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Case Report - *Olgu Sunumu*

ORIGINAL ARTICLE

Evaluation of the impact of donor site size on treatment outcomes in experimental deep second-degree burns treated with non-cultured autologous cell spray

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ABSTRACT

BACKGROUND: Deep second-degree burn treatment is often time-consuming and expensive, with split-thickness autografts being the current standard of care. Recently, noncultured autologous cell sprays have shown comparable efficacy. This study utilized an experimental animal model to determine the optimal donor-to-burn area ratio for this method.

METHODS: Twenty-four male Wistar-albino rats were assigned to three groups (A, B, and C), each receiving two standardized second-degree burn wounds (2 cm^2) on the dorsal skin. On day 5 post-injury, treatments were applied as follows: Group A wounds were left untreated or underwent tangential excision; Group B received autologous cell spray from 2 cm^2 and 1 cm^2 donor sites; Group C received cell spray from 0.5 cm^2 and 0.25 cm^2 donor sites. On day 14, all animals were sacrificed. Wound healing was assessed macroscopically (necrosis percentage) and histopathologically (ulcer size and inflammation score, 0–3).

RESULTS: Necrotic area percentage in the first and second burn site of the groups A, B, and C were 15±0.15%, 13±0.1%, 6±0.05%, 6±0.05%, 17±0.15%, and 9±0.1% (mean±standard deviation [SD]), ulcer size was 1.5±2.0 mm, 0.8±1.6 mm, 0.4±0.7 mm, 0.1±0.4 mm 2.4±2.1 mm, and 1.3±1.7 mm (mean±SD), and the inflammatory response was 1.8±1.5, 1.5±1.2, 0.8±1.0, 0.5±1.1, 2.0±1.1, and 1.5±1.4 (mean±SD), respectively. All evaluated parameters were statistically significantly better in the second burn area of Group B compared to the untreated group (p=0.007, p=0.041, p=0.043).

CONCLUSION: While previous research supports the use of small donor sites for extensive burns, our findings suggest that, in smaller burn injuries, a donor-to-burn area ratio of 1:2 provides more effective wound healing than further donor site reduction. The 14-day follow-up and reliance on a single thermal burn model limit the generalizability of these results. Future studies with extended observation, varied burn etiologies, and molecular or immunohistochemical analyses are needed to validate and expand upon these findings.

Keywords: Autologous cell spray; keratinocyte suspension; noncultured cell spray.

INTRODUCTION

Burns are defined as traumatic injuries to the skin or other organic tissues resulting from acute destruction caused by heat, cold, electricity, radiation, or caustic chemicals. The severity of the burn is one of the primary factors determining the treatment approach.[1]

The standard treatment for deep burn wounds typically involves excising the burned tissue and covering the area with either full-thickness or split-thickness autologous skin grafts.[2,3] However, in cases of major burns affecting a large area of the body surface, the limited availability of donor sites, coupled with complications like infection or unsatisfactory cosmetic

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results at these sites, can lead to prolonged hospitalization, increased treatment costs, and reduced patient satisfaction.[4] While cultured epidermal cells have been used in burn treatment for a while, several disadvantages such as the prolonged treatment period due to the required culture time, the loss of progenitor cells and epidermal stem cells during the in vitro culture process, and the subsequent premature differentiation of these cells have led to ongoing efforts to develop alternative treatment approaches.[5]

The introduction of the noncultured autologous cell spray technique has eliminated the need for a culture period. Furthermore, since this method does not involve in vitro cell culture processes, it provides significant advantages over cultured epidermal autografts by reducing both treatment time and overall costs.[6] These advantages have led to the growing popularity of the noncultured epidermal autograft technique in treating deep burns. Several studies in the literature have demonstrated that minimizing the ratio between the donor site area and the treated area can yield both functionally and cosmetically acceptable outcomes.[7,8] Further reduction of the donor site required for harvesting autologous graft cells would allow larger burn areas to be treated with grafts obtained from smaller donor sites, thereby enhancing the advantages of this technique. Such an approach would minimize donor site complications, lower treatment costs and hospitalization time, and ultimately improve patient satisfaction.

A review of the literature reveals that the autologous cell grafting method is highly effective in the treatment of burns; however, no comparative studies have been conducted regarding the optimal size of the donor area required for the preparation of autologous cells. This study aimed to determine the optimal donor site size using an experimental model involving noncultured autologous cell grafting.

MATERIALS AND METHODS

The study protocol was reviewed and approved by the Hacettepe University Animal Experiments Local Ethics Committee on February 23, 2021 (Project No: 2021/02. Approval No: 2021/02–07). All experimental procedures were carried out at the Hacettepe University Experimental Animals Application and Research Center, following institutional guidelines, the European Union Directive 2010/63/EU on the protection of animals used for scientific purposes, and the ethical principles outlined in the Declaration of Helsinki.

In this study, a total of 24 male Wistar albino rats weighing between 250 and 350 grams were used. The animals were randomly divided into three groups labeled A, B, and C, with eight rats in each group. Following recommendations from prior experimental burn model studies, the dorsal region of the animals was selected as the burn site to prevent them from accessing the wound area, thereby minimizing the risk of additional injury caused by scratching or biting the wound. Furthermore, the dorsal skin exhibits less contraction compared to other body regions, providing a more stable wound model.[9]

Two burn areas, each measuring 2 cm^2, were created on the dorsal skin of each rat. Consequently, six burn area subgroups were established to receive different treatment protocols (Fig. 1).

In group A, no treatment was applied to the first burn area (group 1), while only debridement was performed on the second burn area (group 2). In Group B, the first burn area (group 3) was treated with a cell spray prepared from a 2 cm^2 donor site, and the second burn area (group 4) received a cell spray obtained from a 1 cm^2 donor site. In Group C, the first burn area (group 5) received a cell spray derived from a 0.5 cm^2 donor site, while the second burn area (group 6) was treated with a cell spray prepared from a 0.25 cm^2 donor site. Accordingly, the donor-to-treated burn area ratios were 1:1 in group 3, 1:2 in group 4, 1:4 in group 5, and 1:8 in Group 6. The distribution of rats across the groups is summarized in Figure 1.

The animals were housed individually in separate cages for a 10-day acclimatization period before the experiment, with free access to water and standard chow. They were maintained under controlled environmental conditions at a constant temperature with a 12-h light/12-h dark cycle.

Before the experimental procedures, anesthesia was induced in the rats by intraperitoneal administration of a mixture of 90 mg/kg ketamine hydrochloride (Ketalar®, Eczacıbaşı, Istanbul, Turkey) and 10 mg/kg xylazine HCl (Alfazyne® 2%, 20 mg/mL, 30 mL, Alfasan Int B.V., The Netherlands). In accordance with the animal model described by Tavares Pereira et al.[10] for inducing second-degree burns, a 51-g aluminum plate with a surface area of 2 cm^2 was immersed in water heated to 100°C under thermometer control and maintained in the water until the temperature returned to 100°C. After shaving the dorsal skin, two deep second-degree burn wounds, each measuring 2 cm^2, were induced on the dorsal area of anesthetized rats by applying the heated plate, using its weight, for 15 s. Immediately after burn induction, analgesia was provided through subcutaneous administration of 40 mg/kg metamizole sodium (Onpyron®, Onfarma, Samsun) into the dorsal neck region, followed by oral administration of 200 mg/kg metamizole sodium mixed into the drinking water. In addition, to ensure hydration, 5 mL of physiological saline was injected subcutaneously into the dorsal neck area.[10]

Five days after burn induction, the animals were re-anesthetized for debridement and application of autologous cell spray. Anesthesia was achieved through intraperitoneal administration of a mixture of 90 mg/kg ketamine hydrochloride (Ketalar®, Eczacıbaşı, Istanbul, Turkey) and 10 mg/kg xylazine HCl (Alfazyne® 2%, 20 mg/mL, 30 mL, Alfasan Int B.V., The Netherlands).

In group A, no treatment was applied to the first burn area (group 1). The second burn area (group 2) was disinfected

using chlorhexidine (Dermanios Scrub®, Anios) and then underwent debridement through tangential excision with a handheld dermatome (Wecprep™ Blades, Pilling Weck Surgical, PA, USA).

Based on the recommendations of the studies conducted by Zhai et al.,[11] the right inguinal region of the subjects was used as the donor site for skin graft harvesting. Following appropriate anesthesia, the donor sites of the animals in Groups B and C were disinfected with chlorhexidine (Dermanios Scrub®, Anios). Two healthy skin grafts were harvested from each donor site using a scalpel. In Group B, skin grafts measuring 2 cm^2 (for group 3) and 1 cm^2 (for group 4) were obtained from each animal. In Group C, skin grafts measuring 0.5 cm^2 (for group 5) and 0.25 cm^2 (for group 6) were harvested from each animal. The skin grafts harvested from the animals in groups B and C were placed into sterile containers and cut into small pieces. The specimens were then incubated in prewarmed dispase II solution (Dispase II Neutral Protease, NC, USA) at 37°C for 40 min until the separation of the dermis-epidermis junction was achieved.

Subsequently, the tissue samples were transferred into Ringer's lactate solution to remove residual enzyme. The epidermis and dermis were mechanically separated using a scalpel and forceps in a separate sterile container. The isolated epidermis was then placed into a tube containing Trypsin/ ethylenediaminetetraacetic acid (EDTA) solution (Trypsin EDTA Solution C 0.05%/0.02%, Biological Industries, USA) and incubated with intermittent agitation for 15 min. Following enzymatic digestion, the specimens were washed with Ringer's lactate solution to remove any remaining enzyme. The cell suspension, previously washed with Ringer's lactate solution, was filtered through a 70- µm cell strainer (70 µm Cell Strainer, Orange Scientific, Belgium). The resulting suspension, which contained regenerative basal keratinocytes, was then centrifuged at 200 g for 5 min after adding Ringer's lactate solution. Following centrifugation, the supernatant (Ringer's lactate) was carefully removed using a syringe, leaving the cell pellet at the bottom of the tube. Fresh Ringer's lactate solution was added to the pellet, resulting in the preparation of the noncultured cell spray containing regenerative basal keratinocytes.[7]

In Groups B and C, following disinfection of the burn areas with chlorhexidine (Dermanios Scrub®, Anios), tangential excision was performed using a handheld dermatome (Wecprep™ Blades, Pilling Weck Surgical, PA, USA). Noncultured cell suspensions obtained from donor sites measuring 2 cm^2 and 1 cm^2 (Group 3 and Group 4, respectively) in Group B, and 0.5 cm^2 and 0.25 cm^2 (Group 5 and Group 6, respectively) in Group C, were applied to the debrided wounds using a syringe with a 22 G black needle tip. The suspension was sprayed from approximately 5 cm to ensure uniform coverage of the wound surface. After the procedure, all animals were housed individually in separate cages. Routine wound care was continued postoperatively by dressing the burn areas with sterile gauze soaked in petrolatum.

On day 14 following treatment, all animals from the three groups were sacrificed under high-dose anesthesia. Biopsy samples were collected from both the burn areas and from healthy skin. After sacrifice, all animals were evaluated macroscopically through direct observation, and photographs were taken for documentation. In all groups, wound healing and the presence of necrotic areas were assessed using millimetric grid drawings. If more than half of a square showed signs of healing, it was scored as 1; if necrosis was present, it was scored as 0. Based on the total number of squares, the percentage of macroscopic wound healing was calculated. Excisional biopsy samples were collected parallel to the long axis of the burn areas. The specimens were fixed in formalin and embedded in paraffin blocks. Sections of 5 µm thickness were prepared and stained with hematoxylin and eosin. Histopathological evaluation was performed under a light microscope. Tissue samples were assessed semi-quantitatively for wound healing parameters, specifically for the presence of non-epithelialized areas and inflammation. Inflammation was scored histologically on a scale from 0 to 3. (Table 1).

Statistical Analysis

Intra-group and inter-group factors were identified using Generalized Estimating Equations modeling. The significance of changes in cross-sectional ulcer size, inflammation score, and macroscopic necrosis percentage was analyzed by comparing these variables to the untreated control group. In this model, ulcer size and necrosis percentage were treated as continuous variables, while the inflammation score was modeled as an ordinal variable. The correlation between necrosis percentage and ulcer size was evaluated using Spearman correlation analysis. A $p<0.05$ was considered statistically significant.

RESULTS

Macroscopic Evaluation

Evaluation of necrotic area percentage

When evaluating all experimental animals, macroscopic analysis of post-sacrifice photographs revealed that the percentage

Table 1. Acute inflammation scoring system

	0	1	2	3
Acute inflammation score	None	Scant	Moderate	Abundant

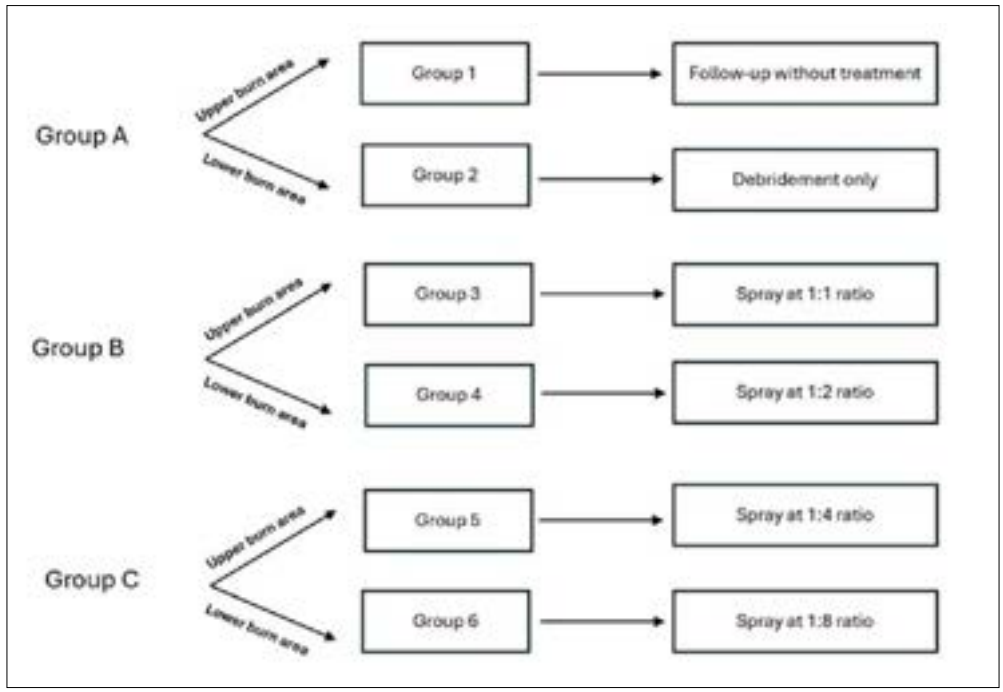

Figure 1. Allocation of rats across experimental groups.

of necrotic area (mean±standard deviation [SD]) within the burn sites was 14±0.11%, 6±0.6%, and 13±0.09% in groups A, B, and C, respectively. A more detailed group-wise assessment revealed necrotic area percentages (the mean±SD) of 15±0.15%, 13±0.1%, 6±0.05%, 6±0.05%, 17±0.15%, and 9±0.1% in the first (control), second, third, fourth, fifth, and sixth groups, respectively (p=0.43, p=0.035, p=0.007, p=0.70 and p=0.15). Each group was compared to the first control group. The box plot illustrating the percentage of necrotic area in experimental animal groups is given in Figure 2.

Histopathological Evaluation

Ulcer size

In the histopathological evaluation, the mean±SD ulcer size was 1.5±2.0 mm, 0.8±1.6 mm, 0.4±0.7 mm, 0.1±0.4 mm, 2.4±2.1 mm, and 1.3±1.7 mm in the first, second, third, fourth, and sixth groups, respectively (p=0.009, p=0.11, p=0.041, p=0.37, and p=0.77). Each group was compared to the first control group. Box plots illustrating ulcer size across experimental animal groups are given in Figure 3.

Inflammation score

When the subjects were assessed for inflammation, the mean±SD inflammation scores were 1.8±1.5, 1.5±1.2, 0.8±1.0, 0.5±1.1, 2.0±1.1, and 1.5±1.4 in the first, second, third, fourth, fifth, and sixth groups, respectively (p=0.97, p=0.10, p=0.043, p=0.66, p=0.25). Each group was compared to the first control group. Box plots illustrating inflammation

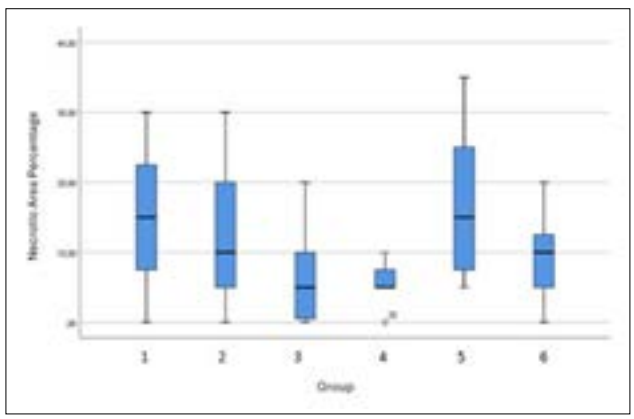

Figure 2. Box plot illustrating the percentage of necrotic area in experimental animal groups.

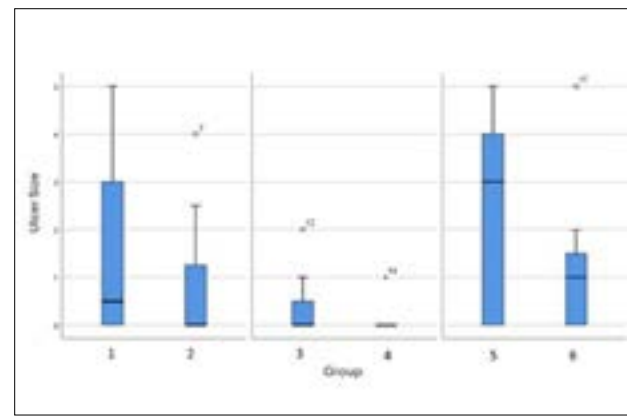

Figure 3. Box plot illustrating ulcer size across experimental animal groups.

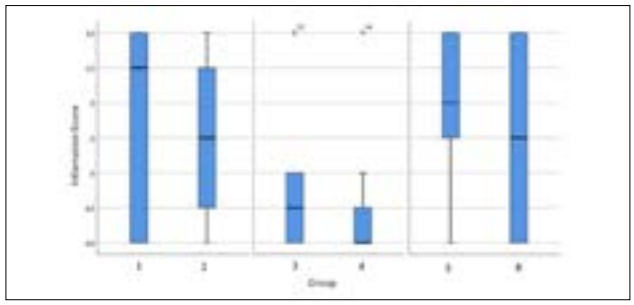

Figure 4. Box plot illustrating ınflammation scores across experimental animal groups.

scores across experimental animal groups are given in Figure 4.

The relationship between the percentage of macroscopic necrosis and ulcer size observed in histopathological evaluation was analyzed. Necrotic area percentages (mean±SD) were 15±0.15%, 13±0.1%, 6±0.05%, 6±0.05%, 17±0.15%, and 9±0.1% in the first (control), second, third, fourth, fifth, and sixth groups, respectively. The mean±SD ulcer sizes were 1.5±2.0 mm, 0.8±1.6 mm, 0.4±0.7 mm, 0.1±0.4 mm, 2.4±2.1 mm, and 1.3±1.7 mm for the first, second, third, fourth, fifth, and sixth groups, respectively. A statistically significant positive correlation was identified between the percentage of necrotic area and the size of non-epithelialized ulcers ($r=0.83$, $p<0.001$), as determined by Spearman correlation analysis.

DISCUSSION

Numerous studies and case series have employed varying donor-to-burn area ratios, yielding a range of outcomes. However, the direct impact of donor site size on wound healing has not been specifically investigated in these reports. In the present study, the most favorable macroscopic and microscopic results were observed in the group with a donor-to-burn area ratio of 1:2. A smaller donor site is inherently associated with improved cosmetic healing outcomes. Ratios ranging from 1:10 to 1:100 have been reported in the literature, accompanied by variable treatment results.[8,12,13]

Gerlach et al.[7] described a case series involving eight patients with deep second-degree burns who exhibited no signs of re-epithelialization after 14 days of conservative management. These patients were treated with a non-cultured autologous cell spray, using donor-to-treated area ratios ranging from 1:20 to 1:60. All patients achieved complete re-epithelialization within an average of 12–20 days, resulting in cosmetically acceptable outcomes. In our study, the follow-up period was limited to 14 days. It is plausible that a longer follow-up might have resulted in complete re-epithelialization in the animal models. Nonetheless, it is essential to note that prolonged epithelialization is generally considered undesirable, both from the patient's perspective and from the perspective of healthcare resource utilization. Gerlach et al.[7] did not assess the relationship between donor-to-burn area ratios and the rate or quality of treatment response. Moreover, histopathological evaluation was not conducted during the healing period to assess tissue regeneration across different donor-to-treated area ratios. Long-term complications such as hypo- or hyperpigmentation, hypertrophic scarring, and functional or cosmetic sequelae like contracture formation were evaluated at 6-month follow-up as treatment outcome. However, in our study, the experimental period was limited to 14 days; thus, long-term consequences were not assessed, as they fell beyond the scope of this investigation. Esteban-vives et al.[8] examined the therapeutic outcomes of non-cultured cell spray using donor-to-treated area ratios of 1:40–1:100 in six patients with burns of varying etiologies. Clinical assessments were performed between post-operative days 14 and 20, focusing on contracture development, hypertrophic scarring, and pigmentary alterations (i.e., hyperpigmentation or hypopigmentation). All patients exhibited rapid re-epithelialization, with both functional and aesthetic outcomes deemed satisfactory. No histopathological evaluation was performed, and the effect of different burn etiologies on treatment outcomes was not analyzed. In our experimental model, burn injuries were consistently induced using an aluminum bar, following the thermal contact burn protocol described by Tavares Pereira et al.[10] Consequently, only the therapeutic response to thermal contact burns was evaluated. Future studies should aim to compare the efficacy of non-cultured autologous cell therapies across various types of burn injuries to better understand the generalizability of this treatment modality.

In our study, the lowest mean inflammation score (0.5±1.1, $p=0.043$) was observed in Group 4, in which the donor-to-burn area ratio was 1:2. Burn wound healing proceeds through distinct and sequential phases: İnflammation, proliferation, and remodeling.[14] The inflammatory phase represents an essential immune response that initiates tissue repair and regeneration. However, excessive or prolonged inflammation may hinder this process, resulting in adverse outcomes such as increased fibrosis and scar formation.[15] Chronic, non-healing wounds are often characterized by persistent inflammation, which is recognized as a significant contributing factor to impaired wound healing.[16]

Recent studies have shown that the type and timing of immune cells present in the wound, and more importantly, the level of inflammation, are key indicators of whether the healing process is proceeding appropriately.[15] These observations support our findings, where improved outcomes were associated with a donor-to-burn area ratio of 1:2, in terms of both reduced inflammation and enhanced healing. In our study, groups with elevated levels of inflammation also exhibited a higher proportion of necrotic tissue relative to other groups. An increased percentage of necrotic tissue may be regarded as a macroscopic indicator of impaired wound healing. Considering that the evaluation was conducted on postoperative day 14, it can be inferred that wound healing was de-

layed in groups with higher inflammation and necrosis scores.

A statistically significant correlation was identified between the macroscopic percentage of necrosis and the ulcer area as determined by histopathological analysis. These findings suggest that macroscopic necrosis may serve as a reliable surrogate endpoint for evaluating treatment efficacy, potentially minimizing the need for time- and resource-intensive histopathological assessments. The lowest percentage of necrotic tissue was recorded in Group 4 (6±0.05%, p=0.007), which had a donor-to-treated area ratio of 1:2. This outcome indicates superior wound healing in this group. It suggests that a 1:2 ratio may offer an optimal balance between donor site limitations and therapeutic effectiveness.

On postoperative day 14, inadequate wound healing was observed both macroscopically and histopathologically in the group treated solely with tangential excision. This observation is consistent with existing literature, which indicates that tangential excision alone is insufficient for the effective management of deep second-degree burns.[17] Failure to achieve appropriate wound coverage following excision frequently leads to invasive infection or, at best, desiccation of the exposed wound surface. It is, in fact, widely acknowledged that performing excision without the capacity to ensure proper coverage may be more detrimental than leaving the eschar intact.

Based on the overall findings, the most favorable macroscopic and histopathological outcomes were achieved using the noncultured autologous cell spray technique with a donor-to-burn area ratio of 1:2.

This study has several notable limitations. First, the follow-up period was limited to 14 days, which may have been insufficient to observe complete re-epithelialization or long-term healing outcomes. Extending the observation period could provide more comprehensive data on scar maturation, tissue remodeling, and functional recovery. Second, although the burn model employed—contact burns induced using an aluminum bar—is widely accepted in experimental research, it may not fully replicate the clinical characteristics and variability of scald or flame burns commonly encountered in patients. In addition, the absence of burn depth standardization due to uneven heat distribution may have introduced variability in injury severity, potentially affecting the consistency of results. Finally, the study focused exclusively on macroscopic and histological parameters, without incorporating molecular or immunohistochemical analyses, which could have offered more profound insights into the biological processes underlying wound healing.

CONCLUSION

While existing research suggests that smaller donor sites may be enough for treating extensive burns, our study results indicate that for smaller burn injuries, the best wound healing is more likely with a donor-to-burn area ratio of 1:2, rather than further reducing donor site size. In addition, the strong link between macroscopic necrosis and the ulcer area measured histopathologically supports using macroscopic necrosis as a practical marker for evaluating treatment response. The limited follow-up period of 14 days and the use of only a single thermal burn model limit how broadly these results can be applied. Future studies should include longer observation times, different burn causes, and molecular and immunohistochemical analyses to validate and build on these findings.

Ethics Committee Approval: This study was approved by the Hacettepe University Animal Experiments Local Ethics Committee (Date: 23.02.2021, Decision No: 2021/02–07).

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Kültüre-edilmemiş otolog hücre spreyi ile tedavi edilen derin ikinci derece yanıkların deneysel modelinde donör alanı büyüklüğünün tedavi sonuçlarına etkisinin değerlendirilmesi

AMAÇ: Derin ikinci derece yanıkların tedavisi genellikle zaman alıcı ve maliyetlidir; bu durumda, kısmi kalınlıkta deri greftleri halen standart tedavi yöntemidir. Son yıllarda, kültüre-edilmemiş otolog hücre spreyleri benzer etkinlik göstermeye başlamıştır. Bu çalışmada, bu yöntemin uygulanmasında en uygun donör alanı/yanık alanı oranını belirlemek amacıyla deneysel bir hayvan modeli kullanılmıştır.

GEREÇ VE YÖNTEM: Yirmi dört erkek Wistar-albino sıçan üç gruba (A, B ve C) ayrıldı ve her birinin sırt bölgesine standart boyutta (2 cm²) iki adet ikinci derece yanık oluşturuldu. Yanık sonrası 5. günde aşağıdaki tedaviler uygulandı: Grup A'da yaralar ya tedavisiz bırakıldı ya da tangensiyel eksizyon uygulandı; Grup B'de 2 cm² ve 1 cm² donör alanlarından elde edilen otolog hücre süspansiyonu uygulandı; Grup C'de ise 0.5 cm² ve 0.25 cm² donör alanlarından elde edilen hücre süspansiyonu uygulandı. Tüm hayvanlar 14. günde sakrifiye edildi. Yara iyileşmesi makroskopik olarak nekroz yüzdesi, histopatolojik olarak ise ülser boyutu ve inflamasyon skoru (0–3) ile değerlendirildi.

BULGULAR: Grup A, B ve C'nin birinci ve ikinci yanık alanlarında gözlenen ortalama nekrotik alan yüzdeleri sırasıyla %15±0.15, %13±0.1, %6±0.05, %6±0.05, %17±0.15 ve %9±0.1 idi. Ortalama ülser boyutları sırasıyla 1.5±2.0 mm, 0.8±1.6 mm, 0.4±0.7 mm, 0.1±0.4 mm, 2.4±2.1 mm ve 1.3±1.7 mm olarak ölçüldü. Enflamatuvar yanıt skorları ise sırasıyla 1.8±1.5, 1.5±1.2, 0.8±1.0, 0.5±1.1, 2.0±1.1 ve 1.5±1.4 idi. Grup B'nin ikinci yanık alanında değerlendirilen tüm parametrelerde, tedavisiz gruba kıyasla istatistiksel olarak anlamlı düzeyde daha iyi sonuçlar elde edildi (p=0.007, p=0.041, p=0.043).

SONUÇ: Önceki çalışmalar geniş yanıklar için küçük donör alanlarının yeterli olabileceğini öne sürerken, bu çalışmanın bulguları küçük yüzeyli yanıklarda donör/yanık alan oranının 1: 2 olarak belirlenmesinin yara iyileşmesini daha etkin şekilde desteklediğini göstermektedir. Ancak 14 günlük takip süresi ve yalnızca tek bir termal yanık modelinin kullanılması, sonuçların genellenebilirliğini sınırlamaktadır. Gelecekte daha uzun takip süreleri, farklı yanık etiyolojileri ve moleküler ya da immünohistokimyasal analizlerin yer aldığı çalışmalar ile bulguların doğrulanması ve genişletilmesi gerekmektedir.

Anahtar sözcükler: Keratinosit süspansiyonu; kültüre-edilmemiş hücre spreyi; otolog hücre spreyi.

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ORIGINAL ARTICLE

Evaluation of predictive factors for morbidity and mortality in patients undergoing surgery for peptic ulcer perforation

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ABSTRACT

BACKGROUND: Peptic ulcer perforation (PUP) is a life-threatening complication with high mortality caused by the leakage of gastric contents into the peritoneal cavity, leading to peritonitis. Systemic inflammatory indices, such as the C-reactive protein (CRP)/lymphocyte ratio, neutrophil-to-lymphocyte ratio (NLR), and multi-inflammatory indices (MII), reflect inflammation severity. This study aimed to investigate the predictive value of the CRP/Lymphocyte ratio, NLR, platelet-to-lymphocyte ratio (PLR), systemic immune-inflammation index (SII), and MII indices for estimating morbidity and mortality in patients undergoing surgery for PUP.

