73)	
Age >65 years		25 (56.8%)
Sex		
Male		25 (56.8%)
Female		19 (43.2%)
DM		4 (9.1%)
CAD		7 (15.9%)
HT		11 (25%)
COPD		4 (9.1%)
Previous gastric ulcer surgery		20 (45.5%)
Previous abdominal surgery		30 (68.2%)
Bezoar location		
Ileum		20 (45.5%)
Jejunum		23 (52.3%)
Stomach		1 (2.3%)
Surgical technique		
Fragmentation and milking		30 (68.2%)
Enterotomy/gastrotomy		14 (31.8%)
CD classification		
Grade I		40 (90.9%)
Grade II		2 (4.5%)
Grade IIIb		1 (2.3%)
Grade V		1 (2.3%)
Length of stay, days	7 (5-10)	
Follow-up, months	56 (33-105.5)	
Bridal MBO		8 (18.2%)

CD: Clavien–Dindo classification; MBO: Mechanical bowel obstruction; DM: Diabetes mellitus; HT: Hypertension; COPD: chronic obstructive pulmonary disease.

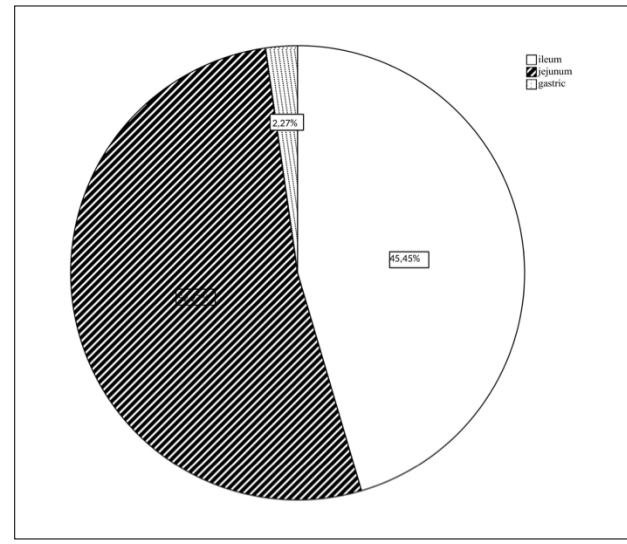

Figure 1. Distribution of bezoar in patients with mechanical intestinal obstruction.

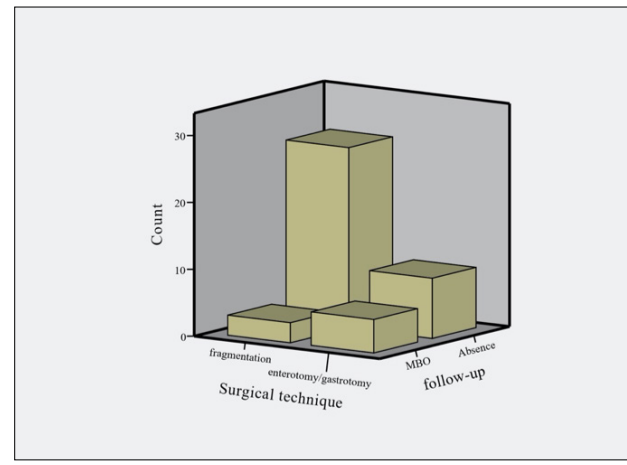

Figure 2. Comparison of late postoperative complications between fragmentation and enterotomy groups.

patients (68.2%), most commonly for duodenal ulcer. Bezoars were most frequently located in the jejunum (52.3%) and ileum (45.5%), while one patient (2.3%) had a gastric bezoar (Table 2, Fig. 1).

Patients were divided into two groups according to surgical technique: FM (68.2%) and enterotomy (31.8%). During postoperative follow-up, one patient died, and one patient required reoperation (CD grade 3b). The median length of hospital stay was 7 (5-10) days. During post-discharge follow-up, adhesive small bowel obstruction developed in eight patients (18.2%) (Table 2).

Reviewing the medical histories of our patients, we found that 30 (68.2%) had previously undergone abdominal surgery, of whom 20 (45.5%) had a history of duodenal ulcer surgery (Billroth I or II).

Comparative analysis between groups showed no significant differences in age, sex, comorbidities, bezoar location, history of previous abdominal surgery, or length of hospital stay. However, severe (CD grade 3b–5) morbidity and mortality occurred only in the enterotomy group and not in the FM group (p=0.034). Additionally, post-discharge adhesive small bowel obstruction was more frequent in patients who underwent enterotomy (five patients, 35.7%; p=0.039) (Table 3, Fig. 2).

In multivariate logistic regression analysis, postoperative mechanical bowel obstruction (1=no, 2=yes) was identified as an independent predictor associated with enterotomy. Patients undergoing enterotomy had a significantly increased likelihood

Table 3. Univariate analysis of surgical techniques

Variables	FM		Enterotomy/Gastrotomy		p-value
	Median (Q1–Q3)	n (%)	Median (Q1¬–Q3)	n (%)	
Age, years	64 (56–73)		68 (57–76)		0.273
Age >65 years		15 (50%)		10 (71.4%)	0.181
Sex					
Male		17 (56.7%)		8 (57.1%)	0.976
Female		13 (43.3%)		6 (42.9%)	
DM		3 (10%)		1 (7.1%)	0.759
CAD		6 (20%)		1 (7.1%)	0.277
HT		7 (23.3%)		4 (28.6%)	0.709
COPD		2 (6.7%)		2 (14.3%)	0.413
Previous gastric ulcer surgery		16 (53.3%)		4 (28.6%)	0.124
Previous abdominal surgery		22 (73.3%)		8 (57.1%)	0.283
Bezoar location					
Ileum		13 (43.3%)		7 (50%)	0.275
Jejunum		17 (56.7%)		6 (42.9%)	
Stomach		0 (0%)		1 (7.1%)	
CD classification					
Mild		30 (100%)		12 (85.7%)	0.034*
Severe		0 (0%)		2 (14.3%)	
Length of stay, days	7 (4-10)		7 (6-10)		0.455
Bridal MBO		3 (10%)		5 (35.7%)	0.039*

CD: Clavien–Dindo classification; MBO: Mechanical bowel obstruction; DM: Diabetes mellitus; HT: Hypertension; COPD: chronic obstructive pulmonary disease.

Table 4. Logistic regression analysis comparing enterotomy and fragmentation

Estimate (β)	SE	Z	p	95% CI (β)	Odds ratio	95% CI (OR)
0.511	0.730	0.700	0.484	−0.921–1.942	1.667	0.398–6.992
Postoperative MBO (1=No, 2=Yes)						
−1.861	0.845	−2.203	0.028	−3.516–−0.206	0.156	0.029–0.814
Clavien–Dindo grade (1=Mild, 2=Severe)						
17.916	1696.734	0.011	0.992	−3307.622–3343.454	6.04×10^{7}	0.00–very large

MBO: Mechanical bowel obstruction; SE: Standard error; CI: Confidence interval. Odds ratio (OR) >1 indicates increased odds of undergoing enterotomy.

of developing MBO, with approximately 6.4-fold higher odds (β=−1.861, SE=0.845, Z=−2.203, p=0.028; OR=0.156, 95% CI: 0.029–0.814). In contrast, Clavien–Dindo grade (1=mild, 2=severe) was not significantly associated with enterotomy (β=17.916, SE=1696.734, Z=0.011, p=0.992), and the wide confidence intervals indicate statistical instability. These findings demonstrate that enterotomy is an independent risk factor for postoperative MBO in this cohort (Table 4).

DISCUSSION

Bezoars are reported to account for 4% of cases presenting to the emergency department with GI obstruction.[9] In patients requiring emergency abdominal surgery, the least invasive and least aggressive approach should be preferred whenever feasible. This is particularly important because bezoar-related bowel obstruction frequently occurs in frail geriatric populations. In the study by Davis et al.,[10] morbid-

ity (28% vs. 10%) and mortality (15.2% vs. 2.5%) were significantly higher in elderly patients compared with younger individuals following emergency surgery. Similarly, our study population predominantly consisted of elderly patients with multiple comorbidities, with 56.8% classified as geriatric. Accordingly, FM was primarily preferred as the initial surgical approach.

The risk of adhesive bowel obstruction increases following abdominal surgery.[9,10] In our study, long-term postoperative follow-up revealed a significantly higher rate of obstruction episodes in the enterotomy group compared with the FM group (p=0.039). This finding may be explained by impaired bowel motility at the enterotomy and suture site, as well as an increased tendency for adhesion formation in these areas. When the bezoar is firmly impacted or causing deformation of the bowel wall, FM should be considered as the first-line surgical option. However, although FM avoids anastomosis-related complications, it carries a potential risk of intraluminal hemorrhage due to the milking maneuver.[9]

Postoperative complications such as leakage at the repair or anastomosis site may occur in patients undergoing enterotomy or bowel resection. These complications can lead to abscess formation, peritonitis, or sepsis, as well as surgical site infections and prolong hospitalization. Furthermore, relaparotomy due to anastomotic leakage is associated with increased mortality.[11] In our study, severe complications were significantly more frequent in the enterotomy group (p=0.034). These findings further support the preferential use of FM in appropriately selected patients to minimize postoperative morbidity.

In adults without psychiatric disorders, bezoar formation is most commonly associated with prior gastric surgery, which disrupts normal pyloric function and impairs mechanical digestion. In our cohort, 30 patients (65%) had a history of abdominal surgery, including 20 patients (43%) who had undergone duodenal ulcer surgery (Billroth I or II procedures). Consistent with the literature[5] previous abdominal surgery, particularly peptic ulcer surgery, appears to be a major risk factor for bezoar-related obstruction. Therefore, in patients presenting with mechanical small bowel obstruction and a history of such procedures, bezoars should be considered in the differential diagnosis, and management should be planned accordingly.

In addition to prior surgery, other important factors in the etiology of bezoar formation include excessive consumption of high-fiber foods, inadequate mastication, and impaired gastric motility, particularly diabetic gastroparesis.[12,13] Diabetes, especially when associated with poor glycemic control, is a well-known cause of gastroparesis. The prevalence of gastroparesis has been reported as 5% in patients with type 1 diabetes and 1% in those with type 2 diabetics.[14] In our study, DM was present in 8.7% of patients. Since gastric motility disorders increase with age,[15] elderly individuals are at greater risk of bezoar formation. Thus, advancing age and the increasing prevalence of diabetes may contribute to a higher incidence of bezoars through the mechanism of gastroparesis. According to Laiteerapong et al.,[16] the prevalence of diabetes in individuals over 65 years of age is approximately 21%,whereas in our study it was 12%. Despite the lower prevalence in our cohort, gastroparesis-related bezoars should still be considered in the differential diagnosis of geriatric patients presenting with mechanical GI obstruction.

The lifetime risk of developing mechanical small bowel obstruction following abdominal surgery has been reported to be as high as 25%.[17] Particularly after open surgical procedures, the increased risk of adhesion formation means that patients may develop mechanical intestinal obstruction later in life. Our findings indicate that enterotomy is an independent risk factor for the development of postoperative mechanical bowel obstruction. Clinicians should therefore be aware that patients who undergo enterotomy for bezoar-related obstruction may be at increased risk of recurrent obstruction and may present again with similar symptoms in the future.

A review of the literature reveals a limited number of studies comparing surgical techniques in bezoar-induced gastrointestinal obstruction. Altıntoprak et al.[5] evaluated 121 patients by stratifying them into age groups (≥65 vs. <65 years), whereas Wang et al.[9] surgical and non-surgical management in 40 patients with bezoar-related small bowel obstruction. In contrast, in our study, patients who underwent surgery were grouped according to the surgical technique used, and outcomes were analyzed accordingly. We believe that our findings contribute to addressing this gap in the literature.

The retrospective design and the relatively small sample size of our study represent limitations, which may introduce bias and limit the generalizability of the findings. In our patient grouping, the use of enterotomy for impacted bezoars may have introduced bias in the assessment of postoperative complications and long-term readmission due to mechanical obstruction. Additionally, the relatively small sample size limits the strength of our findings. More reliable results could be obtained through prospective, multicentric studies with larger, randomized cohorts. Another limitation is the inability to classify bezoar types— particularly in cases managed with fragmentation and milking. Therefore, we were only able to identify which bezoar-related intestinal obstruction cases were suitable for the fragmentation technique.

CONCLUSION

In patients undergoing emergency surgery for GI obstruction caused by bezoars, fragmentation and distal milking appear to be less invasive approaches associated with reduced postoperative morbidity and should be considered as the first-line surgical option when feasible. Furthermore, our findings suggest that the fragmentation and milking technique may reduce the incidence of postoperative intestinal obstruction

compared with enterotomy.

In patients presenting with mechanical gastrointestinal obstruction, especially those with a history of conditions or prior surgeries that impair gastrointestinal motility, bezoars should be considered in the differential diagnosis.

Ethics Committee Approval: This study was approved by the Inonu University Health Sciences Non-Interventional Clinical Research Ethics Committee (Date: 26.07.2022, Decision No: 2022/3417).

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Gastrointestinal sistem bezorlarında cerrahi tekniklerin kısa ve uzun dönem sonuçları

AMAÇ: Bezolar, gastrointestinal (GI) sistemde sindirilemeyen gıda veya yabancı cisimlerin birikmesiyle oluşan yapılardır. Çalışmamızda, GI sistemde tıkanmaya neden olan bezoarı olan hastalara uygulanan fragmentasyon+sağma(FS) ve enterotomi cerrahi tekniklerinin sonuçlarını karşılaştırmayı ve sonuçları literatür eşliğinde değerlendirmeyi amaçladık.
GEREÇ VE YÖNTEM: Kliniğimizde 2009-2021 yılları arasında gastrointestinal sistem mekanik tıkanıklığı nedeniyle ameliyat edilen ve perioperatif etiyolojide bezoar tespit edilen 44 hastanın verilerini retrospektif olarak inceledik. Demografik veriler, ek hastalıklar (komorbiditeler), geçirilmiş karın ameliyatı öyküsü, gastrointestinal sistem yerleşim yeri, ameliyat sonrası komplikasyonlar ve takip süreleri analiz edildi. Bezoarlı hastalar, FS yapılanlar ve enterotomi yapılanlar olarak iki gruba ayrıldı. Kategorik değişkenler ki-kare testleri ile analiz edildi ve sonuçlar frekans ve yüzde olarak sunuldu. İstatistiksel anlamlılık p<0.05 olarak tanımlandı.
BULGULAR: Çalışmaya dahil edilen hastaların 25'i (%54,3) erkekti ve medyan yaş 65 (56-73) idi. Popülasyon, 30 (%65.2) hastadan oluşan FS uygulanan grup ile 16 (%34.8) hastadan oluşan enterotomi uygulanan grup olarak ikiye ayrıldı. Enterotomi yapılan hastalarda şiddetli (CD 3b-5) morbidite gözlenirken, FS grubunda hiç görülmedi (p=0.034). Taburculuk sonrası enterotomi yapılan hastaların 6'sında (%37.5) tekrarlayan mekanik bağırsak tıkanıklığı gözlendi (p=0.025).
SONUÇ: Bezoarlarda FS yönteminin, daha az invaziv olması ve ameliyat sonrası morbiditeleri azaltması nedeniyle, acil ameliyat edilen gastrointestinal sistem tıkanıklığı olan hastalarda ilk seçenek yöntem olduğuna inanıyoruz. Ayrıca, FS yönteminin, enterotomi tekniğine kıyasla ameliyat sonrası tıkanıklık ataklarını azalttığını literatüre sunmaktayız.

Anahtar sözcükler: Bezoar; cerrahi; mekanik bağırsak tıkanıklığı.

Ulus Travma Acil Cerrahi Derg 2026;32(5):582-587 DOI: 10.14744/tjtes.2026.29130

ORIGINAL ARTICLE

Inattention and impulsivity in attention-deficit/hyperactivity disorder (ADHD) and pediatric extremity fractures: an association between neurobehavioral traits and trauma presentation

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ABSTRACT

BACKGROUND: This study aimed to investigate whether the severity of attention-deficit/hyperactivity disorder (ADHD) symptoms, particularly inattention and impulsivity, is associated with extremity fractures in children. Additionally, ADHD symptom scores were compared between surgically and conservatively treated fracture cases, and the relationship between trauma energy level and ADHD symptoms was evaluated.

METHODS: In this cross-sectional study, 160 children aged 7–17 years were evaluated. Participants were divided into three groups: children with surgically treated fractures (n=40), children with conservatively treated fractures (n=40), and fracture-free controls (n=80). ADHD symptoms were assessed using a parent-completed Screening and Assessment Scale based on the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV). Sociodemographic data, trauma mechanisms, and fracture characteristics were also documented.

RESULTS: Children with fractures had significantly higher inattention scores (6.13±3.44 vs. 4.26±2.34; p<0.001), impulsivity scores (6.50±4.70 vs. 4.45±2.10; p=0.001), and total ADHD scores (12.60±6.41 vs. 8.74±3.62; p<0.001) compared with controls. No significant differences were observed between the surgical and conservative treatment groups or between low- and high-energy trauma subgroups. Sociodemographic variables and fracture history among siblings did not differ significantly between the groups.

CONCLUSION: Higher ADHD symptom scores were significantly associated with the occurrence of extremity fractures in children. These findings suggest that assessing ADHD-related symptoms may provide useful insights during pediatric trauma evaluations. However, due to the cross-sectional design, temporality and causality cannot be established. Longitudinal studies are needed to confirm these associations.

Keywords: ADHD; attention-deficit/hyperactivity disorder; behavioral risk factors; impulsivity; inattention; injury prevention; orthopedic injury; pediatric fractures; trauma.

Cite this article as: Korkmaz T, Afacan MY, İnce Y, Özer M, Öz F, Talmaç MA. Inattention and impulsivity in attention-deficit/hyperactivity disorder (ADHD) and pediatric extremity fractures: An association between neurobehavioral traits and trauma presentation. Ulus Travma Acil Cerrahi Derg 2026;32:588-596.

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Ulus Travma Acil Cerrahi Derg 2026;32(5):588-596 DOI: 10.14744/tjtes.2026.56002

Submitted: 17.12.2025 Revised: 03.03.2026 Accepted: 06.03.2026 Published: 05.05.2026

INTRODUCTION

Children may present with a variety of behavioral disorders, including conduct disorder, attention-deficit/hyperactivity disorder (ADHD), anxiety disorders, and somatic symptom disorders. Among these, ADHD—characterized by difficulties in sustaining attention, excessive activity, and impaired impulse control—has been identified as a potential risk factor for accidental injuries.[1-4] Previous studies have reported that children with fractures exhibit higher rates of behavioral problems and reduced social competence, suggesting that psychosocial factors may contribute to fracture risk and should be considered in injury prevention strategies.[5] According to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), ADHD is a neurodevelopmental disorder characterized by persistent patterns of inattention and/or hyperactivity–impulsivity that interfere with academic, social, or occupational functioning. Inattention includes difficulties maintaining focus, following instructions, organizing tasks, resisting distractions, and remembering routine responsibilities.[6] Hyperactivity and impulsivity manifest as excessive movement, difficulty remaining seated, frequent talking, interrupting others, and difficulty waiting for one's turn.[6,7]

A substantial proportion of children and adolescents experience traumatic events, which may lead to significant psychological and developmental consequences.[8] Children with ADHD may be particularly vulnerable to traumatic experiences, likely due to impulsivity and difficulties with self-regulation.[9-12] Previous studies have demonstrated that trauma-exposed children with ADHD often exhibit more severe symptoms and greater externalizing behaviors compared with those without trauma exposure, although these associations may weaken after adjustment for confounding factors.[13] Although children with ADHD may recognize potentially dangerous situations, they often underestimate the severity of the potential consequences of their actions.[12,14] Given the high frequency of trauma exposure in this population, clinicians are encouraged to routinely assess trauma history in children presenting with ADHD. However, existing evidence regarding the prevalence of trauma exposure among individuals with ADHD remains limited and shows considerable variability across studies.[13]

Despite these associations, the direct relationship between ADHD symptom severity and fracture occurrence in children remains insufficiently explored. Therefore, this study aimed to investigate whether ADHD symptom scores—particularly inattention and impulsivity—are associated with the occurrence of extremity fractures in the pediatric population. Additionally, ADHD symptom scores were compared between surgically and conservatively treated pediatric fracture cases, and the potential relationship between trauma energy level and ADHD symptom severity was evaluated.