METHODS: This retrospective analysis included 319 patients who underwent surgery for PUP between October 2012 and January 2025. Pre-operative inflammatory indices were calculated from laboratory data and correlated with post-operative complications, length of hospital stay, and mortality.

RESULTS: Higher CRP/Lymphocyte ratio, PLR, MII-1, MII-2, and MII-3 values were associated with fatal outcomes ($p<0.05$). The MII-2 and MII-3 indices best predicted post-operative complications with superior area under the curve (AUC) values (AUC: 0.655, 0.661, respectively) ($p<0.001$). All analyzed markers were significantly elevated in patients with prolonged hospitalization. Notably, the MII-2 index and CRP/lymphocyte ratio showed balanced sensitivity and high specificity for predicting mortality (AUC: 0.780, 0.787, respectively) ($p<0.001$).

CONCLUSION: The MII-2 index and CRP-to-lymphocyte ratio are strong predictors of mortality in PUP patients, whereas the MII-2 and MII-3 indices are most effective for predicting complications. Incorporating these easily calculated indices into clinical practice can enhance risk stratification and decision-making.

Keywords: C-reactive protein/lymphocyte ratio; inflammatory markers; multi-inflammatory index; peptic ulcer perforation; prognosis.

INTRODUCTION

Peptic ulcer disease (PUD) is defined as ulceration resulting from full-thickness disruption of the gastric or duodenal mucosa. Although its prevalence varies geographically, South Asian countries represent the region with the highest reported rates. Helicobacter pylori infection, the use of non-steroidal anti-inflammatory drugs (NSAIDs), and aspirin intake are among the major etiological factors. The disease may present asymptomatically or with clinical manifestations such as retrosternal discomfort, epigastric pain, nausea, and vomiting. However, in cases complicated by bleeding or perforation (19.5–57% and 3.8–14%/100,000 individuals, respectively), it can lead to clinical scenarios associated with high mortality

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rates. Although the incidence of perforation as a complication has declined over time due to advances in medical therapy, it remains an important cause of mortality and accounts for approximately 10.4% of hospital admissions related to PUD.[1] In patients presenting with peptic ulcer perforation (PUP), the initial assessment should include prompt resuscitation, initiation of broad-spectrum antibiotics, and discontinuation of oral intake. The most frequently utilized surgical approach involves laparoscopic closure of the perforated site using a combination of an omental patch and suturing techniques.[2]

As a consequence of a perforated peptic ulcer (PPU), the entry of gastric contents, including gastric acid, into the peritoneal cavity leads to severe pain with initially localized and subsequently generalized peritonitis. Laboratory parameters are not diagnostic; however, they play a significant role in detecting inflammatory responses, assessing organ functions, and excluding differential diagnoses. Furthermore, they are essential for identifying life-threatening conditions such as systemic inflammatory response syndrome, multiple organ failure, and sepsis, as well as for predicting prognosis.[3] In response to conditions in which systemic inflammation is activated, alterations occur in hematological parameters, including neutrophilia, lymphopenia, thrombocytosis, and elevated C-reactive protein (CRP) levels.[4] Using these hematological parameters, several indices reflecting the severity of inflammation have been developed, including the neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), systemic immune-inflammation index (SII; NLR × platelet count), multi-inflammatory index-1 (MII-1; NLR × CRP), multi-inflammatory index-2 (MII-2; PLR × CRP), and multi-inflammatory index-3 (MII-3; SII × CRP). In the literature, these indices have been shown to play a decisive role in various diseases associated with inflammation.[4-7] Their major advantage is that they can be measured from routine hematological parameters obtained from peripheral venous blood without incurring additional costs. Such scoring systems enhance clinical risk assessment and allow the pre-operative identification of patients at high risk for post-operative morbidity and mortality.[8]

Systemic inflammation develops in PPU; however, there is a paucity of research in the literature regarding the efficacy of various laboratory markers in predicting morbidity and mortality. In our study, we aimed to investigate the relationship between clinical outcomes and these markers in patients who underwent surgery for PPU.

MATERIALS AND METHODS

Study design and setting

The medical records of patients aged 18 years and older who were diagnosed with PPU and underwent surgical intervention between October 2012 and January 2025 in the emergency medicine and general surgery departments of a tertiary care hospital were retrospectively reviewed using data from the hospital's electronic medical record system. The preliminary diagnosis of PPU was established based on clinical examination and the detection of free air on an erect chest radiograph, an upright abdominal radiograph, or abdominal computed tomography, with the definitive diagnosis confirmed intraoperatively. Before the commencement of the study, approval was obtained from the Gaziantep University Clinical Research Ethics Committee (Date: 26.03.2025, Decision no: 2025/54). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

A total of 326 patients underwent surgery for PPU; seven patients were excluded due to incomplete laboratory data, and 319 patients were included in the study.

Inclusion and exclusion criteria

Inclusion criteria

Patients aged ≥18 years with a diagnosis of PPU were included in the study.

Exclusion criteria

Patients aged <18 years; pregnancy or lactation; presence of chronic inflammatory disease, hematologic or autoimmune disorders, malignancy, chronic hepatic or renal failure; receipt of specific treatments such as radiotherapy or chemotherapy before surgery; and death attributable to causes unrelated to PUP were excluded from the study.

Data collection

The data collected for each patient included: Demographic characteristics (age and sex), comorbidities, smoking status, alcohol abuse, illicit drug use (amphetamine [AMP], methamphetamine, cannabis, and heroin), use of chronic medication, type of surgical procedure performed (primary closure + omental patch, gastroenterostomy, and others), location of perforation (corpus, antrum, prepylorus, pylorus, duodenum, and anastomosis), long-axis diameter of the perforation site (cm), post-operative intubation status, estimated duration between onset of symptoms and surgery (days), laboratory parameters (white blood cell count, neutrophil count, lymphocyte count, platelet count, hemoglobin, CRP, albumin, urea, creatinine, and amylase), histopathology report of the specimen (benign or malignant), post-operative hospital length of stay (days), presence of post-operative complications, need for reoperation, etiology (NSAIDs use, illicit drugs, PUD, gastritis, marginal ulcer, and others), and outcome (mortality or survival).

Definitions

Smoking status: Patients' smoking habits were categorized into two groups: Never smokers and former or current daily smokers. Never smokers were defined as individuals who had never smoked in their lifetime. Former smokers were defined as those who had smoked regularly in varying amounts or intermittently in the past but had quit. Current daily smokers were defined as individuals who smoked every day, with variable daily consumption.

Table 1. Baseline characteristics of the patients

	n (%)
Gender	
Man	245 (76.80)
Woman	74 (23.20)
Chronic illness	
No	182 (57.05)
Yes	137 (42.95)
Smoking status	
No	236 (73.98)
Yes	83 (26.02)
Alcohol consumption status	
No	307 (96.24)
Yes	12 (3.76)
Illicit drugs abuse	
AMP	
No	313 (98.12)
Yes	6 (1.88)
MAMP	
No	310 (97.18)
Yes	9 (2.82)
Cannabis	
No	310 (97.18)
Yes	9 (2.82)
Heroin	
No	314 (98.43)
Yes	5 (1.57)
Chronic medication use	
No	223 (69.91)
Yes	96 (30.09)
Type of surgical procedure performed	
PC+OP	308 (96.55)
Gastroenterostomy	6 (1.88)
Others	5 (1.57)
Location of perforation	
Corpus	16 (5.02)
Antrum	14 (4.39)
Pre-pylorus	111 (34.8)
Pylorus	125 (39.18)
Duodenum	39 (12.23)
Anastomosis	14 (4.39)
Postoperative intubation status	
No	260 (81.5)
Yes	59 (18.5)
Histopathology report of the specimen	
Benign	287 (89.97)
Malignant	9 (2.82)
No	23 (7.21)
Presence of postoperative complications	
No	274 (85.89)
Yes	45 (14.11)
Need for Re-operation	
No	313 (98.12)
Yes	6 (1.88)
Etiology of perforation	
Unknown	149 (46.86)
NSAID	9 (2.8)
Illicit drug''	14 (4.4)
Peptic Ulcer	90 (28.3)
Gastritis	8 (2.52)
Marginal Ulcer	15 (4.72)
Others	33 (10.38)
Postoperative length of hospital stay	
Short (≤8 days)	189 (59.25)
Long (>8 days)	130 (40.75)
Outcome	
Mortality	67 (21)
Survival	252 (79)

PC+OP: Primary closure+Omental Patch; NSAID: Non-steroidal anti-inflammatory drug; AMP: Amphetamine; MAMP: Methamphetamine.

Alcohol consumption status: Individuals who had never consumed alcohol in their lifetime were classified as "never consumers;" those who had consumed alcohol in the past but had abstained for at least the past year were classified as "former consumers;" and those who had consumed alcohol within the past 12 months were classified as "current consumers."

Post-operative complications: Defined as the occurrence of infection, anastomotic leakage, intra-abdominal abscess, peritonitis, ileus, respiratory complications, cardiovascular complications, hemorrhage, fistula formation, multiple organ failure, or wound complications.

Length of hospital stay: A short hospital stay was defined as ≤8 days, and a long hospital stay as >8 days.

Inflammatory indices calculation

From the data collected in each patient's medical record, the following indices were calculated using neutrophil, lymphocyte, and platelet counts, as well as CRP levels:

NLR=Neutrophil/lymphocyte, PLR=Platelet/lymphocyte, SII=NLR×Platelet, MII-1=NLR×CRP, MII-2=PLR×CRP, MII-3=SII×CRP.

Statistical analysis

The dataset was constructed, and all statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS) software, version 22.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics of the data obtained from the study were presented as mean, standard deviation, median, minimum, and maximum values for numerical variables, and as frequency and percentage for categorical variables. The normality of distribution for numerical variables was assessed using the Shapiro–Wilk test. Comparisons of numerical variables according to categorical variables were performed using the Mann–Whitney U test. In addition, receiver operating characteristic (ROC) analysis was applied to determine the cutoff values of inflammatory parameters. All analyses were conducted using SPSS version 22.0, with a significance level set at $p<0.05$.

RESULTS

A total of 319 patients were included in the study. The mean age of the patients was 50.72±20.81 years, and 76.8% were male. Chronic comorbidities were present in 42.95% of patients, whereas the rates of smoking, alcohol consumption, and illicit drug use were 26.02%, 3.76%, and 5.33%, respectively. The most common site of PUP was the pylorus (39.18%). In most patients (46.86%), the etiology could not be determined; among the identified causes, the most frequent was PUD (28.3%). The most commonly performed surgical procedure was a primary closure with an omental patch and suturing (96.55%). Post-operative complications occurred in 14.11% of patients, and reoperation was required in six cases. Of the pathological specimens sent for post-operative analysis, the majority (89.97%) were benign; pathological results were unavailable for 23 patients. The mean hospital length of stay was 9.1±4.57 days, with more than half of the patients (59.25%) hospitalized for ≤8 days. Mortality was observed in 67 patients (21%) (Table 1).

The comparison of inflammatory indices according to survival status is presented in Table 2. Accordingly, CRP/lymphocyte ratio, PLR, MII-1, MII-2, and MII-3 values showed statistically significant differences based on survival status ($p<0.05$), with significantly higher levels observed in patients with a fatal course compared to survivors. In contrast, the NLR and SII inflammatory indices did not demonstrate statistically significant differences according to survival status ($p>0.05$).

The comparison of inflammatory indices according to the development of post-operative complications is presented in Table 3. CRP/lymphocyte ratio, PLR, SII, MII-1, MII-2, and MII-3 values showed statistically significant differences based on complication status ($p<0.05$), with significantly higher levels observed in patients who developed complications compared to those who did not. In contrast, the NLR inflammatory index value did not demonstrate a statistically significant difference according to the occurrence of complications ($p>0.05$).

When the statistical relationship between post-operative length of hospital stay and inflammatory indices was evaluated, CRP/lymphocyte ratio, PLR, NLR, SII, MII-1, MII-2, and MII-3 values showed statistically significant differences according to hospital stay duration ($p<0.05$), with significantly higher levels observed in patients with prolonged hospitalization compared to those with shorter stays (Table 4).

According to the results of the ROC analysis for predicting mortality, the CRP/lymphocyte ratio, MII-1, MII-2, and MII-3 indices demonstrated significant and good discriminatory per-

Table 2. Comparison of inflammatory indices according to survival status

	Mortality		Survival		
Variables	**Mean±SD**	**Median (Q1-Q3)**	**Mean±SD**	**Median (Q1-Q3)**	**p**
CRP/Lymphocyte	0.38±0.43	0.3 (0.07–0.56)	0.31±3.16	0.02 (0–0.12)	0.001*
PLR	516.55±440.58	373.02 (218.31–670.97)	2212.96±30267.52	243.95 (127.63–378.71)	0.001*
NLR	13.03±12.31	9.03 (4.25–17.18)	98.1±1365.78	8.73 (3.87–16.48)	0.440
SII	4183753.68± 4481890.23	2915000 (1195833.33–4823404.96)	25086596.51± 341422057.99	2324548.25 (980897.31–4478973.66)	0.141
MII-1	2949.43±3493.15	1798.3 (559.83–3956)	3559.98±35695.17	192.49 (21.31–1141.01)	0.001*
MII-2	121237.72±145953.36	75150 (17690.63–181325.4)	80700.67±790677.65	5485.5 (588.01–34061.93)	0.001*
MII-3	979471847.83± 1245174079.5	532145833.33 (132679687.5–1143720172.66)	965560181.69± 8943159338.83	45192325.56 (5817808.86–301586958.27)	0.001*

*p<0.05; Mann–Whitney U Test. NLR: Neutrophil/lymphocyte ratio; PLR: Platelet/lymphocyte ratio; SII: Systemic immune inflammation index (NLR × platelet); MII-1: Multi-inflammatory index-1 (NLR×CRP); MII-2: Multi-inflammatory index-2 (PLR×CRP); MII-3: Multi-inflammatory index-3 (SII×CRP).

Table 3. Comparison of inflammatory indices according to the development of complications

	No		Yes		
Variables	**Mean±SD**	**Median (Q1-Q3)**	**Mean±SD**	**Median (Q1-Q3)**	**p**
CRP/Lymphocyte	0.34±3.04	0.03 (0–0.18)	0.2±0.21	0.11 (0.02–0.3)	0.002*
PLR	2091.99±29025.64	246.26 (135.15–406.45)	423.75±345.89	306.38 (235.57–519.15)	0.039*
NLR	91.15±1309.81	8.06 (3.75–16.62)	13.75±10.66	11.33 (5.32–16.82)	0.134
SII	23304551.36± 327432163	2261284.31 (994953.85–4448707.32)	4815260.94± 5298696.34	3368712.33 (1912500–4658636.36)	0.043*
MII-1	3626.82±34249.07	269.2 (22.23–1580.95)	2243.96±2750.34	1477.15 (180.12–3121.59)	0.001*
MII-2	92860.58±760957.98	9046.9 (682.03–48564.29)	67015.52±82915.12	40815.5 (8933.64–77529.49)	0.001*
MII-3	998387169.44± 8583367379.02	72196954.55 (6555939.56–428378600)	786393225.85± 1192332280.97	283108800 (59080000–1023144022.73)	0.001*

*p<0.05; Mann–Whitney U Test. NLR: Neutrophil/lymphocyte ratio; PLR: Platelet/lymphocyte ratio; SII: Systemic immune inflammation index (NLR×platelet); MII-1: Multi-inflammatory index-1 (NLR×CRP); MII-2: Multi-inflammatory index-2 (PLR×CRP); MII-3: Multi-inflammatory index-3 (SII×CRP).

Table 4. Comparison of inflammatory indices according to hospital length of stay

	≤8 (n=189) Short		>8 (n=130) Long		
Variables	**Mean±SD**	**Median (Q1-Q3)**	**Mean±SD**	**Median (Q1-Q3)**	**p**
CRP/Lymphocyte	0.4±3.65	0.01 (0–0.14)	0.22±0.27	0.09 (0.02–0.34)	0.001*
PLR	2857.6±34949.35	217.42 (119.62–383.13)	401.45±322.8	293.15 (210–525.26)	0.001*
NLR	125.67±1577.12	7.58 (3.31–15.9)	14.18±14.14	9.79 (4.96–17.49)	0.048*
SII	31817518.56± 394255259.68	2126380.95 (953286.22–4267301.59)	4527867.75± 5370262.38	2882852.94 (1195833.33–5246290.6)	0.019*
MII-1	4214.69±41173.42	134.21 (14.62–1224.32)	2293.47±3569.98	814.01 (177.91–2992)	0.001*
MII-2	107228.35±914863.25	3565.57 (458.76–37376.27)	63025.68±83950.04	26620 (7689.71–81700)	0.001*
MII-3	1129757664.18± 10302991363.73	32360000 (3813144.88–330205586.21)	734012162± 1272170681.72	233004499.86 (44616774.19–760519328.24)	0.001*

*p<0.05; Mann–Whitney U Test. NLR: Neutrophil/lymphocyte ratio; PLR: Platelet/lymphocyte ratio; SII: Systemic immune inflammation index (NLR×platelet); MII-1: Multi-inflammatory index-1 (NLR×CRP); MII-2: Multi-inflammatory index-2 (PLR×CRP); MII-3: Multi-inflammatory index-3 (SII×CRP).

formance (area under the curve [AUC] values: 0.780, 0.741, 0.787, and 0.751, respectively; p<0.001). Notably, MII-2 and the CRP/lymphocyte ratio stood out with balanced sensitivity and high specificity values (Fig. 1). In contrast, the NLR and SII indices had low AUC values (0.531 and 0.559, respectively) and statistically non-significant results, indicating no clinical value as predictors of mortality.

In the ROC analysis results for predicting the development of post-operative complications, the CRP/lymphocyte ratio, PLR, SII, MII-1, MII-2, and MII-3 indices were statistically significant and demonstrated low-to-moderate discriminatory performance (AUC values: 0.648, 0.596, 0.594, 0.654, 0.655, and 0.661, respectively; p<0.05). Among these, the MII-2 and MII-3 indices stood out with higher AUC values compared to the other parameters (Fig. 2). In contrast, the NLR index, with a low AUC value (0.570) and a statistically non-significant result (p=0.123), did not have clinical value as a predictor of the development of post-operative complications.

DISCUSSION

A review of the literature revealed no studies evaluating the inflammatory indices investigated in our study for predicting morbidity and mortality in patients undergoing surgery for PUP. This study aimed to elucidate the potential value of these novel markers in predicting survival, the development of complications, and the length of hospital stay.

In our study, the CRP/lymphocyte ratio, PLR, MII-1, MII-2,

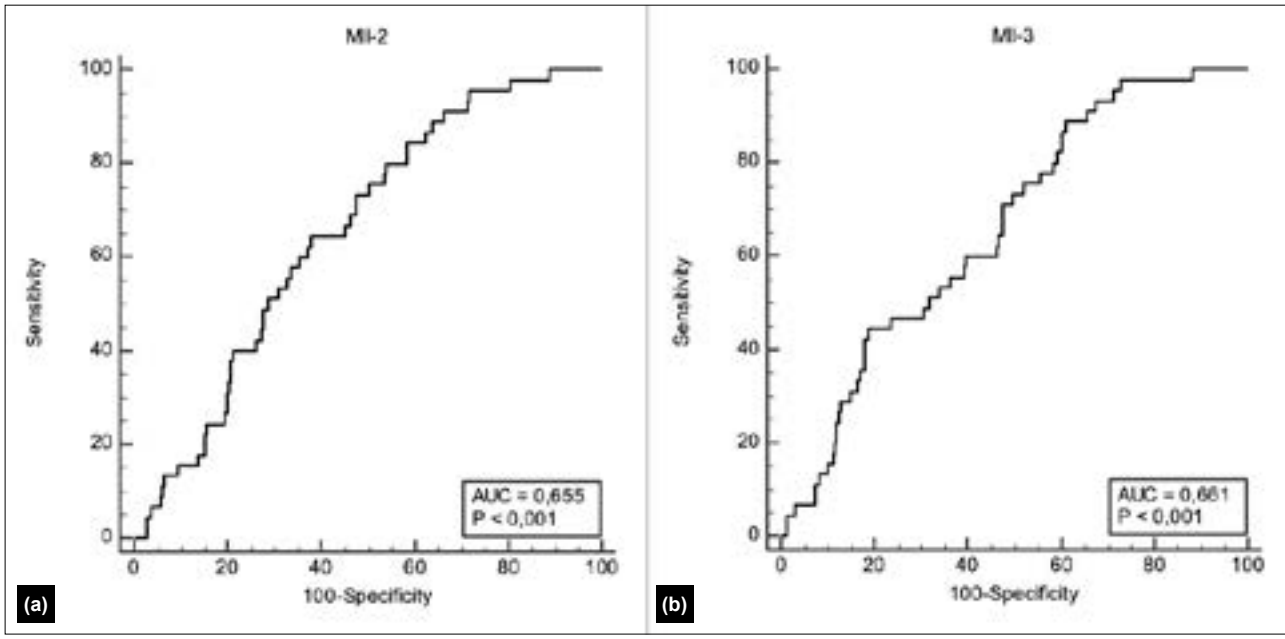

Figure 1. Receiver operating characteristic curve analysis of multi-inflammatory index (MII)-2 **(a)** and MII-3 **(b)** for predicting complications.

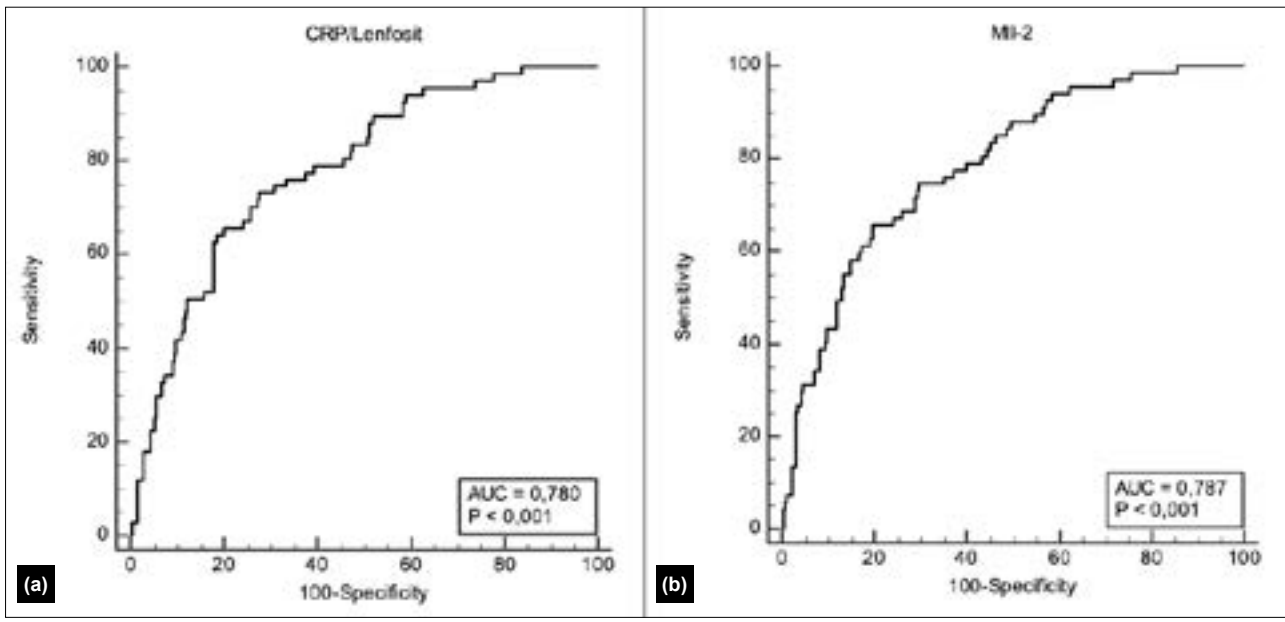

Figure 2. Receiver operating characteristic curve analysis of C-reactive protein/lymphocyte ratio **(a)** and Multi-inflammatory index-2 **(b)** for predicting mortality.

and MII-3 indices were found to be significantly associated with mortality, whereas the NLR and SII inflammatory indices did not demonstrate statistically significant differences according to survival status. Based on the ROC analysis results for predicting mortality, MII-2 and the CRP/lymphocyte ratio, in particular, stood out with balanced sensitivity and high specificity values (AUC: 0.787 and 0.780, respectively; p<0.001) and hold clinical value as predictors of mortality. These findings suggest that inflammatory indices and their combinations may aid in risk stratification for mortality. In a study by Gozdas et al.[5] evaluating mortality associated with COVID-19 infections, multiple logistic regression analysis revealed that the MII-1 index (odds ratio [OR]: 0.999; 95% confidence interval [CI]: 0.9991–0.9998; p=0.003) had the

strongest independent predictive value compared to the other indices. In another multicenter study comparing inflammatory marker scoring systems with conventional inflammatory markers in patients over 65 years of age admitted to the intensive care unit, the importance of monitoring CRP/albumin ratio, NLR, SII, and MII-1, -2, and -3 indices was emphasized for accurately predicting 28-day mortality.[9] In another study conducted on intensive care patients, it was reported that higher values of the NLR and PLR indices were significantly associated with mortality prediction.[10] In a multicenter prospective study investigating the predictive effects of the NLR index on mortality during hospitalization in geriatric patients, regardless of diagnosis, it was suggested that NLR could be used as a cost-effective marker.[11]

CRP is an acute-phase reactant synthesized by the liver in inflammatory conditions such as infection, malignancy, and sepsis, and it rises markedly in persistent inflammatory states. Therefore, the significant association observed between mortality and indices incorporating CRP multipliers, such as MII and the CRP/lymphocyte ratio, may be attributable to this mechanism. Furthermore, neutrophilia and lymphopenia, which occur in trauma and systemic inflammatory response states, together with the interaction of cytokines released into the circulation in conditions of heightened inflammatory activity, may stimulate platelet production in the bone marrow,[12] leading to increases in NLR and PLR values.

In recent years, inflammatory indices derived from routine laboratory parameters have increasingly been investigated in various surgical emergencies. Several studies have demonstrated that biomarkers such as the SII and the pan-immune-inflammation value (PIV) may provide valuable prognostic information in acute abdominal conditions, including appendicitis and other emergency surgical pathologies. These indices reflect the balance between inflammatory and immune responses and have been associated with disease severity, post-operative complications, and overall clinical outcomes. Because they are easily calculated from routine hematological parameters without additional cost, they have been proposed as practical tools for early risk stratification in emergency surgical settings. Recent studies evaluating inflammatory biomarkers in emergency surgical patients have also highlighted the potential clinical value of indices such as SII and PIV in predicting disease severity and clinical outcomes.[13,14]

The results in the literature regarding the predictive value of these markers for mortality are inconsistent. Some studies have reported that indices such as NLR, PLR, and SII are strong predictors and should be monitored. These discrepancies may be attributable to a variety of factors, including differences in demographic distribution, etiological causes, and clinical parameters. For this reason, we believe that instead of relying solely on inflammatory indices, it would be more reasonable to interpret them in conjunction with clinical evaluation and established traditional indices or scoring systems. Multicenter studies with more heterogeneous patient populations and a more standardized design may contribute to improving the assessment of the clinical course.

In the comparison of inflammatory indices according to the according to the development of post-operative complications, the CRP/lymphocyte ratio, PLR, SII, MII-1, MII-2, and MII-3 values were found to be significantly higher in patients who developed complications ($p<0.05$), whereas the NLR index did not show a significant difference ($p>0.05$). In the ROC analysis results, the MII-2 and MII-3 indices, in particular, stood out with higher AUC values compared to the other parameters. In contrast, the low AUC value of the NLR index (0.570) and its statistically non-significant result ($p=0.123$) indicate that its clinical value in predicting the development of post-operative complications is limited. Inflammation and infection are the most critical determinants in the etiology of preterm premature rupture of membranes (PPROM), a complication that initiates the onset of labor. In a study investigating the predictive value of inflammatory indices during the latency phases of delivery (≤72 h and >72 h) in PPROM, the MII-1, MII-2, and MII-3 indices were found to be higher in the ≤72-h group. ROC analysis revealed that, although these indices had weaker discriminatory performance compared to other indices, they were statistically significant (AUC ≈ 0.6; $p<0.05$).[4] In several other studies, the NLR and PLR indices did not predict the timing of delivery within 72 h and, in this regard, were not shown to have prognostic value.[12,15] In a study evaluating the indices for predicting the development of walled-off pancreatic necrosis (WOPN), a complication of acute pancreatitis characterized by a localized, encapsulated collection of necrotic tissue, ROC analysis demonstrated that MII-1, MII-2, and MII-3 had statistically significant predictive value (AUC: 0.676, 0.706, and 0.674, respectively; $p<0.05$), whereas SII was found to be non-predictive (AUC: 0.570; $p=0.313$).[16] In the aforementioned study, elevated CRP levels were found to be associated with the development of WOPN, and it was emphasized that, since the MIIs are calculated using a CRP multiplier, their elevation may serve as an important parameter for predicting this complication of acute pancreatitis. In contrast to our findings, Aziret et al.[17] reported that among patients who underwent surgery for WOPN, those with higher NLR values at admission had a greater likelihood of developing complications and experiencing poor prognosis ($p=0.01$). In a study conducted in China investigating risk factors for poor prognosis in gastrointestinal perforations, multiple regression analysis identified elevated NLR as an independent risk factor for predicting poor prognosis ($p=0.03$) and septic shock ($p=0.007$).[18] The results in the literature regarding the prognostic value of NLR are inconsistent. For example, in certain specific clinical conditions such as gastrointestinal perforation and WOPN, elevated NLR has been associated with poor prognosis, whereas in some studies – particularly those involving obstetric conditions such as PPROM – the predictive value of NLR and PLR has been shown to be limited. These discrepancies may be attributed to patient heterogeneity, differences in the etiology

of inflammation, and variations in the timing of blood parameter measurements. Regarding the subject of our study, no prior research has investigated inflammatory indices for predicting the likelihood of complication development following surgery for PUP. This limits the possibility of directly comparing our results with those of similar studies. We believe that although inflammatory indices and their combinations may be statistically significant when considered in isolation, in clinical practice, they should be interpreted alongside other factors to ensure a comprehensive, patient-centered approach.

In our study, the CRP/lymphocyte ratio, PLR, NLR, SII, MII-1, MII-2, and MII-3 values were significantly higher in patients with prolonged hospital stays compared to those with shorter stays ($p<0.05$). In a study investigating the diagnostic utility of pre-operative and post-operative NLR, PLR, and MI-1 and MI-2 indices in pain scoring for degenerative intervertebral disc disease, a strong positive correlation was found between MI-1 and MI-2 indices and length of hospital stay ($r=0.613$ and $r=0.741$, respectively; $p<0.001$).[19] A study conducted in Romania investigated the importance of systemic inflammatory indices in predicting early post-operative complications in patients with colorectal cancer. The results demonstrated a significant association between post-operative length of hospital stay and NLR, SII, and PLR values ($p<0.001$).[8] In a separate study investigating the predictive value of inflammatory markers derived from complete blood count in terms of the risk of developing pneumothorax and length of hospital stay in cases with thoracic trauma, a positive correlation was identified between NLR and SII and the length of hospital stay ($p<0.05$).[20] When evaluated in conjunction with the aforementioned studies, our findings are consistent with the existing literature. We believe that, when applied alongside clinical assessment, systemic inflammatory indices may play a determinative role in predicting patients' clinical course and length of hospital stay.

One of the major limitations of our study is its single-center design and retrospective evaluation of a population-specific cohort. Therefore, the results should not be generalized, as they are not supported by multicenter studies. Another important limitation is the lack of comparison between the inflammatory markers investigated and conventional inflammatory biomarkers. The validity of our findings should be supported by multicenter, large-scale, population-based studies.

CONCLUSION

In our study, the predictive value of simple, easily calculable, and cost-effective indices derived from the blood parameters of patients who underwent surgery for PUP was investigated in terms of morbidity and mortality. Among these indices, MII-2 and the CRP/lymphocyte ratio stood out in mortality prediction due to their balanced sensitivity and high specificity, whereas MII-2 and MII-3 were found to have greater clinical predictive power than other parameters in anticipating the development of complications. CRP/lymphocyte ratio, PLR, NLR, SII, MII-1, MII-2, and MII-3 indices also demonstrated clinically significant value in predicting the length of hospital stay.

Considering the studies available in the literature, these easily accessible and calculable indices may be incorporated into standard clinical practice to aid in early risk assessment in the management of patients operated on for PUP, thereby contributing to the decision-making process.

This study was presented as an oral presentation at the 5th International Emergency Congress, held on October 27–30, 2025.'

Ethics Committee Approval: This study was approved by the Gaziantep University Clinical Research Ethics Committee (Date: 26.03.2025, Decision No: 2025/54).

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Peptik ülser perforasyonu nedeniyle cerrahi uygulanan hastalarda morbidite ve mortaliteye yönelik prediktif faktörlerin değerlendirilmesi

AMAÇ: Peptik ülser perforasyonu (PÜP), mide içeriğinin periton boşluğuna sızması sonucu gelişen peritonit nedeniyle yüksek mortaliteye yol açabilen, yaşamı tehdit eden bir komplikasyondur. C-reaktif protein (CRP)/lenfosit oranı, nötrofil/lenfosit oranı (NLR) ve multi-enflamatuvar indeksler (MII) gibi sistemik enflamatuvar belirteçler, enflamasyonun şiddetini yansıtmaktadır. Bu çalışmada, CRP/lenfosit oranı, NLR, trombosit/lenfosit oranı (PLR), sistemik immün-enflamasyon indeksi (SII) ve MII'nin, PÜP nedeniyle cerrahi uygulanan hastalarda morbidite ve mortaliteyi öngörmedeki değerinin araştırılması amaçlandı.

GEREÇ VE YÖNTEM: Bu retrospektif çalışmaya, Ekim 2012–Ocak 2025 tarihleri arasında PÜP nedeniyle cerrahi uygulanan 319 hasta dahil edildi. Preoperatif enflamatuvar indeksler laboratuvar verilerinden hesaplanarak postoperatif komplikasyonlar, hastanede yatış süresi ve mortalite ile ilişkilendirildi.

BULGULAR: Yüksek CRP/lenfosit oranı, PLR, MII-1, MII-2 ve MII-3 değerleri fatal sonuçlarla ilişkili bulundu ($p<0.05$). MII-2 ve MII-3 indeksleri, postoperatif komplikasyonları en iyi öngören ve en yüksek eğri altında kalan alan (AUC) değerlerine sahip parametrelerdi (AUC: 0.655 ve 0.661; sırasıyla) ($p<0.001$). İncelenen tüm belirteçler, hastanede yatış süresi uzamış olan hastalarda anlamlı düzeyde yüksek saptandı. Özellikle MII-2 indeksi ve CRP/lenfosit oranı, mortalite öngörüsünde dengeli duyarlılık ve yüksek özgüllük gösterdi (AUC: 0.780 ve 0.787; sırasıyla) ($p<0.001$).

SONUÇ: MII-2 indeksi ve CRP/lenfosit oranı, PÜP hastalarında mortalite için güçlü prediktörlerdir; MII-2 ve MII-3 indeksleri ise komplikasyon öngörüsünde en etkili parametrelerdir. Klinik uygulamaya kolayca entegre edilebilen bu indekslerin kullanımı, risk sınıflandırmasını ve klinik karar verme süreçlerini geliştirebilir.

Anahtar sözcükler: CRP/lenfosit oranı; enflamatuvar belirteçler; multi-enflamatuvar indeks (MII); peptik ülser perforasyonu; prognoz.

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ORIGINAL ARTICLE

Predictors of surgical intervention and timing of ileus presentation in patients with adhesive small bowel obstruction

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ABSTRACT

BACKGROUND: Adhesive small bowel obstruction remains a common long-term complication following abdominal surgery and continues to represent a significant cause of morbidity and healthcare utilization. While several factors contributing to adhesion formation have been described, determinants influencing both the need for surgical intervention and the timing of clinical presentation are not yet fully understood. This study aimed to identify factors associated with surgical management in patients presenting with adhesive ileus after a single prior abdominal operation and to evaluate the relationship between operative duration and the timing of ileus onset.

METHODS: This retrospective study included 450 patients (n=450) diagnosed with adhesive ileus at a tertiary care center between January 1, 2021 and January 1, 2026. Patients with mechanical obstruction or multiple prior abdominal surgeries were excluded. Patients were categorized into operative (n=302) and conservative (n=148) management groups. Baseline characteristics, including age, sex, and American Society of Anesthesiologists scores, were comparable between groups (p>0.05). Clinical variables such as type of prior surgery, operative duration, surgical approach, contamination status, and time to ileus presentation were analyzed. Statistical analyses included an independent samples t-test, Chi-square test, Pearson correlation analysis, and multivariate logistic regression.

RESULTS: Of the 450 patients, 302 (67.1%) required surgical intervention. Operative duration was significantly longer in the operative group compared to the conservative group (4.3±1.8 vs. 3.1±1.6 h, p=0.003). Open surgery (75% vs. 52%, p=0.037) and contaminated surgical fields (78% vs. 60%, p=0.030) were more frequent in the operative group. The time to ileus presentation was significantly shorter in patients requiring surgery (5.5±1.9 vs. 6.8±2.1 months, p=0.002). A significant inverse relationship was observed between operative duration and time to ileus presentation (r=−0.32, p<0.05).

CONCLUSION: Operative duration, surgical approach, and intraoperative contamination are important determinants of surgical management in adhesive ileus. The inverse relationship between operative duration and time to presentation suggests that increased surgical burden may contribute to an earlier onset of clinically significant obstruction. These findings highlight the potential value of surgical factors in risk stratification and post-operative surveillance.

Keywords: Abdominal surgery; adhesive ileus; ileus onset; operative duration; post-operative adhesions; small bowel obstruction; surgical trauma.

INTRODUCTION

Post-operative adhesions are among the most common long-term consequences of abdominal surgery and constitute a leading cause of small bowel obstruction globally.[1-3] Adhesive small bowel obstruction (ASBO) represents a significant clinical burden, frequently resulting in recurrent hospital admissions, increased healthcare utilization, and the need for re-

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peated surgical interventions.[2-5] Despite advances in surgical techniques, adhesion-related complications remain difficult to prevent and continue to pose challenges in both acute management and long-term follow-up.

The development of post-operative adhesions is a multifactorial process influenced by surgical trauma, inflammatory response, and alterations in peritoneal healing mechanisms.[3,6,7] Several intraoperative factors, including surgical approach, operative duration, and the presence of contamination, have been identified as important contributors.[7-9] Minimally invasive techniques are generally associated with reduced adhesion formation due to less tissue manipulation, whereas open procedures and contaminated surgical fields may exacerbate peritoneal injury and inflammatory activation.[8-11] In this context, operative duration may also reflect the overall surgical burden, encompassing procedural complexity and intraoperative tissue stress.[12,13]

Although the risk factors for adhesion formation have been widely investigated, the timing of clinical presentation remains less clearly understood. Adhesion-related ileus may occur at variable intervals following surgery, and the determinants of early versus delayed onset are not well established.[2,14,15] Furthermore, most existing studies include heterogeneous patient populations with multiple prior operations, which may confound the interpretation of surgical risk factors.[5,14,15] Therefore, evaluating these associations in a more homogeneous cohort may provide clearer insights into the relationship between surgical characteristics, the need for operative intervention, and the timing of ileus development. In this context, the present study aimed to identify predictors of surgical management and to examine the association between operative duration and time to ileus presentation in patients with a history of a single prior abdominal surgery.

MATERIALS AND METHODS

This retrospective study was conducted at a tertiary care center and included patients treated between January 1, 2021 and January 1, 2026. Patients diagnosed with adhesive ileus who had a history of only one prior abdominal surgery were included in the study. Patients with obstructive bowel obstruction due to mechanical causes and those with a history of multiple abdominal surgeries were excluded.

Demographic and clinical data were obtained from the hospital database. Baseline demographic characteristics, including age, sex, and American Society of Anesthesiologists (ASA) score, were recorded. The evaluated parameters included type of prior surgery, duration of surgery (hours), surgical approach (open vs. laparoscopic), contamination status of the surgical field (contaminated vs. clean), time to presentation with ileus after the initial surgery (months), and treatment modality (operative vs. conservative). Patients were divided into two groups: those who required surgical intervention and those who were managed conservatively.

Baseline characteristics, including age, sex, and ASA score, were compared between groups to assess comparability.

Ethics committee approval was obtained from the Ethics Committee of University of Health Science Sancaktepe Şehit Prof. Dr. Training and Research Hospital, (File No: 336; Date: October 23, 2024). The study was conducted in accordance with the Declaration of Helsinki. As the analysis was retrospective in nature, the requirement for informed consent was waived by the ethics committee.

Statistical Analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences software (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean±standard deviation, whereas categorical variables were presented as frequencies and percentages. The normality of data distribution was assessed using appropriate tests.

Comparisons between the operative and conservative groups were performed using the independent samples t-test for continuous variables and the chi-square test for categorical variables. Baseline characteristics were specifically analyzed to confirm group comparability.

The relationship between operative duration and time to ileus presentation was evaluated using Pearson correlation analysis.

To identify independent predictors of surgical intervention, multivariate logistic regression analysis was performed, including variables that were clinically relevant and/or found to be significant in univariate analyses. Odds ratios with 95% confidence intervals were calculated. A value of $p<0.05$ was considered statistically significant.

RESULTS

A total of 450 patients were included in the study. The mean age of the study population was approximately 54.3±14.1 years, and 252 patients (56%) were male. When the operative and conservative groups were compared, no statistically significant differences were observed in terms of age, sex distribution, or ASA scores ($p>0.05$ for all), indicating that the groups were comparable (Table 1).

Appendectomy was the most common prior surgery (39.5%), followed by colon resection (22.4%) and trauma-related small bowel resection (13.7%). Regarding surgical approach, 67.6% of patients had undergone open surgery, whereas 32.2% had laparoscopic procedures. Contaminated surgical fields were observed in 72.2% of patients, whereas 27.5% had clean procedures. The mean operative duration was approximately 3.8±2.0 h, with a median of approximately 3.5 h (range: 0.5–8 h). The mean time to presentation with ileus after the initial surgery was approximately 6.1±2.2 months.

Of the patients, 302 (67.1%) required surgical intervention, whereas 148 (32.9%) were successfully managed conserva-

Table 1. Baseline characteristics of operative and conservative groups

Variable	Operative (n=302)	Conservative (n=148)	p
Age (years)	54.8±14.2	53.6±13.9	0.42[1]
Male, n (%)	172 (57)	80 (54)	0.58[2]
American Society of Anesthesiologists score (mean±standard deviation)	2.3±0.7	2.2±0.6	0.31[1]

[1]Independent samples t-test. [2]Chi-square test.

Table 2. Comparison of operative and conservative groups

Variable	Operative (n=302)	Conservative (n=148)	p
Operative duration (hours)	4.3±1.8	3.1±1.6	0.003[1]
Open surgery, n (%)	227 (75)	77 (52)	0.037[2]
Contaminated surgery, n (%)	236 (78)	89 (60)	0.030[2]
Time to ileus presentation (months)	5.5±1.9	6.8±2.1	0.002[1]
Appendectomy, n (%)	96 (32)	82 (55)	0.018[2]

[1]Independent samples t-test. [2]Chi-square test.

Table 3. Correlation between operative duration and time to ileus presentation

Variables	Correlation (r)	p
Operative duration-Time to ileus presentation	−0.32	<0.05[1]

[1]Pearson correlation analysis.

tively. Comparison between the operative and conservative groups demonstrated that operative duration was significantly longer in the operative group (approximately 4.3±1.8 vs. 3.1±1.6 h, p=0.003). The rate of open surgery was significantly higher in the operative group (75% vs. 52%, p=0.037). Similarly, contaminated surgical fields were more frequent in patients who required surgical intervention (78% vs. 60%, p=0.030). In addition, the time to ileus presentation after the initial surgery was significantly shorter in the operative group compared to the conservative group (approximately 5.5±1.9 vs. 6.8±2.1 months, p=0.002) (Table 2).

In terms of surgical type, more complex procedures involving resections were more common in the operative group, whereas relatively simpler procedures such as appendectomy were more frequently observed in the conservatively managed group (Table 2).

Correlation analysis demonstrated a significant inverse relationship between operative duration and time to ileus presentation (r=−0.32, p<0.05), indicating that longer operative times were associated with earlier onset of ileus symptoms (Table 3).

DISCUSSION

The present study evaluated both the determinants of surgical intervention and the temporal characteristics of ileus development in patients with ASBO following a single prior abdominal surgery. Our findings demonstrate that operative duration, surgical approach, and intraoperative contamination are independently associated with the need for surgical management. In addition, the observed inverse relationship between operative duration and time to ileus presentation suggests that surgical burden may influence not only the occurrence but also the timing of adhesion-related complications.

ASBO remains a major post-operative complication and is responsible for a substantial proportion of emergency surgical admissions worldwide.[1-3] While the mechanisms underlying adhesion formation have been extensively investigated, our findings emphasize that the characteristics of the initial surgical insult may also influence downstream clinical behavior. The higher rate of operative management observed in patients with a history of open surgery is consistent with previous studies demonstrating reduced adhesion-related complications following minimally invasive approaches.[5-7]

Intraoperative contamination was also identified as a significant determinant of surgical intervention. The presence of contamination is known to intensify peritoneal inflammation, impair fibrinolysis, and promote fibrous adhesion formation.[8-10] Similarly, prolonged operative duration, which often re-

flects increased surgical complexity and tissue handling, has been associated with higher complication rates and worse post-operative outcomes.[11-13] Our findings support the role of operative duration as a surrogate marker of cumulative surgical stress.

A particularly important observation in this study is the inverse relationship between operative duration and time to ileus presentation. This suggests that patients exposed to more extensive surgical trauma may develop symptoms earlier in the post-operative period. Although limited data exist regarding the timing of ileus onset, recent evidence suggests that adhesion-related complications may follow distinct temporal patterns influenced by both surgical and biological factors.[2,14,15]

Furthermore, the earlier presentation of ileus in patients requiring surgical intervention suggests the presence of a more aggressive adhesion phenotype. Such patients may be less responsive to conservative management and more likely to require operative treatment. Similar patterns have been reported in studies evaluating recurrence risk and treatment failure in ASBO.[5,14]

From a clinical perspective, these findings indicate that patients undergoing prolonged, open, or contaminated procedures may represent a high-risk group for early and clinically significant adhesion-related complications. Closer post-operative monitoring in this population may facilitate earlier diagnosis and timely intervention.

This study has several limitations, including its retrospective design and single-center setting, which may limit generalizability. However, the relatively homogeneous patient population and the consistency of the observed associations strengthen the validity of the findings.

CONCLUSION

Operative duration, surgical approach, and contamination status were significant determinants of the need for surgical intervention in patients with adhesive ileus, with longer operations, open techniques, and contaminated fields associated with increased surgical management rates. A moderate inverse correlation between operative duration and time to ileus presentation suggests that more prolonged and complex procedures may be linked to earlier onset of symptoms. These findings indicate that patients exposed to a higher surgical burden may benefit from closer and earlier post-operative surveillance for timely diagnosis and management of ileus.

Ethics Committee Approval: This study was approved by the University of Health Science Sancaktepe Şehit Prof. Dr. Training and Research Hospital (Date: 23.10.2024, Decision No: 336).

Informed Consent: As the analysis was retrospective in nature, the requirement for informed consent was waived by the ethics committee.

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Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Yapışıklığa bağlı ince bağırsak tıkanıklığı olan hastalarda cerrahi müdahale gereksiniminin belirleyicileri ve ileus gelişme zamanı

AMAÇ: Tek bir abdominal cerrahi öyküsü bulunan yapışıklığa bağlı ileus hastalarında cerrahi müdahale gereksinimi ile ilişkili faktörleri değerlendirmek ve operasyon süresi ile ileus gelişim zamanı arasındaki ilişkiyi incelemektir.

GEREÇ VE YÖNTEM: Bu retrospektif çalışmaya, 1 Ocak 2021 ile 1 Ocak 2026 tarihleri arasında üçüncü basamak bir merkezde yapışıklığa bağlı ileus tanısı alan 450 hasta (n=450) dahil edilmiştir. Mekanik obstrüksiyonu olan hastalar ve birden fazla abdominal cerrahi geçirmiş olanlar dışlanmıştır. Hastalar cerrahi (n=302) ve konservatif (n=148) tedavi gruplarına ayrılmıştır. Yaş, cinsiyet ve ASA skorları açısından gruplar benzer bulunmuştur (p>0.05). Önceki cerrahi tipi, operasyon süresi, cerrahi yaklaşım, kontaminasyon durumu ve ileus gelişim süresi gibi klinik değişkenler analiz edilmiştir. İstatistiksel analizlerde bağımsız örneklem t-testi, ki-kare testi, Pearson korelasyon analizi ve çok değişkenli lojistik regresyon kullanılmıştır.

BULGULAR: Toplam 450 hastanın 302'sinde (%67.1) cerrahi müdahale gerekmiştir. Cerrahi grupta operasyon süresi konservatif gruba göre anlamlı derecede daha uzun bulunmuştur (4.3±1.8 vs. 3.1±1.6 saat, p=0.003). Açık cerrahi oranı (%75 vs. %52, p=0.037) ve kontamine cerrahi saha (%78 vs. %60, p=0.030) cerrahi grupta daha yüksek saptanmıştır. Cerrahi gereksinimi olan hastalarda ileus gelişim süresi daha kısa bulunmuştur (5.5±1.9 vs. 6.8±2.1 ay, p=0.002). Operasyon süresi ile ileus gelişim zamanı arasında anlamlı negatif korelasyon tespit edilmiştir (r=-0.32, p<0.05).

SONUÇ: Operasyon süresi, cerrahi yaklaşım ve kontaminasyon durumu, yapışıklığa bağlı ileus hastalarında cerrahi müdahale gereksiniminin önemli belirleyicileridir. Operasyon süresi ile ileus gelişim zamanı arasında orta derecede negatif ilişki bulunması, daha uzun süren ameliyatların daha erken semptom başlangıcı ile ilişkili olabileceğini düşündürmektedir. Bu bulgular, cerrahi faktörlerin hem komplikasyon gelişme olasılığını hem de zamanlamasını etkileyebileceğini göstermektedir.

Anahtar sözcükler: Abdominal cerrahi; ameliyat süresi; cerrahi travma; ileus başlangıcı; ince bağırsak tıkanıklığı; postoperatif yapışıklıklar; yapışıklığa bağlı ileus.

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ORIGINAL ARTICLE

Survival status, mortality predictors, and scores in patients with severe traumatic brain injury in the intensive care unit

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ABSTRACT

BACKGROUND: Patients with traumatic brain injury (TBI) occupy an important place in intensive care units (ICUs) with high morbidity and mortality rates. The aim of this study was to determine the parameters predictive of mortality as the primary outcome and the distribution of these parameters as a secondary outcome in patients admitted to the ICU with TBI.

METHODS: After ethics committee approval and informed consent of the patient's relatives, TBI patients over 18 years of age treated in the anesthesia and reanimation ICU of our hospital between 2021 and 2023 were retrospectively included in our cohort study. The association and distribution of 18 different parameters, including demographic and clinical characteristics of TBI patients at ICU admission, with mortality were compared. Univariate and multivariate analyses were used to estimate the odds ratio for mortality.

RESULTS: Of the 194 patients included in the study, 80.4% were male, the mean age was 39.1±19.8 years, and the mortality rate was 35,1%. When comparing patients in 2 groups as survivor and non-survivor, patients in non-survivor group had a significantly lower mean Glasgow Coma Scale (GCS) score (5.7±3.1 vs. 10.1±3.1, p<0.001), revised trauma score (RTS) (5.25±2.1 vs. 10.6±2.7), the rate of surgery (33.8% vs. 53.2%, p<0.01), and the rate of epidural hematoma (EDH) (33.8% vs. 53.2%, p<0.01). The mean Acute Physiology and Chronic Health Evaluation II (APACHE II) score (29 vs. 13, p<0.001), the estimated mortality rate based on the mean APACHE II score (55% vs. 12%, p<0.001), the stress index (SI), (62.3±29.5 vs. 42.4±19.2, p<0.001), the rate of intracerebral hematoma/hemorrhage (ICH) (52.9% vs. 30.2%, p<0.01), the rate of skull fracture (80.9% vs. 24.6%, p<0.01), and the rate of intubation (94.1% vs. 60.3%, p<0.01) were found to be higher in non-survivor group. In multivariate analysis, the significant independent predictors of mortality were high APACHE II score (OR: 1.292 [1.192–1.400, p<0.001]), high SI (OR: 0.820 [0.699–0.921], p<0.001), and the presence of concomitant skull fracture (OR: 4.982 [1.894–13.103], p<0.001).

CONCLUSION: our study, high APACHE II score, high SI, presence of skull fracture, low GCS score, low RTS, intubation, and presence of ICH were associated with high mortality, while operability and presence of EDH were associated with low mortality. Therefore, we believe that these parameters should be prioritized when following TBH cases to initiate treatment earlier and prevent high mortality.

Keywords: Acute physiology and chronic health evaluation ii; mortality; presence of skull fractures; revised trauma score; stress index; subdural hematoma; traumatic brain injury.

INTRODUCTION

In the case of patients suffering from traumatic brain injury (TBI), particularly those with severe cases, referral to a neurotrauma center is recommended. These patients are then managed in neurosurgical intensive care units (ICUs) or anesthesia-reanimation ICUs, as is the case in Türkiye. Such patients comprise a significant portion of patients managed in

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ICU with high rates of mortality and morbidity even with the best medical and neurosurgical care.

TBI may present as part of a multifaceted physical body trauma, encompassing a broad spectrum of symptoms, or as a standalone injury to the head.

Annually, 1.5–2.8 million people in the United States experience TBI, resulting in 50,000–56.000 deaths.[1,2] Worldwide, it is estimated that sixty-nine million people will sustain TBI each year.[3] Although the causes and distribution of TBI vary among age groups, its prevalence is unfortunately steadily rising.

In Türkiye, comprehensive statistical data on TBI were unavailable. Instead, a general death rate was calculated for trauma-related incidents, labeled as external causes of injury and poisoning. External causes of injury and poisoning were responsible for approximately 3.1% of deaths in 2021, with 73.6% being male and 26.4% female in Türkiye.[4]

TBI results mainly in intracranial hemorrhage which may occur within the brain parenchyma or the surrounding meningeal spaces and diffuse axonal injury.[2]

Risk factors for TBI may include age and male gender. Some of the scoring systems and some of the parameters are used to predict the severity of the disease and survival rates of these patients in the ICU. Such parameters may include the following: age, gender, cause and type of hemorrhage, Glasgow Coma Scale (GCS) score, revised trauma score (RTS), neurosurgical procedures, duration in ICU, and ventilatory days.[1,2,5-7]

It is crucial to identify the factors that contribute to mortality in cases of TBI, given its high incidence rate, which is accompanied by significant mortality and morbidity.

Despite the extensive research conducted on this subject, utilizing diverse factors and scoring systems, the quest for a system that is both expeditious and straightforward with a limited number of parameters persists.

The principal aim of this study was to identify parameters that could be used to predict mortality. The secondary aim was to determine the distribution of etiology and these parameters.

MATERIALS AND METHODS

This retrospective, cross-sectional, single-center clinical study was conducted after receiving approval from the Clinical Research Ethics Committee, Ümraniye Training and Research Hospital (decision: B.10.1.TKH.4.34.H.GP.0.01/182, date: 26/05/2022) in the Health Sciences University, Ümraniye Training and Research Hospital, Anesthesiology and Reanimation Unit (ICU). This study was conducted in accordance with the Declaration of Helsinki.

The approval of the patient's relative was obtained.

Inclusion Criteria

The patients over the age of 18 who were diagnosed with TBI in the emergency department and subsequently hospitalized in the 3rd stage ICU for a period exceeding 24 h within the 2-year period from 2021 to 2023.

Patients with head trauma due to causes other than gunshot wounds (including traffic accidents, falls and bumps, etc.), patients were evaluated in two groups as survivors (Group 1) and non-survivors (Group 2).

The trauma was evaluated in two categories according to etiology as head trauma accompanied by general body trauma (GBT) and isolated head trauma (iHT).

Consequences of brain injury/hemorrhage due to head trauma were determined as traumatic subarachnoid hemorrhage (tSAH), intracerebral/intraparenchymal hematoma/hemorrhage (ICH), subdural hematoma (SDH), epidural hematoma (EDH), and cerebral concussion/diffuse axonal injury (DAI).[8]

Parameters included age, gender, GCS, RTS and stress index (SI) at admission, Acute Physiology and Chronic Health Evaluation II (APACHE II) score, estimated mortality by APACHE II Score, the presence or absence of surgical intervention, causes/types of brain injury (associated pathology with TBI) tSAH, ICH, SDH, EDH, DAI, presence or absence of intubation and duration, length of ICU stay, presence or absence of cranial fracture, etiology of head trauma (GBT associated with head trauma/GBT, iHT), and outcome of disease/actual mortality.

The data concerning the previously specified 18 parameters were extracted from the patient files and the hospital's electronic database.

For the purposes of this study, the following surgical interventions were selected for analysis: Operations performed by the neurosurgical department with indications of bleeding control and/or control of intracranial pressure.

The diagnosis was made in all patients on the basis of computed tomography scans and/or magnetic resonance imaging scans obtained at the time of admission to the emergency department as part of the emergency protocol.

It was aimed to assess the relationship between mortality and the above-mentioned 18 parameters in cases with TBI as the primary outcome; it was also aimed to determine the distribution of etiology and these parameters over the TBI patients as a secondary outcome.

Statistical Analyses

Mean, standard deviation, median, lowest, highest, frequency, and ratio values were used in the descriptive statistics of the data. The distribution of variables was measured with the Kolmogorov–Smirnov test. Mann–Whitney U-test was used in the analysis of quantitative independent data. Chi-square test was used to analyze qualitative independent data. The effect level and cut-off value were investigated with the receiver operating characteristic (ROC) curve. The effect level was investigated by univariate and multivariate logistic regression.

Table 1. Demographic and clinical data of all patients

	Min-Max	Median	Mean±SD/n	%
Age	18.0–84.0	33.0	39.1±19.8	
Gender				
Female			38	19.6
Male			156	80.4
GCS score	3.0–15.0	9.5	8.6±3.9	
APACHE II score	5.0–43.0	17.0	19.2±10.1	
Estimated Mortality	10.0–88.0	25.0	31.7±28.0	
by APACHE II score (%)				
RTS	3.0–12.0	9.0	7.9±2.4	
SI	22.0–59.0	52.4	54±23.9	
Etiology of TBI				
General body trauma			120	61.9
Isolated head trauma			74	38.1
Surgical ınterventıon				
(−)			104	53.6
(+)			90	46.4
Causes/types of TBI				
tSAH				
(−)			144	74.2
(+)			50	25.8
ICH				
(−)			120	61.9
(+)			74	38.1
SDH				
(−)			144	74.2
(+)			50	25.8
EDH				
(−)			126	64.9
(+)			68	35.1
DAI				
(−)			156	80.4
(+)			38	19.6
Intubation				
(−)			54	27.8
(+)			140	72.2
Duration time of intubation (day)	1.0–60.0		4.0	6.8±10.0
Duration time of ICU stay (day)	1.0–175.0		5.0	10.5±20.6
Cranial fracture				
(−)			108	55.7
(+)			86	44.3
Died (outcome of disease)				
No (−)			126	64.9
Yes (+)			68	35.1

GCS: Glasgow Coma Scale; APACHE II: Acute Physiology and Chronic Health Evaluation II; RTS: Revised Trauma Score; SI: Stress Index; TBI: Traumatic Brain Injury. Causes/types of TBI: tSAH: Traumatic Subarachnoid Hemorrhage; ICH: Intracerebral/Intraparenchymal Hemorrhage; SDH: Subdural Hematoma; EDH: Epidural Hematoma; DAI: Cerebral Contusion/Diffuse Axonal Injury; ICU: Intensive Care Unit.