By examining demographic variables, familial fracture history, and trauma-related characteristics, this study further sought to determine whether ADHD symptomatology may represent an independent risk factor for fractures in children.

MATERIALS AND METHODS

This observational, cross-sectional study was conducted to investigate the association between childhood extremity fractures and attention-deficit/hyperactivity disorder-related symptomatology. This study was approved by the Başakşehir Çam ve Sakura City Hospital Ethics Committee (Date: 15.05.2025, Decision no: KAEK-11/09.04.2025.123), and all procedures were performed in accordance with the Declaration of Helsinki. Written informed consent was obtained from the legal guardians of all participants.

A total of 160 pediatric patients aged 7–17 years who presented to the orthopedics and traumatology outpatient clinic in 2025 were included. Participants were classified into three groups:

Group 1: Children with upper or lower extremity fractures requiring surgical treatment (n=40),

Group 2: Children with comparable fractures managed conservatively (n=40),

Group 3: Age- and sex-matched controls without a history of fractures, presenting with non-traumatic orthopedic complaints (n=80).

Children with chronic systemic or neurological diseases, previously diagnosed psychiatric disorders (including ADHD), those receiving psychotropic medications, or those with comorbid conditions or a history of open fractures were excluded. Therefore, ADHD-related measures in this study reflect parent-reported symptom scores rather than clinician-confirmed diagnoses.

Sociodemographic and clinical data were collected through structured interviews and review of medical records. The following variables were recorded: age, sex, parental age and age at childbirth, number of siblings, personal history of prior fractures, and fracture history among siblings. Trauma-related variables included mechanism of injury (categorized as fall, sports injury, traffic accident, or fall from height), trauma energy level (low-energy: fall or sports injury; high-energy: traffic accident or fall from height), and fracture laterality (right vs. left).

ADHD symptoms were assessed using the first 18 items of the DSM-IV-Based Screening and Assessment Scale for Attention Deficit and Disruptive Behavior Disorders, originally developed by Atilla Turgay[15] and subsequently validated in Turkish by Ercan et al.[16] This instrument evaluates two core dimensions: inattention and hyperactivity-impulsivity. The parent-completed questionnaire consists of two subscales: inattention (9 items) and impulsivity/hyperactivity (9 items). Each item is rated on a 4-point Likert scale. Subscale scores and a total score were calculated, with total scores ranging from 0 to 54.

Table 1. Normality was confirmed, as the skewness and kurtosis values of all variables fell within the acceptable range of −3 to +3

	Skewness	Kurtosis
Age	-0.124	-1.302
Maternal age	-0.046	-0.407
Paternal age	0.093	-0.887
Inattention score	1.055	1.475
Impulsivity score	1.546	2.814
Total ADHD score	1.030	0.933
Maternal age at childbirth	0.208	-0.711
Paternal age at childbirth	0.210	-0.814

Normality was assessed using skewness and kurtosis values. All variables fell within the acceptable range of −3 to +3.

Fracture cases were additionally categorized based on fracture history as either first-time fractures (coded as 1) or recurrent fractures in children with a prior fracture history (coded as 2).

Statistical analysis

An a priori power analysis was conducted using G*Power (version 3.1.9.7) to determine the minimum sample size required to detect a statistically significant difference in ADHD symptom scores between children with fractures and the control group. Assuming a medium effect size (Cohen's d=0.5), a significance level (α) of 0.05, and a statistical power ($1-\beta$) of 0.80 for a two-tailed independent samples t-test, the required minimum sample size was calculated as 64 participants (32 per group). To enhance statistical reliability and account for potential data loss, a total of 160 participants were included: 80 in the fracture group (40 surgical, 40 conservative) and 80 in the control group.

All statistical analyses were performed using IBM SPSS Statistics for Windows (version 26.0; IBM Corp., Armonk, New York, USA). The normality of continuous variables was assessed using skewness and kurtosis values, with values between −3 and +3 considered acceptable (Table 1).[17-19] As all variables fell within the acceptable range of −3 to +3, normal distribution was assumed, and parametric tests were applied. The primary comparison was prespecified as children with fractures (Groups 1 and 2 combined) versus fracture-free controls (Group 3), in accordance with the a priori power calculation. Secondary prespecified analyses included comparisons between surgically and conservatively treated fractures (Group 1 vs. Group 2) and between low- and high-energy trauma subgroups. Continuous variables were analyzed using independent-samples t-tests, while categorical variables were compared using chi-square tests. Subgroup analyses evaluated differences between fracture cases (Groups 1 and 2) and controls (Group 3), between surgical and conservative treatment groups (Group 1 vs. Group 2), and between low- and high-energy trauma within fracture subgroups. Additionally, associations between ADHD scores and both trauma energy level and surgical indication were examined. As these analyses were prespecified and addressed distinct clinical questions, hypothesis testing was limited to the defined contrasts; however, the potential for inflated type I error due to multiple comparisons is acknowledged as a limitation. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 160 pediatric participants were included and categorized into three groups: surgically treated fractures (Group 1, n=40), conservatively treated fractures (Group 2, n=40), and fracture-free controls (Group 3, n=80).

No significant association was observed between sex and group classification (p=1.000). The proportion of males and females were identical in the fracture group (Groups 1 and 2: 72.5% and 27.5%, respectively) and the control group (Group 3). This distribution was intentionally balanced to minimize potential confounding. Similarly, the total number of siblings did not differ significantly between groups (p=0.591). In Groups 1 and 2, the distribution of participants with 1, 2, 3, and ≥4 siblings was 6.3%, 41.3%, 32.5%, and 20.0%, respectively, compared with 5.0%, 45.0%, 37.5%, and 12.5% in Group 3. There was no significant association between group status and a history of fractures in siblings (p=0.738). In Groups 1 and 2, 35.0% of participants had siblings with a history of fracture, compared with 32.5% in Group 3. Likewise, the prevalence of prior fractures in the participants themselves did not differ significantly between groups (p=0.717). In Groups 1 and 2, 23.8% of participants reported a previous fracture, compared with 27.5% in Group 3 (Table 2).

No significant differences were observed in mean age between the fracture group (Groups 1 and 2: 11.7±3.01 years) and the control group (Group 3: 12.5±2.88 years; p=0.088). Similarly, no significant differences were observed between groups in terms of maternal age (Groups 1 and 2: 40.21±6.15 vs. Group 3: 41.03±6.48; p=0.417) or paternal age (Groups 1 and 2: 44.81±6.69 vs. Group 3: 45.35±6.83; p=0.616). No significant differences were observed in maternal age at childbirth between Groups 1 and 2 (28.46±5.18) and Group 3 (28.43±4.98; p=0.963), nor in paternal age at childbirth (Groups 1 and 2: 33.06±5.28 vs. Group 3: 32.75±5.27; p=0.708) (Table 2).

Inattention scores were significantly higher in the fracture group (Groups 1 and 2: 6.13±3.44) compared with the control group (Group 3: 4.26±2.34; p=0.000). Similarly, impulsivity scores were elevated in Groups 1 and 2 (6.50±4.70) compared to Group 3 (4.45±2.10; p=0.001). Total ADHD scores were also significantly higher in Groups 1 and 2 (12.6±6.41) relative to Group 3 (8.74±3.62; p=0.000), indicating a greater overall symptom burden in the fracture group (Table 2, Fig. 1).

No significant association was found between sex and treat-

Table 2. Comparison of categorical and continuous variables, including sociodemographic characteristics and attention-deficit/hyperactivity disorder (ADHD) subscale scores, between the fracture group (Groups 1–2) and the control group (Group 3)

Variable	Groups 1-2	Group 3	Total	
*Chi-square test	n (%)	n (%)	n (%)	p*
Sex				
Male	58 (72.5%)	58 (72.5%)	116 (72.5%)	1.000*
Female	22 (27.5%)	22 (27.5%)	44 (27.5%)	
Number of siblings				
1	5 (6.3%)	4 (5%)	9 (5.6%)	0.591*
2	33 (41.3%)	36 (45%)	69 (43.1%)	
3	26 (32.5%)	30 (37.5%)	56 (35%)	
≥4	16 (20%)	10 (12.5%)	26 (16.3%)	
History of fracture in a sibling				
Yes	28 (35%)	26 (32.5%)	54 (33.8%)	0.738*
No	52 (65%)	54 (67.5%)	106 (66.3%)	
Prior fracture history				
Yes	19 (23.8%)	22 (27.5%)	41 (25.6%)	0.717*
No	61 (76.3%)	58 (72.5%)	119 (74.4%)	
**Independent-samples t test	Mean±SD	Mean±SD	Mean±SD	p**
Age	11.7±3.01	12.5±2.88	12.1±2.96	0.088**
Maternal age	40.21±6.15	41.03±6.48	40.62±6.31	0.417**
Paternal age	44.81±6.69	45.35±6.83	45.08±6.74	0.616**
Maternal age at childbirth	28.46±5.18	28.43±4.98	28.44±5.06	0.963**
Paternal age at childbirth	33.06±5.28	32.75±5.27	32.91±5.26	0.708**
Inattention score	6.13±3.44	4.26±2.34	5.19±3.08	0.001**
Impulsivity score	6.5±4.7	4.45±2.1	5.48±3.77	0.001**
Total score	12.6±6.41	8.74±3.62	10.67±5.54	0.001**

SD: Standard deviation.

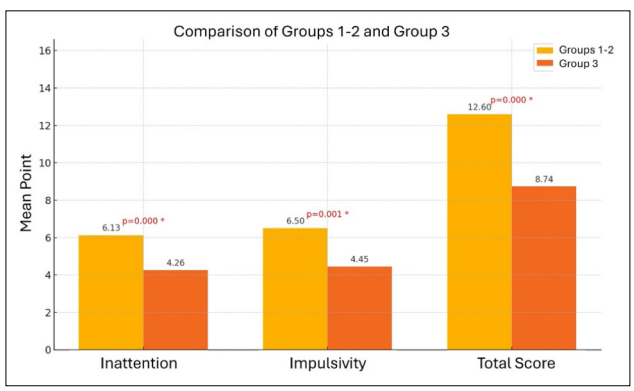

Figure 1. Comparison of inattention, impulsivity, and total attention-deficit/hyperactivity disorder (ADHD) scores between the fracture group (Groups 1 and 2) and the control group (Group 3). Children with fractures had significantly higher mean scores for inattention (p<0.001), impulsivity (p=0.001), and total score (p<0.001) compared with controls. Statistical significance was determined using independent-samples t tests.

ment group (p=0.802). In Group 1, 75% of participants were male and 25% female, compared with 70% male and 30% female in Group 2. The number of siblings did not differ significantly between groups (p=0.715). In Group 1, 7.5% of participants had one sibling, 35% had two, 35% had three, and 22.5% had four or more compared with 5%, 47.5%, 30%, and 17.5% in Group 2, respectively. There were no significant differences between groups in terms of sibling fracture history (p=0.101), reported in 25% of Group 1 and 45% of Group 2. Similarly, prior personal fracture history did not differ significantly (p=0.115). In Group 1, 15% of children had a previous fracture, while 85% did not. In Group 2, 32.5% had a previous fracture and 67.5% did not. The mechanism of trauma did not differ significantly between the groups (p=0.242). In Group 1, falls accounted for 50% of injuries, sports-related injuries for 25%, traffic accidents for 20%, and falls from height for 5%. The corresponding proportions in Group 2 were 57.5%, 30%, 5%, and 7.5%, respectively. Trauma energy levels were also

Table 3. Comparison of demographic, clinical, and trauma-related variables between surgically and conservatively treated pediatric fracture groups

Variable	Groups 1	Group 2	Total	
*Chi-square test	n (%)	n (%)	n (%)	p*
Sex				
Male	30 (75%)	28 (70%)	58 (72.5%)	0.802
Female	10 (25%)	12 (30%)	22 (27.5%)	
Number of siblings				
1	3 (7.5%)	2 (5%)	5 (6.3%)	0.715
2	14 (35%)	19 (47.5%)	33 (41.3%)	
3	14 (35%)	12 (30%)	26 (32.5%)	
≥4	9 (22.5%)	7 (17.5%)	16 (20%)	
History of fracture in a sibling				
Yes	10 (25%)	18 (45%)	28 (35%)	0.101
No	30 (75%)	22 (55%)	52 (65%)	
Prior fracture history				
Yes	6 (15%)	13 (32.5%)	19 (23.8%)	0.115
No	34 (85%)	27 (67.5%)	61 (76.3%)	
Mechanism of trauma				
Fall	20 (50%)	23 (57.5%)	43 (53.8%)	0.242
Sports injury	10 (25%)	12 (30%)	22 (27.5%)	
Traffic accident	8 (20%)	2 (5%)	10 (12.5%)	
Fall from height	2 (5%)	3 (7.5%)	5 (6.3%)	
Trauma energy level				
Low	30 (75%)	34 (85%)	64 (80%)	0.402
High	10 (25%)	6 (15%)	16 (20%)	
Injury side (laterality)				
Right	23 (57.5%)	18 (45%)	41 (51.3%)	0.371
Left	17 (42.5%)	22 (55%)	39 (48.8%)	
**Independent-samples t test	Mean±SD	Mean±SD	Mean±SD	p**
Age	12.08±3.12	11.33±2.88	11.7±3.01	0.268
Maternal age	40.03±5.78	40.4±6.57	40.21±6.15	0.787
Paternal age	44.58±6.71	45.05±6.75	44.81±6.69	0.753
Maternal age at childbirth	27.9±4.89	29.03±5.46	28.46±5.18	0.335
Paternal age at childbirth	32.45±5.57	33.68±4.98	33.06±5.28	0.303
Inattention score	5.9±3.51	6.35±3.39	6.13±3.44	0.562
Impulsivity score	6.73±5.42	6.28±3.91	6.5±4.7	0.672
Total score	12.58±6.99	12.63±5.87	12.6±6.41	0.972

SD: Standard deviation.

similar between the groups (p=0.402). In Group 1, 75% of injuries were low-energy and 25% were high-energy, whereas in Group 2, 85% were low-energy and 15% were high-energy. Laterality of injury showed no significant difference between the groups (p=0.371). In Group 1, 57.5% of fractures occurred on the right side and 42.5% on the left, while in Group 2, 45% were on the right and 55% on the left (Table 3).

There was no statistically significant difference between the groups in terms of age (p=0.268). The mean age in Group 1 was 12.08±3.12 years, compared to 11.33±2.88 years in

Table 4. Comparison of inattention, impulsivity, and total attention-deficit/hyperactivity disorder (ADHD) scores according to trauma energy level in surgically and conservatively treated fracture groups

	Trauma energy level		p*
	Low energy	High energy	
*Independent-samples t test	Mean±SD	Mean±SD	
Groups			
Group 1			
Inattention score	6.07±3.68	5.4±3.1	0.610
Impulsivity score	7.33±5.64	4.9±4.46	0.223
Total score	13.33±7.27	10.3±5.81	0.239
Group 2			
Inattention score	6.03±3.28	8.17±3.76	0.158
Impulsivity score	6.24±4.02	6.5±3.51	0.881
Total score	12.26±5.76	14.67±6.62	0.362
Total			
Inattention score	6.05±3.44	6.44±3.52	0.687
Impulsivity score	6.75±4.84	5.5±4.08	0.345
Total score	12.77±6.48	11.94±6.3	0.647

SD: Standard deviation.

Group 2. Similarly, maternal age did not differ significantly between groups (p=0.787), with a mean of 40.03±5.78 years in Group 1 and 40.40±6.57 years in Group 2. No significant difference was found in paternal age (p=0.753); the mean was 44.58±6.71 years in Group 1 and 45.05±6.75 years in Group 2. The groups also showed no statistically significant difference in maternal age at childbirth (p=0.335), with means of 27.9±4.89 years in Group 1 and 29.03±5.46 years in Group 2. Similarly, paternal age at childbirth was not significantly different between groups (p=0.303), averaging 32.45±5.57 years in Group 1 and 33.68±4.98 years in Group 2 (Table 3).

No statistically significant difference was found between Group 1 and Group 2 in terms of inattention scores (Group 1: 5.90±3.51; Group 2: 6.35±3.39; p=0.562). Similarly, impulsivity scores did not differ significantly between the groups (Group 1: 6.73±5.42; Group 2: 6.28±3.91; p=0.672). Total ADHD scores were also comparable between Group 1 (12.58±6.99) and Group 2 (12.63±5.87), with no significant difference (p=0.972) (Table 3).

There was no statistically significant difference in inattention scores between children with low-energy trauma (6.07±3.68) and those with high-energy trauma (5.40±3.10) in Group 1 (p=0.610). Similarly, impulsivity scores were not significantly different between the low-energy (7.33±5.64) and high-energy (4.90±4.46) subgroups (p=0.223). Total ADHD scores also showed no significant difference (low-energy: 13.33±7.27; high-energy: 10.30±5.81; p=0.239). In Group 2, the inattention score was 6.03±3.28 in the low-energy group and 8.17±3.76 in the high-energy group, with no statistically significant difference (p=0.158). Impulsivity scores were also similar between low- and high-energy subgroups (6.24±4.02 vs. 6.50±3.51; p=0.881). Likewise, total ADHD scores were not significantly different (low-energy: 12.26±5.76; high-energy: 14.67±6.62; p=0.362). When all fracture cases (Groups 1 and 2 combined) were analyzed together, no statistically significant differences were found in inattention scores between low-energy (6.05±3.44) and high-energy (6.44±3.52) trauma (p=0.687). Impulsivity scores were also comparable (6.75±4.84 vs. 5.50±4.08; p=0.345), as were total ADHD scores (12.77±6.48 vs. 11.94±6.30; p=0.647) (Table 4).

DISCUSSION

In this study, children with extremity fractures exhibited significantly higher inattention, impulsivity, and total ADHD scores compared to age- and sex-matched controls without fractures. These differences were statistically significant, suggesting a potential association between ADHD symptomatology and an increased risk of fractures in pediatric populations. However, no significant differences were observed between the surgical and conservative treatment groups in terms of ADHD scores. Similarly, subgroup analyses based on trauma energy levels revealed no statistically significant variations in ADHD symptom scores. Sociodemographic variables, including age, sex, parental age, number of siblings, and fracture history among siblings, did not differ significantly between groups. This suggests that ADHD-related behavioral charac-

teristics, rather than background factors, may play a more prominent role in fracture susceptibility.