Variables included in the univariate and multivariate logistic regression analyses were selected based on their statistical relevance in univariate analyses and their clinical significance. Model performance and effect level were assessed using ROC curve analysis, including the determination of cut-off values.

The Statistical Package for the Social Sciences 28.0 program (IBM Corp., Armonk, NY, USA) was used in the analyses.

RESULTS

A total of 204 patients who met the study criteria were identified. As a result of the incomplete nature of the medical information of 10 patients, the study's sample size was reduced, resulting in the inclusion of 194 patients (38 females and 156 males). The mean age of the patients was 39.1±19.8 years. The 30-day mortality rate was found to be 35.1%. The distribution of demographic data and the parameters analyzed is illustrated in Table 1.

In the present study, it was found that 61.9% of TBI patients were associated with GBT, the most common type of which was ICH (38%), and the rate of skull fracture was 44.3% (Table 1).

A comparison was made between Survivor (Group 1) and Non-survivor (Group 2) patients. The results indicated that GCS score, RTS, operation rate, and EDH rate were statistically significantly higher in Group 1 ($p<0.05$). The findings of this study demonstrate that Group 1 exhibited significantly lower APACHE II scores, estimated mortality percentages according to APACHE II scores, SI, ICH rates, fracture rates in the cranium, and intubation rates ($p<0.05$). No significant variations were observed in the remaining parameters (Table 2, Figs. 1 and 2).

In the present study, it was found that 94.1% of subjects who did not survive were intubated, 80.9% had fractures in the cranium, and the rate of EDH was only 8.8% (Table 2).

In the univariate model, the GCS score, the RTS, the presence of surgical intervention, ICH, EDH, and intubation were found to have a significant effect on the discrimination of patients into survivors and non-survivors. In the multivariate model, a significant independent efficacy of the APACHE II score, SI, and cranial fracture rate was observed in differentiating between patients who survived and those who did not (Table 3).

The sensitivity of the APACHE II mortality score, which is used to predict which patients will not survive, was 72.1% at a cut-off point of 50%. The positive predictive value was 94.2%, the sensitivity was 97.6%, and the negative predictive value was 86.6% (Table 4 and Fig. 3).

When the estimated mortality rate according to the APACHE II score was compared as <50% (low mortality) and >50% (high mortality) in two separate groups, significant differences

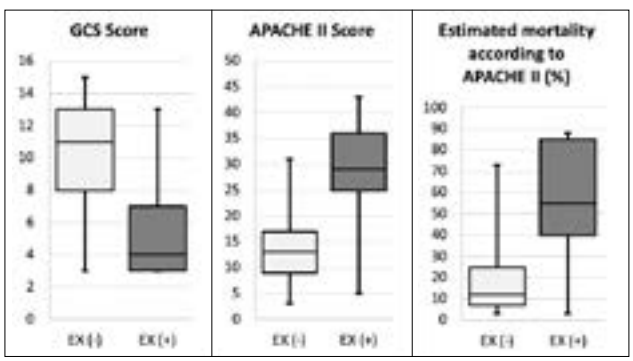
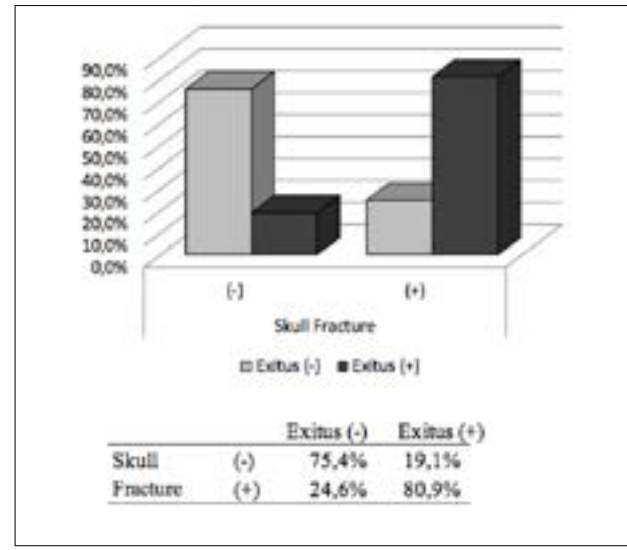


Figure 1. Comparison of GCS score, APACHE II score, and estimated mortality according to APACHE II score between groups. GCS: Glasgow Coma Scale, APACHE II: Acute Physiology and Chronic Health Evaluation.



		Exitus (-)	Exitus (+)
Skull Fracture	(-)	75,4%	19,1%
	(+)	24,6%	80,9%

Figure 2. Comparison of cranial fracture among groups.

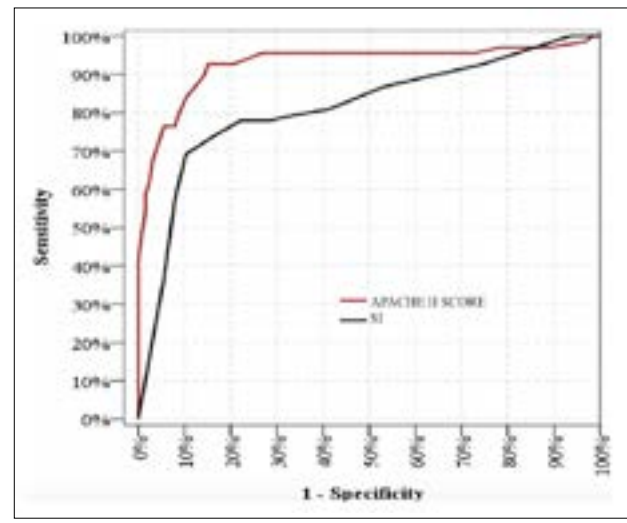


Figure 3. Estimation of mortality by receiver operating characteristic curve of APACHE II and SI. APACHE II: Acute Physiology and Chronic Health Evaluation II; SI: Stress index.

Table 2. Comparison of Group 1 (Survivors) and Group 2 (Non-survivors) in terms of demographic and clinical data

	Survivors (Group 1)			Non-survivors (Group 2)			
	Mean±SD/n	%	Median	Mean±SD/n	%	Median	P
Age	38.4±18.8	33.0	40.3±21.7	32.0	0.804m		
Gender							
Female	26	20.6		12	17.6		0.617$^{x^2}$
Male	100	79.4		56	82.4		
GCS Score	10.1±3.1		11.0	5.7±3.5		4.0	0.000^{m}
APACHE II Score	13.7±5.8		13.0	29.3±8.3		29.0	0.000^{m}
Estimated mortality by APACHE II Score (%)	15.7±13.0		12.0	61.3±23.8		55.0	0.000^{m}
RTS	10.6±2.7		11.0	5.25±2.1		6.3	0.000^{m}
SI	42.4±19.2		32.6	62.3±29.5		59.1	0.000^{m}
Surgical Intervention							
(−)	59	46.8		45	66.2		0.010$^{x^2}$
(+)	67	53.2		23	33.8		
tSAH							
(−)	96	76.2		48	70.6		0.395$^{x^2}$
(+)	30	23.8		20	29.4		
ICH							
(−)	88	69.8		32	47.1		0.002$^{x^2}$
(+)	38	30.2		36	52.9		
SDH							
(−)	97	77.0		47	69.1		0.232$^{x^2}$
(+)	29	23.0		21	30.9		
EDH							
(−)	64	50.8		62	91.2		0.000$^{x^2}$
(+)	62	49.2		6	8.8		
DAI							
(−)	105	83.3		51	75.0		0.163$^{x^2}$
(+)	21	16.7		17	25.0		
Cranial Fracture							
(−)				13	19.1		0.000$^{x^2}$
(+)				55	80.9		
Trauma							
General body trauma	74	58.7		46	67.6		0.222$^{x^2}$
Isolated head trauma	52	41.3		22	32.4		
Intubation							
(−)	50	39.7		4	5.9		0.000$^{x^2}$
(+)	76	60.3		64	94.1		
Duration time of intubation (Day)	7.6±12.6		3.0	5.9±5.3		4.0	0.301^{m}
Duration time of ICU stay (day)	12.0±24.6		5.0	7.8±9.0		4.0	0.477^{m}

GCS: Glasgow Coma Scale; APACHE II: Acute Physiology and Chronic Health Evaluation II; RTS: Revised Trauma Score; SI: Stress Index; tSAH: Traumatic Subarachnoid Hemorrhage; ICH: Intracerebral/Intraparenchymal Hemorrhage; SDH: Subdural Hematoma; EDH: Epidural Hematoma; DAI: Cerebral Contusion/Diffuse Axonal Injury; ICU: Intensive Care Unit. mMann–Whitney U test/χ^2 (Chi-square) test.

were observed in several parameters. Specifically, the GCS score, SI, EDH, and operation rate were significantly lower ($p<0.05$) in the high-mortality predicted group. Conversely, the APACHE II score, RTS, ICH, skull fracture rate, and intubation rate were significantly higher ($p<0.05$) in this group. No significant differences were observed in the remaining parameters (Table 5).

Table 3. Logistic regression analysis of the factors independently associated with mortality

	Univariate Model			Multivariate Model		
	OR	95% CI	p	OR	95% CI	p
GCS score	0.702	0.635–0.777	0.000			
APACHE II Score	1.320	1.222–1.425	0.000	1.292	1.192–1.400	0.000
RTS	0.803	0.695–0.978	0.000			
SI	0.834	0.728–0.989	0.000	0.820	0.699–0.921	0.000
Surgical Intervention	0.450	0.244–0.830	0.011			
ICH	2.605	1.416–4.792	0.002			
EDH	0.100	0.040–0.248	0.000			
Intubation	10.526	3.606–30.729	0.000			
Cranial fracture	12.965	6.262–26.845	0.000	4.982	1.894–13.103	0.001

Logistic Regression (Forward LR) (OR: Odds Ratio; CI: Confidence Interval; GCS: Glasgow Coma Scale; APACHE II: Acute Physiology and Chronic Health Evaluation II; RTS: Revised Trauma Score; SI: Stress Index; ICH: Intracerebral/Intraparenchymal Hemorrhage; EDH: Epidural Hematoma).

Table 4. ROC curve data of APACHE II score and SI

	Area under the curve	95% Confidence ınterval	p
APACHE II score	0.928	0.881–0.974	0.000
SI	0.834	0.718–0.865	0.000

ROC Curve. APACHE II: Acute Physiology and Chronic Health Evaluation II; SI: Stress index; ROC: Receiver operating characteristic.

DISCUSSION

The aim of this study was to determine a scoring system and/or other parameters that could assess the increased mortality risk in TBI patients in the early period. For this purpose, the effect of 18 different parameters on mortality was assessed.

TBI is frequently designated the "silent epidemic,"[3,9,10] and it is a growing public health problem. It is the largest contributor to mortality and disability worldwide among all trauma-related injuries.[11]

The aim of this study was to determine a scoring system and/or other parameters that could assess the increased mortality risk in TBI patients in the early period. For this purpose, the effect of 18 different parameters on mortality was assessed.

The presence of skull fracture, SI, and APACHE II score were found to be significant independent parameters in determining mortality in trauma patients. The following factors were found to be significant: GCS, RTS, operative rate, the presence of EDH, the presence of ICH, and the presence of intubation.

In the present study, a mortality rate of 35.1% was observed in patients with TBI who were followed in the ICU. As is evident in the extant literature, there is considerable variation in the reported mortality rates. However, an analysis of the study group in the studies conducted reveals that the severity of TBI varies.

For instance, Saadat et al.[1] reported a mortality rate of 16.9% among all TBI patients admitted to the hospital, while Ozyurt et al.[6] reported a mortality rate of 28.7% among TBI patients in the ICU, with the exclusion of patients with a GCS score above 8. In a similar vein, Réa-Neto et al.[12] documented a mortality rate of 27.6% among adult patients suffering from TBI who were subsequently observed in the ICU.

It is hypothesized that the elevated mortality rate observed in our study is attributable to the fact that the study population comprised moderate to severe critically injured patients. Because the present study did not include patients with more severe conditions who presented to the emergency department and subsequently died, nor did it include patients with mild conditions who were not admitted to the ICU and whose treatment was completed in a ward setting.

In the present study, no significant correlation was identified

Table 5. Comparison of the estimated mortality rate according to the APACHE II score, with a cutoff of <50% (low mortality) and >50% (high mortality), was conducted in two separate groups

	Estimated Mortality Rate According to the APACHE II score						p
	<50% (Low mortality)			>50% (High mortality)			
	ROC curve		ROC curve	ROC curve		ROC curve	
Age	37.9±18.5		33.0	42.4±23.0		32.5	0.316[m]
Gender							
Female	28	19.7		10	19.2		0.940[x²]
Male	114	80.3		42	80.8		
GCS Score	9.7±3.5		11.0	5.4±3.1		4.0	0.000[m]
APACHE II Score	14.2±5.8		13.5	32.9±5.3		33.0	0.000[m]
RTS	9.2±2.7		9.7	4.7±2.9		3.9	0.000[m]
SI	42.1±22		37.8	62.9±28.8		55.09	0.000[m]
Surgical Intervention							
(−)	67	47.2		37	71.2		0.003[x²]
(+)	75	52.8		15	28.8		
tSAH							
(−)	110	77.5		34	65.4		0.088[x²]
(+)	32	22.5		18	34.6		
ICH							
(−)	96	67.6		24	46.2		0.006[x²]
(+)	46	32.4		28	53.8		
SDH							
(−)	109	76.8		35	67.3		0.182[x²]
(+)	33	23.2		17	32.7		
EDH							
(−)				50	96.2		0.000[x²]
(+)				2	3.8		
DAI							
(−)	117	82.4		39	75.0		0.250[x²]
(+)	25	17.6		13	25.0		
Cranial fracture							
(−)	99	69.7		9	17.3		0.000[x²]
(+)	43	30.3		43	82.7		
Trauma							
General Body Trauma	86	60.6		34	65.4		0.540X²
Isolated Head Trauma	56	39.4		18	34.6		
Intubation							
(−)	54	38.0		0	0.0		0.000[x²]
(+)	88	62.0		52	100.0		
Duration time of Intubation (day)	6.6±11.1	3.0		7.1±7.9		5.0	0.068[m]
Duration time of ICU stay (day)	10.7±23.0	4.0		9.8±12.0		5.0	0.642[m]
Exitus							
(−)	123	86.6		3	5.8		0.000[x²]
(+)	19	13.4		49	94.2		

[m]Mann–Whitney U test/[x²] Chi-square test. GCS: Glasgow Coma Scale; APACHE II: Acute Physiology and Chronic Health Evaluation II; RTS: Revised Trauma Score; SI: Stress Index; TBI: Traumatic Brain Injury. Causes/types of TBI: tSAH: Traumatic Subarachnoid Hemorrhage; ICH: Intracerebral/Intraparenchymal Hemorrhage; SDH: Subdural Hematoma; EDH: Epidural Hematoma; DAI: Cerebral Contusion/Diffuse Axonal Injury; ICU: Intensive Care Unit.

between mortality and age, gender, trauma etiology (GBT/head trauma only), presence of tSAH, SDH, DAI, duration of intubation, and total hospital days.

The mean age of the patients in the present study was 39.1±19.8 years. This finding was consistent with the age group reported in the extant literature. A substantial body of research has indicated that TBI manifests in young adults, a demographic that is typically characterized by its high level of productivity.[1,6,7,12-14] The present study corroborates this finding, as it documented a lower prevalence of TBI in female patients compared to male patients, a phenomenon that aligns with the existing literature.[1,6,7,12-15] However, the mortality rate did not exhibit a significant disparity between female and male patients. The low number of female patients may be due to the fact that the traumatized population is more likely to be male and to participate in life, be active workers, and work in physically demanding jobs. However, the mortality response to trauma was similar in both sexes in the present study. This finding contradicts the prevailing notion that the female body is inherently more fragile and susceptible to injury from equivalent trauma. In addition, three distinct studies, one of which was multicenter, reported that there was no difference in mortality between men and women.[1,6,12] Conversely, Mikolic et al.[16] compared the 6-month outcomes of male and female TBI survivors and classified patients into two groups according to GCS score: Mild and moderate/severe. The findings of the study indicated that the hospitalization rate in the mild group was lower in females compared to males. However, the long-term disability rate was higher in females. Furthermore, the total hospitalization time was shorter in the m/s group in females. Finally, the 6-month outcome was worse in females younger than 45 and older than 65 years compared to males. In contrast, our study did not involve a comparison of patients by subgrouping them according to GCS score and age group. A comparison of patients based on categorized parameters may have yielded different results.

It is well established that APACHE II and GCS scores are effective in predicting mortality in ICU patients and have been utilized for a considerable period.[1,6,7,13,15,17,18]

The GCS score is a method of rapidly ascertaining the level of coma in patients, irrespective of the underlying cause. The categorization of conditions is not based on the severity of the condition, whether it is acute, chronic, traumatic, or medical. The GCS score continues to be utilized extensively due to its simplicity, the fact that it does not require laboratory results, and its reliability, as demonstrated in numerous studies. A low GCS score has been reported to be associated with high mortality in many cases.[18] It was also determined that a low GCS score was an effective mortality indicator in our study group of TBI patients.

In contrast to the GCS, the APACHE II scoring system was developed to evaluate the severity of acute and chronic conditions based on physiological and laboratory parameters. However, when it was first introduced, it contained a number of parameters that were difficult to calculate. It was subsequently simplified to make it more user-friendly. This version is still widely used in many centers. Despite the APACHE IV update, APACHE II remains more popular. The limited use of APACHE IV is generally attributed to a lack of technological advances in healthcare. In our study, we found that the APACHE II score, which was not developed specifically for trauma, is an independent predictor of mortality in patients with severe head trauma. Even though more up-to-date scoring systems are available today,[18] we think that the APACHE II score can also be used to predict mortality in patients with head trauma.

The SI score is a simple scoring system that uses only two parameters (the ratio of blood glucose to serum potassium levels) to calculate the score.[19-20] The mechanism by which SI predicts TBH mortality risk is unclear. However, the two parameters that make up the SI score are important factors affected by the physiological stress response to trauma and the resulting metabolic impairment. This may contribute to its ability to predict TBH mortality. As is well known, a series of cellular events are triggered in response to TBI that can lead to cerebral edema and cellular necrosis. These events can cause serum electrolyte and glucose imbalances, exacerbating secondary damage and increasing mortality. SI evaluates serum glucose and potassium levels together and can therefore be used to assess the severity of these metabolic disturbances and the extent of cellular damage that develops during TBH monitoring.[19-21] In their study, Huang et al.[19] reported that, even after adjusting for other variables in the analysis, higher SI scores were significantly associated with an increased risk of mortality, confirming its value as a prognostic indicator. In our study, we found that SI scores were an independent predictor of mortality in trauma patients. Due to its simplicity and the fact that it requires fewer parameters than the APACHE II, it may become more widely used in predicting mortality in the future. We believe that its efficacy could be further supported by studies involving a larger number of patients.

RTS is calculated using only three parameters (GCS, systolic blood pressure, respiratory rate) from APACHE II. RTS was developed primarily for cases of major head trauma without concomitant major physiological changes or multiple system injuries. It is recommended that an RTS <4 threshold should be used for the purpose of evaluation at the trauma center. The RTS has been demonstrated to be inversely correlated with clinical status, suggesting that as the RTS score declines, the severity of the clinical condition concomitantly increases. In our study, we found it to be effective in predicting mortality but not as an independent factor. It can be used as a simple and reliable scoring system that can be calculated by simply monitoring the patient without waiting for laboratory results in trauma patients[18,22,23]

If a GBT combined with a head trauma is considered to be a higher-energy trauma compared to a pure head trauma, one might think that it is associated with a higher mortality risk. However, in our study, the risk of death was similar for both types of trauma.

It was hypothesized that the age of the patients in our study might be the underlying cause of the observed phenomenon. The patients in our study were younger. A further factor that may be pertinent to this issue is the relatively low number of sample size. It is hypothesized that this result could be demonstrated more clearly in a study with a larger sample size.

However, apart from these scores, one of the most significant findings of our study was that the presence of a skull fracture was an important determinant of mortality, independent of other parameters. The underlying factors contributing to this phenomenon may include the potential risks associated with compression and/or damage to the brain, the heightened risk of hemorrhage, the unavailability of surgical correction according to anatomical location, and the risk of central nervous system infection. It is imperative that the presence of a skull fracture, which can be detected by a simple physical examination or imaging, is met with a high degree of seriousness and consideration so that it is not overlooked in terms of mortality.

The present study found that the presence of intubation was associated with high mortality, regardless of the duration of intubation and length of hospital stay. The present study did not identify a mortality-increasing effect associated with prolonged ICU stay and prolonged intubation. The fact that the patient had just been intubated was a significant factor in determining mortality. Patients who are unable to protect their airway are susceptible to aspiration and/or intubation-induced complications from the moment of trauma. Consequently, this scenario has the potential to result in elevated mortality rates.

In the cohort study conducted by Corrigan et al.[24] on TBI patients who were treated and sent to a rehabilitation center, it was reported that the types of TBI (e.g., EDH, SDH...) were one of the parameters that could be used to determine the outcome. In our study, when we evaluated the relationship between TBI types and mortality, we found that EDH was associated with low mortality and ICH with high mortality.

In patients with EDH, a rapid diagnosis and surgical evacuation of the hematoma generally results in an excellent functional prognosis.[25] In the majority of cases, EDHs that are within the limits of the operation have generally yielded favorable outcomes following timely surgical intervention. The correlation between the presence of EDH and low mortality in our study may be elucidated as follows. Conversely, it was hypothesized that the elevated mortality rate associated with ICH was attributable to the widespread nature of the hemorrhage, as opposed to its localized distribution, and the absence of a suitable surgical intervention. It may be concluded that the mortality rate is subject to reduction if the brain damage that develops as a result of trauma can be operated on. Nevertheless, this assertion requires substantiation through rigorous studies encompassing numerous cases across multiple centers.

In another study conducted by Maas et al.[26] in TBI patients, they reported SDH as an indicator of poor prognosis.

As evidenced by the extant literature, studies have been conducted which compare the varying parameters that may affect clinical outcomes and mortality to differing extents. The findings reported in these studies are inconsistent, presumably due to the inclusion of disparate populations.

In a study of all TBI patients with 3< GCS ≤8 who presented to hospital, older age was reported to be an important determinant of poor outcome, and similar to our study, the presence of EDH was reported to be an important determinant of good outcome.[27]

Einarsen et al.[28] reported that older age, presence of SDH, and, similar to our study, low GCS score and presence of hypoxia were associated with poor recovery in their study of TBI patients over 16 years of age with GCS between 9 and 13.

In a study by Otal and Baydin[15] in head trauma patients of all ages, including children presenting to the emergency department, it was reported that SDH was seen at a rate of 10–20% and that SDH was the most lethal type of injury, and similar to our study, head trauma was more common in the male gender and the presence of skull fracture rate was 43%, GCS plays an important role in determining the prognosis and early surgical intervention reduces the mortality rate.

Klemenc-Ketis et al.[29] reported that short hospital stay and similar to our study, the presence of EDH were good outcome markers in their study in which patients who were admitted to hospital due to TBI and who did not die on admission and GCS <9 were included.

Our study group was different from those in the studies mentioned above and included only TBI patients over 18 years of age who were admitted to the ICU. Different results may be due to the exclusion of more severe patients who came to the emergency department and died and less serious patients who were admitted to the ward and completed their treatment there. It can be said that our study evaluated TBI patients with moderate to severe condition.

We believe that the strength of our study lies in the inclusion of moderate-severe TBI patients admitted to the ICU during the specified time period, the clarity of the study parameters, the absence of the risk of subjective-differential assessment during recording, and the evaluation of 19 parameters, including not only the scoring parameters but also the presence of surgery, skull fractures, and types of trauma-related bleeding in TBI patients.

Limitations

This retrospective, single-center trial, with a relatively limited number of patients who were comparatively younger in age, evaluated patients admitted to the ICU only. Among the treatment modalities, it assessed the relationship between mortality and neurosurgical operations. In this study, management of patients was achieved based on guidelines and evidence from current literature.[30-33] The decision of whether to perform surgery was made by the neurosurgery department either before or after admission to the ICU.

CONCLUSION

An accurate and early evaluation of patients with severe head trauma, a condition that can be considered a "silent epidemic" with a high mortality rate woærldwide, and prompt planning of a treatment algorithm can be lifesaving.

Our assessment of mortality in patients with head trauma revealed that the APACHE II and SI scoring systems, which are widely used for other conditions, are valuable. We also found that certain significant clinical findings, such as skull fractures, should be considered alongside these scores.

We recommend evaluating patients to predict mortality, doing so as soon as possible, even before ICU admission, using both clinical conditions and scoring systems.

Ethics Committee Approval: This study was approved by the Clinical Research Ethics Committee, Ümraniye Training and Research Hospital (Date: 26.05.2022, Decision No: B.10.1.TKH.4.34.H.GP.0.01/182).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Yoğun bakım ünitesindeki ağır travmatik beyin hasarlı hastalarda sağkalım durumu, mortalite belirleyicileri ve skorları

AMAÇ: Travmatik beyin hasarı (TBH) hastaları, yüksek morbidite ve mortalite oranlarıyla yoğun bakım ünitelerinde (YBÜ) takip ettiğimiz hastalar içinde önemli bir yere sahiptir. Çalışmamızın amacı, YBÜ'de TBH nedeniyle yatan hastalarda primer olarak mortaliteyi öngören parametreleri ve skorlamaları belirlemek, sekonder olarak ise etiyoloji ile bu parametrelerin TBH hastaları üzerindeki dağılımını değerlendirmektir.

GEREÇ VE YÖNTEM: Etik kurul onayı ve hasta yakını onamı sonrasında, 2021–2023 yılları arasında hastanemiz Anesteziyoloji ve Reanimasyon YBÜ'süne kabul edilen 18 yaş ve üzeri TBH hastaları retrospektif kohort çalışmamıza dahil edildi. TBH hastalarının demografik özellikleri ile YBÜ'ye kabul sırasındaki klinik özelliklerini içeren 18 ayrı parametrenin mortalite ile ilişkisi ve dağılımları karşılaştırıldı. Tek değişkenli ve çok değişkenli analizler, mortalite için odds oranını tahmin etmek amacıyla kullanıldı.

BULGULAR: Çalışmaya dahil edilen 194 hastanın %80.4'ü erkek olup, yaş ortalamaları 39.1±19.8 yıl, mortalite oranı ise %35.1 idi. Exitus olmayan ve olan hastalar karşılaştırıldığında, exitus olan hastalarda ortalama Glasgow Koma Skoru (GKS) (5.7±3.1'e karşı 10.1±3.1, p<0.001), Revize Travma Skoru (RTS) (5.25±2.1'e karşı 10.6±2.7), operasyon varlığı oranı (%33.8'e karşı %53.2, p<0.01) ve epidural hematom (EDH) varlığı oranı (%33.8'e karşı %53.2, p<0.01) daha düşüktü. Ortalama APACHE II skoru (29'a karşı 13, p<0.001), APACHE II skoruna göre tahmini mortalite yüzdesi (55'e karşı 12, p<0.001), stres indeksi (SI) (62.3±29.5'e karşı 42.4±19.2, p<0.001), intraserebral hematom/hemoraji (ICH) varlığı oranı (%52.9'a karşı %30.2, p<0.01), kafatası kemiğinde kırık varlığı oranı (%80.9'a karşı %24.6, p<0.01) ve entübasyon varlığı oranı (%94.1'e karşı %60.3, p<0.01) ise daha yüksek olarak saptandı. Çok değişkenli analizde mortalitenin anlamlı bağımsız belirleyicileri; yüksek APACHE II skoru (OR: 1.292 [1.192–1.400], p<0.001), yüksek SI (OR: 0.820 [0.699–0.921], p<0.001) ve eşlik eden kafatası kemiği kırığı varlığı (OR: 4.982 [1.894–13.103], p<0.001) idi.

SONUÇ: Çalışmamızda özellikle yüksek APACHE II skoru, yüksek SI, kafatası kemiği kırığı varlığı, düşük GKS skoru, düşük RTS, entübasyon ve ICH varlığı yüksek mortalite ile ilişkiliyken; operabilite ve EDH varlığı düşük mortalite ile ilişkiliydi. Bu nedenle, TBH olgularının takibinde erken tedaviye başlanması ve yüksek mortalitenin önlenmesi amacıyla bu parametrelerin öncelikli olarak göz önünde bulundurulması gerektiği kanaatindeyiz.

Anahtar sözcükler: APACHE II; kafa kemiklerinde kırık varlığı; mortalite; revize travma skoru; stres indeksi; subdural hematom; travmatik beyin hasarı.

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ORIGINAL ARTICLE

Factors predicting need for intervention and mortality in patients with spontaneous rectus sheath hematoma

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ABSTRACT

BACKGROUND: Spontaneous rectus sheath hematoma (RSH) is a potentially life-threatening cause of acute abdominal pain, particularly in elderly and anticoagulated patients. While most cases are managed conservatively, a significant proportion requires interventional procedures, and mortality remains substantial. The aim of the study was to identify the predictors of interventional procedure requirements and 90-day mortality in patients with spontaneous RSH.

METHODS: This retrospective study included consecutive adult patients diagnosed with spontaneous RSH at a tertiary care center between January 2017 and December 2023. Clinical, laboratory, and imaging data were collected. Multivariate logistic regression was used to identify independent predictors of interventional radiology treatment and 90-day all-cause mortality.

RESULTS: The study consisted of 59 patients with a median age of 72 years, and 77.9% were females. Interventional radiology procedures were performed in 27.1% of cases, and 90-day mortality was 22.0%. Hematoma volume was independently associated with the need for intervention (odds ratio [OR]: 1.002; p=0.004). In a subgroup of patients undergoing computed tomography angiography (n=36), contrast extravasation was also a significant predictor (OR: 17.460; p=0.009). Independent predictors of 90-day mortality were advanced age (OR: 1.088; p=0.045) and greater hemoglobin decline (OR: 1.086; p=0.008).

CONCLUSION: Hematoma volume and contrast extravasation are significant predictors of the need for interventional treatment, while advanced age and hemoglobin decline predict 90-day mortality in spontaneous RSH. These findings support the use of objective radiologic and laboratory parameters for early risk stratification. Prospective multicenter validation is warranted to guide standardized management strategies in this high-risk population.

Keywords: Intervention; mortality; prognosis; rectus sheath hematoma.

INTRODUCTION

Rectus sheath hematoma (RSH) is an increasingly recognized clinical entity that poses significant diagnostic and therapeutic challenges. While historically considered rare, the incidence of spontaneous RSH has risen in parallel with the increased use of anticoagulant and antiplatelet therapies, particularly among elderly patients with multiple comorbidities.[1,2] This condition results from bleeding into the rectus sheath space, most commonly due to rupture of the epigastric vessels or direct muscle injury, and often presents with acute abdominal pain and a palpable mass.[3] The clinical significance of RSH lies in its potential to mimic acute abdominal emergencies and its association with substantial morbidity, including hemorrhagic shock and mortality rates reaching 22% in high-risk populations.[4,5]

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Current understanding of RSH management remains largely based on retrospective studies and small case series, revealing critical gaps in evidence-based decision-making. While conservative management with blood product support and anticoagulation reversal is effective for the majority of patients, approximately 20–30% require invasive interventions such as angiographic embolization or surgical exploration.[6,7] Identifying patients at risk of conservative management failure who may require urgent intervention remains a persistent clinical challenge.[8,9] Recent efforts, such as the scoring model by Contrella et al.,[2] have proposed radiological and clinical predictors – hematoma volume, transfusion requirement, active extravasation – but lack prospective validation and widespread clinical adoption.

Despite technical success rates approaching 100%, previous studies have also reported mortality rates ranging from 14% to 44% in patients undergoing embolization for spontaneous RSH, underscoring the limited physiologic reserve of this patient population.[10] Early identification of patients likely to require intervention may help reduce mortality by enabling timely and appropriate management, while also preventing unnecessary procedures in low-risk individuals. Importantly, once minimal hemodynamic deterioration is observed, delaying intervention in these patients may worsen outcomes. Earlier treatment may allow for the use of less invasive strategies, thereby reducing procedure-related morbidity and improving overall prognosis.[10,11]

This study was designed to address these knowledge gaps by analyzing a consecutive cohort of patients with spontaneous RSH managed at a tertiary care center. We aimed to identify factors associated with the need for interventional radiology procedures and to determine independent predictors of 90-day mortality in patients with spontaneous RSH.

MATERIALS AND METHODS

Study Design and Patients

The study was conducted in accordance with the Helsinki Declaration. Following the approval of the Institutional Ethics Committee of Gulhane Scientific Research Ethics Committee (date: 10.09.2024, decision number: 2024-391), a retrospective study was conducted to evaluate patients diagnosed with spontaneous RSH between January 2017 and December 2023 at a tertiary care center. All adult patients were identified from the hospital electronic database. Patients aged 18 years or older who were diagnosed with spontaneous RSH and either presented to the emergency department or were inpatients in other departments and consulted by general surgery during the study period were included. Patients were excluded if the hematoma was iatrogenic or traumatic in origin or if their data were incomplete.

Data Collection and Variables

Patient data were retrospectively collected from hospital medical records. The variables included demographic characteristics, comorbidities, use of anticoagulant or antiplatelet medications, type of hospital admission, laboratory values (hemoglobin, hematocrit, platelet count, prothrombin time, international normalized ratio, creatinine), diagnostic methods, hematoma volume, blood transfusion status, treatment strategies, length of hospital stay, and clinical outcomes.

Definitions

Hematoma volume was calculated using the ABC/2 method, defined as maximal length × maximal width × maximal thickness divided by 2.[10] When abdominal computed tomography (CT) was performed, the hematoma was classified according to the Berná classification.[12] 90-day mortality was defined as death from any cause within 90 days of the index admission. 90-day readmission was defined as any hospital readmission occurring within 90 days after discharge from the index hospitalization.

Patient Follow-up and Outcomes

All patients were followed for a period of 90 days after discharge to assess survival and clinical outcomes. The primary outcome of the study was 90-day mortality. The secondary outcome was the requirement for interventional procedures during hospitalization.

Statistical Analysis

Normal distribution of continuous variables was evaluated with quantile-quantile plots, histograms, and the Shapiro–Wilk test. Continuous variables were presented as median values with minimum and maximum ranges. Categorical variables were expressed as counts and percentages. The Wilcoxon Mann–Whitney U test was used for comparison of continuous variables, while the Pearson χ^2 test or Fisher's exact test was employed for categorical variables. Multivariate logistic regression analysis was performed using the backward stepwise method based on the likelihood ratio to identify independent predictors of 90-day mortality and the need for interventional procedures. All variables with a $p<0.20$ in the univariate analysis and all clinically significant variables regardless of statistical significance were included in the multivariate models. The linearity assumption between continuous independent variables and the logit of the dependent variable was evaluated using the Box-Tidwell procedure,[13] and multicollinearity was assessed using the variance inflation factor and tolerance statistics. The goodness-of-fit of the final multivariate models was assessed using the Hosmer-Lemeshow test. Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) were reported for statistically significant predictors. A two-tailed $p<0.05$ was considered statistically significant. All statistical analyses were conducted using the Statistical Package for the Social Sciences version 26.0 (IBM Corp., Armonk, NY, USA), and data visualizations were created using GraphPad Prism version 8.0 (GraphPad Software, San Diego, CA, USA).

RESULTS

Patient Characteristics

A total of 59 patients diagnosed with spontaneous RSH were included in the study. The median age was 72 years (range: 18–94), and 77.9% were female. During hospitalization, 16 patients underwent interventional radiology procedures (27.1%), of whom 3 required repeat embolization. Surgical intervention was required in only one patient due to persistent hemodynamic instability and failure to achieve hemorrhage control with radiological intervention. Surgical exploration successfully achieved hemostasis and resulted in stabilization of the patient's condition. The overall 90-day mortality rate was 22.0%. Demographic, laboratory, and clinical characteristics of the patients are presented in Table 1.

Predictors of Interventional Procedure Requirement

Comparative analysis revealed that patients requiring interventional management had significantly lower admission hemoglobin (9.9 vs. 11.5 g/dL, p=0.038) and hematocrit levels (29.3% vs. 36.8%, p=0.032), greater hemoglobin (25.3% vs. 10.7%, p=0.002) and hematocrit decline rates (27.8% vs. 11.8%, p=0.004), and higher hematoma volumes (1070 vs. 49 cm^3, p<0.001). In addition, Berna Type III classification and contrast extravasation on CT angiography (CTA) were significantly more common among these patients (p=0.007 and p<0.001, respectively). Blood transfusion, intensive care unit (ICU) admission, and length of hospital stay were also significantly more prevalent in the interventional group (p=0.002, p=0.016, and p<0.001, respectively) (Table 2).

In the multivariate analysis, hematoma volume was independently associated with the need for interventional procedures (OR: 1.002; 95% CI: 1.001–1.003; p=0.004), whereas blood transfusion was retained in the final model but did not reach statistical significance (OR: 5.158; 95% CI: 0.940–28.316; p=0.059) (Figure 1).

Furthermore, a subgroup analysis of 36 patients who underwent evaluation with CTA revealed that, in addition to hematoma volume, the presence of contrast extravasation on imaging was also an independent predictor of interventional radiologic management (OR: 17.460; 95% CI: 2.065–147.615; p=0.009).

Predictors of 90-Day Mortality

A total of 7 patients (11.9%) died within 30 days, and 13 patients (22.0%) experienced 90-day mortality. Table 3 shows univariate analysis of demographic and clinical factors associated with 90-day mortality. Patients experiencing mortality tended to be significantly older (81 vs. 69 years; p=0.002). They also had higher rates of inpatient-onset hematomas (p=0.018), greater hemoglobin and hematocrit decline rates (p=0.005 and p=0.003, respectively), elevated serum creatinine levels (p=0.019), and higher hematoma volumes (p=0.043). The mortality group had significantly more frequent blood product transfusions and ICU admissions (p=0.016 and p=0.018, respectively).

Table 1. Demographic, clinical, and laboratory characteristics of patients with spontaneous rectus sheath hematoma

	n=59 (%)
Age, years	72 (18–94)
Female gender, n (%)	46 (77.9)
Hypertension, n (%)	45 (76.3)
Coronary artery disease, n (%)	19 (32.2)
Diabetes mellitus, n (%)	20 (33.9)
COPD, n (%)	19 (32.2)
Anticoagulation, n (%)	41 (69.5)
Antiplatelet agents, n (%)	33 (55.9)
Admission types, n (%)	
Emergency department admission	40 (67.8)
Inpatient-onset events	19 (32.2)
Hemoglobin (at admission), g/dL	11.1 (7.2–17.0)
Hemoglobin decline rate, %	18.2 (0–61.7)
Hematocrit (at admission), %	34.5 (22.9–50.0)
Hematocrit decline rate, %	20.3 (0–59.5)
Platelets,×10^9/L	237 (16–579)
Prothrombin time, s	13.0 (8.5–144.3)
INR	1.1 (0.9–14.2)
Creatinine, mg/dL	0.98 (0.53–4.66)
Diagnostic procedures, n (%)	
Only US	23 (39.0)
US and CT	36 (61.0)
CT classification, n (%)*	
Berna I	12 (33.3)
Berna II	6 (16.7)
Berna III	18 (50.0)
Extravasation on CTA, n (%)*	15 (41.7)
Hematoma volume, cm^3	144 (10–10927)
Blood transfusion, n (%)	28 (47.5)
Red blood cell transfusion, units	0 (0–27)
Fresh frozen plasma transfusion, units	0 (0–35)
Platelet transfusion, units	0 (0–11)
Management, n (%)	
Conservative treatment	43 (72.9)
Interventional procedure	16 (27.1)
Surgical treatment, n (%)	1 (1.7)
Intensive care unit stay, n (%)	19 (32.2)
Length of hospital stay, day	7 (0–58)
90-day readmission, n (%)	6 (10.2)
90-day mortality, n (%)	13 (22.0)

CT: Computed tomography; CTA: Computed tomography angiography; COPD: Chronic obstructive pulmonary disease; US: Ultrasound. *Only patients who underwent CT were analyzed (n=36).

Table 2. Comparison of patients' characteristics between those managed conservatively and those who underwent interventional procedures for spontaneous rectus sheath hematoma

	Conservative management (n=43) (%)	Interventional procedure (n=16) (%)	p
Age, years	71 (18–94)	73.5 (21–88)	0.573
Female gender, n (%)	35 (81.4)	11 (68.8)	0.311
Hypertension, n (%)	32 (74.4)	13 (81.3)	0.738
Coronary artery disease, n (%)	14 (32.6)	5 (31.3)	0.924
Diabetes mellitus, n (%)	13 (30.2)	7 (43.8)	0.329
COPD, n (%)	15 (34.9)	4 (25.0)	0.470
Anticoagulation, n (%)	27 (62.8)	14 (87.5)	0.111
Antiplatelet agents, n (%)	22 (51.2)	11 (68.8)	0.226
Admission types, n (%)			0.247
Emergency department admission	31 (72.1)	9 (56.3)	
Inpatient-onset events	12 (27.9)	7 (43.7)	
Hemoglobin (at admission), g/dL	11.5 (7.4–17.0)	9.9 (7.2–14.1)	0.038
Hemoglobin decline rate, %	10.7 (0–61.7)	25.3 (13.2–52.3)	0.002
Hematocrit (at admission), %	36.8 (22.9–50.0)	29.3 (23.5–42.1)	0.032
Hematocrit decline rate, %	11.8 (0–59.5)	27.8 (14.6–48.5)	0.004
Platelets,×10^9/L	239 (16–479)	229 (100–579)	0.805
Prothrombin time, s	13.2 (8.5–144.3)	13.1 (8.6–105.8)	0.580
INR	1.1 (0.9–14.2)	1.2 (0.9–9.7)	0.429
Creatinine, mg/dL	1.01 (0.53–4.66)	0.91 (0.54–3.93)	0.727
Diagnostic procedures, n (%)			0.052
Only US	20 (46.5)	3 (18.7)	
US and CT	23 (53.5)	13 (81.3)	
CT classification, n (%)*			0.007
Berna I	11 (47.8)	1 (7.7)	
Berna II	5 (21.7)	1 (7.7)	
Berna III	7 (30.4)	11 (84.6)	
Extravasation on CTA, n (%)*	4 (17.4)	11 (84.6)	<0.001
Hematoma volume, cm^3	49 (10–1566)	1070 (38–10927)	<0.001
Blood transfusion, n (%)	15 (34.9)	13 (81.3)	0.002
Red blood cell transfusion, units	0 (0–27)	3.5 (0–10)	<0.001
Fresh frozen plasma transfu-sion, units	0 (0–35)	2 (0–14)	<0.001
Platelet transfusion, units	0 (0–11)	0 (0–3)	0.480
Intensive care unit stay, n (%)	10 (23.3)	9 (56.3)	0.016
Length of hospital stay, day	4 (0–50)	15 (1–58)	<0.001
90-day readmission, n (%)	4 (9.3)	2 (12.5)	0.658
90-day mortality, n (%)	8 (18.6)	5 (31.3)	0.311

CT: Computed tomography; CTA: Computed tomography angiography; COPD: Chronic obstructive pulmonary disease; US: Ultrasound. *Only patients who underwent CT were analyzed (n=36).

In multivariate analysis, two independent predictors of 90-day mortality were identified: advanced age (OR: 1.088; 95% CI: 1.002–1.182; p=0.045) and greater hemoglobin decline (OR: 1.086; 95% CI: 1.021–1.154; p=0.008). Admission hemoglobin level showed a borderline association with mortality (OR: 0.699; 95% CI: 0.458–1.066; p=0.096) (Fig. 1).

Table 3. Comparative analysis of patient characteristics in terms of 90-day mortality among patients with spontaneous rectus sheath hematoma

	Alive at 90 days (n=46) (%)	90-day mortality (n=13) (%)	p
Age, years	69 (18–94)	81 (40–88)	0.002
Female gender, n (%)	36 (78.3)	10 (76.9)	1.000
Hypertension, n (%)	33 (71.7)	12 (92.3)	0.159
Coronary artery disease, n (%)	15 (32.6)	4 (30.8)	1.000
Diabetes mellitus, n (%)	15 (32.6)	5 (38.5)	0.746
COPD, n (%)	14 (30.4)	5 (38.5)	0.738
Anticoagulation, n (%)	29 (63.0)	12 (92.3)	0.049
Antiplatelet agents, n (%)	25 (54.3)	8 (61.5)	0.645
Admission types, n (%)			0.018
Emergency department admission	35 (76.1)	5 (38.5)	
Inpatient-onset events	11 (23.9)	8 (61.5)	
Hemoglobin (at admission), g/dL	11.7 (7.2–17.0)	10.7 (7.8–14.1)	0.104
Hemoglobin decline rate, %	15.0 (0–51.4)	30.4 (0–61.7)	0.005
Hematocrit (at admission), %	36.2 (22.9–50.0)	29.1 (23.5–42.1)	0.122
Hematocrit decline rate, %	15.6 (0–53.0)	32.5 (0–59.5)	0.003
Platelets, $\times 10^9$/L	229 (100–579)	255 (16–517)	0.674
Prothrombin time, s	13 (8.5–144.3)	13.7 (9.4–80.5)	0.712
INR	1.1 (0.9–14.2)	1.2 (0.9–7.7)	0.937
Creatinine, mg/dL	0.91 (0.53–4.34)	1.41 (0.78–4.66)	0.019
Diagnostic procedures, n (%)			0.548
Only US	17 (37.0)	6 (46.2)	
US and CT	29 (63.0)	7 (53.8)	
CT classification, n (%)*			0.109
Berna I	12 (41.4)	0 (0)	
Berna II	4 (13.8)	2 (28.6)	
Berna III	13 (44.8)	5 (71.4)	
Extravasation on CTA, n (%)*	11 (37.9)	4 (57.1)	0.418
Hematoma volume, cm^3	77.7 (10–10927)	424 (10–3443)	0.043
Blood transfusion, n (%)	18 (39.1)	10 (76.9)	0.016
Red blood cell transfu-sion, units	0 (0–10)	2 (0–27)	0.015
Fresh frozen plasma transfusion, units	0 (0–14)	1 (0–35)	0.094
Platelet transfusion, units	0 (0–0)	0 (0–11)	0.007
Management, n (%)			0.311
Conservative treatment	35 (76.1)	8 (61.5)	
Interventional procedure	11 (23.9)	5 (38.5)	
Intensive care unit stay, n (%)	11 (23.9)	8 (61.5)	0.018
Length of hospital stay, day	5 (0–58)	11 (0–50)	0.041
90-day readmission, n (%)	4 (8.7)	2 (15.4)	0.605

CT: Computed tomography; CTA: Computed tomography angiography; COPD: Chronic obstructive pulmonary disease; US: Ultrasound. *Only patients who underwent CT were analyzed (n=36).

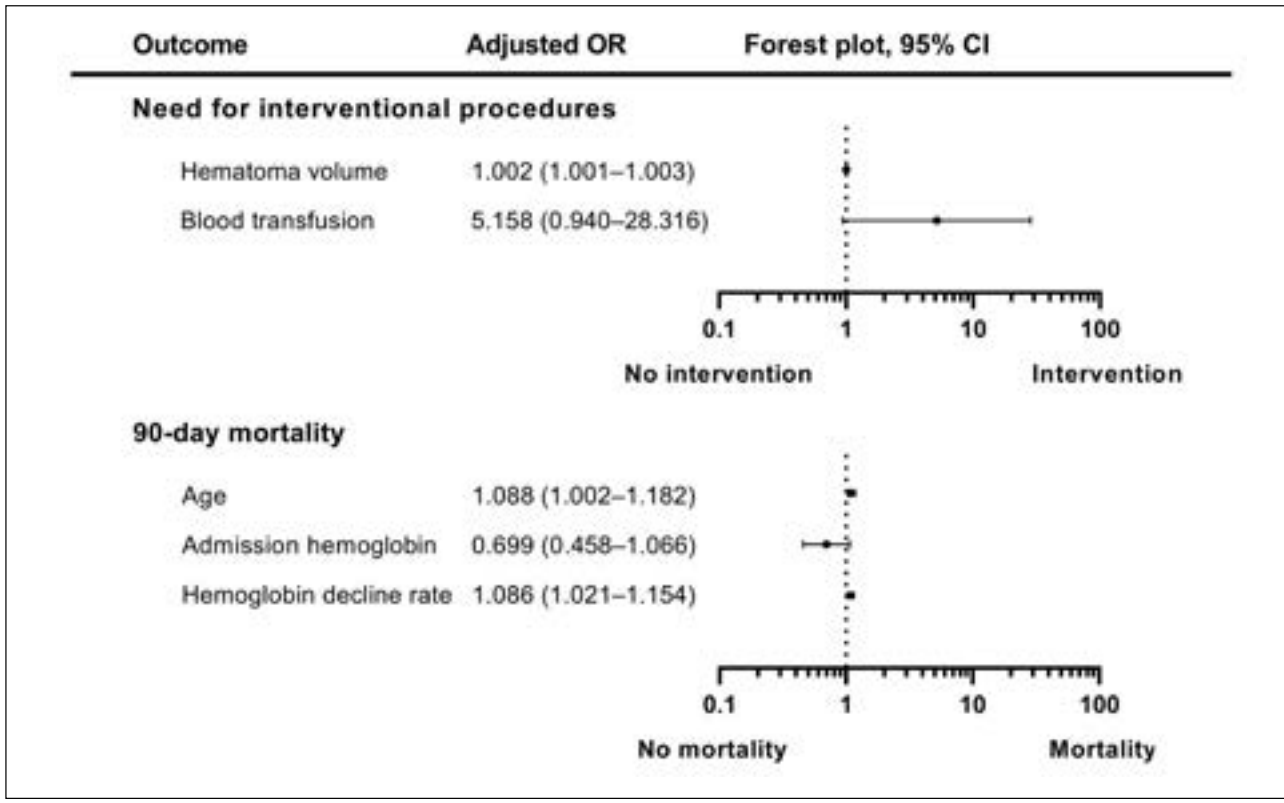

Figure 1. Multivariate analysis for predictors of the need for interventional procedures and 90-day mortality in patients with spontaneous rectus sheath hematoma. In a predefined computed tomography angiography subgroup, contrast extravasation emerged as an additional independent predictor (odds ratio: 17.460; 95% confidence interval: 2.065–147.615). CI: Confidence interval.

DISCUSSION

This study investigated factors predicting the need for intervention and 90-day mortality in patients diagnosed with spontaneous RSH at a tertiary care center. Our analysis revealed that hematoma volume is a significant independent predictor for requiring interventional procedures, while advanced age and hemoglobin decline independently predict 90-day mortality. These findings underscore the complex clinical profile of spontaneous RSH, highlighting distinct risk factors associated with procedural necessity versus overall survival in this vulnerable patient population.

The need for angiographic embolization in our cohort (27.1%) was consistent with rates reported in previous studies, typically ranging from 20% to 30%.[6,7] Our multivariate analysis for the entire cohort identified hematoma volume as a significant independent predictor for requiring intervention (OR 1.002/cm³ increase, p=0.004). Blood transfusion showed a borderline association, likely reflecting its common use in patients already deemed unstable or having large bleeds, rather than being an independent driver for the decision to intervene. Furthermore, a specific subgroup analysis focusing on the patients who underwent CTA revealed that, alongside hematoma volume, the presence of contrast extravasation on imaging was also an independent predictor of the need for interventional radiology management. This finding is consistent with a previous report by Contrella et al.,[2] which identified extravasation on CTA, larger hematoma volume, transfusion of ≥4 units of packed red blood cells, and a rate of hemoglobin decrease (>0.25 g/dL/h) as key predictors of conservative management failure in patients with spontaneous RSH. In addition, our results also align with those of Porras Fimbres et al.,[14] who conducted a multivariate analysis in an independent cohort and similarly found hematoma volume and contrast extravasation on CTA to be the two most significant independent predictors of failure of conservative management. Other parameters, such as hemoglobin nadir and transfusion requirement, were not retained in their final model. Clinically, these results suggest that both a large hematoma volume and the presence of active contrast extravasation on CTA serve as crucial indicators of likely failure of conservative management, warranting early consultation with interventional radiology.

Although the majority of RSH cases are managed conservatively, mortality rates remain non-negligible, ranging between 14% and 44% in previous series involving interventional treatment.[2,3,5,10] The 90-day mortality rate observed in our cohort (22%) is in line with existing literature and reinforces the concept that RSH, particularly in frail and elderly patients, often serves as a marker of systemic decompensation rather

than an isolated event. Baekgaard et al.[4] documented an in-hospital mortality rate of 22%, with only 27% of deaths clearly linked to hemorrhagic complications. Similarly, Sheth et al.[3] reported a 14.8% overall mortality, none of which were directly ascribed to RSH. Jawhari et al.[10] noted a 30-day mortality rate of 44%, yet only one-third of these deaths were directly related to persistent or recurrent bleeding; the remainder resulted from secondary complications such as sepsis or cardiovascular events, reflecting the role of RSH as a marker of systemic deterioration. Contrella et al.[2] observed a 19% 30-day mortality in embolized patients, though most deaths were associated with underlying comorbidities rather than the bleeding episode itself. Collectively, these findings highlight that adverse outcomes in RSH are often driven by multisystem compromise rather than isolated hemorrhage. This broader pathophysiological context is further supported by our findings, in which advanced age and greater hemoglobin decline emerged as independent predictors of 90-day mortality in multivariate analysis. These results are consistent with those of Baekgaard et al.,[4] who similarly identified age and hemodynamic instability as major contributors to mortality risk.

Departing from prior studies, this study targeted 90-day all-cause mortality, enabling a more comprehensive understanding of the determinants of patient outcomes. While 30-day or in-hospital mortality primarily reflects early procedural or bleeding-related events, a 90-day timeframe captures delayed complications such as infection, deconditioning, or organ failure – particularly relevant in older adults. While the extended follow-up period may introduce confounding from unrelated comorbidities, it offers a more comprehensive understanding of patient vulnerability and underscores the importance of holistic management beyond initial hemostasis. This study has several strengths that enhance the robustness and clinical applicability of its findings, foremost among them the inclusion of a consecutive patient cohort over a 7-year period at a tertiary care center, which supports internal validity, reduces selection bias, and ensures the representativeness of real-world clinical practice. Moreover, the 90-day follow-up allowed for a more comprehensive assessment of outcomes beyond the immediate phase of hemorrhagic control. However, it is not without limitations. The retrospective design inherently limits causal inference and introduces potential for missing data, misclassification, and unmeasured confounding – particularly in transfusion practices and intervention timing, which were not standardized. CTA was not uniformly applied, possibly introducing verification bias, and hematoma volume estimation through the ABC/2 method, although practical, may be imprecise in irregularly shaped hemorrhages. Finally, as a single-center study, external generalizability remains limited. Future studies should aim to validate these findings in prospective, multicenter cohorts and facilitate the development of standardized, evidence-based risk stratification models incorporating hematoma volume, contrast extravasation, and dynamic clinical parameters. Integration of bedside assessment tools—such as serial hemoglobin monitoring and point-of-care ultrasonography – may further enhance early identification of patients at risk of deterioration. In parallel, investigations assessing the feasibility, cost-effectiveness, and clinical impact of incorporating routine volumetric analysis into emergency imaging protocols are warranted. Finally, emphasis should be placed on evaluating long-term outcomes, including post-discharge functional status, quality of life, and the role of geriatric assessment in guiding comprehensive care strategies for this high-risk population.

CONCLUSION

This study identifies hematoma volume and contrast extravasation as significant predictors of the need for interventional treatment, while advanced age and hemoglobin decline independently predict 90-day mortality in patients with spontaneous RSH. These findings underscore the importance of integrating objective radiological and laboratory parameters into early clinical assessment to guide timely intervention and prognostication. Prospective validation and the development of standardized management pathways are warranted to improve risk stratification and optimize outcomes in this complex clinical entity.

Ethics Committee Approval: This study was approved by the Gulhane Scientific Research Ethics Committee (Date: 10.09.2024, Decision No: 2024-391).

Informed Consent: Retrospective study.

Peer-review: Externally peer-reviewed.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Spontan rektus kılıf hematomu olan hastalarda girişimsel tedavi gereksinimi ve mortaliteyi öngören faktörler

AMAÇ: Spontan rektus kılıf hematomu (RKH), özellikle yaşlı ve antikoagülan tedavi alan hastalarda akut karın ağrısının potansiyel olarak yaşamı tehdit eden bir nedenidir. Olguların çoğu konservatif olarak yönetilmekle birlikte, anlamlı bir kısmında girişimsel işlemler gerekebilmekte, bazı hastalarda ise mortal seyir izlenmektedir. Bu çalışmanın amacı, spontan RKH hastalarında girişimsel işlem gereksinimini ve 90 günlük mortaliteyi öngören belirteçleri tanımlamaktır.

GEREÇ VE YÖNTEM: Bu retrospektif çalışmaya, Ocak 2017 ile Aralık 2023 tarihleri arasında üçüncü basamak bir merkezde spontan RKH tanısı almış ardışık erişkin hastalar dahil edildi. Klinik, laboratuvar ve görüntüleme verileri toplandı. Girişimsel radyoloji tedavisi gereksinimini ve 90 günlük tüm nedenlere bağlı mortaliteyi öngören bağımsız değişkenleri belirlemek amacıyla çok değişkenli lojistik regresyon analizi uygulandı.

BULGULAR: Çalışmaya alınan 59 hastanın medyan yaşı 72 idi ve %77.9'u kadındı. Vakaların %27.1'ine girişimsel radyoloji işlemi uygulandı ve 90 günlük mortalite oranı %22.0 olarak saptandı. Hematom hacmi, girişim gereksinimi ile bağımsız olarak ilişkili bulundu (OR: 1.002; p=0.004). Bilgisayarlı tomografi anjiyografi yapılan alt grup hastalarında (n=36), kontrast ekstravazasyonu da anlamlı bir öngörücüydü (OR: 17.460; p=0.009). Doksan günlük mortalitenin bağımsız öngörücüleri ise ileri yaş (OR: 1.088; p=0.045) ve hemoglobin düşüşü (OR: 1.086; p=0.008) olarak belirlendi.

SONUÇ: Hematom hacmi ve kontrast ekstravazasyonu, girişimsel tedavi gereksiniminin anlamlı öngörücüleridir. İleri yaş ve hemoglobin düşüşü ise 90 günlük mortaliteyi öngörmektedir. Bu bulgular, erken risk sınıflandırması için objektif radyolojik ve laboratuvar parametrelerinin kullanılmasını desteklemektedir. Bu yüksek riskli hasta grubunda standart yönetim stratejilerine yön vermek amacıyla prospektif, çok merkezli doğrulama çalışmalarına ihtiyaç vardır.

Anahtar sözcükler: Girişimsel tedavi; mortalite; prognoz; rektus kılıf hematomu.

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ORIGINAL ARTICLE

The role of negative-pressure wound therapy in Fournier's gangrene: Association with mortality

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ABSTRACT

BACKGROUND: Fournier's gangrene (FG) is a rare but life-threatening necrotizing fasciitis of the perineal and genital regions characterized by rapid progression, fulminant sepsis, and high mortality. Negative-pressure wound therapy (NPWT), also called vacuum-assisted closure (VAC), is becoming more commonly utilized today in the treatment of complex wounds. This study aimed to evaluate the association between NPWT/VAC and in-hospital mortality among patients with FG requiring extensive surgical debridement.

METHODS: This retrospective cohort study included 95 patients treated for FG at a tertiary referral center between January 2022 and January 2025. Patients were divided into two groups according to post-operative wound management: Conventional dressing (n=31) and NPWT/VAC (n=64). Demographic, clinical, and laboratory data – including the FG severity index (FGSI), quick sequential organ failure assessment, and procalcitonin – were analyzed. Multivariable logistic regression identified independent predictors of in-hospital mortality, and model performance was evaluated using receiver-operating characteristic curves.