These findings are consistent with the growing body of evidence linking ADHD symptomatology to an increased risk of injury. A meta-analysis by Seens et al.[20] reported that children with ADHD are approximately 2.5 times more likely to sustain bone fractures than their peers, with a pooled fracture prevalence of 4.83%. Most fractures occurred in the upper extremities, highlighting the need for targeted prevention strategies.[20] Similarly, Guo et al.,[21] in a nationwide cohort study of over 43,000 Taiwanese children, found a significantly higher fracture incidence in those with ADHD compared to controls (21.0 vs. 15.0 per 1,000 person-years). This increased risk persisted after adjusting for confounding variables such as age, sex, and geographic region, and was observed across all anatomical sites and age groups, with the highest risk seen in lower extremity fractures and in girls over the age of 10. These findings underscore the importance of age- and sex-specific prevention strategies in children with ADHD.[21] Similarly, Prasad et al.,[22] using national health records from England, reported that children with ADHD had a 25% higher risk of fractures compared to those without ADHD, with particularly elevated rates of long bone fractures. These results further emphasize the need for early injury prevention strategies and targeted counseling in this population.

Consistent with our findings, Loder et al.[5] identified increased behavioral difficulties, including impulsivity and hyperactivity, among children with fractures, along with reduced social competence, highlighting the contribution of psychosocial factors to pediatric injury risk. Uslu et al.[1] similarly demonstrated that children with extremity fractures had significantly higher impulsivity-hyperactivity scores compared to those with non-traumatic orthopedic conditions, suggesting that these behavioral traits may predispose children to fractures. Ziv-Baran et al.,[12] in a large-scale cohort study, reported a higher overall fracture incidence in children with ADHD compared to matched controls. The risk was further elevated in cases of recurrent fractures, while pharmacological treatment appeared to reduce this risk, suggesting a potential protective effect of early therapeutic intervention. However, this protective role should be interpreted with caution. Ortiz et al.[23] found that psychostimulant medications, including methylphenidate and mixed amphetamine salts, were associated with delayed bone healing and reduced bone density in children with distal radius fractures. This effect was most pronounced in patients treated for up to five years, although it appeared to diminish with longer treatment durations beyond five years. These findings suggest that, while stimulant medications may reduce injury incidence, they may concurrently impair fracture healing. This dual effect highlights the importance of considering medication history in orthopedic treatment planning and of providing appropriate counseling to families. Additionally, Kaya et al.[10] demonstrated that adult ADHD was more prevalent among patients presenting with trauma—particularly high-energy injuries—compared to those without a trauma history. This finding suggests a lifelong vulnerability to injury in individuals with ADHD, leading the authors to recommend that patients presenting with high-energy trauma be evaluated for ADHD. The association between ADHD symptoms and trauma has also been examined in specific contexts, such as dental injuries. Thikkurissy et al.[11] reported that children with recent dental trauma exhibited significantly higher hyperactivity/impulsivity scores, reinforcing the role of behavioral dysregulation in predisposing individuals to injury.

The impact of trauma exposure in children with ADHD has been further explored by Schilpzand et al.,[13] who identified a higher lifetime prevalence of traumatic experiences in children with ADHD compared to controls. Trauma-exposed children with ADHD also demonstrated greater symptom severity and more externalizing problems; however, these effects diminished after adjusting for confounding variables. Consistent with these findings, Alisic et al.[8] reported that 15.9% of trauma-exposed children developed posttraumatic stress disorder (PTSD), with girls exposed to interpersonal trauma being at the highest risk. This suggests that the relationship between trauma and psychiatric symptoms may be moderated by both gender and trauma type. From a developmental perspective, Lara et al.[9] found that ADHD often persists into adulthood, with symptom severity and the presence of both inattentive and impulsive features predicting long-term persistence. This supports the notion that early behavioral dysregulation not only increases injury risk during childhood but may also contribute to ongoing functional impairments across the lifespan. Martin et al.[24] highlighted that inattentive ADHD symptoms are associated with an increased risk of disordered eating in young adults, mediated by depressive symptoms and impulsivity, thereby illustrating the broader impact of ADHD beyond injury susceptibility.

Our results, showing elevated ADHD scores among injured children, are consistent with those of Brehaut et al.'s[3] population-based study, which reported a significantly higher risk of injuries—including fractures—among children prescribed methylphenidate for behavioral disorders, independent of socioeconomic and demographic variables. Rowe et al.[4] found that ADHD, but not conduct disorder, was significantly associated with unintentional injuries such as fractures, underscoring the unique behavioral risks linked to ADHD symptom profiles. Farmer et al.[14] provided further insight by demonstrating that although children with ADHD can recognize hazards, they often underestimate the severity of potential consequences and lack effective injury-prevention strategies—factors that may explain their increased injury risk despite intact hazard recognition. Byrne et al.[2] reported that while preschoolers with ADHD exhibited significantly more risk-related behaviors than controls, this did not correspond to a higher rate of severe injuries requiring emergency care,

suggesting a possible behavioral threshold at which impulsivity increases the risk of minor injuries without necessarily leading to major trauma. Ibáñez-Tejedor et al.[7] highlighted the influence of modifiable risk factors, such as smoking, in exacerbating ADHD symptoms in university students. Although focused on a different population, their findings reinforce the importance of considering environmental and behavioral contributors to ADHD symptom burden across developmental stages. Taken together, our findings align with a substantial body of literature identifying ADHD—particularly inattention and impulsivity—as significant contributors to pediatric fracture risk. While trauma energy level and treatment modality were not associated with ADHD symptom severity in our cohort, the elevated scores observed among injured children overall highlight the importance of screening for neurobehavioral vulnerabilities in pediatric trauma patients. Multidisciplinary collaboration among orthopedic surgeons, pediatricians, and mental health professionals is essential for early identification and targeted intervention, which may help mitigate future injury risk.

This study has several strengths and limitations. It is among the few to investigate the relationship between ADHD symptom severity and fracture risk in children. It includes a well-matched control group, analyzes both surgical and conservative fracture cases, and incorporates trauma energy levels into its assessment. The use of a validated ADHD symptom scale adds reliability to the findings. However, the cross-sectional design precludes causal inference. ADHD symptoms were assessed solely based on parent-reported questionnaires without clinical confirmation. Specifically, symptoms were measured using a parent-completed DSM-based screening scale rather than a structured clinical interview; therefore, reporting bias and misclassification are possible. Potential confounding factors, such as socioeconomic status and medication use, were not evaluated. Moreover, the control group consisted of children presenting with non-traumatic orthopedic complaints rather than a community-based sample, which may limit representativeness and introduce selection bias related to health-seeking behavior or activity patterns. Although basic sociodemographic characteristics were comparable between groups, multivariable analyses were not performed to adjust for potential confounders. Therefore, the findings should be interpreted as associative and potentially influenced by unmeasured or residual confounding. Although the primary and secondary comparisons were prespecified, the use of multiple planned pairwise tests may still increase the probability of type I error. Lastly, the single-center design and relatively limited sample size (despite power analysis) may restrict generalizability.

CONCLUSION

This study demonstrates a significant association between higher parent-reported ADHD symptom scores—particularly inattention and impulsivity—and the presence of extremity fractures in children. Although ADHD symptom scores did not differ significantly between surgically and conservatively treated fracture cases, children with fractures overall exhibited more behavioral symptoms than peers without fractures. These findings suggest that neurobehavioral factors may be relevant when interpreting pediatric fracture presentations and may help inform clinical history-taking and risk assessment. However, due to the cross-sectional design and reliance on a parent-reported symptom scale rather than a diagnostic evaluation, causal inferences cannot be made. Prospective, longitudinal, and multicenter studies are warranted to confirm these associations, evaluate potential confounders, and clarify underlying mechanisms.

Ethics Committee Approval: This study was approved by the Başakşehir Çam ve Sakura City Hospital Ethics Committee (Date: 15.05.2025, Decision No: KAEK-11/09.04.2025.123).

Peer-review: Externally peer-reviewed.

Informed Consent: Written informed consent was obtained from the legal guardians of all participants.

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

Conflict of Interest: None declared.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Dikkat eksikliği ve hiperaktivite bozukluğunda dikkatsizlik ve dürtüselliğin pediatrik ekstremite kırıkları ile ilişkisi: Nörodavranışsal özellikler ile travma arasındaki bağlantı

AMAÇ: Bu çalışmanın amacı, çocuklarda dikkat eksikliği/hiperaktivite bozukluğu (DEHB) semptom şiddetinin, özellikle dikkatsizlik ve dürtüsellik boyutlarının, ekstremite kırıkları ile ilişkili olup olmadığını araştırmaktır. Ayrıca, cerrahi ve konservatif olarak tedavi edilen kırık olguları arasında DEHB skorlarının karşılaştırılması ve travma enerji düzeyi ile DEHB semptomları arasındaki ilişkinin değerlendirilmesi amaçlanmıştır.

GEREÇ VE YÖNTEM: Bu kesitsel çalışmaya 7–17 yaş aralığında toplam 160 çocuk dahil edilmiştir. Katılımcılar üç gruba ayrılmıştır: cerrahi olarak tedavi edilen kırık olguları (n=40), konservatif olarak tedavi edilen kırık olguları (n=40) ve kırık öyküsü olmayan kontrol grubu (n=80). DEHB semptomları, ebeveynler tarafından doldurulan DSM-IV Temelli Tarama ve Değerlendirme Ölçeği kullanılarak değerlendirilmiştir. Sosyodemografik veriler, travma mekanizması ve kırık özellikleri kaydedilmiştir.

BULGULAR: Kırık saptanan çocuklarda, kontrol grubuna kıyasla dikkatsizlik (6.13±3.44'e karşı 4.26±2.34; p<0.001), dürtüsellik (6.50±4.70'e karşı 4.45±2.10; p=0.001) ve toplam DEHB puanlarının (12.60±6.41'e karşı 8.74±3.62; p<0.001) anlamlı derecede daha yüksek olduğu görülmüştür. Cerrahi ve konservatif tedavi grupları arasında ya da düşük ve yüksek enerjili travma alt grupları arasında DEHB skorları açısından anlamlı bir fark saptanmamıştır. Sosyodemografik değişkenler ve kardeşlerde kırık öyküsü açısından gruplar arasında anlamlı fark bulunmamıştır.

SONUÇ: Yüksek DEHB semptom puanlarının, çocuklarda ekstremite kırığı görülme sıklığı ile anlamlı şekilde ilişkili olduğu saptanmıştır. Bu bulgular, pediatrik travma değerlendirmelerinde DEHB ile ilişkili semptomların dikkate alınmasının yararlı olabileceğini düşündürmektedir. Ancak kesitsel tasarım nedeniyle nedensellik kurulamaz; bu ilişkinin yönünü ve olası klinik etkilerini değerlendirmek için ileriye dönük uzunlamasına çalışmalara ihtiyaç vardır.

Anahtar sözcükler: Davranışsal risk faktörleri; dikkat eksikliği ve hiperaktivite bozukluğu; dikkatsizlik; dürtüsellik; ortopedik yaralanmalar; pediatrik kırıklar; travma; yaralanma önleme.

Ulus Travma Acil Cerrahi Derg 2026;32(5):588-596 DOI: 10.14744/tjtes.2026.56002

ORIGINAL ARTICLE

Hand trauma associated with non-professional animal slaughter during Eid al-Adha: an emergency and hand surgery experience

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ABSTRACT

BACKGROUND: Eid al-Adha is an important religious holidays celebrated annually in Muslim communities, during which the ritual of animal sacrifice is performed. The demand for butchery services rises significantly during this period; however, due to the limited availability of professional butchers, many individuals undertake the slaughter themselves. This practice is associated with an increased incidence of traumatic injuries, particularly involving the hands and upper extremities. This study aims to characterize the pattern of hand and upper limb injuries associated with non-professional animal slaughter during Eid al-Adha and to raise awareness of these preventable traumas.

METHODS: In this retrospective study, we evaluated patients who presented to our clinic with hand injuries requiring surgical intervention during multiple Eid al-Adha periods. The study population primarily consisted of individuals injured during animal slaughter who were admitted to the hospital for hand or upper extremity trauma. Demographic data and injury types were evaluated.

RESULTS: Over an eight-year period, a total of 259 extensor tendon injuries, 76 flexor tendon injuries, and 275 superficial soft tissue injuries related to Eid al-Adha were surgically treated at our clinic.

CONCLUSION: This study provides a retrospective analysis of hand tendon and superficial tissue injuries observed over eight Eid al-Adha periods. The findings indicate that non-professional slaughter of sacrificial animals poses a significant risk, particularly for hand and tendon injuries. Ensuring that slaughter procedures are performed by trained individuals, along with the use of protective measures, may play an important role in reducing these preventable injuries.

Keywords: Eid al-Adha; emergency; hand surgery; tendon.

INTRODUCTION

Two major religious festivals are celebrated in Muslim communities. The first is Eid al-Fitr, observed at the end of the month of Ramadan. The second, Eid al-Adha, occurs approximately two months after the Ramadan festival during the month of Hajj.[1-7] This latter festival involves the ritual sacrifice of animals such as cattle, sheep, lambs, goats, and

Cite this article as: Horoz U, Inozu E, Özakpınar HR, Seven E, Eryılmaz AT, Keleş MK, et al. Hand trauma associated with non-professional animal slaughter during Eid al-Adha: an emergency and hand surgery experience. Ulus Travma Acil Cerrahi Derg 2026;32:597-601.

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Ulus Travma Acil Cerrahi Derg 2026;32(5):597-601 DOI: 10.14744/tjtes.2026.94145
Submitted: 06.09.2025 Revised: 11.03.2026 Accepted: 03.04.2026 Published: 05.05.2026

less commonly, camels or buffalo. The type of animal varies according to regional and cultural traditions; in Türkiye, sheep and cattle are most commonly sacrificed. As part of this religious practice, animals are sacrificed annually in accordance with Islamic principles. Traumatic injuries frequently occur during Eid al-Adha as a result of non-professional animal slaughter, often exhibiting distinct clinical characteristics in terms of injury mechanism, anatomical involvement, and surgical requirements.

In many cases, individuals perform animal sacrifice themselves, despite having limited experience.[1-3] Slaughter is commonly carried out in informal settings such as gardens, streets, or backyards.[1,4] During these procedures, injuries most frequently involve the upper extremities, whereas injuries of other body regions are less common.[1-5] Hand injuries present a broad clinical spectrum, ranging from soft tissue damage to complex injuries involving neurovascular structures, tendons, and even amputations.[1-5] These injuries occur predominantly on the first day of the festival and are strongly associated with male gender and non-professional practices. Injuries peak on the first day within a short time frame, with cutting and penetrating traumas predominating and placing a significant patient burden on emergency hand surgery services.

Although previous studies have documented the epidemiology of hand injuries during Eid al-Adha, comprehensive data on their specific clinical presentation, surgical complexity, and regional patterns, particularly within Türkiye, remain limited. This study aims to address this gap by evaluating not only demographic and epidemiologic characteristics but also the clinical features and surgical management of these injuries. By addressing both practical management challenges and region-specific factors, this study provides novel insights that may assist clinicians in optimizing patient care and inform targeted preventive strategies. This combined focus on clinical detail and operational context highlights the originality and relevance of the research within the field of festival-related hand trauma.

The aim of this study was to evaluate the demographic characteristics of patients and the management of hand injuries associated with non-professional animal slaughter.

MATERIALS AND METHODS

A retrospective analysis was conducted on the medical records of patients who presented to the emergency department with hand trauma related to non-professional animal slaughter during the Eid al-Adha period and were subsequently evaluated in our clinic. Between 2011 and 2019, a total of 219 patients were admitted with hand tendon injuries during the festival. Nearly all injuries were associated with festival-related activities. The majority of patients (89%) were male, and all underwent surgical treatment on the day of injury. Collected data included patient age, sex, level of experience in animal slaughter, and type of injury. At the time the study was conducted, ethics committee approval was not required.

RESULTS

A total of 219 patients were included in the study, with annual distribution as follows: 35 in 2011, 29 in 2012, 35 in 2013, 20 in 2014, 35 in 2015, 18 in 2016, 25 in 2017, and 22 in 2018. All injuries were caused by sharp instruments. Patient ages ranged from 17 to 59 years, with a mean age of 37 years. Of the patients, 83% had no prior experience in animal slaughter or meat processing. Most patients were admitted on the first day of the festival. A total of 335 tendon injuries were identified in 219 patients (Figs. 1-5). Additionally, 275 superficial injuries were recorded. Among tendon injuries, 259 involved extensor tendons and 76 involved flexor tendons. Overall, 119 partial tendon injuries and 216 complete tendon inju-

Table 1. Demographic characteristics and injury patterns of patients with hand injuries related to non-professional animal slaughter during Eid al-Adha

Variable	Value
Total number of patients	219
Age, mean (years)	37
Age range (years)	17–59
Total number of injuries	610
Soft tissue injuries	275 (45.1%)
Tendon injuries (total)	335 (54.9%)
Flexor tendon injuries	76 (22.7%)
Extensor tendon injuries	259 (77.3%)
Complete tendon injuries	216 (64.5%)
Partial tendon injuries	119 (35.5%)

Figure 1. Extensor pollicis longus tendon injury.

Figure 2. Extensor communis tendon injuries of the second, third, fourth, and fifth fingers.

Figure 3. Flexor tendon injury of the small finger.

Figure 4. Extensor tendon injury.

Figure 5. Partial flexor tendon injury.

ries were surgically repaired. Following surgery, all patients were referred to an experienced hand physiotherapy team. Patients were followed for three weeks using a static hand splint, tailored according to the type of injury.

DISCUSSION

Previous studies have demonstrated that injuries related to Islamic festivals most frequently occur on the first day of Eid al-Adha, when slaughtering activities are typically performed, particularly during daytime hours.[1-5] Consistent with the literature, such injuries predominantly affect male individuals.[1-3] In our retrospective analysis, a similar gender distribution was observed, with injuries in female patients occurring mainly during meat processing or while assisting family members. Additionally, the non-dominant (left) hand was more frequently affected, likely due to its role in stabilizing the animal during the cutting procedure.[1,2,4,5] In the present study, 90% of injuries involved the left hand, while Avşaroğullari et al.[3] reported nearly equal distribution between both hands. In another clinical report, 458 patients with tendon injuries were evaluated on non-festival days; 362 had right-hand tendon injuries, with a total of 396 injuries affecting the dominant hand.[8] These findings suggest a distinct injury pattern associated with festival-related activities. Although such injuries may initially appear minor, they often involve complex structures and require surgical intervention. Jong et al.[8] reported that acute traumatic tendon injuries of the hand and wrist are most commonly associated with sharp instruments such as knives, as well as glass (mirror) or saw injuries.

Hospital admission rates on the first day of the festival have been reported as 64%,[1] 73%,[5] and 80%[4] in previous studies. Rahman et al.[5] described 298 patients injured during animal slaughter. In Saudi Arabia, 219 patients presented to the emergency department with hand injuries during the festival over a four-year period. Similarly, Sarifakioğlu et al.[1] reported 98 patients over two years, while Bildik et al.[4] analyzed 120

patients within a two-year period. In hand trauma, the severity and depth of injury can range from superficial soft tissue damage to complex injuries involving tendons and neurovascular structures. These variations depend on factors such as the type of cutting instrument used, the technique applied, sudden movements of the animal, and the practitioner's level of experience. Dizen et al.[2] reported 122 injuries during the festival period, including injuries beyond those involving the hand. Avsarogullari documented 50 patients with hand injuries over a five-year period.[3] Similarly, Sica et al.[7] reported 50 patients with hand injuries in Tunis within a one-year period, of whom 75% had injuries to the dorsal aspect of the non-dominant hand and 46% required surgical intervention.

In the present study, we focused specifically on tendon and soft tissue injuries of the hand associated with the slaughter ritual. Similarly, the literature indicates that hand injuries increase significantly during holiday periods, with injuries caused by cutting and penetrating instruments being particularly prevalent. The frequent involvement of the thumb and index finger is attributed to their role in stabilizing the hand during cutting.[9] A multicenter study from Türkiye similarly demonstrated that the majority of injuries involve the upper extremities, particularly the hand. A significant proportion of patients were non-professional butchers, and most injuries were self-inflicted. Although most cases were managed in the emergency department and discharged, injuries requiring surgical intervention, such as tendon and nerve injuries, are clinically significant. Hand trauma associated with Eid al-Adha exhibits distinct demographic and clinical patterns. These injuries predominantly affect male patients and are typically caused by cutting or penetrating trauma involving knives. Clinically, tendon and soft tissue injuries are most frequently observed, with extensor tendons being particularly affected.[10]

These findings indicate that hand trauma during holiday periods imposes a substantial burden on hand surgery services, not only in terms of increased case volume but also due to the complexity of surgical management. Studies on general trauma epidemiology have shown that hand and finger injuries are among the most frequently affected anatomical regions, and this trend becomes even more pronounced during holiday periods involving animal slaughter.[11] In the present study, 219 patients underwent surgical treatment for hand tendon and soft tissue injuries over eight consecutive festival periods. Most injuries occurred on the first day of the festival, consistent with previous reports; Dizen reported that up to 87% of cases presented on the first day.[2] Similarly, 85% of patients in our series were admitted on the first day of the festival. The majority of injured individuals performed the slaughter themselves, often with family members or friends, and lacked prior experience. One contributing factor to these injuries is the sudden movement of animals, particularly large ones, which are difficult to stabilize during the procedure. In our study, 85% of injuries involved extensor tendons. These tendons are more vulnerable than flexor tendons due to their anatomical location and the typical hand position during slaughter, in which the palmar surface is relatively protected while the dorsal surface remains exposed to injury. The primary cause of slaughter-related hand injuries appears to be the cutting process itself, frequently performed without professional assistance. The high concentration of slaughtering activities on the first day of Eid al-Adha further limits access to appropriate facilities, leading many individuals to perform the procedure in domestic settings. Additionally, the limited availability of professional butchers during peak periods results in inexperienced individuals undertaking the task, sometimes with assistance from family members. Under these conditions, the risk of hand injuries associated with slaughtering activities increases substantially. The present findings indicate that hand injuries sustained during Eid al-Adha predominantly involve tendon structures, with a marked predominance of extensor tendon injuries. Compared with previously published series, these injury patterns appear consistent across different populations, supporting the reproducibility of slaughter-related hand trauma mechanisms.

CONCLUSION

This study characterizes hand injuries occurring during Eid al-Adha, demonstrating a consistent pattern predominantly affecting extensor tendons. Over eight festival periods, 219 patients presented with tendon and soft tissue injuries, most occurring on the first day and primarily among male individuals performing animal sacrifice without professional assistance. Injuries most commonly involved the non-dominant hand and the dorsal surface, reflecting the stabilizing role of the hand during cutting. In addition to identifying epidemiological trends, this study highlights the surgical challenges and clinical management of these injuries, addressing operative aspects that are often underreported in the literature. These findings underscore the substantial burden placed on emergency and hand surgery services and emphasize the importance of preventive strategies and increased public awareness, while integrating epidemiological data with clinical insights.

Ethics Committee Approval: This study was conducted as a retrospective record analysis; according to the local regulations at the time of the study, formal ethics committee approval was not required.

Peer-review: Externally peer-reviewed.

Informed Consent: Written informed consent was obtained.

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

Conflict of Interest: None declared.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Kurban Bayramı'nda profesyonel olmayan hayvan kesimlerine bağlı el travmaları: Acil ve klinik el cerrahisi deneyimi

AMAÇ: Kurban Bayramı, Müslüman toplumlarda her yıl kutlanan ve geleneksel olarak kurban kesim ritüelinin gerçekleştirildiği önemli dini bayramlardan biridir. Bu dönemde kurban kesimi için kasaplık hizmetlerine olan talep belirgin şekilde artmasına rağmen profesyonel kasap sayısının yetersiz olması nedeniyle birçok kişi kurban kesimini kendi imkânlarıyla gerçekleştirmektedir. Bu durum özellikle el ve üst ekstremite yaralanmaları başta olmak üzere çeşitli travmatik yaralanmaların görülme sıklığını artırmaktadır. Bu çalışmanın amacı, Kurban Bayramı sırasında profesyonel olmayan kişiler tarafından gerçekleştirilen kesim işlemleri sırasında ortaya çıkan el ve üst ekstremite yaralanmalarına dikkat çekmek ve bu önlenebilir travmalar konusunda farkındalık oluşturmaktır.

GEREÇ VE YÖNTEM: Bu retrospektif çalışmada, Kurban Bayramı dönemlerinde kliniğimize başvuran ve cerrahi tedavi gerektiren el yaralanmaları incelendi. İncelenen vakalar, çoğunlukla hayvan kesimi sırasında yaralanan ve el veya üst ekstremite travması nedeniyle hastaneye başvuran bireylerden oluşmaktadır. Demografik veriler ve yaralanma tipleri değerlendirilmiştir.

BULGULAR: Sekiz yıllık dönem boyunca kliniğimizde Kurban Bayramı ile ilişkili olarak 259 ekstansör tendon, 76 fleksör tendon ve 275 yüzeyel yumuşak doku yaralanması cerrahi olarak tedavi edilmiştir.

SONUÇ: Bu çalışma, sekiz farklı Kurban Bayramı döneminde meydana gelen el tendon ve yüzeyel doku yaralanmalarının retrospektif analizini sunmaktadır. Bulgular, kurban kesiminin profesyonel olmayan kişiler tarafından gerçekleştirilmesinin özellikle el ve tendon yaralanmaları açısından önemli bir risk oluşturduğunu göstermektedir. Kurban kesim işlemlerinin eğitimli kişiler tarafından gerçekleştirilmesi ve koruyucu önlemlerin artırılması, bu tür önlenebilir yaralanmaların azaltılmasında önemli rol oynayabilir.

Anahtar sözcükler: Acil; el cerrahisi; Kurban Bayramı; tendon.

Ulus Travma Acil Cerrahi Derg 2026;32(5):597-601 DOI: 10.14744/tjtes.2026.94145

ORIGINAL ARTICLE

Does autologous bone grafting provide better outcomes than tricalcium phosphate synthetic grafting in tibial plateau fractures with articular depression?

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ABSTRACT

BACKGROUND: This study aimed to compare the radiological and functional outcomes of autologous iliac bone grafting and tricalcium phosphate synthetic grafting in the treatment of tibial plateau fractures (TPFs) with articular depression.

METHODS: In this retrospective comparative study, 94 patients who underwent surgical treatment for Schatzker type II–III tibial plateau fractures with metaphyseal depression between January 2015 and June 2022 were evaluated. Patients were divided into two groups according to the graft material used: autologous iliac bone graft (n=42) and tricalcium phosphate (TCP) synthetic graft (n=52). Radiological evaluation included measurement of articular depression (mm) and the modified Rasmussen Radiological Score (RRS) preoperatively, postoperatively, and at final follow-up (≥36 months). Functional outcomes were assessed using the Lysholm Knee Score and the modified Rasmussen Functional Score (RFS). The minimum follow-up duration was 36 months.

RESULTS: Both groups achieved satisfactory initial correction of articular depression. At final follow-up, depression was smaller in the autograft group (2.10 [0.00–2.60] mm) than in the TCP group (2.50 [1.68–3.75] mm; U=771.5, p=0.014), indicating better maintenance of reduction. RRS values were comparable between groups preoperatively and immediately postoperatively, but were higher in the autograft group at final follow-up (16 [16–18] vs. 16 [14–16]; U=1453.5, p=0.002). Consistent with this finding, a greater proportion of excellent RRS outcomes was observed in the autograft group (40.5% vs. 21.2%; $\chi^2(1)=4.15$, p=0.042). Functional outcomes were similar between groups (RFS: 27 [26–28] vs. 26 [26–28]; U=1285, p=0.136; Lysholm: 86 [81–90] vs. 86 [81–90]; U=1271.5, p=0.159). Donor-site morbidity occurred in 4.7% of patients in the autograft group, whereas no graft-related complications were observed in the TCP group.

CONCLUSION: In Schatzker type II–III TPFs with articular depression, autologous iliac crest bone grafting demonstrated better radiological maintenance of reduction and higher final RRS compared to TCP grafting, although mid-term functional scores were similar. These level III data suggest that autograft remains a reliable option for structural support in metaphyseal defects; however, prospective randomized comparative studies are needed to confirm any potential advantage over tricalcium phosphate grafts.

Keywords: Autograft; functional outcome; reduction loss; tibial plateau fracture; tricalcium phosphate synthetic graft.

INTRODUCTION

Tibial plateau fractures account for approximately 1% of all fractures and represent one of the most challenging periarticular injuries because they involve the weight-bearing surface of the knee joint.[1] Among these injuries, Schatzker type II and III fractures, characterized by articular depression, are particularly prone to instability, post-traumatic malalignment,

Cite this article as: Süer O, Ferhatoğlu M, Eyceyurt RS, Uzakgider M, Tahta M, Kayalı C. Does autologous bone grafting provide better outcomes than tricalcium phosphate synthetic grafting in tibial plateau fractures with articular depression? Ulus Travma Acil Cerrahi Derg 2026;32:602-609.

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Ulus Travma Acil Cerrahi Derg 2026;32(5):602-609 DOI: 10.14744/tjtes.2026.23622

Submitted: 01.12.2025 Revised: 01.12.2025 Accepted: 15.01.2026 Published: 05.05.2026

and early-onset osteoarthritis if anatomical reduction is not achieved and maintained.[2,3] Therefore, restoration of the articular surface and provision of stable metaphyseal support are fundamental goals of surgical treatment.

Following reduction of the depressed fragment, a residual metaphyseal void often requires bone grafting to prevent secondary subsidence.[4] Autologous iliac crest bone graft (AIBG) has traditionally been considered the gold standard because of its osteogenic, osteoinductive, and osteoconductive properties.[5,6] However, its use may be limited by donor-site morbidity, prolonged operative time, and postoperative pain.[7,8]

In recent years, calcium phosphate-based synthetic bone substitutes—particularly β-tricalcium phosphate (β-TCP)—have gained popularity as void fillers because of their biocompatibility, compressive strength, and resorbable properties.[9,10] Several studies have reported satisfactory outcomes with β-TCP in the treatment of tibial plateau fractures, suggesting radiological support comparable to that of autograft.[10,11] However, evidence remains inconclusive regarding its long-term ability to maintain reduction under physiological loading and whether it provides equivalent functional recovery.

Given the ongoing debate regarding the advantages of autograft versus synthetic substitutes in depressed tibial plateau fractures, additional comparative clinical evidence is needed. Therefore, the present study aimed to compare the radiological and functional outcomes of autologous iliac bone grafting and tricalcium phosphate synthetic grafting in patients with tibial plateau fractures associated with metaphyseal depression.

MATERIALS AND METHODS

Study Design and Patient Characteristics

This retrospective comparative study included patients who underwent surgical treatment for tibial plateau fractures with joint depression at our institution between January 2015 and June 2022. The study protocol was approved by the Medical Research Ethics Committee of University of Health Sciences, İzmir Bozyaka Training and Research Hospital (Date: 14.06.2023, Decision no: 2023/81), and written informed consent was obtained from all participants.

Because of the retrospective design, patients were not randomized to treatment groups. A total of 94 patients were divided into two groups according to the graft material used to fill the metaphyseal defect: the autologous iliac bone graft group (autograft group, n=42) and the tricalcium phosphate synthetic graft group (TCP group, n=52). The choice of graft material was based on the treating surgeon's preference and graft availability at the time of surgery; no institutional guidelines directed more complex fractures toward a specific graft type.

The inclusion criteria were: (1) Schatzker type II or III tibial plateau fracture with ≥5 mm articular depression confirmed by preoperative computed tomography (CT); (2) age between 18 and 65 years; and (3) a minimum follow-up duration of 36 months. The exclusion criteria included open fractures, pathological fractures, concomitant ligamentous reconstruction, previous ipsilateral knee surgery, active infection, and insufficient radiological follow-up.

Patient demographics and injury characteristics, including age, sex, mechanism of injury, and follow-up duration, were recorded and compared between groups. Baseline demographic and injury characteristics were comparable between the two groups (Table 1).

Radiological and Functional Evaluation

Radiological assessment was performed using anteroposterior and lateral radiographs, with CT scans obtained when necessary. Depression correction was calculated as the difference between preoperative and immediate postoperative depression height. The modified Rasmussen Radiological Score (RRS) was evaluated in all patients preoperatively, postoperatively, and at the final follow-up.[13,14] Outcomes were categorized as excellent (18), good (12–17), fair (6–11), or poor (<6), based on articular depression, varus–valgus alignment, and condylar widening. Radiographic parameters were independently assessed by three orthopedic surgeons, who were blinded to all clinical data.

Functional outcomes were assessed at the final clinical follow-up using the Lysholm Knee Score and the modified Rasmussen Functional Score (RFS). According to the modified Rasmussen Functional Score, clinical assessment includes pain, walking capacity, extension lag, range of motion, and stability. Each patient receives a total score ranging from 0 to 30, which is classified as poor (<10), fair (10–19), good (20–26), or excellent (27-30).[12,13]

Complications—including nonunion, delayed union, reoperation, and superficial or deep infection—were recorded and compared between the groups.

Surgical Technique

All procedures were performed by senior orthopedic trauma surgeons from a single surgical team using a standardized anterolateral approach. After exposure of the lateral plateau, the depressed articular fragment was elevated using a cortical window or bone tamp under fluoroscopic guidance. The resulting metaphyseal void was filled with either autologous cancellous bone graft or tricalcium phosphate synthetic graft according to the surgeon's usual practice and graft availability; graft selection was not guided by a formal protocol based on fracture severity or the magnitude of depression.

In the autograft group, cancellous bone was harvested from the anterior iliac crest through a separate 3–4 cm incision. The graft was morselized and tightly packed into the defect to provide structural support. Standard plate fixation was then performed using a proximal tibial lateral locking plate (Fig. 1).

In the TCP group, the defect was filled with tricalcium phos-

Table 1. Demographic and clinical characteristics of the two groups

	Autograft group	TCP group	p-value
n	42	52	
Age (years), median (Q1–Q3)	47.5 (34–57)	48 (39–58)	U=960.5 p=0.319*
Sex, n (%)			
Female	12 (28.5)	22 (42.3)	χ^2=1.90
Male	30 (77.5)	30 (57.7)	p=0.168#
Mechanism of injury, n (%)			
Traffic accident	10 (23.8)	14 (27)	χ^2=0.118
Fall	32 (76.2)	38 (73)	p=0.731#
Fracture classification			χ^2=0.118
Schatzker type II	34 (80.1)	41 (78.8)	p=0.800#
Schatzker type III	8 (19.9)	11 (21.2)	U=1309.5
Follow-up time [months], median (Q1–Q3)	79.5 (64.5–87.7)	70.0 (65.5–78.2)	p=0.099*

Normality was assessed using the Shapiro–Wilk test, and homogeneity of variances was evaluated using Levene's test. *The Mann–Whitney U test was used to compare age and follow-up duration between the groups. #Pearson's chi-square test was used to compare sex, mechanism of injury, and fracture classification between the groups. TCP: Tricalcium phosphate.

Figure 1. Radiological images of a Schatzker type II tibial plateau fracture treated with a proximal tibial lateral locking plate in the autograft group: **(a)** preoperative anteroposterior (AP) radiograph, **(b)** preoperative lateral radiograph, **(c)** preoperative coronal computed tomography (CT) image, **(d)** preoperative sagittal CT image, **(e)** early postoperative AP radiograph, **(f)** early postoperative lateral radiograph, **(g)** four-year follow-up AP radiograph, and **(h)** four-year follow-up lateral radiograph.

Figure 2. Radiological images of a Schatzker type II tibial plateau fracture treated with a proximal tibial lateral locking plate in the tricalcium phosphate synthetic graft group: **(a)** preoperative anteroposterior (AP) radiograph, **(b)** preoperative lateral radiograph, **(c)** preoperative coronal computed tomography (CT) image, **(d)** preoperative sagittal CT image, **(e)** early postoperative AP radiograph, **(f)** early postoperative lateral radiograph, **(g)** four-year follow-up AP radiograph, and (h) four-year follow-up lateral radiograph.

phate synthetic graft according to the manufacturer's instructions. Fixation was achieved using the same plating technique as in the autograft group (Fig. 2).

Postoperative Rehabilitation Protocol

All patients were immobilized in a hinged knee brace for the first two weeks. Passive range-of-motion exercises were initiated on postoperative day one. Non–weight-bearing was maintained for the first six weeks, followed by gradual progression to partial weight-bearing until 12 weeks. Full weight-bearing was permitted thereafter based on radiographic evidence of healing.

Statistical Analysis

Categorical variables were reported as frequencies and percentages and compared using Pearson's chi-square test or Fisher's exact test. Continuous variables were expressed as mean ± standard deviation (SD) for normally distributed data or as median with interquartile range (Q1–Q3) for non-normally distributed data. Normality was assessed using the Shapiro–Wilk test, and homogeneity of variance was evaluated using Levene's test. Between-group comparisons were performed using the independent samples t-test for parametric data and the Mann–Whitney U test for nonparametric data.

To partially address the lack of randomization, baseline demographic and injury characteristics were first compared between the groups and were confirmed not to differ significantly (Table 1). Interobserver reliability was assessed using the intraclass correlation coefficient (ICC) based on a two-way mixed-effects, absolute-agreement model. A p-value <0.05 was considered statistically significant. Statistical analyses were performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). No a priori power analysis was conducted because the sample size was determined by the number of eligible cases available during the study period.