RESULTS: Overall mortality was 20.0% (19/95). Mortality was significantly lower in the NPWT/VAC group than in the conventional group (15.6% vs. 29.0%, p<0.05). On multivariable analysis, NPWT/VAC was independently associated with lower mortality (adjusted odds ratio [OR] 0.42, 95% confidence interval [CI] 0.18–0.95, p<0.05), whereas higher FGSI (OR 1.28 per point, 95% CI 1.10–1.55, p<0.01) and procalcitonin (OR 1.95, 95% CI 1.35–2.75, p<0.01) were independently associated with higher mortality.

CONCLUSION: NPWT/VAC use was associated with a lower mortality rate and may represent a valuable adjunct in the management of severe FG.

Keywords: Fournier's gangrene; fournier's gangrene severity index; mortality; negative-pressure wound therapy; sepsis.

INTRODUCTION

Fournier's gangrene (FG) is a rare but life-threatening necrotizing fasciitis of the genitalia and perineum. It presents with an acute onset, fulminant sepsis, and high mortality.[1] Despite advances in intensive care and surgery, mortality has remained high at 20–40% in recent series.[2-5] The disease, hence still poses a life-threatening challenge to urological and surgical practice. Management of FG involves early hemodynamic stabilization, broad-spectrum antibiotic therapy, and aggressive surgical debridement of all necrotic tissue.[6] Additional procedures, such as fecal or urinary diversion, hyperbaric oxygen therapy, and reconstructive techniques, have been described to improve outcomes.[7,8] Delayed diagnosis, insufficient debridement, and systemic dissemination are, however, established predictors of adverse prognosis, and additional measures to further decrease mortality are yet needed.

Negative-pressure wound therapy (NPWT), also called vacuum-assisted closure (VAC), is becoming more commonly utilized today in the treatment of complex wounds.[9] Through

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the application of subatmospheric pressure on the wound surface, NPWT/VAC improves granulation tissue, promotes perfusion, reduces bacterial load, and aids in wound closure.[10] Its efficacy has been demonstrated for clinical application in diabetic foot ulcers, pressure sores, and post-operative wounds.[11,12] Based on these benefits, NPWT/VAC has also been found to be increasingly applied following radical debridement of FG patients. However, routine use of NPWT/VAC has not been advised by international guidelines for this condition. According to the European Association of Urology (EAU) urological infection guidelines, which indicate that evidence for a survival benefit remains limited, with a level of evidence graded as 4.[13] As a result, the role of NPWT/VAC in FG remains controversial. Recent reports, although limited in number, suggest that NPWT/VAC may improve wound control, shorten hospitalization, and support reconstructive surgery.[14,15] Importantly, no definite consensus on its effect on mortality, which remains the most relevant outcome in this devastating disease.[16,17]

The purpose of the study was to evaluate the association between NPWT/VAC and mortality in patients with FG who required extensive debridement and had systemic involvement.

MATERIALS AND METHODS

This retrospective cohort study was performed at a tertiary referral center and included patients who underwent emergency surgical debridement for FG between January 2022 and January 2025. This study was approved by the Ankara Etlik City Hospital (Date: 02/12/2025, Decision no: AESH-BADEK-2025-629), and written informed consent was obtained from all participants. The study was performed in accordance with the Declaration of Helsinki.

Inclusion and Exclusion Criteria

Patients were eligible if they presented with FG involving systemic extension to the perianal and/or inguinal regions and required urgent debridement. Patients with localized disease not affecting the Colles fascia (limited to the penis or scrotum only) or those with simple abscesses were excluded.

Study-Group Design

A total of 95 patients were included in the final analysis. Patients were stratified into two treatment groups according to post-operative wound management: Group A: Conventional wound dressing (n=31). Group B: NPWT/VAC (n=64).

Treatment allocation was not standardized. The decision to use NPWT/VAC or conventional dressing was made at the discretion of the treating surgeon based on clinical judgment, wound characteristics, and device availability, without predefined criteria. The extent of necrotizing fasciitis may have influenced treatment decisions as part of the overall clinical assessment; however, this was not evaluated using standardized criteria.

Data Collection

Demographic data, clinical presentation, and laboratory parameters were extracted from hospital records. Collected data included age, sex, and comorbidities (diabetes mellitus, chronic kidney disease, malignancy, obesity, etc.). Clinical severity markers such as the quick sequential organ failure assessment (qSOFA) score, the FG Severity Index (FGSI) score, the presence of sepsis or septic shock, and the extent of infection were documented. Vital signs (temperature, respiratory rate, blood pressure, heart rate, and mental status) and laboratory results (white blood cell count, serum creatinine, sodium, potassium, lactate, procalcitonin, and C-reactive protein [CRP]) were recorded at admission. Operative details, including the timing of surgery, number and adequacy of debridements, and wound management modality (NPWT/VAC vs. conventional dressing), were collected. Post-operative outcomes included intensive care requirement, total length of hospital stay, and in-hospital mortality.

Primary and Secondary Outcomes

The primary outcome of the study was in-hospital mortality. Secondary outcomes included the FGSI, the qSOFA score (evaluated as ≥2 vs. <2), perioperative parameters such as respiratory rate and hemodynamic instability, laboratory markers including procalcitonin, lactate, and CRP, the number of comorbidities, the number of surgical debridements, the need for intensive care unit admission, and the total length of hospital stay.

Statistical Analysis

Statistical analyses were conducted using IBM Statistical Package for the Social Sciences Statistics v21.0 (Armonk, NY, USA). Continuous variables were summarized as mean ± standard deviation or median interquartile range according to the Kolmogorov-Smirnov test and compared with the independent-samples t-test or the Mann-Whitney U test, as appropriate; categorical variables were compared with the χ^2 test or Fisher's exact test. The primary endpoint was in-hospital mortality. To limit overfitting and collinearity, a prespecified parsimonious multivariable logistic regression model was fitted, including age, comorbidity burden (number of comorbidities), one severity metric (FGSI), one inflammatory biomarker (procalcitonin), and wound management (NPWT/VAC vs. conventional); variables measured after treatment initiation (e.g., number/adequacy of debridements) were not entered. Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were reported, and multicollinearity was assessed using variance inflation factors. A sensitivity analysis re-estimated the model by replacing FGSI with qSOFA (≥2 vs. <2). Model discrimination and calibration were assessed using the area under the receiver operating characteristic curve (AUC-ROC) and the Hosmer-Lemeshow test, respectively; ROC analyses were performed only for continuous/ordinal predictors (FGSI, qSOFA, procalcitonin), and no ROC analysis was undertaken for the binary exposure (NPWT/VAC). For power appraisal, a balanced sample of 30 patients per group (n=60) was considered; using α=0.05 and the observed mortality contrast (29.0% vs. 15.6%), the achieved

power was ≈74%, whereas substantially larger totals (on the order of a few hundred patients) would be required to attain ≈80% power under similar assumptions. Inference was therefore based primarily on effect sizes and 95% CIs. Two-sided p<0.05 was considered statistically significant.

RESULTS

A total of 95 patients were analyzed; Group A: conventional wound dressing (n=31) and Group B: NPWT/VAC (n=64). Non-survivors were significantly older than survivors (p<0.05). The most frequent comorbidities were diabetes mellitus, chronic kidney disease, and obesity. Patients with qSOFA ≥2 had higher FGSI scores, more comorbidities, and higher procalcitonin levels than those with qSOFA <2 (all p<0.05). The overall in-hospital mortality was 20.0% (19/95); mortality was 29.0% (9/31) in the conventional group versus 15.6% (10/64) in the NPWT/VAC group (p<0.05). Mortality was also significantly higher in patients with qSOFA ≥2 (p<0.05). The demographic characteristics of the patients are summarized in Table 1.

On univariable analysis, advanced age, multiple comorbidities, sepsis or septic shock, infection extending beyond the perineum, higher FGSI, laboratory abnormalities (elevated creatinine, lactate, procalcitonin, and hyponatremia), fewer/inadequate debridements, and absence of NPWT/VAC were each associated with mortality (all p<0.05). In a prespecified

Table 1. Demographic and clinical characteristics of the patients

Variable	All patients (n=95)	Group A (conventional, n=31)	Group B (NPWT/VAC, n=64)	p
Age (years)	61.8±13.7	65.3±12.9	59.9±13.9	<0.05
Male sex, n (%)	78 (82.1)	25 (80.6)	53 (82.8)	0.78
Diabetes mellitus, n (%)	46 (48.4)	18 (58.1)	28 (43.8)	0.19
Chronic kidney disease, n (%)	21 (22.1)	9 (29.0)	12 (18.8)	0.28
Obesity, n (%)	18 (18.9)	7 (22.6)	11 (17.2)	0.56
qSOFA ≥2, n (%)	28 (29.5)	12 (38.7)	16 (25.0)	0.18
FGSI score (mean±SD)	6.8±3.2	7.6±3.4	6.4±3.1	<0.05
Procalcitonin (ng/mL)	7.2±5.9	8.9±6.4	6.3±5.4	<0.05
Mortality, n (%)	19 (20.0)	9 (29.0)	10 (15.6)	<0.05

Data are presented as mean±standard deviation or n (%). Statistical tests: Student's t-test for continuous variables and Chi-square or Fisher's exact test for categorical variables. NPWT: Negative-pressure wound therapy; VAC: Vacuum-assisted closure; qSOFA: Quick sequential organ failure assessment; FGSI: Fournier's gangrene severity index; SD: Standard deviation.

Table 2. Factors associated with in-hospital mortality: Univariate and multivariable logistic regression analysis

Variable	Univariate analysis OR (95% CI)	p	Multivariable analysis adjusted OR (95% CI)	p
Age (per year)	1.04 (1.01–1.08)	<0.05	1.03 (0.99–1.07)	0.09
Multiple comorbidities	2.65 (1.30–5.45)	<0.01	1.85 (0.92–3.95)	0.11
Sepsis or septic shock	3.42 (1.55–7.55)	<0.01	—	—
Infection beyond the perineum	2.78 (1.25–6.22)	<0.05	—	—
FGSI (per point)	1.35 (1.15–1.60)	<0.01	1.28 (1.10–1.55)	<0.01
Elevated creatinine	2.10 (1.05–4.25)	<0.05	—	—
Elevated lactate	2.55 (1.20–5.40)	<0.05	—	—
Elevated procalcitonin (per ng/mL)	2.05 (1.40–3.00)	<0.01	1.95 (1.35–2.75)	<0.01
Hyponatremia	2.60 (1.15–5.90)	<0.05	—	—
Fewer/Inadequate debridements	3.15 (1.40–7.10)	<0.01	—	—
Absence of NPWT/VAC	0.36 (0.16–0.80)	<0.05	0.42 (0.18–0.95)	<0.05

Covariates included in the multivariable model: Age, comorbidity burden, FGSI, procalcitonin, and treatment group (NPWT/VAC vs. conventional). OR: Odds ratio; CI: Confidence interval; FGSI: Fournier's gangrene severity index; NPWT: Negative pressure wound therapy; VAC: Vacuum-assisted closure.

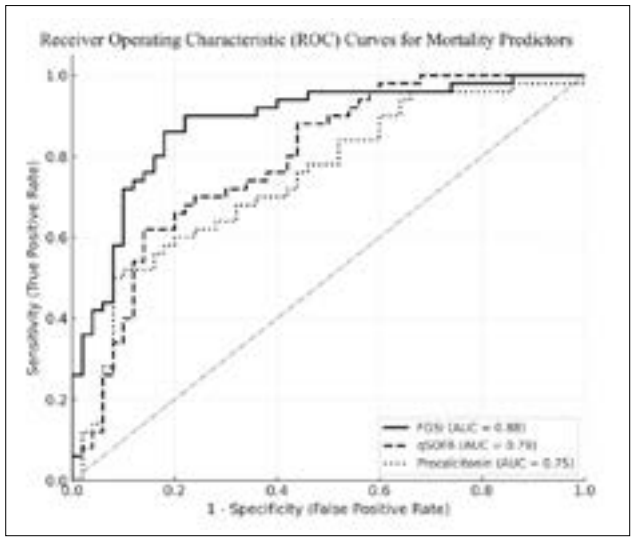

Figure 1. Receiver operating characteristic curves of continuous predictors for in-hospital mortality in Fournier's gangrene severity index, quick sequential organ failure assessment, and procalcitonin.

parsimonious multivariable logistic regression model (covariates: age, comorbidity burden, FGSI, procalcitonin, and treatment group), NPWT/VAC remained independently associated with lower in-hospital mortality (adjusted OR 0.42, 95% CI 0.18–0.95, p<0.05), whereas higher FGSI (adjusted OR 1.28 per point, 95% CI 1.10–1.55, p<0.01) and higher procalcitonin (adjusted OR 1.95, 95% CI 1.35–2.75, p<0.01) were independently associated with mortality. Findings were consistent in a sensitivity analysis substituting qSOFA (≥2 vs. <2) for FGSI, wherein qSOFA ≥2 was independently associated with mortality (adjusted OR 2.85, 95% CI 1.40–5.80, p<0.01), and the association between NPWT/VAC and lower mortality persisted. Univariate and multivariable logistic regression analyses of factors associated with in-hospital mortality are summarized in Table 2. Receiver operating characteristic analyses demonstrated good discrimination for FGSI (AUC 0.82, 95% CI 0.74–0.91, p<0.01), qSOFA (AUC 0.78, 95% CI 0.68–0.88, p<0.01), and procalcitonin (AUC 0.80, 95% CI 0.70–0.89, p<0.01) (Fig. 1).

DISCUSSION

In the present study, we analyzed the prognostic factors of mortality in FG patients and directly assessed the association between NPWT/VAC and survival. Our case series of 95 FG patients within a tertiary care center presented an overall in-hospital mortality rate of 20%, which is comparable with reported mortality rates ranging from 20% to 40% in the literature.[2-4] Interestingly, we observed a lower mortality rate in the NPWT/VAC group (15.6% vs. 29.0%, p<0.05). Multivariate logistic regression confirmed that NPWT/VAC therapy was independently associated with lower mortality (adjusted OR 0.42, 95% CI 0.18–0.95, p<0.05), moreover, higher FGSI (adjusted OR 1.28 per point, 95% CI 1.10–1.55, p<0.01) and elevated procalcitonin (adjusted OR 1.95, 95% CI 1.35–2.75, p<0.01) were independently associated with increased mortality. In our study, we found that NPWT/VAC therapy was independently associated with lower mortality and may represent a promising adjunct to standard surgical treatment.

The mortality rate of 20% observed in our cohort aligns with the established range in contemporary literature, confirming that despite advances in critical care and surgical management, FG continues to carry a substantial risk of death.[2-5] This continued risk supports the imperative of the identification of robust prognostic indicators and optimization of adjunctive treatments for this destructive disease. Our investigation identified many classic predictors of mortality. Older age was associated with poor outcomes, which supports prior studies that found that older patients had less physiological reserve and more comorbidities.[18] Shet et al.[19] in their study showed that patients above 60 years of age had close to double the mortality rate compared to younger patients. Similarly, comorbid diseases such as diabetes mellitus and chronic kidney disease were prevalent in our series and were associated with increased mortality due to the compromised host defense and microvascular mechanisms in these individuals. Scoring systems such as FGSI and qSOFA were also strongly associated with mortality in our series. Baseline differences between treatment groups should be considered when interpreting the mortality findings. Patients in the conventional group had higher FGSI and procalcitonin levels and were older, indicating more severe disease at baseline. Although adjusted analysis showed that NPWT/VAC was independently associated with lower mortality, residual confounding cannot be excluded.

In our study, multivariable analysis suggested that FGSI was independently associated with increased mortality (OR 1.28, 95% CI 1.10–1.55), with good discrimination (AUC 0.82). Previous studies have reported inconsistent findings regarding its prognostic value.[20] In a more recent study evaluating alternative indices such as the HALP score, HALP was not found to be associated with survival, whereas FGSI remained a significant predictor of outcomes.[21]

One of the key findings of our study is the observed association between NPWT/VAC therapy and survival. We observed a significantly lower mortality rate with NPWT/VAC therapy in comparison to conventional dressing, a difference that persisted even after controlling for additional confounding variables. While ROC analysis is not applicable for this categorical variable, multivariable analysis demonstrated that NPWT/VAC therapy was independently associated with lower mortality. This finding should be interpreted in the context of current EAU guidelines, which state that there is no evidence of benefit for the usage of NPWT/VAC in FG (level of evidence 4).[13] Our data indicate that NPWT/VAC therapy may enhance local wound healing and seems to be associated with lower mortality rates.

In contrast to prior studies that did not show a survival benefit, there are several possible explanations for the observed association between NPWT/VAC therapy and lower mortality. The well-defined inclusion criteria and exclusion of localized cases allowed the association between NPWT/VAC and outcomes to be observed more distinctly in patients with more extensive and severe disease. Furthermore, the use of biomarkers such as procalcitonin made earlier therapeutic modifications possible, and multivariable analysis confirmed the association between NPWT/VAC therapy and lower mortality. Collectively, these factors may partly account for the observed association between NPWT/VAC therapy and lower mortality.[16-17,22] While NPWT/VAC was associated with lower mortality in our cohort, this finding should be interpreted with caution, given the retrospective design and potential for selection bias. Current EAU guidelines indicate that evidence for a survival benefit remains limited. Importantly, the primary role of NPWT/VAC lies in wound management, including improved drainage, enhanced granulation, and facilitation of reconstruction.[10-12,14,15] In many centers, NPWT/VAC is typically initiated after serial debridements once infection control is achieved.[6,14,15] In our practice, NPWT/VAC was applied early after initial debridement, based on the surgeon judgment and wound characteristics. This approach may help enhance wound drainage and promote granulation tissue formation. In addition, the multidisciplinary tertiary care setting may have supported both local wound management and overall sepsis control. However, the optimal timing of NPWT/VAC application remains uncertain.

Our study has several limitations. This was a single-center retrospective study with non-randomized, surgeon-dependent treatment allocation, introducing a potential risk of selection bias and unmeasured confounding. Although the sample size is larger than in many previous studies, it remains limited, and external validation in larger multicenter cohorts is necessary. The follow-up period was restricted to in-hospital outcomes, and long-term morbidity, quality of life, and reconstructive results were not assessed. Another limitation of this study is the inability to calculate the Uludag FGSI (UFGSI). While the UFGSI incorporates age and the extent of infection and may provide a more comprehensive assessment of disease severity,[23] the retrospective nature of our dataset did not allow consistent and standardized documentation of disease extent. Consequently, UFGSI could not be reliably calculated for all patients. Instead, FGSI and qSOFA were used as clinically applicable indicators of disease severity, with qSOFA serving as a simple tool for risk stratification.[24] Prospective studies with standardized data collection are needed to directly compare FGSI and UFGSI in predicting mortality.

Despite these limitations, our findings have important clinical implications. Although NPWT/VAC therapy may offer advantages beyond wound care, its effect on survival is still not clear. This has direct applicability for daily clinical practice, as NPWT/VAC therapy is widely available and can be implemented alongside standard surgical debridement. Future studies should focus on multicenter prospective cohorts or randomized controlled trials to validate the survival benefit of NPWT/VAC therapy and to further refine prognostic scoring systems by integrating clinical, laboratory, and treatment-related variables. The potential effects of NPWT/VAC on long-term functional and reconstructive outcomes, as well as the use of medical resources, will also be better understood with larger sample sizes and longer follow-up.

CONCLUSION

FG remains a high-mortality condition. NPWT/VAC was associated with lower mortality and may be considered a useful adjunct in the management of FG. However, its effect on survival remains uncertain, and further prospective studies are required to confirm these findings.

Ethics Committee Approval: This study was approved by the Ankara Etlik City Hospital (Date: 02.12.2025, Decision No: AESH-BADEK-2025-629).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Fournier kangreninde negatif basınçlı yara tedavisinin rolü: Mortalite ile ilişkisi

AMAÇ: Fournier gangreni (FG), hızlı ilerleme, fulminan sepsis ve yüksek ölüm oranı ile karakterize, nadir ancak yaşamı tehdit eden perineal ve genital bölgelerin nekrotizan fasiitidir. Vakum destekli kapatma (VAC) olarak da adlandırılan negatif basınçlı yara tedavisi (NPWT), günümüzde karmaşık yaraların tedavisinde giderek daha yaygın olarak kullanılmaktadır. Bu çalışma, kapsamlı cerrahi debridman gerektiren FG hastalarında negatif basınçlı yara tedavisinin (NPWT/VAC) hastane içi ölüm oranı ile ilişkisini değerlendirmeyi amaçlamıştır.

GEREÇ VE YÖNTEM: Bu retrospektif kohort çalışması, Ocak 2022 ile Ocak 2025 tarihleri arasında üçüncü basamak bir sevk merkezinde FG nedeniyle tedavi gören 95 hastayı içermiştir. Hastalar, ameliyat sonrası yara yönetimine göre iki gruba ayrılmıştır: geleneksel pansuman (n=31) ve NPWT/VAC (n=64). Demografik, klinik ve laboratuvar verileri (Fournier Gangreni Şiddet İndeksi [FGSI], hızlı Ardışık Organ Yetmezliği Değerlendirmesi [qSOFA] ve prokalsitonin dahil) analiz edilmiştir. Çok değişkenli lojistik regresyon, hastane içi mortalitenin bağımsız belirleyicilerini tanımlamış ve model performansı alıcı işletim karakteristik (ROC) eğrileri kullanılarak değerlendirilmiştir.

BULGULAR: Genel ölüm oranı %20.0 (19/95) idi. Ölüm oranı, NPWT/VAC grubunda geleneksel gruba göre anlamlı derecede daha düşüktü (%15.6'ya karşı %29.0, p<0.05). Çok değişkenli analizde NPWT/VAC bağımsız olarak daha düşük mortalite (düzeltilmiş OR 0.42, %95 GA 0.18–0.95, p<0.05) ile ilişkili kalırken, daha yüksek FGSI (OR 1.28/puan, %95 GA 1.10–1.55, p<0.01) ve prokalsitonin (OR 1.95, %95 GA 1.35–2.75, p<0.01) bağımsız olarak daha yüksek mortaliteyle ilişkiliydi.

SONUÇ: NPWT/VAC kullanımı daha düşük mortalite oranı ile ilişkilidir ve şiddetli FG yönetiminde değerli bir yardımcı tedavi olabilir.

Anahtar sözcükler: FGSI; fournier gangreni; mortalite; negatif basınçlı yara tedavisi; sepsis.

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ORIGINAL ARTICLE

A multidimensional approach to frailty in emergency surgery for perforated peptic ulcer

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ABSTRACT

BACKGROUND: Perforated peptic ulcer (PPU) remains a high-risk surgical emergency. Although sarcopenia has been proposed as an objective surrogate of frailty, its independent prognostic value in emergency surgery is unclear. This study evaluated sarcopenia within a multidimensional frailty framework incorporating nutritional, inflammatory, and clinical parameters.

METHODS: This retrospective cohort study included adult patients who underwent emergency surgery for PPU at a tertiary center. Sarcopenia was assessed using computed tomography-derived psoas muscle area and psoas muscle index with population-specific cut-off values. Immunonutritional and inflammatory indices (hemoglobin–albumin–lymphocyte–platelet [HALP], neutrophil-to-lymphocyte ratio [NLR], platelet-to-lymphocyte ratio [PLR], and systemic immune-inflammation index [SII]) were calculated from admission laboratory data. The primary outcome was in-hospital mortality. Multivariable logistic regression and receiver operating characteristic (ROC) curve analyses were performed to identify independent predictors and discriminatory performance.

RESULTS: Ninety-seven patients were included; 30.9% were sarcopenic. Sarcopenic patients exhibited lower serum albumin, higher inflammatory markers, higher clinical severity scores, and longer intensive care unit and hospital stays (all $p<0.05$). However, sarcopenia was not independently associated with in-hospital mortality. In multivariable analysis, advanced age (odds ratio [OR] 1.07, $p=0.010$) and low serum albumin (OR 0.75, $p<0.001$) were the strongest independent predictors of mortality. Low HALP score and elevated NLR and PLR were significantly associated with sarcopenia. ROC analysis showed that age and albumin had superior discriminatory ability for mortality compared with morphometric muscle parameters.

CONCLUSION: In PPU surgery, frailty is better characterized as a multidimensional biological phenotype rather than isolated muscle loss. While sarcopenia reflects increased vulnerability, mortality risk is more strongly driven by age and nutritional–inflammatory reserve. Integrated frailty assessment may improve risk stratification in emergency surgical patients.

Keywords: Albumin; emergency surgery; frailty; perforated peptic ulcer; sarcopenia.

INTRODUCTION

Perforated peptic ulcer (PPU) remains a life-threatening surgical emergency with considerable morbidity and mortality despite advances in operative techniques, antimicrobial therapy, and perioperative care. Mortality rates of 10–30% are still reported, particularly in older patients and those with limited physiological reserve.[1,2] Widely used risk stratification tools, such as the Boey score and the American Society of Anesthesiologists (ASA) physical status classification, assist clinical decision-making but largely reflect acute disease severity and comorbidity burden.[3,4] They provide limited insight into a patient's baseline ability to tolerate surgical stress.

Frailty has been increasingly discussed as a contributor to adverse outcomes in surgical populations.[5] Broadly, it describes diminished physiological reserve and reduced capacity to recover from acute stressors.[6] While frailty has been associated with poor outcomes in elective and oncologic surgery,

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its assessment in emergency settings remains challenging due to time constraints, acute presentation, and lack of functional baseline data.[7]

Sarcopenia, characterized by reduced skeletal muscle mass and function, has been proposed as an objective, imaging-based parameter related to frailty.[8] Computed tomography (CT)-derived measurements, including psoas muscle area and psoas muscle index (PMI), are readily available from routine pre-operative imaging.[9] Several studies have linked these measures to adverse outcomes in acute abdominal conditions.[10,11] However, evidence regarding their independent prognostic value in emergency surgery is inconsistent, suggesting that muscle morphometry alone may not fully capture surgical vulnerability.

Nutritional reserve and systemic inflammation also influence physiological response to acute illness.[12] Hypoalbuminemia is a well-recognized marker associated with post-operative morbidity and mortality, reflecting both nutritional and inflammatory states.[13] Composite immunonutritional indices, such as the hemoglobin–albumin–lymphocyte–platelet (HALP) score, and inflammatory markers including the neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and systemic immune-inflammation index (SII), have demonstrated prognostic relevance in acute surgical and critical care settings.[14-18] These four indices were chosen for their complementary biological profiles: NLR and PLR capture different inflammatory cell ratios, SII integrates three different lineages, and HALP uniquely combines nutritional and inflammatory parameters.

Taken together, vulnerability in emergency surgery may be better understood through a multidimensional biological perspective that incorporates muscle reserve, nutritional status, inflammatory burden, and clinical severity rather than any single parameter alone. The aim of this study was to evaluate whether combining CT-based sarcopenia measures with immunonutritional and inflammatory indices improves risk stratification in patients undergoing surgery for PPU, and to clarify the relative contribution of sarcopenia within this broader physiological context.

MATERIALS AND METHODS

Study Design and Setting

This retrospective observational cohort study was conducted in accordance with the STROCSS 2024 guideline for reporting cohort studies in surgery.[19] The study was performed at a tertiary referral academic hospital with a dedicated emergency general surgery service. This study was approved by the Ankara Etlik City Hospital Scientific Research Evaluation and Ethics Committee (Date: 10/06/2025, Decision no: AEŞH-BADEK2-2025-252), and the requirement for informed consent was waived due to the retrospective nature of the study (AEŞH-BADEK2-2025-252 Date: June 10, 2025). This study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Selection

During the study period (October 2022–April 2025), a total of 111 consecutive adult patients with intraoperatively confirmed PPU were screened for eligibility. Of these, 14 patients were excluded for the following reasons: Malignant gastric or duodenal perforation (n=4), traumatic perforation (n=1), and incomplete clinical or radiological data (n=9). After applying these criteria, 97 patients remained eligible and constituted the final study cohort.

Data Collection

Demographic characteristics, comorbid conditions, clinical presentation, laboratory parameters, operative findings, and post-operative outcomes were retrieved from electronic medical records and institutional databases. Disease severity was assessed using the Boey score, and perioperative risk was classified according to the ASA physical status classification.

Clinical outcomes included post-operative complications, need for reoperation, intensive care unit (ICU) length of stay, total length of hospital stay, and in-hospital mortality.

The Boey score assigns one point for each of the following: Presence of major medical illness, pre-operative shock (systolic blood pressure <90 mmHg), and duration of perforation exceeding 24 h (range 0–3).[3]

Assessment of Sarcopenia and Morphometric Parameters

Pre-operative abdominal CT scans performed at admission were reviewed for morphometric analysis. Skeletal muscle assessment was performed at the level of the third lumbar vertebra (L3), where available, using standardized measurement techniques. Psoas muscle area was measured bilaterally, and the PMI was calculated by normalizing total psoas area to patient height squared (cm^2/m^2).

Sarcopenia was defined using sex-specific psoas muscle area and PMI cut-off values derived by Bahat et al.[20] from a large Turkish adult population on standardized L3-level CT measurements. This reference framework was deliberately selected to align the diagnostic threshold with the demographic and anthropometric characteristics of the present cohort, thereby reducing the misclassification that can arise when cut-offs developed in ethnically or anthropometrically discordant populations are externally applied. CT imaging at L3 reliably reflects total body skeletal muscle mass and is widely accepted as a surrogate for generalized muscle quantity. All measurements were performed manually by a single trained investigator blinded to clinical outcomes.

Laboratory and Immunonutritional Parameters

Laboratory values obtained at admission were recorded, including hemoglobin, leukocyte count, lymphocyte count, platelet count, C-reactive protein (CRP), and serum albumin levels. Inflammatory and immunonutritional indices were calculated as follows:

• NLR=Neutrophil count/Lymphocyte count

• PLR=Platelet count/Lymphocyte count

• SII=Platelet count×Neutrophil count/Lymphocyte count

• HALP=Hemoglobin (g/dL)×Albumin (g/dL)×Lymphocyte count (/L)/Platelet count (/L).

Cut-off values for these indices were determined using receiver operating characteristic (ROC) curve analysis based on optimal Youden index values.

Definition of Frailty Phenotype

Frailty was conceptualized as a multidimensional biological phenotype, integrating morphometric sarcopenia parameters, nutritional reserve, systemic inflammatory burden, and clinical severity indicators. Rather than applying a single frailty score, this phenotype-based approach was adopted to better reflect physiological vulnerability in the emergency surgical setting.