RESULTS

Demographic and Clinical Characteristics

A total of 94 patients were included in the analysis (autograft group, n=42; TCP group, n=52). There were no significant differences between the groups in baseline characteristics: age, median (interquartile range [IQR]) 47.5 (34–57) vs. 48 (39–58) years (p=0.319); male sex, 71.5% vs. 57.7% (p=0.168); fall-related injuries, 76.2% vs. 73.0% (p=0.731); and Schatz-

Table 2. Radiological parameters of the two groups

	Autograft group	TCP group	p-value
n	42	52	
Preoperative depression (mm), median (Q1–Q3)	8.05 (6.83–9.35)	8.25 (6.70–9.70)	U=1128.5 p=0.784*
Last follow-up depression (mm), median (Q1–Q3)	2.1 (0.0–2.6)	2.5 (1.68–3.75)	U=771.5 p=0.014*
Preoperative Rasmussen Radiological Score, median (Q1–Q3)	10 (10–12)	12 (10–12)	U=0.990
Excellent, n (%)	0 (0)	0 (0)	p=0.398*
Good, n (%)	20 (48)	26 (50)	χ^2=0.053
Fair, n (%)	21 (50)	24 (46)	p=0.818#
Poor, n (%)	1 (2)	2 (4)	
Postoperative Rasmussen Radiological Score, median (Q1–Q3)	18 (16–18)	18 (16–18)	U=1221
Excellent, n (%)	30 (72)	35 (67)	p=0.237*
Good, n (%)	12 (28)	17 (33)	χ^2=0.192
Fair, n (%)	0 (0)	0 (0)	p=0.661#
Poor, n (%)	0 (0)	0 (0)	
Last follow-up Rasmussen Radiological Score, median (Q1–Q3)	16 (16–18)	16 (14–16)	U=1453.5
Excellent, n (%)	17 (40.5)	11 (21)	p=0.0021*
Good, n (%)	25 (59.5)	41 (79)	χ^2=4.15
Fair, n (%)	0 (0)	0 (0)	p=0.042#
Poor, n (%)	0 (0)	0 (0)	

*The Mann–Whitney U test was used to compare articular depression (preoperative and final follow-up) and modified Rasmussen Radiological Scores (preoperative, postoperative, and final follow-up) between the groups. #Group differences in the modified Rasmussen Radiological Score categories were assessed using Pearson's chi-square test. TCP: Tricalcium phosphate.

ker type II fractures, 80.1% vs. 78.8% (p=0.800). The median follow-up duration was also comparable between the groups: 79.5 (64.5–87.7) vs. 70.0 (65.5–78.2) months (p=0.099) (Table 1).

Radiological Outcomes

Interobserver agreement for radiological measurements was excellent, with ICC values ranging from 0.955 to 0.972. Both groups achieved satisfactory initial correction of articular depression. Preoperative articular depression was comparable between the groups (autograft: 8.05 [6.83–9.35] mm vs. TCP: 8.25 [6.70–9.70] mm; U=1128.5, p=0.784). At final follow-up, depression was smaller in the autograft group (2.10 [0.00–2.60] mm) than in the TCP group (2.50 [1.68–3.75] mm; U=771.5, p=0.014), indicating better maintenance of reduction. Preoperative and immediate postoperative modified Rasmussen Radiological Scores did not differ between groups (preoperative: 10 [10–12] vs. 12 [10–12], U=0.990, p=0.398; postoperative: 18 [16–18] vs. 18 [16–18], U=1221, p=0.237). However, at the final follow-up, the autograft group demonstrated higher radiological scores than the TCP group (16 [16–18] vs. 16 [14–16]; U=1453.5, p=0.002). Similarly, RRS category distributions were comparable between groups preoperatively (good: 47.6% vs. 50.0%; χ^2=0.053, p=0.818) and postoperatively (excellent: 71.4% vs. 67.3%; χ^2=0.192, p=0.661). At the final follow-up, however, the autograft group demonstrated a higher proportion of excellent outcomes compared to the TCP group (40.5% vs. 21.2%; χ^2=4.15, p=0.042) (Table 2).

Functional Outcomes

At final follow-up, functional outcomes were comparable between the groups. The modified Rasmussen Functional Score was 27 (IQR 26–28) in the autograft group and 26 (26–28) in the TCP group (U=1285, p=0.136). The Lysholm Knee Score was 86 (81–90) in both groups (U=1271.5, p=0.159). Similarly, categorical RFS distributions did not differ significantly between the groups: excellent outcomes were observed in 31 of 42 patients (73.8%) and good outcomes in 11 of 42 patients (26.2%) in the autograft group, compared with excellent outcomes in 30 of 52 patients (57.7%) and good outcomes in 22 of 52 patients (42.3%) in the TCP group (χ^2(1)=2.64, p=0.104). No patients were classified as fair or poor (Table 3).

Superficial surgical-site infection occurred in two patients

Table 3. Functional outcomes at final follow-up

	Autograft group	TCP group	p-value
n	42	52	
Rasmussen Functional Score, median (Q1–Q3)	27 (26–28)	26 (26–28)	U=1285
			p=0.136**
Excellent, n (%)	31 (74)	30 (58)	
Good, n (%)	11 (26)	22 (42)	χ^2=2.64
Fair, n (%)	0 (0)	0 (0)	p=0.168#
Poor, n (%)	0 (0)	0 (0)	
Lysholm Knee Score, median (Q1–Q3)	86 (81–90)	86 (81–90)	U=1271.5
			p=0.159*

*The Mann–Whitney U test was used to compare functional scores between groups. #Pearson's chi-square test was used to compare modified Rasmussen Functional Score categories between the groups. TCP: Tricalcium phosphate.

(4.7%) in the autograft group and three patients (5.7%) in the TCP group (p=1.000); all cases were successfully treated with oral antibiotics and routine wound care. No deep infections were observed in either group. Donor-site morbidity occurred in two patients (4.7%) in the autograft group, whereas no graft-related complications were recorded in the TCP group. No cases of nonunion were identified in the entire series.

DISCUSSION

In this retrospective comparative study of 94 patients with Schatzker type II–III tibial plateau fractures with articular depression, autologous iliac crest bone grafting (AICBG) demonstrated superior radiological maintenance of reduction (reflected by smaller residual depression and higher final RRS) compared with tricalcium phosphate. However, functional outcomes, including RFS and Lysholm scores, were comparable between the groups at mid-term follow-up. These findings suggest that, in this clinical setting, autograft may provide more durable metaphyseal support than β-TCP without conferring a measurable functional advantage.

High-level evidence from randomized trials and meta-analyses indicates that several modern bone substitutes can provide structural support comparable to that of autograft in tibial plateau fractures. Russell et al.[14] randomized 120 unstable fractures (Schatzker types I–VI) to treatment with autogenous iliac crest graft or endothermic calcium-phosphate cement and reported significantly lower rates of ≥2 mm articular subsidence at 3 and 12 months in the cement group, with similar clinical outcomes and complication rates between the groups. A recent systematic review and meta-analysis including seven randomized controlled trials likewise found no overall differences in joint depression or secondary collapse, while bone substitutes offered procedural advantages such as reduced blood loss and shorter operative time.[15] Similarly, Cooper et al.[4] pooled data from six randomized trials and reported non-significant trends toward better maintenance of reduction with synthetic grafts, along with significantly lower mean blood loss (≈90 mL) and shorter operative time (≈16 minutes) compared with autograft. In the CERTiFy (CERAMENT™ Bone Void Filler in Tibial Plateau Fractures) multicenter randomized controlled trial, a biphasic hydroxyapatite/calcium-sulfate cement was found to be noninferior to autograft with respect to the 26-week 12-Item Short Form Survey physical component summary and visual analog scale pain scores, with no significant differences in fracture healing, defect remodeling, or articular subsidence.[16] Taken together, these findings suggest that certain calcium phosphate-based and other synthetic constructs can match, or in some cases slightly outperform, autograft in selected fracture patterns, particularly in the short term.

In contrast, in our cohort with longer follow-up, a clear between-group difference in radiological outcomes emerged at final evaluation in favor of autograft, despite similar functional scores. This apparent discrepancy may partly be explained by differences in fracture patterns, graft formulations, and duration of follow-up. For example, Russell et al.[14] included higher-energy patterns (Schatzker types IV–VI) and used a calcium phosphate cement rather than pure β-TCP, while most randomized trials included in the meta-analysis evaluated heterogeneous substitutes such as bioactive glass, titanium granules, and various calcium phosphate cements, with follow-up typically limited to one to two years.[14] In contrast, the median follow-up in our study was approximately six years with β-TCP, which may better capture the later phases of graft resorption and load transfer under physiological conditions.

Longer-term observational studies support the notion that substitute-specific resorption behavior and durability influence metaphyseal support. Hanke et al. reported that, 9–12 years after surgery, a brushite/β-TCP composite had largely

resorbed homogeneously, whereas a hydroxyapatite-containing product remained radiographically visible; however, both constructs maintained reduction, and loss of reduction >2 mm was uncommon.[17] These observations are broadly consistent with our finding that TCP provided satisfactory early reduction but was associated with slightly greater residual depression at mid-term follow-up compared to autograft, suggesting that both the mechanical properties and resorption kinetics of individual products are clinically relevant.

Results comparing biologic grafts also show variability. In a comparative series, autograft and allograft yielded similar Rasmussen radiological scores and clinical outcome categories after tibial plateau fixation, with no significant differences between groups.[3] Systematic and narrative reviews likewise noted that, although autograft remains the "gold standard," its limitations, including limited volume and donor-site morbidity, often motivate the use of allografts or synthetic substitutes when biological properties or quantity are constrained.[4]

Our finding of superior radiological outcomes but not superior mid-term functional outcomes parallels the mixed correlation between clinical–functional and radiological Rasmussen scores reported in a 2023 cohort.[13] In that study, score categories differed in 66% of cases, and the authors emphasized the limited concordance between these dimensions in tibial plateau fractures. Accordingly, modest residual depression may not necessarily translate into clinically meaningful limitations when alignment is restored and rehabilitation is standardized.

Beyond graft selection, smoking and high body mass index (BMI) have been associated with greater postoperative articular depression and poorer clinical outcomes. A recent retrospective study of Schatzker type II–III fractures reported similar short-term clinical and radiographic outcomes between autograft and tricalcium phosphate, but significantly greater articular depression in smokers and in patients with BMI >30 kg/m². Lower Lysholm scores were also observed among patients who developed depression. The authors attributed these findings to impaired biology associated with smoking and increased mechanical loading associated with obesity.[11] These observations support our interpretation that patient-related risk factors may influence metaphyseal support over time, regardless of the graft material used.

This study has several limitations. First, its retrospective design and nonrandomized allocation of graft type introduce a risk of selection bias and residual confounding. Although baseline demographic and injury characteristics were comparable between groups, unmeasured variables such as body mass index, smoking status, and bone quality may have influenced both graft selection and outcomes. Second, we did not perform CT-based three-dimensional measurements or include additional patient-reported outcome measures beyond the Lysholm score, which might have provided a more comprehensive evaluation of articular reduction and functional status. Therefore, the present findings should be interpreted as level III evidence and regarded as hypothesis-generating; confirmation in prospective randomized studies is warranted.

When durable metaphyseal support is the primary goal in depressed Schatzker type II–III fractures, our findings support autologous iliac crest bone grafting as a preferred option for maintaining radiographic reduction, while acknowledging its small risk of donor-site morbidity. Tricalcium phosphate remains a reasonable alternative when avoidance of iliac crest harvesting is desirable, with the understanding that long-term subsidence may be slightly greater, even if mid-term functional outcomes are comparable, in line with previous randomized and observational studies.[12,17] Future product-specific trials comparing contemporary tricalcium phosphate formulations (varying in porosity, granule size, and adjunctive augmentation) with autograft are needed. Such studies should incorporate CT-based articular measurements, validated patient-reported outcome measures, and appropriate adjustment for factors such as smoking and body mass index. Additionally, they should build on the methodological rigor of prior randomized controlled trials that have evaluated both radiographic and patient-reported endpoints.

CONCLUSION

In patients with Schatzker type II–III tibial plateau fractures with articular depression, autologous iliac crest bone grafting appeared to provide more durable radiological maintenance of reduction, reflected by higher final Rasmussen Radiological Scores, whereas mid-term functional outcomes were comparable between groups. These findings suggest that autologous iliac crest bone grafting remains a reliable option for structural support in metaphyseal defects. However, the results should be interpreted as hypothesis-generating, and prospective randomized comparative studies are needed to confirm any potential advantage over tricalcium phosphate.

Ethics Committee Approval: This study was approved by the Medical Research Ethics Committee of University of Health Sciences, İzmir Bozyaka Training and Research Hospital (Date: 14.06.2023, Decision No: 2023/81).

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Eklem yüzeyinde çökmesi olan tibia plato kırıklarında otolog kemik greftlemesi, trikalsiyum fosfat sentetik greften daha üstün mü?

AMAÇ: Bu çalışma, eklem yüzeyinde çökmesi olan tibia plato kırıklarının (TPK) tedavisinde otolog iliak kemik grefti ile trikalsiyum fosfat (TCP) sentetik greft kullanımının radyolojik ve fonksiyonel sonuçlarını karşılaştırmayı amaçladı.

GEREÇ VE YÖNTEM: Retrospektif karşılaştırmalı bu çalışmada, Ocak 2015-Haziran 2022 tarihleri arasında metafizer çökmeli Schatzker tip 2–3 tibia plato kırığı nedeniyle cerrahi tedavi uygulanmış 94 hasta analiz edildi. Hastalar kullanılan greft materyaline göre iki gruba ayrıldı: otolog iliak kemik grefti (n=42) ve trikalsiyum fosfat (TCP) sentetik greft (n=52). Radyolojik değerlendirmede eklem yüzeyindeki çökme (mm) ve modifiye Rasmussen Radyolojik Skoru (RRS) preoperatif, postoperatif ve nihai kontrolde (≥36 ay) ölçüldü. Fonksiyonel sonuçlar Lysholm diz skoru ve modifiye Rasmussen Fonksiyonel Skoru (RFS) ile değerlendirildi. Minimum takip süresi 36 ay idi.

BULGULAR: Her iki grupta da başlangıçta eklem yüzeyi çökmesinin düzeltilmesi tatmin ediciydi. Nihai kontrolde rezidüel çökme, TCP grubuna kıyasla otogreft grubunda daha küçüktü (2.10 [0.00–2.60] mm vs 2,50 [1,68–3,75] mm; U=771,5, p=0,014); bu durum redüksiyonun daha kalıcı biçimde korunmasıyla uyumluydu. RRS preoperatif ve erken postoperatif dönemde benzer iken, nihai kontrolde otogreft grubunda daha yüksekti (16 [16–18] vs 16 [14–16]; U=1453.5, p=0.002). Kategori dağılımları da uyumluydu: nihai kontrolde mükemmel RRS oranı otogreft grubunda daha fazlaydı (%40.5 vs %21,2; $\chi^2(1)=4.15$, p=0.042). Fonksiyonel sonuçlar gruplar arasında karşılaştırılabilirdi (RFS 27 [26–28] vs 26 [26–28]; U=1285, p=0.136; Lysholm 86 [81–90] vs 86 [81–90]; U=1271.5, p=0.159). Donör saha morbiditesi otogreft grubunda hastaların %4.7'sinde görüldü; TCP grubunda greftle ilişkili komplikasyon izlenmedi.

SONUÇ: Eklem yüzeyinde çökmesi olan Schatzker tip 2–3 TPK olgularında otolog iliak krista kemik grefti kullanımı, TCP'ye kıyasla redüksiyonun radyolojik olarak daha iyi korunması ve daha yüksek nihai RRS ile ilişkili bulunurken, orta dönem fonksiyonel skorlar benzerdir. Bu Düzey III veriler, otogreftin metafizer defektlerde yapısal destek için güvenilir bir seçenek olmaya devam ettiğini düşündürmektedir; ancak TCP'ye göre olası üstünlüğünü doğrulamak için prospektif randomize karşılaştırmalı çalışmalara ihtiyaç vardır.

Anahtar sözcükler: Fonksiyonel sonuç; otogreft; redüksiyon kaybı; tibia plato kırığı; trikalsiyum fosfat sentetik greft.

Ulus Travma Acil Cerrahi Derg 2026;32(5):602-609 DOI: 10.14744/tjtes.2026.23622

ORIGINAL ARTICLE

Clinical and radiological outcomes of callus preservation versus excision in gunshot-related distal humerus fractures

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ABSTRACT

BACKGROUND: High-energy gunshot injuries to the distal humerus frequently result in extensive comminution, severe soft-tissue damage, and contamination, making definitive fixation both technically demanding and biologically challenging. During staged management with temporary stabilization, extra-articular callus formation may occur prior to definitive fixation, potentially influencing the surgical decision to preserve or excise this tissue. This study aimed to evaluate the clinical and radiological outcomes of a fixation strategy that preserves extra-articular callus in high-energy distal humerus fractures caused by gunshot injuries.

METHODS: This retrospective study included 21 male patients with Gustilo–Anderson type IIIA distal humerus fractures caused by high-velocity gunshot injuries, treated between 2016 and 2024. All patients initially underwent temporary stabilization followed by definitive fixation. Patients were stratified according to whether the extra-articular callus tissue was preserved (n=9) or excised (n=12) during surgery. Functional outcomes were assessed using the Disabilities of the Arm, Shoulder and Hand (DASH) score and the Mayo Elbow Performance Index (MEPI), and radiographic union time was recorded.

RESULTS: The mean patient age was 28 years (range, 22–43). According to the AO/OTA (Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association) classification system, 81% of fractures were type 13C3. Nerve injury was present in five patients (23.8%), and heterotopic ossification developed in five patients (23.8%). No significant intergroup differences were observed in DASH scores, MEPI scores, range of motion, or infection rates (all p>0.05). However, union time was significantly shorter in the callus-preserved group compared with the excision group (18.0±3.1 vs. 23.5±3.3 weeks, p=0.004). Nerve injury (p=0.043) and heterotopic ossification (p=0.025) were associated with higher DASH scores, indicating poorer functional outcomes.

CONCLUSION: A callus-preserving fixation approach may offer a biological advantage in the management of high-energy distal humerus gunshot fractures by promoting earlier bone healing without compromising functional outcomes. When extra-articular callus does not interfere with anatomical reduction, preserving it in situ may be considered as part of a staged damage-control–to–definitive fixation strategy.

Keywords: Callus protection; distal humerus fracture; gunshot injury.

INTRODUCTION

Distal humerus fractures account for approximately 2% of all fractures and one-third of all humeral fractures.[1] Various surgical techniques have been described for their management.[2,3] Open reduction and internal fixation (ORIF) is widely considered the standard treatment for these injuries. Although ORIF facilitates early mobilization and helps prevent joint stiffness, open distal humerus fractures are associated with a high risk of postoperative infection.[4]

Fractures resulting from high-energy gunshot injuries are typically classified as type III according to the Gustilo–Anderson classification.[5] Type III open fractures around the elbow represent some of the most challenging injuries to manage, and

Cite this article as: Basak AM, Aydilek A. Clinical and radiological outcomes of callus preservation versus excision in gunshot-related distal humerus fractures. Ulus Travma Acil Cerrahi Derg 2026;32:610-617.

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Ulus Travma Acil Cerrahi Derg 2026;32(5):610-617 DOI: 10.14744/tjtes.2026.96533

Submitted: 03.01.2026 Revised: 15.03.2026 Accepted: 01.04.2026 Published: 05.05.2026

achieving full functional recovery is often difficult even with appropriate reduction. In addition, these injuries impose substantial economic, psychological, and social burdens on patients. The high kinetic energy and ballistic effects of gunshot trauma further contribute to complex fracture patterns in this region.[6]

Gunshot injuries often produce fracture morphologies that do not conform to conventional classification systems, and no universally accepted treatment protocol exists. Furthermore, patients may present with concomitant injuries, such as internal organ damage or traumatic brain injury. The literature on the management of complex distal humerus fractures caused by gunshot injuries in patients with associated systemic trauma is limited.[7,8] In this study, we aimed to compare the clinical and radiological outcomes of patients with high-energy gunshot-induced distal humerus fractures who underwent definitive fixation either with preservation or excision of extra-articular callus tissue formed proximal to the fracture. All patients had initially been managed with temporary stabilization, either external fixation or splinting, due to prolonged intensive care requirements.

MATERIALS AND METHODS

Study Design and Patient Selection

This retrospective study was conducted at a Level I trauma center that routinely receives referrals for high-energy firearm-related injuries. Patients who sustained distal humerus fractures due to high-velocity gunshot wounds between 2016 and 2024 were included. To minimize potential confounding effects on functional and radiological outcomes, patients with additional fractures in the same limb, those requiring soft-tissue reconstruction with flap or graft coverage, and those with concomitant vascular injuries were excluded. One patient who died during intensive care follow-up was also excluded, resulting in a final study population of 21 patients.

Initial management was performed at referring Level II or III trauma centers and included wound debridement and temporary stabilization using either external fixation or long-arm splinting (Fig. 1). Upon referral, patients were admitted to the intensive care unit due to associated systemic injuries, such as head trauma or internal organ injury. Open fractures were classified according to the Gustilo–Anderson classification, and fracture morphology was categorized using the AO/OTA (Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association) classification system. Preoperative computed tomography (CT) angiography was performed in all patients to assess for potential vascular injuries. Intravenous antibiotic prophylaxis consisting of ceftriaxone, amikacin, and metronidazole was initiated preoperatively and continued for five days.

Data regarding head trauma were obtained from cranial CT scans performed at the referring institutions. Two patients had radial nerve injuries, and one patient had an ulnar nerve injury. During intensive care follow-up, debridement was performed once in four patients and twice in three patients. Primary wound closure was achieved in all cases, and none of the patients required vacuum-assisted closure therapy. This study was approved by the Gülhane Training and Research Hospital Clinical Research Ethics Committee (Date: 25.11.2025, Decision No: 2025-555), and all procedures were conducted in accordance with the principles of the Declaration of Helsinki.

Implants and Surgical Technique

A posterior surgical approach was used in all patients for the treatment of distal humerus fractures. An olecranon osteotomy was performed to provide adequate exposure of the distal humerus and the articular surface. The osteotomy was fixed using tension band wiring, cerclage wiring, or cannulated screw fixation, according to intraoperative preference.

Intra-articular callus tissue was excised in all patients to facilitate anatomical reduction of the joint surface, and the articular fragments were stabilized using headless compression screws. The decision to preserve or excise extra-articular callus was made intraoperatively based on whether it interfered with anatomical reduction or fracture alignment.

To restore mechanical stability, dual locking plates were applied medially and laterally (Fig. 2). Early postoperative elbow range-of-motion exercises were initiated once adequate pain control and wound stability were achieved.

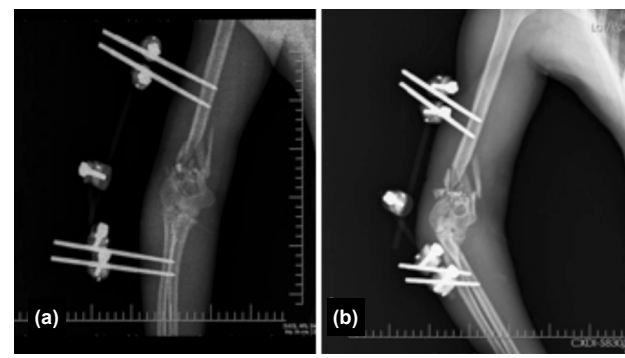

Figure 1. Temporary external fixation used as initial damage-control stabilization for a high-energy open distal humerus fracture caused by a gunshot injury.

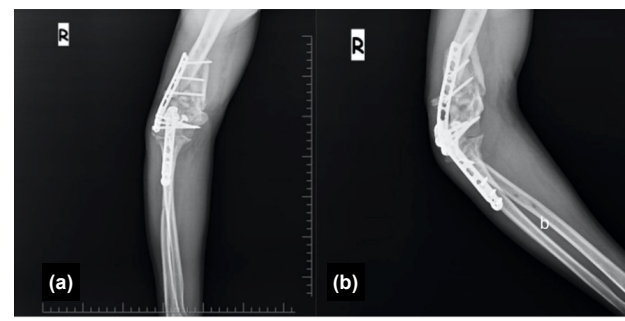

Figure 2. Postoperative anteroposterior **(a)** and lateral **(b)** radiographs demonstrating dual-plate fixation of a distal humerus fracture with preservation of extra-articular callus.

Radiographic and Clinical Evaluation

Standard anteroposterior and lateral radiographs of the elbow were obtained on admission, weekly during the intensive care unit stay, on postoperative day 15, and monthly thereafter throughout the follow-up period. In addition, elbow and cranial CT scans were performed at initial admission. Radiological bone union times were systematically recorded.

Complete union was defined clinically as the absence of tenderness at the fracture site and radiologically as the presence of callus formation in at least three of four cortices. Radiographic signs of post-traumatic arthritis, myositis ossificans, and heterotopic ossification were also evaluated and documented during follow-up.

All clinical and radiological evaluations were performed by a single independent orthopedic surgeon. Functional and clinical assessments were conducted at a minimum follow-up of one year. Elbow range of motion, including flexion, extension, supination, and pronation, was measured. Functional outcomes were assessed using the Disabilities of the Arm, Shoulder and Hand (DASH) score and the Mayo Elbow Performance Index (MEPI).[9,10]

Statistical Analysis

Descriptive statistics are presented as mean ± standard deviation or median (range) for continuous variables, and as frequency (percentage) for categorical variables. The Shapiro–Wilk test was used to assess the normality of data distribution. Between-group comparisons were performed using the Mann–Whitney U test for continuous variables and the chi-square or Fisher's exact test for categorical variables, as appropriate. Associations between DASH scores and continuous variables were evaluated using Spearman's rank correlation coefficient. Multivariate linear regression analysis was conducted to identify independent predictors of DASH scores. All analyses were performed using SPSS software (version 20.0; IBM Corp., Armonk, NY, USA), with statistical significance set at $p<0.05$.

Table 1. Demographic and clinical characteristics of the patients

n=21	Mean±SD Median (Min-Max)
Age (years)	28.81±4.47
	28 (22-43)
Elbow flexion (°)	91.52±8.64
	93 (60-110)
Elbow extension loss (°)	6.48±3.86
	7 (0-20)
Pronation (°)	62.19±5.38
	62 (52-75)
Supination (°)	66.95±8.29
	67 (51-81)
DASH score	38.86±14.11
	35 (20-68)
MEPI score	76.33±13.47
	78 (50-95)
Follow-up (months)	51.62±24.19
	43 (13-84)
Time to union (weeks)	21.1±4.2
	21.1 (13.4-27.4)

RESULTS

A total of 21 male patients were included, with a mean age of 28 years (range, 22–43). Right-sided elbow involvement was observed in nine patients, and left-sided involvement in

Table 2. Distribution of clinical and radiological variables

	n	%
Head trauma		
No	14	66.7
Yes	7	33.3
Associated injury		
No	14	66.7
Yes	7	33.3
HO		
No	16	76.2
Yes	5	23.8
Infection		
No	17	81.0
Yes	4	19.0
Nerve injury		
None	16	76.2
Radial	3	14.3
Ulnar	2	9.5
AO type		
13C2	4	19.0
13C3	17	81.0
Stabilization		
Splint	13	61.9
EF	8	38.1
Injury side		
Right	12	57.1
Left	9	42.9
Callus excision		
No (preserved)	9	42.9
Yes (excised)	12	57.1

Table 3. Comparison of patient characteristics according to callus management

	Callus preserved (n=9)	Callus excised (n=12)	
	Mean±SD Median (Min-Max)	Mean±SD Median (Min-Max)	p value
Age (years)	28.89±2.42	28.75±5.67	
	28 (26-33)	28.5 (22-43)	0.808[b]
Elbow flexion (°)	95.11±2.47	91.08±11.44	
	93 (87-95)	93.5 (60-110)	0.754[b]
Elbow extension loss (°)	5.67±2.23	7.08±4.75	
	6 (1-8)	7 (0-20)	0.508[b]
Pronation (°)	60.89±4.85	63.17±5.75	
	62 (52-66)	62 (54-75)	0.554[b]
Supination (°)	67.78±6.49	66.33±9.67	
	68 (60-81)	65.5 (51-81)	0.702[b]
DASH score	43.11±15.14	35.67±13.06	
	36 (28-68)	32.5 (20-65)	0.199[b]
MEPI score	72.44±14.08	76.73±12.03	
	79 (50-95)	75.5 (63-90)	0.915[b]
Time to union (weeks)	18.03±3.1	23.5±3.3	
	18.0 (13.1-22.1)	22.0 (17.7-27.4)	**0.004[b]**
Follow-up (months)	59.00±26.13	46.08±22.12	
	72 (16-84)	43 (13-82)	0.277[b]

[b]Mann–Whitney U test; DASH: Disabilities of the arm, shoulder and hand.

12. The mean follow-up duration was 51.6 months. According to the AO/OTA classification, 14 fractures were classified as type 13C3 and seven as type 13C2. All injuries were Gustilo–Anderson type IIIA open fractures. Five patients sustained concomitant fractures in other extremities, and seven patients had associated head trauma. Initial temporary stabilization was achieved with a long-arm splint in 13 patients and an external fixator in eight patients. The mean DASH score was 38.9±6.3 (Table 1).

The distribution of clinical and radiological variables is summarized in Table 2. Of the 21 patients, seven (33.3%) had concomitant head trauma and seven (33.3%) had additional musculoskeletal injuries. Heterotopic ossification was observed in five patients (23.8%), and postoperative infection occurred in four patients (19.0%). Nerve injury was present in five patients (three radial, two ulnar). Most fractures were classified as AO type 13C3 (81.0%). Initial stabilization was performed using a splint in 13 cases (61.9%) and an external fixator in eight (38.1%) (Table 2).

Patients were stratified into two cohorts based on whether the extra-articular callus tissue was debrided intraoperatively: Group 1 (callus preserved, n=9) and Group 2 (callus excised, n=12). Intergroup comparisons revealed no statistically significant differences in age, final range of motion, MEPI, or DASH scores (all p>0.05). However, the mean radiographic time to union was significantly longer in the callus-excised group compared with the callus-preserved group (23.5±3.3 vs. 18.0±3.1 weeks, p=0.004) (Table 3).

When DASH scores were analyzed according to clinical and radiological variables, no statistically significant differences were found with respect to the presence of head trauma, associated injuries, infection, or method of initial stabilization (splint vs. external fixator) (all p>0.05). In contrast, patients with peripheral nerve injury and those who developed heterotopic ossification had significantly higher DASH scores, indicating worse functional outcomes (p=0.043 and p=0.025, respectively) (Table 4).

DISCUSSION

Open distal humerus fractures resulting from gunshot injuries are rare and difficult to manage. Treatment typically follows a staged approach, beginning with aggressive debridement and temporary stabilization, followed by definitive fixation once soft-tissue conditions permit. In high-energy gunshot-related

Table 4. Comparison of Disabilities of the Arm, Shoulder and Hand (DASH) scores according to clinical and radiological variables

	n	Mean±SD	Median (Min-Max)	p
Head trauma				
No	14	36.93±14.91	32 (20-68)	0.287[b]
Yes	7	42.71±12.48	44 (27-60)	
Nerve injury				
No	15	30.53±11.48	30 (20-54)	**0.043**[b]
Yes	6	61.57±6.21	62 (52-68)	
HO				
No	16	33.00±9.65	30 (20-60)	**0.025**[b]
Yes	5	57.60±8.38	54 (49-68)	
Infection				
No	17	38.00±13.56	35 (20-65)	0.574[b]
Yes	4	42.50±17.99	38 (26-68)	
Stabilization				
Splint	13	40.00±14.30	38 (23-68)	0.697[b]
EF	8	37.00±14.55	32 (20-65)	

[b]Mann–Whitney U test; DASH: Disabilities of the arm, shoulder and hand.

open fractures, management priorities include preservation of life, limb salvage, infection prevention, and restoration of extremity function.[11] The primary objective of surgical fixation in complex distal humerus fractures is anatomical reconstruction of the articular surface and stable fixation of the distal humerus to both the medial and lateral columns.[12] Because these injuries are both open and intra-articular, elbow range of motion is often significantly compromised. In the present study, all fractures were classified as type 13C according to the AO classification. Jupiter and Morrey reported that even relatively minor elbow trauma may result in joint stiffness due to capsular fibrosis.[13]

Despite the high rate of bone and soft-tissue complications associated with these open injuries, McKee et al.[14] reported generally favorable functional outcomes, including general health, limb-specific, surgeon-based, and radiological measures. In contrast, Min et al.[15] found that open distal humerus fractures were associated with poorer functional outcomes and reduced range of motion compared with closed fractures. Patients with open injuries also demonstrated a trend toward higher complication rates and longer times to union.

Given the relatively young age of these patients, functional expectations are typically high, which may influence postoperative satisfaction. Because we perform definitive joint reconstruction following temporary external fixation and initiate early mobilization, near-complete restoration of elbow range of motion can be achieved. In addition to fracture- and surgery-related factors, soft-tissue complications appear to play a critical role in functional recovery. In the present study, peripheral nerve injury and heterotopic ossification were associated with significantly higher DASH scores, underscoring their negative impact on long-term upper-extremity function. These findings highlight the importance of meticulous intraoperative nerve exploration and protection, as well as consideration of strategies to minimize heterotopic ossification, particularly in young, high-demand patients requiring rapid functional recovery.

None of the patients in our series developed a major joint contracture. Gerardet et al.[16] reported satisfactory to excellent outcomes in up to 90% of intra-articular distal humerus fractures when anatomical reduction, stable fixation, and early initiation of active elbow motion were achieved.

MEPI scores did not differ significantly between groups. This finding suggests that, although callus preservation may facilitate biologically accelerated bone healing, this advantage was not reflected in elbow-specific performance outcomes within the available follow-up period. As the MEPI score is largely influenced by pain and range of motion, it may be less sensitive than the DASH score in detecting subtle functional impairment in young, high-demand patients.

The aim of this surgical technique is to achieve stable fixation by securing the plate to the callus at the fracture margins without extensive soft-tissue dissection, thereby preserving extra-articular callus. The articular surface is reconstructed using headless screws, followed by early postoperative mobilization once adequate pain control and wound stability are achieved.

In open distal humerus fractures, early definitive fixation is often challenging due to the increased risk of infection and soft-tissue complications. ORIF should be avoided in the presence of contamination or active infection at the fracture site.[16] Chapman and Mahoney reviewed the use of primary internal fixation in open fractures and reported high rates of bone and soft-tissue infection.[17]

Dragon et al.[18] compared damage-control surgery with early surgical treatment and found no significant differences in clinical outcomes or infection rates. In the present study, all cases were classified as Gustilo–Anderson type III open fractures and were considered contaminated, as they resulted from high-energy gunshot injuries. One patient developed a superficial infection, which was successfully treated with early debridement and appropriate antibiotic therapy, resulting in resolution of clinical signs and wound discharge. External fixation (EF) is another treatment method for open fractures. Kömürcü et al.[6] applied the Ilizarov technique to intra-articular distal humerus fractures caused by gunshot injuries in a series of 20 patients, reporting pin-site infections in three patients and deep infection in one. In a retrospective study of 18 patients, Mostafavi et al.[19] used a unilateral external fixator followed by a definitive treatment and reported pin-site infections in eight patients. They also noted that 70% of patients achieved good or excellent functional elbow scores. Because union tends to take longer in open fractures, complications such as pin-site infection and pin loosening may occur with external fixators, including the Ilizarov system. However, in our study, EF was used as a temporary rather than definitive treatment, and no pin-site infections were observed.

The concept of preserving extra-articular callus is biologically meaningful, as callus represents a highly vascular and metabolically active reparative tissue that provides osteogenic cells, cytokines, and an early scaffold for bridging the defect and promoting peripheral bone healing. Removal of this tissue may disrupt early biological continuity, create a secondary bone defect, and prolong the time required for cortical bridging. Previous studies on open fractures have primarily focused on the need for grafting in the presence of bone loss rather than on callus preservation. However, Min et al.[20] reported that staged fixation of open distal humerus fractures was associated with prolonged union times and occasional need for bone grafting. In contrast, our findings demonstrated shorter union times without grafting when callus was preserved, suggesting that, when extra-articular callus does not compromise reduction or joint congruency, it may serve as a biological enhancer of early fracture consolidation, particularly in high-energy periarticular injuries.

Open distal humerus fractures are typically caused by high-energy mechanisms and are often associated with additional musculoskeletal or systemic injuries. Brain trauma has been reported to accelerate fracture healing.[21] Following injury, the brain initiates complex cellular and molecular responses, including immune-inflammatory processes involving cytokines, growth factors, and other biomolecules,[22] which may contribute to both local and/or systemic tissue repair, including bone healing. Yang et al.[23] demonstrated that brain injury accelerated fracture union and increased callus formation. In our series, nine patients had associated brain trauma; however, when patients were grouped based on the presence or absence of brain injury, no significant difference in union time was observed ($p=0.08$).

Previous studies have shown that bone defects may occur in third-degree open tibial fractures and open hand injuries, where bone grafting may be required.[24,25] However, grafting may result in donor-site morbidity, as well as increased cost and risk of infection when allografts are used. Therefore, when the fracture does not involve the joint, we believe that preservation of callus tissue is important and may contribute to reduced union time. Min et al.[20] divided patients who underwent definitive treatment for open distal humerus fractures into two groups: primary and staged. The mean union time in the primary group was 23.4 weeks, compared with 25.7 weeks in the staged group. Three patients also required bone grafting due to bone loss. In our study, the mean union time was 21.1 weeks, despite no use of grafting. The shorter union time observed in our study compared with previous reports may be attributed to preservation of extra-articular callus during fixation, as well as reduced soft tissue dissection, both of which likely facilitate faster bone healing. Conversely, removal of callus tissue may lead to bone loss and defect formation, potentially resulting in delayed union.

Limitations

This study has several limitations. First, its retrospective, single-center design limits the generalizability of the findings. Second, the small sample size reduces statistical power, particularly for subgroup analyses involving nerve injury and heterotopic ossification. Third, although predefined intraoperative criteria were applied, surgical decision-making inevitably involved some degree of surgeon judgment, which cannot be fully standardized. Finally, radiographic union was assessed using plain radiographs rather than CT, which may affect the precision of union-time assessment. Future prospective, multicenter studies are needed to validate the clinical utility of callus preservation and to establish standardized decision-making criteria.

CONCLUSION

The findings of this study suggest that preservation of extra-articular callus during definitive fixation of high-energy distal humerus fractures may provide additional biological support without compromising anatomical reduction. In complex firearm-related injuries, this approach may help maintain column stability while preserving the biological environment necessary for fracture healing. From a clinical standpoint, avoiding unnecessary callus excision may represent a reasonable surgical strategy in selected cases. However, further studies with

larger cohorts and longer follow-up durations are required to confirm these findings.

Ethics Committee Approval: This study was approved by the Gülhane Training and Research Hospital Clinical Research Ethics Committee (Date: 25.11.2025, Decision No: 2025-555).

Informed Consent: Written informed consent was obtained.

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Ateşli silah yaralanmalarına bağlı distal humerus kırıklarında kallus korunması ve eksizyonunun klinik ve radyolojik sonuçları

AMAÇ: Distal humerusu içeren yüksek enerjili ateşli silah yaralanmaları sıklıkla belirgin parçalanma, ciddi yumuşak doku hasarı ve kontaminasyon ile sonuçlanır ve bu durum definitif fiksasyonu hem teknik hem de biyolojik açıdan zorlaştırır. Geçici stabilizasyon ile uygulanan evreli tedavi sürecinde, definitif fiksasyon öncesinde ekstraartiküler kallus oluşumu gelişebilir ve bu durum söz konusu dokunun korunması veya eksize edilmesine ilişkin cerrahi karar sürecini etkileyebilir. Bu çalışmanın amacı, ateşli silah yaralanmalarına bağlı yüksek enerjili distal humerus kırıklarında ekstraartiküler kallusun korunmasına dayalı fiksasyon stratejisinin klinik ve radyolojik sonuçlarını değerlendirmektir.