Table 1. Patient characteristics and clinical variables (n=97)

Variable	Category	Total (n=97) (%)
Sex	Male	76 (78.4)
	Female	21 (21.6)
BMI category	Underweight	6 (6.2)
	Normal weight	58 (59.8)
	Overweight	26 (26.8)
	Obesity class I	4 (4.1)
	Obesity class II	3 (3.1)
Sarcopenia	Absent	67 (69.1)
	Present	30 (30.9)
Perforation site	Prepyloric	94 (96.9)
	Duodenal bulb	3 (3.1)
Surgical approach	Open	90 (92.8)
	Laparoscopic	7 (7.2)
Boey score	0	30 (30.9)
	I	36 (37.1)
	2	17 (17.5)
	3	14 (14.4)
ASA physical status	II	45 (46.4)
	III	43 (44.3)
	IV	9 (9.3)
Complications		9 (9.3)
Reoperation		6 (6.2)

Table 1 presents the demographic characteristics, basic clinical variables, and surgical data of the 97 patients included in the study. The gender distribution, body mass index classes, sarcopenia status, perforation location, surgical approach, Boey score, and ASA physical status classification of the patient group are included in the table. Post-operative complication and reoperation rates are also summarized. BMI: Body mass index; ASA: American Society of Anesthesiologists.

Statistical Analysis

Statistical analyses were performed using iamovi statistical analysis software (version 2.7.17), built on the R statistical computing environment, developed by the jamovi project (Sydney, Australia). Continuous variables were assessed for normality using the Shapiro–Wilk test and are presented as median with interquartile range. Categorical variables are expressed as frequencies and percentages.

Comparisons between groups were performed using the Mann–Whitney U-test for continuous variables and the χ^2 test or Fisher's exact test for categorical variables, as appropriate. Factors associated with in-hospital mortality were evaluated using binomial logistic regression analysis. Variables with clinical relevance and/or statistical significance in univariate analyses were entered into the multivariable model.

Discriminatory performance of selected variables was assessed using ROC curve analysis, and area under the curve (AUC) values with 95% confidence intervals were reported. A two-sided $p<0.05$ was considered statistically significant.

RESULTS

A total of 97 patients were included in the study. Most patients were male (n=76, 78.4%), while 21 patients (21.6%) were female. Regarding body mass index (BMI), the majority of patients were of normal weight (n=58, 59.8%), followed by overweight patients (n=26, 26.8%). Obesity class I and II were observed in a small proportion of patients, and the number of underweight patients was limited. Sarcopenia was identified in 30 patients (30.9%), whereas 67 patients (69.1%) were classified as non-sarcopenic. Nearly, all perforations were located in the prepyloric region (n=94, 96.9%). Open surgery was the predominant surgical approach (n=90, 92.8%). Baseline patient characteristics are summarized in Table 1.

Mortality-Based Comparisons

When patients were stratified according to in-hospital mortality, significant differences were observed between survivors (n=80) and non-survivors (n=17) for several variables (Table 2). Male sex was significantly more frequent among survivors, whereas the proportion of female patients was higher in the mortality group (p=0.005). BMI category distribution differed significantly between groups (p=0.002), with a higher proportion of obese patients in the mortality group. No deaths occurred among underweight patients.

The prevalence of sarcopenia was numerically higher among non-survivors; however, this difference did not reach statistical significance (p=0.314). In contrast, mortality was strongly associated with disease severity scores. No mortality was observed among patients with a Boey score of 0, whereas the majority of patients with a Boey score of 3 were in the mortality group (p<0.001). Similarly, mortality rates increased significantly with higher ASA physical status. No deaths occurred in ASA II patients, while mortality was significantly

Table 2. Categorical variables according to mortality

Variable	Category	Survived (n=80) (%)	Died (n=17) (%)	p
Sex	Male	67 (83.8)	9 (52.9)	0.005
	Female	13 (16.3)	8 (47.1)	
BMI class	Underweight	6 (7.5)	0 (0.0)	0.002
	Normal	50 (62.5)	8 (47.1)	
	Overweight	20 (25.0)	6 (35.3)	
	Obese (I–II)	4 (5.0)	3 (17.6)	
Sarcopenia	No	57 (71.3)	10 (58.8)	0.314
	Yes	23 (28.7)	7 (41.2)	
Boey score	0	30 (37.5)	0 (0.0)	<0.001
	1	35 (43.8)	1 (5.9)	
	2	14 (17.5)	3 (17.6)	
	3	1 (1.3)	13 (76.5)	
ASA class	II	45 (56.3)	0 (0.0)	<0.001
	III	31 (38.8)	12 (70.6)	
	IV	4 (5.0)	5 (29.4)	
Complications	No	75 (93.8)	13 (76.5)	0.053
	Yes	5 (6.2)	4 (23.5)	
Reoperation	No	78 (97.5)	13 (76.5)	0.011
	Yes	2 (2.5)	4 (23.5)	

Table 2 compares patients divided into two groups based on mortality status: Survivors and those who died. Gender, body mass index classes, presence of sarcopenia, Boey score, ASA physical status classification, post-operative complications, and reoperation requirement were analyzed as categorical variables. Where appropriate, the Chi-square or Fisher's exact test was used for intergroup comparisons. ASA: American Society of Anesthesiologists.

higher in ASA III and IV patients (p<0.001).

Neither symptom duration nor the interval between admission and surgery was significantly associated with in-hospital mortality. Symptom duration showed no significant group difference (Mann–Whitney U, p=0.163) and poor discriminatory performance (AUC=0.608, p=0.160). Although surgery interval reached borderline significance in parametric testing (p=0.045), this finding was not supported by non-parametric analysis (p=0.729) or ROC analysis (AUC=0.525, p=0.758).

Post-operative complications were more frequent in the mortality group, although this difference was of borderline statistical significance (p=0.053). The need for reoperation was significantly higher among non-survivors (p=0.011).

Multivariable Analysis of in-Hospital Mortality

Binomial logistic regression analysis was performed to identify independent predictors of in-hospital mortality (Table 3). Age, BMI, psoas muscle area, PMI, serum albumin, leukocyte count, and hemoglobin level were included in the model.

Increasing age was independently associated with higher mortality risk (odds ratio [OR] 1.07, 95% confidence interval [CI] 1.02–1.13, p=0.010). Serum albumin level showed a strong inverse association with mortality (OR 0.75, 95% CI 0.64–0.87, p<0.001). Leukocyte count was also significantly associated with mortality (p=0.020), although the effect size was small. BMI, hemoglobin level, psoas muscle area, and PMI were not independently associated with mortality.

The overall model fit was moderate (McFadden R2=0.296). The discriminatory performance of the model was high, with an area under the ROC curve of 0.886.

Comparison According to Sarcopenia Status

Clinical and laboratory characteristics were compared between sarcopenic and non-sarcopenic patients (Table 4). Sarcopenic patients were older and had lower BMI values; however, these differences were not statistically significant. As expected, both psoas muscle area and PMI were significantly lower in the sarcopenic group (p<0.001 for both).

Sarcopenic patients had significantly lower serum albumin levels (p<0.001) and higher inflammatory markers, including CRP (p=0.01), NLR (p=0.02), PLR (p=0.01), and SII (p=0.003). HALP scores were significantly lower in sarcopenic patients (p<0.001). High-risk clinical features were more frequent in the sarcopenic group, including Boey score ≥2 (p=0.002) and ASA class III–IV (p=0.001).

Table 3. Independent predictors of in-hospital mortality (binomial logistic regression)

(a). Demographic and body composition model

Predictor	Odds ratio (OR)	95% CI	p
Age (years)	1.07	1.02–1.13	0.010
BMI	1.00	1.00–1.00	0.202
PMI	0.99	0.99–1.00	0.285

(b). Biochemical and inflammatory model

Predictor	Odds ratio (OR)	95% CI	p
Albumin	0.75	0.64–0.87	<0.001
Leukocyte count	1.00	1.00–1.00	0.020
Hemoglobin	0.99	0.98–1.01	0.514

Table 3 presents the results of binomial logistic regression analyses performed to identify independent predictors of in-hospital mortality. Table 3a shows the demographic and body composition model, while Table 3b presents the biochemical and inflammatory model. Variables were selected based on clinical relevance, and collinearity was avoided by not including overlapping morphometric parameters in the same model. For each predictor, the odds ratio (OR) with 95% confidence interval and p-value are reported. Model fit was assessed using McFadden's R2, and discriminatory performance was evaluated using the area under the receiver operating characteristic curve (area under the curve), where applicable.

Table 4. Clinical and laboratory characteristics according to sarcopenia status

Variable	Non-sarcopenic (n=67)	Sarcopenic (n=30)	p
Age (years)	54 (IQR 26)	61 (IQR 28)	0.12
BMI	24.50 (IQR 4.70)	23.50 (IQR 5.20)	0.08
PMI	610 (IQR 240)	420 (IQR 210)	<0.001
Psoas muscle area	175 (IQR 80)	118 (IQR 65)	<0.001
Albumin	38 (IQR 4)	32 (IQR 6)	<0.001
Hemoglobin	130 (IQR 40)	118 (IQR 45)	0.06
CRP	72 (IQR 150)	138 (IQR 190)	0.01
NLR	890 (IQR 980)	1540 (IQR 1400)	0.02
PLR	24 000 (IQR 29 000)	54 000 (IQR 61 000)	0.01
SII	2500 (IQR 2800)	6200 (IQR 5100)	0.003
HALP	310 (IQR 260)	145 (IQR 180)	<0.001
Boey score ≥2	8 (11.9)	12 (40.0)	0.002
ASA III–IV	18 (26.9)	18 (60.0)	0.001
ICU stay (days)	1 (IQR 2)	4 (IQR 6)	<0.001
Length of hospital stay (days)	6 (IQR 3)	11 (IQR 6)	<0.001
Mortality	10 (14.9)	7 (23.3)	0.31

Table 4 compares clinical and laboratory characteristics between patients grouped into sarcopenic and non-sarcopenic categories based on the presence of sarcopenia. Demographic data, morphometric muscle measurements, nutritional and inflammation markers, and clinical outcomes were included in the table. The Mann–Whitney U-test was used for continuous variables, and the Chi-square or Fisher's exact test was used for categorical variables. CRP: C-reactive protein; IQR: Interquartile range; ASA: American Society of Anesthesiologists.

Postoperatively, sarcopenic patients had significantly longer ICU stays and longer overall hospital stays (both p<0.001). Although mortality was numerically higher among sarcopenic patients, this difference was not statistically significant.

Perforation diameter (median 1.0 cm; range 0.5–3.0) was not associated with in-hospital mortality (p=0.999). Although sarcopenic patients tended to have larger perforations, this difference did not reach statistical significance (p=0.057).

Table 5. Association between inflammatory–immunonutritional indices and sarcopenia

Index	Risk category	Non-sarcopenic (n=67) (%)	Sarcopenic (n=30) (%)	OR (95% CI) (%)	p
SII	<9057.5	62 (92.5)	25 (83.3)	Reference	
	≥9057.5	5 (7.5)	5 (16.7)	2.47 (0.65–9.35)	0.19
HALP	>530	64 (95.5)	21 (70.0)	Reference	
	≤530	3 (4.5)	9 (30.0)	9.14 (2.31–36.2)	<0.001
NLR	<1989	57 (85.1)	20 (66.7)	Reference	
	≥1989	10 (14.9)	10 (33.3)	2.85 (1.06–7.63)	0.03
PLR	<63916.5	60 (89.6)	18 (60.0)	Reference	
	≥63916.5	7 (10.4)	12 (40.0)	5.71 (1.98–16.4)	0.002

Table 5 categorically evaluates the relationship between inflammatory and immunonutritional indices and the presence of sarcopenia. Threshold values determined by ROC analyses were used for the systemic immune-inflammation index (SII), HALP score, neutrophil-lymphocyte ratio (NLR), and platelet-lymphocyte ratio (PLR). The association with sarcopenia is presented with unadjusted odds ratios (OR) and 95% confidence intervals (CI).

Immunonutritional and Inflammatory Signature of Sarcopenia

Unadjusted categorical analysis demonstrated significant associations between sarcopenia and several inflammatory–immunonutritional indices (Table 5). Low HALP score was strongly associated with sarcopenia (OR 9.14, 95% CI 2.31–36.2, p<0.001). High NLR (OR 2.85, 95% CI 1.06–7.63, p=0.03) and high PLR (OR 5.71, 95% CI 1.98–16.4, p=0.002) were also significantly associated with sarcopenia. Although high SII values were more frequent among sarcopenic patients, this association did not reach statistical significance.

ROC curve analysis demonstrated that age, serum albumin, HALP score, PMI, and psoas muscle area all exhibited discriminatory ability for in-hospital mortality (Fig. 1). Age and albumin showed the highest performance. HALP demonstrated balanced discriminatory capacity, whereas PMI and psoas muscle area showed more limited performance compared with age and albumin.

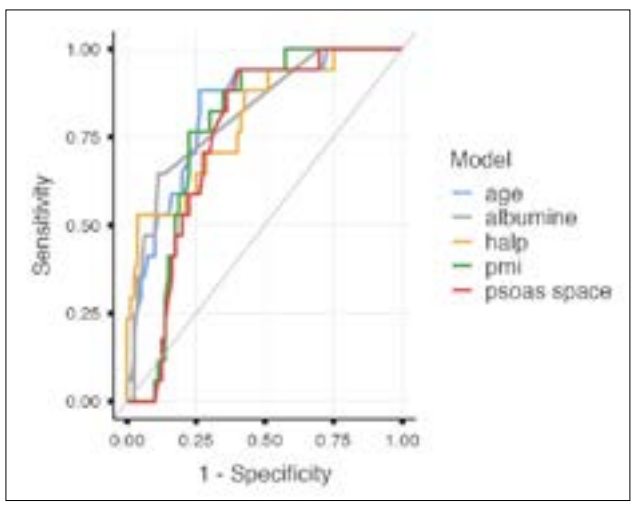

Figure 1. Receiver operating characteristic (ROC) curve analysis of mortality predictors. Figure 1 shows ROC curves predicting in-hospital mortality for age, serum albumin level, hemoglobin–albumin–lymphocyte–platelet score, psoas muscle area, and psoas muscle index. The diagonal line represents random discrimination. Each curve reflects the performance of the respective variable in distinguishing mortality.

DISCUSSION

In this study, we evaluated sarcopenia within a broader biological framework of frailty in patients undergoing emergency surgery for PPU. The principal finding was that while sarcopenia was common and strongly associated with adverse nutritional, inflammatory, and clinical features, it did not independently predict in-hospital mortality. Instead, parameters reflecting physiological reserve and systemic response – particularly age and serum albumin – emerged as the strongest independent determinants of mortality.

Although PPU is an acute surgical emergency, the patient's capacity to withstand its physiological stress is largely determined by chronic baseline biological reserve. Sarcopenia, as a slowly evolving condition reflecting cumulative loss of muscle mass and reserve, therefore does not act as a competing illness but as a pre-existing substrate that conditions host response to acute insult. Sarcopenia has been increasingly proposed as a surrogate marker of frailty, especially in surgical populations where functional frailty scales are difficult to apply.[21] In our cohort, sarcopenic patients clearly represented a more vulnerable subgroup, characterized by lower albumin levels, higher inflammatory markers, higher disease severity scores, and prolonged ICU and hospital stays. These observations are consistent with prior work showing that sarcopenia is more closely linked to increased morbidity than to mortality in emergency surgical settings, and they suggest that morphometric muscle loss alone may be insufficient to capture the full extent of physiological vulnerability in acute abdominal conditions.

Direct comparison with the existing literature provides important context for our findings. Brincat et al.,[22] in a systematic review of frailty in emergency surgery for older adults, reported that composite frailty assessment outperformed isolated morphometric markers in predicting adverse outcomes. Wang et al.,[23] in a cohort of older patients with PPU, demonstrated that sarcopenia added incremental prognostic value beyond the PULP score but did not replace conventional clinical predictors. Similarly, Yu et al.,[24] in patients with peptic ulcer bleeding, found that immunonutritional status was more closely associated with short-term outcomes than sarcopenia alone. Our results align with these reports: sarcopenia identified a vulnerable phenotype but lost its independent prognostic weight once age and albumin were accounted for, reinforcing the observation that in acute surgical stress, nutritional and inflammatory reserve may be more immediately relevant than muscle morphometry.

The discrepancy between univariate and multivariable findings deserves specific interpretation. Sarcopenia coexisted with – rather than replaced – other determinants of outcome, particularly malnutrition and systemic inflammation. Serum albumin, which integrates both nutritional status and acute-phase response, likely served as a more proximal biological marker of the patient's immediate capacity to tolerate surgical stress, thereby absorbing much of the prognostic signal initially attributable to sarcopenia.

The relationship between sarcopenia and immunonutritional indices offers additional mechanistic insight. Sarcopenic patients demonstrated significantly lower HALP scores and higher NLR and PLR values at presentation, indicating that even under an identical acute inflammatory insult, the magnitude of the host response differed systematically according to baseline muscle reserve.[25] This suggests that sarcopenia reflects not merely a structural deficit but a state of reduced biological resilience that modulates the patient's response to acute stress.[26]

ROC analysis demonstrated that morphometric muscle parameters retained discriminatory ability for mortality; however, their performance was inferior to that of age and albumin. This discrepancy between univariate discrimination and multivariable independence highlights the complex and overlapping biological pathways underlying frailty in emergency surgery.

Taken together, these findings suggest that in PPU surgery, frailty is better understood as a composite phenotype integrating muscle reserve, nutritional status, inflammatory response, and clinical severity. Sarcopenia remains a relevant component of this phenotype, but its prognostic value appears to be mediated through broader biological vulnerability rather than acting as an isolated determinant of mortality.

Limitations

This study has several limitations. Its retrospective and single-center design may limit generalizability and introduce selection bias. Post hoc power analysis indicated that the current sample (n=97; sarcopenic n=30 vs. non-sarcopenic n=67) provided relatively low statistical power (two-sided α=0.05) to detect the observed 8.4%-point difference in mortality between sarcopenic and non-sarcopenic groups (23.3% vs. 14.9%; odds ratio 1.73; Cohen's h=0.22). Furthermore, with only 17 in-hospital deaths, the events-per-variable ratio limited the stability of multivariable modeling. The reported odds ratios require external validation in larger, multicenter cohorts. Finally, psoas-based morphometry is widely used in emergency surgical research and correlates with whole-body muscle mass, it remains a regional surrogate and may not fully capture global skeletal muscle quality.

CONCLUSION

In patients undergoing emergency surgery for PPU, frailty is best conceptualized as a multidimensional biological phenotype rather than a single morphometric condition. Although sarcopenia was frequent and closely associated with malnutrition, systemic inflammation, and greater clinical severity, it did not independently predict in-hospital mortality. Instead, age and serum albumin – reflecting physiological reserve and acute systemic response – emerged as the strongest determinants of outcome. These findings suggest that effective risk stratification in PPU surgery should move beyond isolated muscle measurements and incorporate integrated markers of nutritional status, inflammatory burden, and clinical severity to better identify high-risk patients.

Ethics Committee Approval: This study was approved by the Ankara Etlik City Hospital Scientific Research Evaluation and Ethics Committee (Date: 10.06.2025, Decision No: AEŞH-BADEK2-2025-252).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Acil peptik ülser cerrahisinde kırılganlığa kapsamlı bir bakış

AMAÇ: Perfore peptik ülser (PPÜ), acil cerrahinin en yüksek riskli tablolarından biri olmaya devam etmektedir. Sarkopeni, kırılganlığın objektif bir göstergesi olarak önerilmiş olsa da, acil cerrahi hastalarında mortalite üzerindeki bağımsız prognostik değeri net değildir. Bu çalışmada sarkopeni, nütrisyonel, inflamatuvar ve klinik bileşenleri birlikte ele alan bütüncül bir kırılganlık yaklaşımı içerisinde değerlendirilmiştir.

GEREÇ VE YÖNTEM: Bu retrospektif kohort çalışmaya, üçüncü basamak bir merkezde perfore peptik ülser nedeniyle acil cerrahi uygulanan erişkin hastalar dahil edildi. Sarkopeni, bilgisayarlı tomografi görüntülerinden elde edilen psoas kas alanı ve psoas kas indeksi (PMI) kullanılarak, popülasyona özgü eşik değerleri temel alınarak tanımlandı. İmmün-nütrisyonel ve inflamatuvar belirteçler (HALP, NLR, PLR, SII) başvuru anındaki laboratuvar verilerinden hesaplandı. Birincil sonlanım noktası hastane içi mortalite olarak belirlendi. Bağımsız prediktörleri ve ayırt edici gücü değerlendirmek amacıyla çok değişkenli lojistik regresyon ve ROC analizleri yapıldı.

BULGULAR: Toplam 97 hasta çalışmaya dahil edildi ve hastaların %30.9'unda sarkopeni saptandı. Sarkopenik hastalarda serum albümin düzeyleri daha düşük, inflamatuvar belirteçler ve klinik şiddet skorları daha yüksek olup, yoğun bakım ve hastanede yatış süreleri anlamlı olarak daha uzundu (tüm karşılaştırmalar için $p<0.05$). Ancak sarkopeni, hastane içi mortalite ile bağımsız olarak ilişkili bulunmadı. Çok değişkenli analizde ileri yaş (OR 1.07; $p=0.010$) ve düşük serum albümin düzeyi (OR 0.75; $p<0.001$) mortalitenin en güçlü bağımsız belirleyicileri olarak saptandı. Düşük HALP skoru ile yüksek NLR ve PLR değerleri sarkopeni varlığı ile anlamlı şekilde ilişkiliydi. ROC analizinde yaş ve albüminin mortaliteyi öngörmedeki ayırt edici gücünün, kas morfometrik parametrelerinden daha üstün olduğu görüldü.

SONUÇ: Perfore peptik ülser cerrahisinde kırılganlık, izole kas kaybından ziyade çok bileşenli bir biyolojik fenotip olarak ele alınmalıdır. Sarkopeni artmış hassasiyeti yansıtmakla birlikte, mortalite riskini esas olarak yaş ve nütrisyonel–inflamatuvar rezerv belirlemektedir. Entegre bir kırılganlık değerlendirmesi, acil cerrahi hastalarında risk sınıflamasını iyileştirebilir.

Anahtar sözcükler: Acil cerrahi; albümin; kırılganlık; perfore peptik ülser; sarkopeni.

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ORIGINAL ARTICLE

Fourteen consecutive free flaps in 14 days for reconstruction of crush injuries in the 2023 Kahramanmaraş earthquake: A retrospective university hospital experience from the disaster zone

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ABSTRACT

BACKGROUND: Earthquakes frequently result in high-energy extremity injuries requiring complex soft-tissue reconstruction. Performing microsurgical free-flap procedures in the acute post-disaster setting poses significant challenges due to resource limitations and logistic constraints.

METHODS: This retrospective study reviewed patients who underwent free-flap soft-tissue reconstruction in our tertiary university hospital, located within the disaster zone, during the acute phase of the 2023 Kahramanmaraş earthquake (February 06–21, 2023). Of 145 patients hospitalized in our plastic and reconstructive surgery service during this period, 14 underwent free-flap reconstruction and were included. Demographics, flap types, recipient vessels, perioperative details, and outcomes were analyzed.

RESULTS: Fourteen consecutive free flaps were performed over 14 days. The mean patient age was 32.8 years (range: 6–60 years); 50% were female. Twelve reconstructions (86%) involved the lower extremity, and two (14%) involved the upper extremity. The anterolateral thigh flap was the most frequently used flap (71.4%), followed by the latissimus dorsi flap (28.6%). In 75% of lower-extremity cases, the anterior tibial vessels of the injured limb were used; cross-leg anastomoses were required in three patients. Flap survival was achieved in 13/14 patients (92.8%). One total flap loss resulted in amputation.

CONCLUSION: Early free-flap reconstruction can be successfully integrated into acute trauma care even under disaster conditions when resources are organized efficiently, and surgical teams are coordinated. Our results support incorporating microsurgical capability into disaster-preparedness planning.

Keywords: Earthquake; extremity; free flap; limb salvage; microsurgery; reconstruction.

INTRODUCTION

Earthquakes are among the most devastating natural disasters, causing a wide spectrum of injuries and considerable morbidity. Soft-tissue and extremity injuries account for a major proportion of earthquake-related trauma and represent the second most common type of injury after life-threatening conditions have been addressed.[1] Early recognition and prompt surgical intervention are crucial to prevent infection, preserve limb function, and minimize the risk of amputation.[2] In the acute

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post-disaster period, emergency fasciotomy plays a vital role in preventing irreversible ischemic muscle necrosis in crush and compartment syndromes. Thorough surgical debridement is essential for removing devitalized tissue, reducing bacterial load, and lowering the risk of sepsis and late amputations.[3] When limb salvage is impossible, timely amputation may be life-saving by preventing systemic complications.[4] After these life- and limb-saving measures, the next priority is early soft-tissue coverage to protect exposed structures, prevent chronic infection, and restore function. In selected earthquake-related injuries, soft-tissue defects can be reconstructed using skin grafts or local flap techniques;[5] however, extensive or complex defects often require microsurgical free-flap reconstruction. Free-flap reconstruction has become a cornerstone in managing complex extremity injuries, and performing it in the acute post-disaster setting can reduce the number of additional procedures, shorten hospital stay, and improve both functional and esthetic outcomes for earthquake survivors. This study aims to present our experience with free-flap reconstructions performed during the acute phase of the 2023 Kahramanmaraş earthquake.

MATERIALS AND METHODS

On February 06, 2023, two major earthquakes of 7.7 and 7.5 magnitude struck Kahramanmaraş province in Türkiye, and these were followed by two additional earthquakes of 6.4 and 5.8 magnitude on February 20, severely affecting eleven cities with a combined population of more than 16 million.[6] Adana, the city where our hospital is located, was among the provinces affected by the Kahramanmaraş-centered earthquakes. Following the disaster, all elective surgeries were immediately canceled, inpatients were discharged, and our hospital was rapidly converted into a trauma center. Surgical interventions commenced on the 1st day. Two weeks after the initiation of medical treatment for earthquake victims, two significant aftershocks occurred on February 20, 2023, at 20:04 and 20:07 local time, with epicenters in the Defne and Samandağ districts and magnitudes of 6.4 and 5.8, respectively.[7] During inspections conducted the day after the aftershocks, on February 21, two main blocks of the hospital housing inpatient services were classified as "moderately damaged," leading to the suspension of surgical operations and the transfer of existing patients to nearby hospitals. By February 23, all patients had been safely transferred to nearby hospitals, and the evacuation process was fully completed.[8]

In this retrospective study, patients who underwent free-flap soft-tissue reconstruction during the acute post-earthquake period, between February 06 and 21, 2023, when our hospital was still functioning as a trauma center, were reviewed. Fourteen consecutive patients operated on within this period were included in the study. Demographic data, flap types used, recipient vessels, post-operative complications, and flap survival rates were analyzed, and perioperative management was described in detail.

To place these reconstructions in context, the overall surgical workload of our service during the same period was also recorded. During this acute operational window, 145 patients were admitted to our plastic and reconstructive surgery service, the majority referred from the severely affected provinces of Hatay and Kahramanmaraş. These patients required a wide range of interventions – including debridement, split- and full-thickness skin grafting, fasciotomy, locoregional flap reconstruction, and maxillofacial fracture repair—of whom 14 underwent microsurgical free-flap reconstruction and form the subject of the present report.

Free-flap reconstruction was not undertaken during the initial emergency phase, with the exception of one patient who underwent reconstruction on the 1st day following the earthquake. Patients first received resuscitation and, where indicated, fasciotomy and serial debridement; definitive microsurgical coverage was performed only once the patient's general condition had stabilized and the wound bed was judged suitable for free-tissue transfer, generally after several days of repeated debridement. On average, reconstruction was undertaken approximately 5 days after admission to our hospital. Over the 14-day operational period, 14 free flaps were performed, corresponding to 1 flap per operative day.

This study was approved by the local ethics review board (Approval No: 136/28, Date: September 01, 2023) and conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all individual participants included in the study.

RESULTS

Demographic characteristics, flap types, recipient vessels, and complications of the patients are shown in Table 1.

The mean age of the 14 patients included in the study was 32.8 years, with a median age of 32 years. The youngest patient was 6 years old (Fig. 1), and the oldest was 60 years old (Fig. 2). There were seven female patients (50%) and seven male patients (50%). All reconstructions were performed for extremity injuries caused by crush trauma. Twelve of these reconstructions involved the lower extremity (86%), while two involved the upper extremity (14%).

The most frequently used flap type was the anterolateral

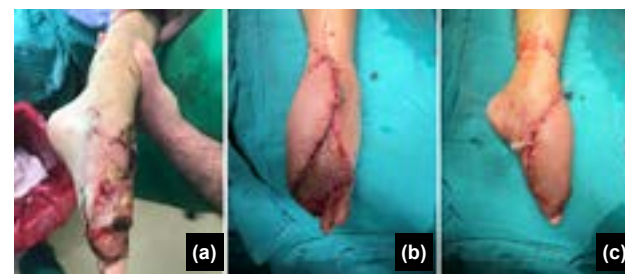

Figure 1. A 6-year-old patient who underwent anterolateral thigh free-flap reconstruction for coverage of a foot amputation stump. **(a)** Preoperative view; **(b and c)** intraoperative views.

Table 1. Demographic Characteristics, Flap Types, Recipient Vessels, and Complications of the Patients

#	Age	Gender	Recipient Area	Flap	Recipient Artery	Recipient Vein	Complication
1	42	Female	LE	ALT	ATA	GSV	-
2	23	Female	LE	LD + SA	Cross-leg PTA	VC (x2)	serratus muscle necrosis
3	16	Female	LE	ALT	ATA	VC	-
4	39	Male	LE	ALT	Cross-leg PTA	VC (x2)	-
5	38	Male	LE	ALT	ATA	VC	-
6	60	Male	LE	LD	ATA	VC	donor site suture dehiscence
7	26	Female	UE	ALT + VL	RA	VC	Venous thrombosis/revision at 2nd postoperative hour/flap salvaged
8	58	Male	LE	ALT	ATA	VC	-
9	20	Male	LE	ALT + VL	ATA	VC	Superficial skin necrosis
10	58	Female	UE	LD	RA	VC	Flap loss/amputation
11	42	Male	LE	ALT	ATA	VC	-
12	22	Female	LE	ALT	ATA	VC	-
13	6	Male	LE	ALT	ATA	VC	-
14	9	Female	LE	LD	Cros-leg PTA	VC	-

LE: Lower extremity; UE: Upper extremity; LD: Latissimus dorsi; SA: Serratus anterior; VL: Vastus lateralis; ATA: Anterior tibial artery; PTA: Posterior tibial artery; RA: Radial artery; VC – Vena comitans; GSV: Great saphenous vein.