GEREÇ VE YÖNTEM: Bu retrospektif çalışmaya 2016–2024 yılları arasında yüksek enerjili ateşli silah yaralanmasına bağlı Gustilo–Anderson tip IIIA distal humerus kırığı nedeniyle tedavi edilen 21 erkek hasta dahil edildi. Tüm hastalarda definitif fiksasyon öncesinde geçici stabilizasyon uygulanmıştır. Hastalar intraoperatif olarak ekstraartiküler kallus dokusunun korunmasına (n=9) veya eksize edilmesine (n=12) göre iki gruba ayrılmıştır. Fonksiyonel sonuçlar Disabilities of the Arm, Shoulder and Hand (DASH) ve Mayo Elbow Performance Index (MEPI) skorları ile değerlendirilmiş, radyolojik kaynama süreleri kaydedilmiştir.

BULGULAR: Hastaların ortalama yaşı 28 yıl (22-43) idi. AO/OTA sınıflamasına göre kırıkların %81'i 13C3 tipindeydi. Beş hastada (%23.8) periferik sinir yaralanması, beş hastada (%23.8) heterotopik ossifikasyon saptandı. Gruplar arasında DASH, MEPI, eklem hareket açıklığı veya enfeksiyon oranları açısından anlamlı fark bulunmadı (tüm p>0.05). Bununla birlikte kallusun korunduğu grupta kaynama süresi anlamlı olarak daha kısa bulundu (18.0±3.1 vs. 23.5±3.3 hafta, p=0.004). Periferik sinir yaralanması (p=0,043) ve heterotopik ossifikasyon (p=0.025) daha yüksek DASH skorları ile ilişkili bulunarak daha kötü fonksiyonel iyileşmeye işaret etti.

SONUÇ: Ekstraartiküler kallusun korunduğu fiksasyon yaklaşımı, yüksek enerjili ateşli silah yaralanmalarına bağlı distal humerus kırıklarının tedavisinde biyolojik avantaj sağlayabilir ve fonksiyonel sonuçları olumsuz etkilemeden daha erken kemik kaynamasına olanak tanıyabilir. Ekstraartiküler kallusun anatomik redüksiyonu engellemediği durumlarda, evreli hasar kontrolünden definitif fiksasyona uzanan tedavi stratejisinin bir parçası olarak yerinde korunması düşünülebilir.

Anahtar sözcükler: Ateşli silah yaralanması; distal humerus kırığı; kallus korunması.

Ulus Travma Acil Cerrahi Derg 2026;32(5):610-617 DOI: 10.14744/tjtes.2026.96533

CASE REPORT

Conservative management of gastroesophageal junction perforation secondary to eosinophilic esophagitis: a case report

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ABSTRACT

Eosinophilic esophagitis (EoE) is a chronic inflammatory disorder of the esophagus characterized by dysphagia and food impaction. Although uncommon, spontaneous esophageal perforation may occur, most frequently involving the distal esophagus and the gastroesophageal junction. These perforations are typically managed with surgical or endoscopic interventions. Early diagnosis and prompt initiation of treatment within the first 24 hours significantly reduce morbidity and mortality. The aim of this report is to demonstrate that gastroesophageal junction perforation secondary to eosinophilic esophagitis can be successfully managed conservatively, even in delayed presentations, and to contribute to the understanding of treatment strategies for this rare but potentially life-threatening complication. We report the case of a 35-year-old male with a 12-year history of EoE who presented to the emergency department with retrosternal pain, dyspnea, and hematemesis. Five days prior to presentation, he developed a sore throat and cherry-colored diarrhea after consuming grilled chicken and self-administered ibuprofen for symptom relief. Contrast-enhanced imaging and upper endoscopy revealed a perforation at the gastroesophageal junction. Due to the location of the lesion, endoscopic stenting or clipping was considered inappropriate. In the absence of signs of acute abdomen, mediastinitis, or significant fluid collection, a conservative management strategy was adopted. The patient was admitted to the intensive care unit and initially treated with intravenous ceftriaxone (2 g/day) and metronidazole (1.5 g/day), which were later changed to piperacillin–tazobactam (4.5 g every 6 hours) following infectious disease consultation. The patient remained clinically stable, and oral intake was initiated on day 6. Antibiotic therapy was discontinued on day 10, and the patient was discharged without complications. At the three-month follow-up, the patient reported recurrent and progressively worsening dysphagia. Control endoscopy performed at the previously visited center revealed a distal esophageal stricture preventing passage of the gastroscope; therefore, a 12-cm fully covered self-expandable esophageal stent was placed. The stent was removed 20 days later, and the patient remained asymptomatic during the subsequent six-month follow-up period. Spontaneous esophageal perforation secondary to EoE is a rare but potentially life-threatening complication. This case highlights that conservative management may be a viable alternative to surgical or endoscopic intervention not only in early-detected cases but also in carefully selected delayed presentations managed in a multidisciplinary setting. Long-term follow-up remains essential for the early detection and treatment of late complications, such as stricture formation.

Keywords: Conservative management; eosinophilic esophagitis; esophageal perforation; stricture.

Cite this article as: Esin H, Üreyen O, Şahin H, Özer Sarı S, Derviş Hakim G, İlhan E. Conservative management of gastroesophageal junction perforation secondary to eosinophilic esophagitis: a case report. Ulus Travma Acil Cerrahi Derg 2026;32:618-622.

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Ulus Travma Acil Cerrahi Derg 2026;32(5):618-622 DOI: 10.14744/tjtes.2026.99978
Submitted: 02.10.2025 Accepted: 12.01.2026 Published: 05.05.2026

INTRODUCTION

Eosinophilic esophagitis (EoE) is a chronic, immune-mediated esophageal disease characterized by symptoms of esophageal dysfunction and eosinophilic inflammation that persists despite acid suppression. It was first described in 1978, and its pathological features and phenotype were subsequently defined by Attwood et al.[1] in 1993 and Straumann et al.[2] in 1994.[1-3] In recent years, the incidence of EoE has increased markedly, and if left untreated, the disease may lead to significant complications.[4] Esophageal perforation (EP) is a life-threatening complication of EoE, occurring in approximately 2% of cases. Perforation most commonly develops as a result of food bolus impaction, esophageal obstruction, or strictures, with an increased risk observed in patients with fibrostenotic disease and prolonged symptom duration.[5] EP is associated with high morbidity and mortality rates; therefore, rapid diagnosis and appropriate treatment are of critical importance. Although no standardized management protocol currently exists, conservative approaches may be effective in cases with small and localized perforations.[6] In this case report, we present a patient with gastroesophageal junction perforation who was successfully managed using conservative treatment.

CASE REPORT

This study was conducted in accordance with the Declaration of Helsinki and was approved by Izmir City Hospital Non-Interventional Ethics Committee (Approval Number: 2025/69, Date: 13.02.2025). Written informed consent was obtained from the patient and his relatives.

A 35-year-old male patient had a 12-year history of dysphagia. An endoscopic biopsy performed previously at another hospital demonstrated eosinophilic infiltration of the esophageal mucosa (>20/hpf) and basal cell hyperplasia, leading to a diagnosis of distal EoE.[7] Approximately five days prior to presentation, the patient consumed grilled chicken, after which he developed a sore throat and dark-red, cherry-colored diarrhea. He self-administered ibuprofen for symptom relief. Two days before admission, he began experiencing persistent epigastric burning, which subsequently progressed to retrosternal pain and hematemesis. He presented to the emergency department of an outside hospital, where computed tomography pulmonary angiography raised suspicion of EP. The patient was then transferred to our hospital for further management.

Upon presentation, the patient complained of chest pain and dyspnea. Apart from EoE, he had no known comorbidities, prior abdominal surgery, or history of alcohol or tobacco use. His medical history was notable only for an allergy to house dust. On physical examination, the patient appeared pale and diaphoretic and was in moderate general condition. Vital signs were as follows: pulse rate 102 bpm, body temperature 36.6°C; respiratory rate 36 breaths/min; oxygen satu-

Figure 1. Oral contrast-enhanced computed tomography (CT) images obtained at diagnosis demonstrate multiple focal air densities in the right distal paraesophageal region consistent with esophageal rupture **(a, solid arrow)**, oral contrast extravasation **(b, dashed arrow)**, and focal paraesophageal air densities within the mediastinum **(c, short arrows)**.

ration 94% on room air, and blood pressure 110/80 mmHg. Abdominal examination revealed mild tenderness in the epigastric region without guarding or rebound tenderness. Laboratory investigations demonstrated marked leukocytosis (17,250/mm³), thrombocytosis (456,000/mm³), and elevated C-reactive protein (CRP) levels (320 mg/L; reference range 0–5 mg/L).

Contrast-enhanced thoracoabdominal computed tomography (CT) performed on admission revealed disruption of the wall integrity at the gastroesophageal junction, contrast extravasation, and paraesophageal free air (Fig. 1a-c).

Upper gastrointestinal endoscopy demonstrated an approximately 15–20 mm area of exudation in the distal esophageal mucosa that could not be removed by irrigation (Fig. 2). In the gastric cardia, just proximal to the Z-line, a linear perforation measuring approximately 10–15 mm was observed. The surrounding mucosa appeared elevated and mildly irregular.

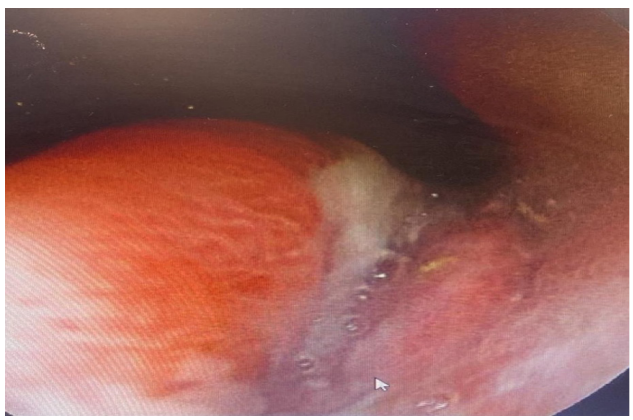

Figure 2. Upper gastrointestinal (GI) endoscopy demonstrates an approximately 15–20 mm exudative area in the distal esophageal mucosa that could not be removed by irrigation.

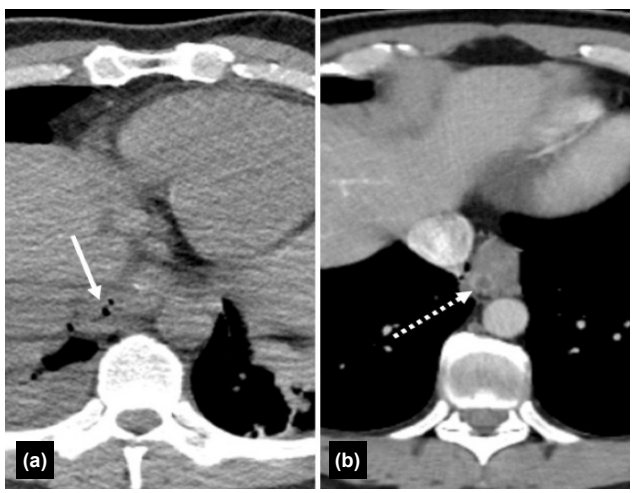

Figure 3. Follow-up computed tomography (CT) scan obtained on day 1 shows decreased air density in the distal paraesophageal region **(a, solid arrow)** with no evidence of oral contrast leakage. A CT scan performed on day 8 demonstrates complete resolution of air densities in this region and a focal collection in the right paraesophageal area **(b, dashed arrow)**.

Due to the location of the lesion in the cardia, a stent could not be securely fixed in place and was therefore not suitable for stenting. As the patient showed no signs of acute abdomen, significant intra-abdominal collection or abscess, or mediastinitis, no interventional procedure was performed initially.

The patient and his relatives were informed in detail about the proposed management plan and follow-up strategy. He was admitted to the intensive care unit, and empirical antibiotic therapy with ceftriaxone (2 g/day, administered intravenously in two divided doses) and metronidazole (1.5 g/day, administered intravenously in two divided doses) was initiated. Following consultation with the infectious diseases department, antibiotic therapy was modified to piperacillin–tazobactam (4.5 g intravenously every 6 hours).

During follow-up, the patient remained conscious, alert, and cooperative, with stable vital signs. A control CT scan performed on the first day demonstrated a reduction in the amount of air and no evidence of contrast leakage (Fig. 3a). Oral intake was initiated on day 6 and was well tolerated. A follow-up CT scan performed on day 8 showed complete resolution of air densities and a residual localized collection (Fig. 3b).

Oral intake was resumed on postoperative day 6. After the patient tolerated a liquid diet, oral intake was gradually advanced. CRP levels subsequently decreased markedly to 24 mg/L. Antibiotic therapy was discontinued on day 10, and the patient was discharged without complications on the same day.

At the three-month follow-up, the patient reported recurrent and progressively worsening dysphagia. Control endoscopy performed at the previously visited center revealed a distal esophageal stricture that prevented passage of the gastroscope; therefore, a 12-cm fully covered self-expandable esophageal stent was placed. The stent was removed 20 days later, and the patient has remained asymptomatic during a six-month follow-up period.

DISCUSSION

Eosinophilic esophagitis is one of the most common causes of esophageal food bolus impaction in both children and adults. It is three times more common in men than in women; however, no sex-related differences in disease severity have been reported.[8] Although uncommon, EoE may lead to life-threatening complications such as EP.[5,7] In the literature, EP associated with EoE has been reported to occur predominantly in the distal esophagus and gastroesophageal junction and is most often managed with surgical or endoscopic interventions.[9]

The pathophysiology of EoE is attributed to transmural infiltration of eosinophils into the esophageal wall, leading to inflammation, fibrosis, and tissue remodeling.[10] In a study by Maria Fontillón and Lucendo, these inflammatory changes were shown to weaken the mechanical integrity of the esophagus, thereby predisposing it to perforation.[11]

The classic symptoms of EP include the Mackler triad—sudden-onset chest pain following vomiting, dyspnea, and subcutaneous emphysema of the neck—although the complete triad is observed infrequently.[12] In the study by Gunasekaran et al.,[13] the Mackler triad was reported to be rarely present in its entirety in cases of spontaneous EP, with the clinical presentation often being atypical. Similarly, in our case, dyspnea and chest pain were the predominant symptoms, and the Mackler triad was absent.

In terms of diagnosis and imaging, contrast-enhanced CT is considered the most reliable modality for detecting gastrointestinal perforations, as it has high sensitivity for identifying extraluminal air and contrast extravasation.[14,15] Although endoscopic evaluation is generally considered contraindicated, it can provide detailed information regarding the location and size of the perforation when performed cautiously. In the systematic review by Sdralis et al.,[16] endoscopy was reported to provide valuable information for both the diagnosis and management of perforations and to assist in treatment planning. However, several studies have emphasized that endoscopy during the acute phase may carry potential risks, including enlargement of the perforation, contamination of adjacent tissues, and an increased risk of mediastinitis. Therefore, it should be performed with caution, and the use of carbon dioxide (CO_2) insufflation is recommended whenever feasible during endoscopic procedures.[17,18] In our case, CT imaging was performed initially, followed by endoscopy with CO2 insufflation.

One of the most critical factors influencing treatment outcomes is the time interval between perforation and initiation of therapy. Our patient presented five days after symptom onset. The literature clearly indicates that treatment initiated within the first 24 hours significantly reduces mortality.[16,19] According to the guideline published in 2021, when endoscopic closure of EPs is feasible, through-the-scope clips or over-the-scope clips are recommended for perforations <2 cm in size, whereas endoscopic suturing is advised for perforations >2 cm. In cases where primary closure is not possible, esophageal stenting with self-expanding metal stents is considered an appropriate treatment option.[18] However, in our patient, neither clipping nor stenting was considered suitable because of the location of the perforation. Some studies suggest that surgical intervention is a safer option in delayed perforations and recommend that conservative management be reserved for carefully selected patients.[20] According to the 2019 World Society of Emergency Surgery (WSES) guidelines, conservative management may be effective in selected cases, particularly in patients diagnosed in the early phase.[6] Nevertheless, in our case, despite a five-day delay from symptom onset, the patient was successfully managed using a conservative approach.

In the long-term management of EoE, dietary elimination, proton pump inhibitors (PPIs), and swallowed topical corticosteroids have been shown to be effective treatment strategies. According to the American College of Gastroenterology Clinical Guideline, these treatment modalities reduce inflammation and help prevent the progression of fibrostenotic complications, and a management algorithm for EoE has been proposed.[21] In our patient, PPI therapy was continued during follow-up. At the three-month follow-up, the development of a stricture at the site of the previous perforation necessitated endoscopic stent placement.

CONCLUSION

In conclusion, EP secondary to EoE is a rare but potentially life-threatening complication. EoE should be considered among the possible etiologies of EP, particularly in young male patients presenting with dysphagia and a history of allergic diseases. This case highlights that conservative management may be a viable alternative to surgical or endoscopic intervention not only in early-detected cases but also in selected delayed presentations when managed carefully in a multidisciplinary setting. Long-term follow-up remains essential for the early detection and treatment of late complications, such as stricture formation.

Ethics Committee Approval: Ethics committee approval was obtained from Izmir City Hospital Non-Interventional Ethics Committee (Date: 13.02.2025, Decision No: 2025/69).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: H.E.; Design: H.E., G.D.H., E.İ.; Supervision: H.E., O.U., H.Ş., S.Ö.S., G.D.H., E.İ.; Data Collection and/or Processing - H.E., H.Ş., S.Ö.S., G.D.H.; Analysis and/or Interpretation - H.E., H.Ş., S.Ö.S., G.D.H.; Literature Review: H.E., O.U., E.İ.; Writing: H.E., O.U.; Critical Review: H.E., O.U., H.Ş., S.Ö.S., G.D.H., E.İ.

Conflict of Interest: None declared.

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

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OLGU SUNUMU - *ÖZ*

Eozinofilik özofajite bağlı gastroözofageal bileşke perforasyonunun konservatif tedavisi: Olgu sunumu

Eozinofilik özofajit (EoE), kronik inflamatuvar bir hastalık olup disfaji ve gıda impaksiyonu ile karakterizedir. Nadir de olsa spontan özofagus perforasyonu gelişebilmektedir. Bu perforasyonlar çoğunlukla distal özofagus ve gastroözofageal bileşkede ortaya çıkmakta, genellikle cerrahi veya endoskopik yöntemlerle tedavi edilmektedir. Erken tanı ve perforasyon sonrası ilk 24 saat içerisinde tedaviye başlanması mortalite ve morbiditeyi belirgin şekilde azaltmaktadır. Bu yazının amacı, eozinofilik özofajite bağlı gelişen gastroözofageal bileşke perforasyonunun, özellikle gecikmiş olgularda da konservatif yöntemle başarılı şekilde yönetilebileceğini vurgulamak ve bu nadir fakat potansiyel olarak hayatı tehdit eden komplikasyonun tedavi stratejilerine katkı sağlamaktır. Otuz beş yaşında, bilinen EoE tanısı ve 12 yıllık disfaji öyküsü bulunan erkek hasta, retrosternal ağrı, nefes darlığı ve hematemez şikâyetleri ile acil servise başvurdu. Öyküsünden yaklaşık beş gün önce ızgara tavuk tüketimi sonrası boğaz ağrısı ve vişne renginde ishal geliştiği, semptomlarını hafifletmek amacıyla ibuprofen kullandığı öğrenildi. Kontrastlı görüntüleme ve endoskopide gastroözofageal bileşkede perforasyon saptandı. Lezyonun lokalizasyonu nedeniyle stentleme veya endoskopik klipsleme uygun bulunmadı. Akut batın, koleksiyon veya mediastinit bulguları olmaması üzerine konservatif tedavi planlandı. Hasta yoğun bakım ünitesinde izleme alındı. Başlangıçta seftriakson (2 g/gün) ve metronidazol (1.5 g/gün) ile başlanan antibiyotik tedavisi, enfeksiyon hastalıkları konsültasyonu sonrası piperasilin–tazobaktam (4.5 g, 6 saatte bir) ile değiştirildi. Klinik seyri stabil olan hastada oral alım 6. günde başlatıldı. Onuncu günde antibiyotik tedavisi sonlandırılarak hasta komplikasyonsuz taburcu edildi. Üçüncü ay takip muayenesinde hasta, tekrarlayan ve progresif olarak kötüleşen disfaji yakınması tarifledi. Önceden değerlendirildiği merkezde yapılan kontrol endoskopisinde, gastroskobun geçişine izin vermeyen distal özofagusta striktür saptanması üzerine 12 cm uzunluğunda, tamamen kaplı, kendi kendine genişleyebilen bir özofagus stenti yerleştirildi. Stent 20 gün sonra çıkarıldı ve hastanın sonraki altı aylık izleminde semptom tekrarı gözlenmedi. EoE bağlı spontan özofagus perforasyonu nadir ancak potansiyel olarak yaşamı tehdit eden bir komplikasyondur. Bu olgu, konservatif tedavinin sadece erken tanı konulan değil, aynı zamanda gecikmiş olgularda da multidisipliner yaklaşımla dikkatle seçilmiş hastalarda cerrahi veya endoskopik girişimlere etkili bir alternatif olabileceğini göstermektedir. Striktür gelişimi gibi geç komplikasyonların erken saptanabilmesi için uzun dönem takip kritik öneme sahiptir.

Anahtar sözcükler: Eozinofilik özofajit; konservatif tedavi; özofagus perforasyonu; striktür.

Ulus Travma Acil Cerrahi Derg 2026;32(5):618-622 DOI: 10.14744/tjtes.2026.99978

CASE REPORT

Sequential use of erector spinae plane block and thoracic epidural analgesia as multimodal regional analgesia in bilateral rib fractures: a case report

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ABSTRACT

Effective pain management is a cornerstone in the treatment of patients with multiple rib fractures, as inadequate analgesia can impair ventilation and increase the risk of pulmonary complications. Bilateral rib fractures, in particular, can significantly compromise respiratory mechanics, leading to hypoventilation, atelectasis, and hypoxemia. Regional analgesic techniques play a crucial role in improving respiratory function while reducing reliance on opioids and their associated adverse effects. We report the case of a patient with multiple bilateral rib fractures following thoracic trauma who presented with severe pain and compromised respiratory function. Initial management with systemic analgesic proved inadequate. Multimodal regional analgesia was therefore initiated with a bilateral erector spinae plane (ESP) block, resulting in rapid pain relief and improved oxygenation. Given the limited duration of analgesia provided by a single-shot ESP block, thoracic epidural analgesia (TEA) was subsequently established via epidural catheter. Continuous low-dose epidural local anesthetic infusion ensured sustained analgesia, prevented pain recurrence, and supported ongoing improvement in respiratory function throughout the clinical course. This case highlights that a multimodal regional analgesic approach, combining an ESP block followed by TEA, may represent an effective and feasible strategy for optimizing pain control and respiratory outcomes in patients with bilateral rib fractures. Such an approach may also reduce the need for systemic opioid therapy while optimizing clinical outcomes and minimizing associated risks.

Keywords: Erector spinae plane block; multimodal regional analgesia; rib fractures; thoracic epidural analgesia; thoracic trauma.

INTRODUCTION

Thoracic trauma is frequently associated with severe pain that directly impairs respiratory mechanics and adversely affects clinical outcomes. Effective pain management in thoracic trauma is therefore essential, given its direct impact on clinical outcomes. Rib fractures, particularly when bilateral and occurring in the setting of multitrauma, can significantly compromise respiratory mechanics and ventilatory function. Pain induced by thoracic wall expansion during inspiration limits deep breathing, impairs effective coughing and secretion clearance, and results in reduced tidal volume, hypoxemia, atelectasis, and an increased risk of pulmonary infections and other respiratory complications.

Optimal analgesic management is therefore a cornerstone in the care of patients with rib fractures. Although systemic administration of opioids and non-opioid analgesics is commonly employed, it may provide inadequate pain relief and is often associated with dose-dependent adverse effects. Thoracic epidural analgesia (TEA) is widely regarded as the gold standard for postoperative pain control in thoracic conditions and has been shown to improve respiratory outcomes.[1,2] It remains a well-established technique for both thoracic sur-

Cite this article as: Ertürk E, Ölmez M, Sarica F, Akdoğan A, Kılıç KN. Sequential use of erector spinae plane block and thoracic epidural analgesia as multimodal regional analgesia in bilateral rib fractures: a case report. Ulus Travma Acil Cerrahi Derg 2026;32:623-627.

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Ulus Travma Acil Cerrahi Derg 2026;32(5):623-627 DOI: 10.14744/tjtes.2026.47646
Submitted: 11.02.2026 Revised: 12.03.2026 Accepted: 17.03.2026 Published: 05.05.2026

gery and trauma.[3,4] However, the invasive nature, technical challenges, and potential complications of central neuraxial blocks have led to the exploration of less invasive regional techniques.

The erector spinae plane (ESP) block is a relatively novel regional analgesia technique that has gained increasing traction in thoracic surgery and trauma due to its technical simplicity and favorable safety profile.[5,6]

In this report, we describe a patient with bilateral rib fractures whose pain was inadequately controlled with conventional systemic analgesia, and demonstrate how a planned sequential regional analgesia strategy, consisting of an initial ESP block followed by TEA, provided effective and sustained pain relief.

CASE REPORT

A 58-year-old male patient was brought to the emergency department after a fall from approximately 10 meters. On initial evaluation, he was hemodynamically stable, with a heart rate of 105 beats per minute, blood pressure of 135/78 mmHg, and a Glasgow Coma Scale score of 15. He reported severe chest pain, along with mild headache and abdominal discomfort. His medical history was significant for hypertension, for which he was receiving antihypertensive therapy.

Thoracic computed tomography (CT) revealed multiple rib fractures: the right 1st and 7th through 12th ribs, and the left 6th and 7th ribs, accompanied by a minimal right-sided pneumothorax. Additional imaging identified minor fractures of the L1 and L2 vertebrae, as well as small perineal and perihepatic hematomas. No other life-threatening injuries requiring surgical intervention were detected.

The patient was admitted to the thoracic surgery ward and initially managed with systemic analgesia, including intravenous paracetamol (1 g four times daily) and ibuprofen (400 mg three times daily). Despite this regimen, he continued to experience severe chest pain and shallow, guarded breathing. On examination, the respiratory rate was 22 breaths per minute, and peripheral oxygen saturation was 88% on room air. Pain intensity, assessed using the Numeric Rating Scale (NRS; 0=no pain, 10=worst pain), was 8/10 (Table 1). Supplemental oxygen was administered via face mask at 4 L/min, and intravenous tramadol (50 mg three times daily) was added. Nevertheless, adequate pain control and clinical improvement were not achieved, and the patient continued to exhibit impaired respiratory mechanics secondary to pain. Chest radiography demonstrated bilateral atelectasis, more pronounced on the right, with reduced lung volumes (Fig. 1).

In light of inadequate pain control and worsening respiratory status, a multimodal regional analgesic approach was adopted. Following standard monitoring in the operating room, procedural sedation and analgesia were achieved with intravenous midazolam (1 mg) and fentanyl (50 µg), with the patient in the sitting position.

An ultrasound-guided bilateral ESP block was then performed. Using a high-frequency ultrasound probe, the relevant muscle layers were identified approximately 3 cm lateral to the transverse processes. The block was first administered on the right hemithorax at the T7 level, followed by the left hemithorax at the T6 level. A 23-gauge needle was advanced under ultrasound guidance, and correct placement was confirmed by hydrodissection with 2 mL of normal saline. After negative aspiration, 20 mL of 0.375% bupivacaine was incrementally injected on each side.

Approximately 30 minutes after the bilateral ESP block, peripheral oxygen saturation increased to 93% on room air, and the NRS score decreased to 3 (Table 1). Thoracic epidural catheterization was subsequently performed at the T6 level under local anesthesia using 2 mL of 2% lidocaine. The patient was then continuously monitored on the ward, where peripheral oxygen saturation further improved to 96% approximately 3 hours after the ESP block.

Although the NRS score initially remained below 3, pain intensity gradually increased to 5–6 after approximately 10 hours. Following administration of a standard epidural test dose, a continuous epidural infusion of 0.125% bupivacaine was initiated at a rate of 5 mL/h via the epidural catheter. Two hours later, the NRS score decreased to 2. The epidural infusion was maintained for 72 hours. Oral diclofenac was initiated twice daily, and previously administered paracetamol,

Table 1. Respiratory and pain parameters before and after analgesia

Time point	Respiratory rate (breaths/min)	SpO_2 (%)	NRS
Pre-ESP block	22	88	8
30 minutes after ESP block	16	93	3
10 hours after ESP block	18	91	5-6
2 hours after initiation of TEA infusion	15	96	2

NRS: Numeric Rating Scale; ESP: Erector spinae plane block; TEA: Thoracic epidural analgesia.

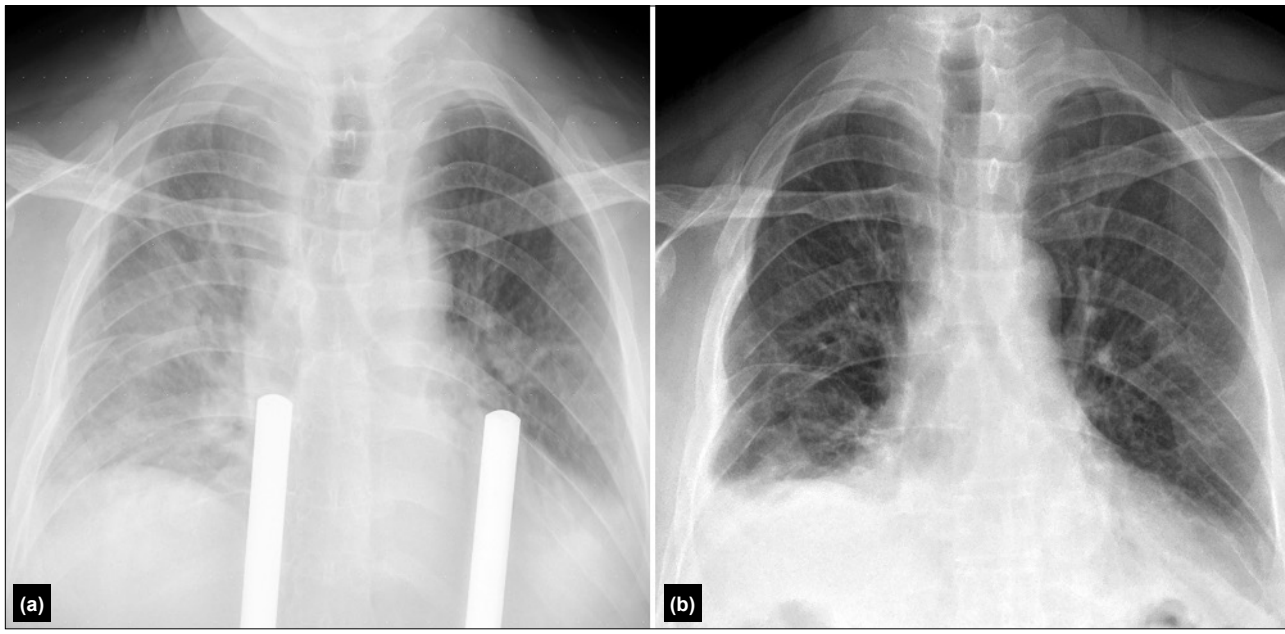

Figure 1. (a) Pre-procedural posteroanterior chest radiograph. **(b)** Post-procedural posteroanterior chest radiograph.

ibuprofen, and tramadol were discontinued. Follow-up imaging demonstrated significant resolution of the previously observed atelectasis (Fig. 1). No adverse events related to tramadol or other analgesic administration were observed. Five days later, the patient was discharged from the hospital with satisfactory respiratory and overall clinical outcomes.

Ethical Considerations

Written informed consent was obtained from the patient for publication of this case report and the accompanying images.

DISCUSSION

This case report underscores the pivotal role of effective analgesia in patients with rib fractures following thoracic trauma, particularly in relation to respiratory function. Inadequate pain control in this population may lead to shallow breathing, reduced tidal volumes, impaired cough, and an increased risk of pulmonary complications. Consequently, multimodal regional analgesia strategies have gained prominence, as they can improve respiratory mechanics, enhance patient comfort, and favorably influence clinical outcomes in patients with chest trauma.[7]

In the present case, severe pain limited the patient's ability to achieve adequate tidal volume, resulting in hypoxemia and clinical deterioration. The implementation of an ESP block followed by TEA provided effective pain relief, improved respiratory mechanics, as reflected by oxygenation parameters, and led to overall clinical improvement.

In patients with bilateral multiple rib fractures, systemic analgesics such as non-steroidal anti-inflammatory drugs and paracetamol are often insufficient. Although escalation to high-dose opioid therapy may enhance analgesia, it is frequently associated with respiratory depression, sedation, and other opioid-related adverse effects. Consequently, regional analgesic techniques that provide effective pain control without compromising respiratory function are increasingly favored in this population.

The ESP block has emerged as a valuable regional analgesia technique with a favorable safety profile. The use of ultrasound guidance reduces the risk of serious procedure-related complications. Since its initial description in 2016, the ESP block has been widely adopted in thoracic trauma and surgical settings, with multiple studies demonstrating effective analgesia and improved respiratory parameters.[5,8] In the present case, the ESP block resulted in a rapid reduction in NRS scores from 8 to below 3, accompanied by an improvement in oxygen saturation from 88% to 93%, and subsequently to 96% on room air.

Thoracic epidural analgesia remains one of the most extensively studied regional techniques in thoracic trauma. Evidence from clinical studies, meta-analyses, and case reports indicates that TEA is associated with improved respiratory function and favorable clinical outcomes in patients undergoing thoracic surgery or sustaining chest trauma.[4,9,10] In line with these findings, initiation of epidural infusion approximately 10 hours after the ESP block in this case provided sustained analgesia and contributed to a favorable clinical course.

Comparative studies evaluating neuraxial and regional analgesic techniques in patients with rib fractures have yielded important insights. Two randomized controlled trials comparing TEA and ESP block in thoracic trauma reported comparable outcomes in terms of pain scores, opioid consumption, and oxygenation parameters, suggesting that both techniques are

effective when appropriately applied.[11,12]

Nevertheless, each technique has inherent limitations. A commonly cited limitation of the ESP block is the relatively short duration of analgesia when administered as a single-shot technique, typically not exceeding 10-12 hours. Although catheter placement may prolong its effect, bilateral thoracic catheterization can be technically challenging due to respiratory movement, insertion difficulties, and issues with catheter fixation. Additionally, variability in local anesthetic spread may result in inconsistent analgesia over time.[13] In contrast, TEA, as a central neuraxial technique, carries a risk of adverse effects, most notably hypotension, particularly with high-dose bolus administration.[12]

Adopting a patient-centered and risk-conscious approach, we prioritized analgesic techniques with proven efficacy while minimizing potential adverse effects. Initial analgesia was achieved with an ESP block to avoid the hemodynamic consequences associated with epidural bolus dosing. Anticipating the limited duration of ESP block analgesia and recognizing the challenges of bilateral ESP catheter placement, a thoracic epidural catheter was inserted during the same session. As the analgesic effect of the ESP block diminished after approximately 10-12 hours, a low-dose continuous epidural infusion was initiated, ensuring uninterrupted pain control, preventing pain recurrence, and supporting sustained clinical improvement.

CONCLUSION

This case illustrates that multimodal regional analgesia, using the sequential application of an erector spinae plane block followed by thoracic epidural analgesia, may provide effective pain control and support respiratory function in patients with bilateral rib fractures. Further prospective studies are needed to confirm these findings and to determine the optimal multimodal analgesic strategy in thoracic trauma.

Peer-review: Externally peer-reviewed.

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

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

Conflict of Interest: None declared.

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

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OLGU SUNUMU - *ÖZ*

Bilateral kosta fraktürlerinde multimodal rejyonal analjezi olarak erektor spina plan bloğu ve torasik epidural analjezinin ardışık kullanımı: Bir olgu sunumu

Yetersiz analjezinin ventilasyonu bozarak pulmoner komplikasyon riskini artırabilmesi nedeniyle, multipl kosta fraktürü olan hastalarda etkin ağrı yönetimi tedavinin temel taşlarından biridir. Özellikle bilateral kosta fraktürleri, solunum mekaniğini belirgin şekilde etkileyerek hipoventilasyon, atelektazi ve hipoksemiye yol açabilmektedir. Rejyonal analjezik teknikler, opioid ilişkili yan etkileri en aza indirirken solunum fonksiyonunun iyileştirilmesinde önemli rol oynamaktadır. Toraks travması sonrası bilateral multipl kosta fraktürleri bulunan bir hasta, şiddetli ağrı ve bozulmuş solunum fonksiyonu ile başvurdu. Sistemik ilaçlarla uygulanan başlangıç analjezi yetersiz kaldı. Bunun üzerine bilateral erektor spina plan (ESP) bloğu uygulanarak multimodal rejyonal analjezi sağlandı ve hızlı ağrı kontrolü ile oksijenasyonda iyileşme elde edildi. Tek doz ESP bloğunun analjezi süresinin sınırlı olması nedeniyle, epidural kateter aracılığıyla torasik epidural analjezi (TEA) başlatıldı. Düşük doz sürekli epidural lokal anestezik infüzyonu, sürdürülebilir analjezi sağlayarak ağrının tekrarını önledi ve klinik seyir boyunca solunum fonksiyonundaki iyileşmeyi destekledi. Bu olgu, ESP bloğunu takiben TEA'nın ardışık kullanımını içeren multimodal rejyonal analjezi yaklaşımının, bilateral kosta fraktürü olan hastalarda ağrı kontrolü ve solunum desteği açısından etkili ve uygulanabilir bir strateji olabileceğini göstermektedir. Bu yaklaşım, sistemik opioid tedavisi ile ilişkili riskleri en aza indirirken klinik sonuçların optimize edilmesine olumlu katkılar sağlayabilir.

Anahtar sözcükler: Erektör spina plan bloğu; kosta fraktürleri; multimodal rejyonal analjezi; torasik epidural analjezi; toraks travması.

Ulus Travma Acil Cerrahi Derg 2026;32(5):623-627 DOI: 10.14744/tjtes.2026.47646