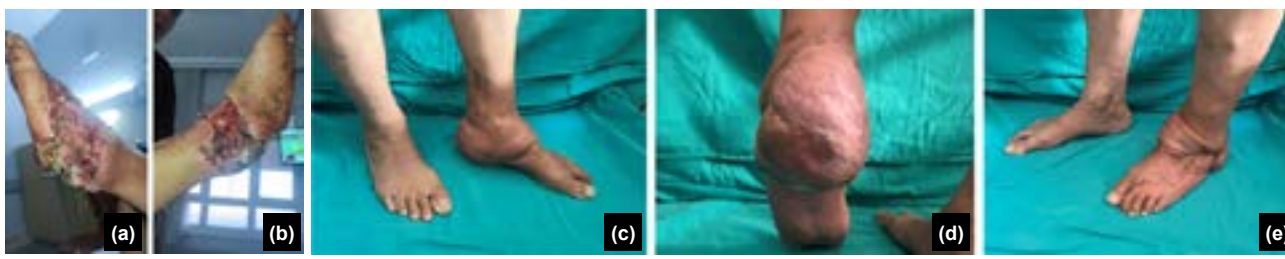

Figure 2. A 60-year-old patient who underwent latissimus dorsi free-flap reconstruction for coverage of calcaneal and dorsal foot defects. **(a and b)** Preoperative views, **(c)** medial, **(d)** posterior, and **(e)** lateral views at 1-year follow-up.

thigh (ALT) flap, which was performed as a fasciocutaneous flap in eight patients (57%) and as a myocutaneous flap including the vastus lateralis muscle in two patients (14%). A latissimus dorsi flap was used in four patients (29%), one of which was designed as a chimeric flap including the serratus anterior muscle (Fig. 3).

In nine of the 12 patients who underwent lower-extremity reconstruction (75%), the anterior tibial artery and, in all but one case, the anterior tibial vein of the same limb were used as recipient vessels. In the patient in whom the anterior tibial vein was unsuitable for anastomosis, the great saphenous vein was used as the recipient vein.

In three patients in whom suitable recipient vessels were not available in the same limb, the anastomoses were performed to the posterior tibial vessels of the contralateral leg. For these cross-leg reconstructions, each branch of the flap artery's Y-configuration was anastomosed to the proximal and distal segments of the recipient artery, ensuring both adequate flap perfusion and preservation of the recipient artery's

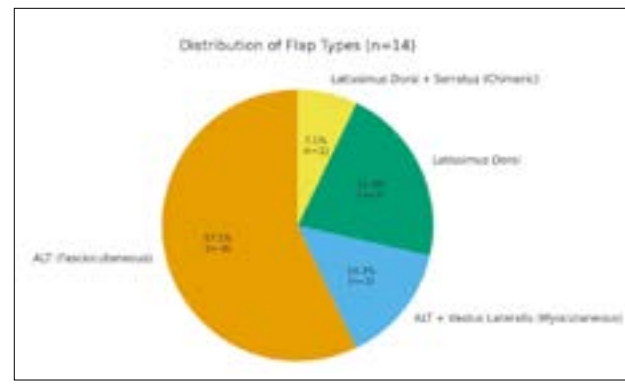

Figure 3. Distribution of flap types among 14 patients.

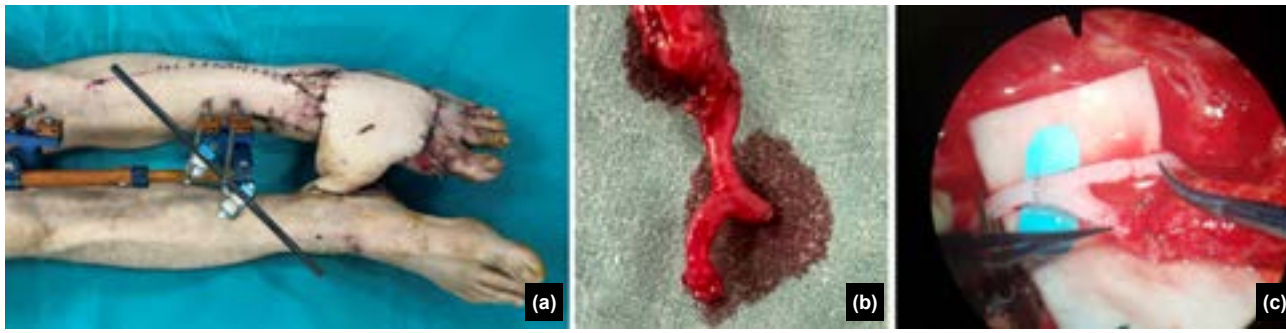

Figure 4. Cross-leg anterolateral thigh (ALT) flap reconstruction. **(a)** Incision made for exploration of the anterior tibial artery. **(b)** Y-configuration of the flap pedicle. **(c)** Anastomosis of the ALT pedicle to the proximal and distal segments of the contralateral posterior tibial artery, ensuring both adequate flap perfusion and preservation of the recipient artery's continuity.

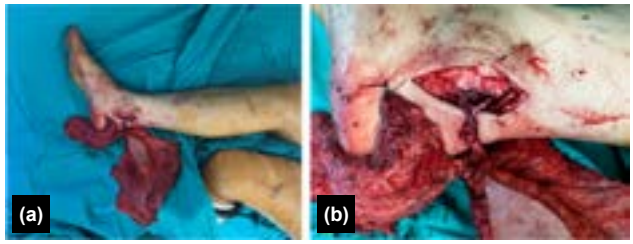

Figure 5. Chimeric latissimus dorsi + serratus anterior muscle flap reconstruction. **(a)** Flap anastomosed to the contralateral posterior tibial vessels. **(b)** Y-configuration of the thoracodorsal artery to the proximal and distal segments of the contralateral posterior tibial artery.

continuity. This technique was successfully applied to both ALT (Fig. 4) and latissimus dorsi flaps (Figs. 5 and 6) without the need for end-to-side anastomosis.

Among the two patients who underwent upper-extremity reconstruction, the pedicle of the ALT flap was anastomosed to the radial artery and vein in one case.

The other upper-extremity injury resulted in flap loss and ultimately amputation. The radial artery was defective. The surgical plan aimed to restore hand vascularization and cover the defect using a flow-through latissimus dorsi myocutaneous flap combined with a saphenous vein graft. The thoracodorsal artery and vein were anastomosed to the proximal stumps of the radial artery and vein. Distally, the radial artery stump was identified at the wrist level, and a 20-cm vein graft was interposed between the serratus branch of the flap and the distal radial artery stump (Fig. 7). Despite revascularization efforts, flap and hand perfusion failed in the early post-operative period, resulting in amputation.

Major complications occurred in two patients (14.2%). One patient developed venous thrombosis, which was successfully managed with early post-operative revision surgery, resulting in flap salvage. The other patient experienced total flap loss, and the treatment course ultimately ended with amputation.

Overall flap survival was achieved in 13 of 14 patients (92.8%).

Figure 6. Chimeric latissimus dorsi + serratus anterior muscle flap reconstruction. **(a)** Flap after completion of arterial and venous anastomoses, before inset. **(b)** Latissimus dorsi muscle used to reconstruct the anterior crural defect. **(c)** Serratus anterior muscle used to reconstruct the Achilles region defect.

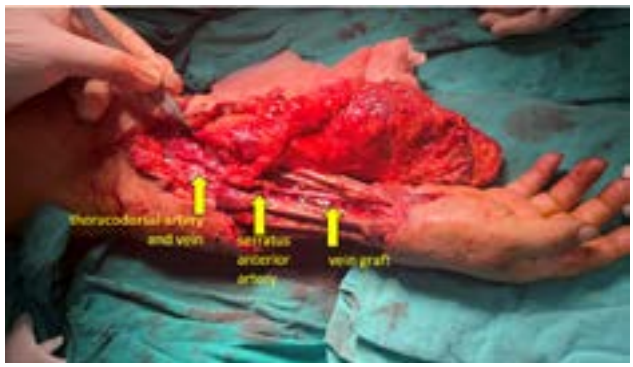

Figure 7. Flow-through latissimus dorsi myocutaneous flap with interposed saphenous vein graft, designed for both soft-tissue coverage and restoration of arterial flow to the hand. Flap and hand perfusion failed in the early post-operative period, necessitating amputation.

DISCUSSION

One may reasonably question whether there was a crucial need for lengthy microsurgical procedures during a period when an overwhelming number of patients were waiting for emergency operations such as fasciotomies, amputations, and maxillofacial trauma. Importantly, none of the emergency surgical interventions for these patients were postponed or delayed to perform free-flap reconstructions. Despite the high patient load, none of the patients were referred to another medical facility, as all necessary surgical interventions were performed within our hospital.

The capacity to sustain both microsurgical and non-microsurgical procedures during the disaster period was made possible by a deliberate reorganization of departmental resources. Inpatient capacity was expanded from approximately 20 to more than 100 beds through the reassignment of wards from other specialties, and the operating-room availability allocated to our department increased from 2 to 5 rooms/day. Our team comprised 16 residents and 3 faculty members, reinforced by the voluntary support of plastic surgeons – both from private practice in Adana and from other provinces, coordinated through the national society – who joined our team. Within the hospital as a whole, all 23 operating theaters remained operational day and night for the management of earthquake-related injuries, supported by a continuously available anesthesia team. As one of the first points of evaluation for arriving patients, our team also participated in emergency-department triage, consistently assigning one and often two physicians to the emergency department and increasing this number as patient volume required, so that timely operative decisions could be made in coordination with anesthesia and the other surgical branches. Within this organizational framework, free-flap reconstruction was integrated into a staged workflow in which emergency stabilization, fasciotomy, and serial debridement preceded definitive microsurgical coverage. This demonstrates that timely microsurgical reconstruction can be integrated into acute trauma care without compromising life-saving procedures, provided that hospital resources are efficiently organized and surgical teams are well-coordinated.

The patients in this series were managed under physiologically demanding conditions. All had sustained high-energy crush trauma, and many had been extricated from collapsed structures after prolonged entrapment, with the attendant risks of crush syndrome, rhabdomyolysis, and acute kidney injury. A number had undergone fasciotomy – frequently performed at referring centers – before transfer, and several required revision fasciotomy or extensive debridement of non-viable tissue before reconstruction. Free-flap reconstruction was therefore undertaken only after the patient's systemic condition had stabilized and the wound bed had been adequately prepared, an approach that influenced both the timing of surgery and the choice of flap.

Several disaster-specific challenges complicated the post-operative course. Microsurgical flaps require close, frequent monitoring for the early detection of vascular compromise, yet nursing and physician resources were stretched across an exceptional patient volume, and standard monitoring ratios could not always be maintained. The single episode of venous thrombosis in our series – salvaged by prompt re-exploration within the early post-operative hours – illustrates both the value of vigilant flap monitoring and the narrow margin available when resources are constrained. The risk of infection was heightened by contaminated crush wounds, delayed presentation, prolonged entrapment, and the austere environment; rigorous serial debridement, early soft-tissue coverage, and culture-directed antimicrobial therapy were central to mitigating this risk. Equally important, and often overlooked, was the toll on the surgical team itself: staff had also lived through the earthquake, some having lost relatives or homes, and worked extended shifts – including through major aftershocks – under considerable physical and psychological strain. We believe that explicit provision for post-operative monitoring capacity, infection control, and staff welfare and rotation should be incorporated into disaster-preparedness planning for reconstructive services.

The ALT flap was the most frequently used flap in our series, accounting for 71.4% of reconstructions. This preference is consistent with the existing literature, as the ALT flap offers several advantages for post-traumatic reconstruction. It provides a long and reliable vascular pedicle and a large skin paddle with relatively low donor-site morbidity, with the option of including the vastus lateralis muscle for myocutaneous coverage when additional bulk or obliteration of dead space is required. A practical advantage of the ALT flap in this setting is that, with the patient supine, two teams can readily work in parallel – harvesting the flap while the recipient site is prepared – without repositioning, thereby reducing operative time and minimizing anesthesia-related risks. We recognize that, with appropriate positioning (for example, a lateral decubitus or modified position that exposes both the donor

and recipient sites), the latissimus dorsi flap can likewise be harvested without a separate repositioning step, as is the routine practice at some centers; the relative convenience of simultaneous two-team access is therefore partly center- and preference-dependent. Nonetheless, in the specific context of high-volume, time-critical disaster surgery, we found the supine ALT approach particularly efficient.

In selected cases, the latissimus dorsi flap was preferred, primarily for larger defects requiring a greater surface area or volume of vascularized tissue, or where its muscle component was advantageous for contouring complex three-dimensional wounds. Historically, muscle flaps were considered superior for the coverage of contaminated or infected wounds; however, a growing body of comparative evidence has shown no significant difference between muscle/musculocutaneous and fasciocutaneous flaps with respect to flap survival, complication rates, or the control of infection in lower-extremity reconstruction, while fasciocutaneous flaps may offer advantages in donor-site morbidity and ease of secondary revision.[9,10] Accordingly, our flap selection was driven primarily by defect dimensions, the need to obliterate dead space, and the available recipient anatomy, rather than by an assumed antimicrobial advantage of muscle. Our decision to use the latissimus dorsi flap in 4 of 14 patients thus reflects an individualized, defect-specific approach.

In the study by Clover et al.,[11] which reported the surgical treatments performed in a field hospital established on a tennis court following the Haiti earthquake, 18 of 158 patients (11%) with complex defects were referred to other centers due to the lack of equipment and suitable facilities for post-operative care. Twelve (66.7%) of these 18 cases subsequently underwent successful free-flap reconstructions. The authors also noted that, of the four lower-limb amputations, two might have been salvageable with free-tissue transfer.

In our series, we achieved a flap survival rate of 92.8%, which is comparable to previously reported rates[2,12] for 2023 Kahramanmaraş earthquake victims. Almost all of the reports on free-flap reconstructions in victims of the 2023 Kahramanmaraş earthquake originate from hospitals outside the disaster zone, where patients were transferred after initial stabilization. This indicates that surgical interventions were generally performed in centers with more controlled conditions and greater resource availability. Our series is distinct in that all procedures were performed during the acute post-disaster period in a university hospital located within the disaster zone. Achieving a comparable flap survival rate under these challenging conditions – characterized by limited resources, logistical difficulties, and a high patient load – highlights the critical importance of multidisciplinary coordination and the experience of the surgical team.

Despite these promising results, our study has several limitations. Flap survival rate alone is not a sufficient indicator of surgical success; functional outcomes, complication rates, and long-term patient quality of life should also be evaluated to comprehensively assess the effectiveness of early free-flap reconstruction. Due to the evacuation of our hospital, the patients were lost to follow-up; when the hospital resumed its operations, most of them had already continued their treatment at other centers. This situation resulted in insufficient long-term follow-up data, which represents an important limitation of our study. Future multicenter prospective studies with extended follow-up are needed, with a particular focus on functional outcomes, rehabilitation progress, complication rates, and long-term quality of life in earthquake survivors undergoing free-flap reconstruction.

Another limitation of this study is the suboptimal quality of some of the photographs. Although it was a chaotic period, careful documentation remains essential.

CONCLUSION

Our experience demonstrates that early free-flap reconstruction is feasible and can be successfully integrated into acute trauma care even under disaster conditions, provided that resources are organized efficiently and surgical teams are well-coordinated. Therefore, disaster-preparedness plans should include dedicated microsurgical teams, adequate equipment, and clear protocols to enable timely and effective limb-salvage procedures in future mass-casualty events.

Ethics Committee Approval: This study was approved by the Cukurova University Faculty of Medicine Non-Interventional Clinical Research Ethics Committee (Date: 01.09.2023, Decision No: 136/28).

Informed Consent: Written informed consent was obtained from all individual participants included in the study.

Peer-review: Externally peer-reviewed.

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ORİJİNAL ÇALIŞMA - *ÖZ*

2023 Kahramanmaraş depreminde ezilme yaralanmalarının rekonstrüksiyonunda 14 gün içinde gerçekleştirilen 14 ardışık serbest flep: Afet bölgesindeki bir üniversite hastanesi deneyiminin retrospektif analizi

AMAÇ: Depremler, sıklıkla kompleks yumuşak doku rekonstrüksiyonu gerektiren yüksek enerjili ekstremite yaralanmalarına yol açar. Afet sonrası akut dönemde mikrocerrahi serbest flep uygulamaları, kaynak kısıtlılıkları ve lojistik engeller nedeniyle önemli zorluklar taşır.
GEREÇ VE YÖNTEM: Bu retrospektif çalışmada, 2023 Kahramanmaraş depremi sonrası akut dönemde (6–21 Şubat 2023) afet bölgesinde yer alan üçüncü basamak üniversite hastanemizde serbest flep ile yumuşak doku rekonstrüksiyonu yapılan hastalar değerlendirildi. Bu dönemde plastik ve rekonstrüktıf cerrahi servisimize yatırılan 145 hastadan 14'üne serbest flep rekonstrüksiyonu uygulandı ve bu hastalar çalışmaya dahil edildi. Demografik veriler, flep tipleri, alıcı damarlar, perioperatif ayrıntılar ve sonuçlar analiz edildi.
BULGULAR: On dört gün içinde toplam 14 ardışık serbest flep operasyonu gerçekleştirildi. Hastaların ortalama yaşı 32.8 (dağılım: 6–60 yıl) olup, %50'si kadındı. On iki rekonstrüksiyon (%86) alt ekstremitede, iki rekonstrüksiyon (%14) ise üst ekstremitede gerçekleştirildi. En sık kullanılan flep anterolateral uyluk (ALT) flebi (%71.4) olup, bunu latissimus dorsi flebi (%28.6) izledi. Alt ekstremite olgularının %75'inde yaralı ekstremitenin anterior tibial damarları alıcı damar olarak kullanıldı; üç hastada çapraz bacak anastomozlar gerekti. Flep yaşama oranı 13/14 (%92.8) idi; bir total flep kaybı ampütasyonla sonuçlandı.
SONUÇ: Afet koşullarında bile, kaynakların etkin biçimde organize edilmesi ve cerrahi ekiplerin koordinasyonu sağlandığında, erken dönemde serbest flep rekonstrüksiyonu akut travma bakımına başarıyla entegre edilebilir. Bulgularımız, mikrocerrahi yeteneğinin afet hazırlık planlamalarına dahil edilmesi gerektiğini desteklemektedir.

Anahtar sözcükler: Deprem; ekstremite; mikrocerrahi; rekonstrüksiyon; serbest flep; uzuv korunması.

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ORIGINAL ARTICLE

Are there missed warning signals before traffic-related traumatic spinal cord injury? An exploratory case–control study using electronic health records

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ABSTRACT

BACKGROUND: Traumatic spinal cord injury (TSCI) is a catastrophic outcome frequently resulting from road-traffic crashes. We investigated whether routinely recorded pre-injury healthcare utilization patterns in electronic health records (EHRs) can serve as pragmatic warning signals for TSCI among drivers and motorcyclists.

METHODS: We conducted a retrospective age- and sex-matched case–control study using national EHR data. Adults aged 18–45 years with traffic-accident-related TSCI as drivers or motorcyclists (2024–2025) were matched 1: 1 with controls (n=35 per group). Pre-index utilization during the preceding 24 months included trauma-related emergency department (ED) visits, orthopedics/traumatology department (OTD) visits, total trauma-related visits, and psychiatry visits. Between-group comparisons used Mann–Whitney U tests. Receiver operating characteristic analyses were used to summarize discriminative performance. Binary risk flags (≥1 ED visit; ≥1 psychiatry visit) were evaluated using multivariable logistic regression.

RESULTS: The analytic sample included 70 participants. Compared with controls, TSCI cases had higher trauma-related ED visits (p<0.001; r=0.45), psychiatry visits (p=0.010; r=0.31), and total trauma-related visits (p=0.035; r=0.25), whereas OTD visits did not differ (p=0.920). ED visits showed the highest discrimination (area under curve [AUC]=0.726). In this sample, the ≥1 versus 0 contrast yielded sensitivity 60.0% and specificity 82.9%. Psychiatry visits showed modest discrimination (AUC=0.649). In this sample, the ≥1 versus 0 contrast yielded sensitivity 45.7% and specificity 80.0%. In multivariable analysis, ≥1 ED visit (odds ratio [OR]=8.85, 95% confidence interval [CI] 2.68–29.23; p<0.001) and ≥1 psychiatry visit (OR=4.52, 95% CI 1.34–15.20; p=0.015) were independently associated with TSCI.

CONCLUSION: Traffic-related TSCI may be preceded by measurable pre-injury patterns – particularly trauma-related ED utilization and psychiatry visits – captured in routinely collected EHR data. These findings support a pragmatic risk-flagging approach that may help identify individuals who could benefit from targeted preventive education, injury-risk counseling, and psychosocial risk-reduction interventions. These findings should be interpreted with caution and require validation in larger prospective studies.

Keywords: Electronic health records; emergency; psychiatry; spinal cord injury; traffic accidents; trauma.

INTRODUCTION

Spinal cord injury (SCI) is damage to the spinal cord resulting in neurological impairment. It is one of the most devastating conditions in clinical practice, often resulting in long-term motor, sensory, and autonomic deficits, severe disability, and high healthcare and societal costs, frequently impacting individuals at relatively young ages.[1] Traumatic SCI (TSCI) mainly affects young and middle-aged adults and usually happens after high-energy events, such as car accidents, falls, and violence between people.[1-3]

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The incidence of TSCI ranges from 8 to 150 cases per million population per year.[4] SCI has a big impact on the economy. The total global macroeconomic cost of SCI, which includes healthcare costs and lost productivity that lowers savings, investment, and capital accumulation, is expected to reach INT$5.58 trillion between 2020 and 2050.[5] Global estimates indicate that by 2050, there will be around 422,611 new cases of SCI each year, with approximately 12.0 million individuals currently living with SCI worldwide.[3]

Epidemiological datasets indicate that men constitute the majority of new SCI cases (approximately 78%), and long-term morbidity is prevalent. Persistent spasticity is frequently observed, cervical injuries often lead to tetraplegia, and the resultant disability burden significantly diminishes employment rates among individuals with SCI compared to the general population.[6] It is known that a significant number of victims of road traffic injuries live with some degree of limitation after injury, and nearly half of them cannot return to work.[7] Together, these features show how important it is to predict an accident before it happens and stop the injury.

Primary prevention continues to be the most efficacious approach to alleviate this burden. Current strategies predominantly depend on extensive public health initiatives, including safety regulations and injury-prevention curricula in schools or communities that focus on road safety, helmet usage, violence prevention, and other safety practices, supplemented by emails, posters, and informational brochures.[8-10] Although crucial at the population level, these "blanket" strategies may not effectively target individuals at disproportionately elevated risk.

Sometimes, a major trauma happens after a person has been to the doctor for less serious injuries several times. Studies on trauma recidivism indicate that individuals who experience recurrent injuries are at a heightened risk for mental health issues.[11,12] Simultaneously, previous utilization of emergency services has been suggested as an early indicator of potential escalation toward severe harm.[13]

Based on these observations, we formulated trauma-related emergency department (ED) and Orthopedic and Traumatology Department (OTD) visits as quantifiable indicators of recurrent exposure to hazardous environments and Psychiatry Department (PD) utilization as an indicator of psychiatric vulnerability.[13,14] Thus, we defined pre-injury healthcare utilization over 24 months as a practical risk-flagging indicator for risk stratification. Previous research in various clinical fields substantiates the conceptual feasibility of utilizing routinely gathered health records to detect heightened risk prior to the manifestation of adverse outcomes.[15,16]

The aim of this study was to identify pre-injury signals associated with a higher risk for TSCI before a catastrophic event happened. This would give us a group of people to focus on for education and prevention efforts. In this study, we aimed to identify pre-injury warning signals in the electronic health records (EHRs) of car drivers and motorcyclists who subsequently sustained a significant trauma leading to SCI. We hypothesized that these individuals would exhibit significantly increased rates of pre-injury healthcare utilization – specifically trauma-related ED and OTD visits, along with interactions with the PD – during the 24 months preceding their injury in comparison to matched controls.

To the best of our knowledge, this study is among the initial investigations into whether routinely collected EHR data contain measurable pre-injury "warning signals" associated with subsequent TSCI resulting from traffic accidents. If validated in independent cohorts, these signals could enable targeted, low-intensity preventive measures before severe injury, including brief traffic safety counseling, referral pathways for psychosocial assessment when required, and structured rehabilitation for individuals at high risk. In theory, even small drops in the number of serious injuries could help people a lot and save health systems money in the long run.

MATERIALS AND METHODS

Study Design and Setting

The study was a retrospective case–control study matched for age and sex. Ethical approval was obtained from the Ethics Committee of the Ministry of Health Antalya City Hospital (08.01.2026–20/176), and EHRs were subsequently screened. Patients who were 18–45 years old and had been seen in the Physical Medicine and Rehabilitation (PMR) clinic of a tertiary hospital with a diagnosis of TSCI between January 1, 2024, and December 31, 2025, were eligible.

Participants, Eligibility Criteria and Matching

Study participants were identified through a systematic screening of the national EHR system between 1 January 2024 and 31 December 2025. To ensure a homogeneous cohort of active-participation road-traffic users, cases were eligible if they were adults aged 18–45 years diagnosed with TSCI (cervical, thoracic, or lumbar) with documented neurological deterioration, provided that accessible longitudinal data were available in the national EHR system. Eligible mechanisms were strictly restricted to "active-participation" road-traffic events, specifically car drivers and motorcyclists.

Exclusion criteria were predetermined to delineate specific risk-taking behaviors and minimize confounding etiologies. We excluded individuals with ineligible mechanisms such as passive road-traffic roles (passengers or bystanders), falls, occupational injuries, and sports-related trauma. In addition, patients with non-traumatic etiologies – such as tumors or iatrogenic complications – were excluded, along with those whose mechanisms of injury involved intentional harm, including self-harm, suicidal intent, or penetrating interpersonal violence. To maintain a clean baseline, individuals with pre-existing neurological disorders or documented deficits before the index event were also excluded from the analytic sample.

Controls were selected from the same PMR clinic and calendar period to maintain consistency. They were people aged 18-45 years who presented with non-traumatic mechanical musculoskeletal complaints like myalgia or arthralgia. Each case was matched 1:1 to a control based on sex and age using a nearest-available match approach. The final analytic sample comprised 70 participants (35 TSCI cases and 35 matched controls). This study is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology statement for observational studies.[17]

Variables and Data Sources

The index date for cases was the date of the TSCI event, while for controls it was the date of the outpatient PMR visit used to choose the controls. In both groups, exposures were evaluated during the 24 months immediately preceding the index date. Data were obtained from the national EHR system, which was connected to the hospital information system.

The primary pre-index variables were trauma-related ED visits, trauma-related OTD visits, the combined total of trauma-related visits (ED+OTD), PD visits, and documentation of alcohol use. Trauma-related utilization was defined as ED/OTD visits in which injury was documented in the EHR (e.g, epicrisis, diagnosis list, and clinical history fields); visits not involving injuries were excluded from the count. Visits were defined as documented outpatient department encounters recorded in the EHR. The driver or motorcycle-rider status of the TSCI patient at the time of the accident was verified by hospital records. Before the analysis, all the data that was taken out was de-identified by taking out personal identifiers and giving each participant a unique study ID number.

Addressing Bias, Study Size and Quantitative Variables

To minimize confounding variables, we employed an age- and sex-matched (1:1) case–control design, selecting controls from the same hospital, clinic environment, and temporal context as the cases. Selection bias is possible because inclusion required accessible longitudinal EHRs; we report exclusions due to restricted access and acknowledge this limitation. Information bias may persist due to underdocumentation of alcohol use and limited detail of psychiatric records; therefore, alcohol use was examined as "documented versus not documented" and interpreted cautiously.

The study size was dictated by case availability: all qualifying TSCI cases within the study timeframe were incorporated and paired with a single control. Quantitative exposures were operationalized as 24-month pre-index count variables (ED trauma visits, OTD trauma visits, total trauma visits, and PD visits) and summarized as medians interquartile range (IQR) due to skewed distributions. Receiver operating characteristic (ROC) analyses were conducted as exploratory assessments of discriminative performance. Youden's index was used descriptively to summarize performance across potential thresholds; no prespecified or clinically validated cut-off values were assumed.

Statistical Analysis

IBM Statistical Package for the Social Sciences Statistics (version 30.0.0.0) was used. Matching was used at the design stage to control for age and sex. Continuous variables were summarized as mean (standard deviation) and as median (IQR) when skewed; categorical variables were summarized as counts and percentages. Due to the non-normal distribution of utilization variables, comparisons between groups were conducted using the Mann–Whitney U test; the effect size was expressed as r.

ROC analyses were conducted as exploratory summaries of discriminative performance within this case–control sample. Given the case–control design, these ROC analyses are presented as descriptive and exploratory assessments rather than as tools for defining clinically applicable thresholds. Youden's index was used descriptively to compare performance across selected contrasts; no clinically validated thresholds or decision cut-offs were proposed. Binary indicators (≥1 vs. 0) for ED visits and psychiatry visits were entered into a multivariable logistic regression model, and associations were reported as odds ratios (ORs) with 95% confidence intervals (CIs). Two-sided $p<0.05$ was considered statistically significant.

RESULTS

Participants and Descriptive Data

The participant selection process is shown in Figure 1. Initially, 64 patients with SCI were screened; after stepwise eligibility assessment, 35 TSCI cases in drivers/motorcyclists were included and matched 1:1 with controls, yielding a final analytic sample of 70 participants.

Baseline demographic characteristics were comparable between groups. Among TSCI cases, thoracic injuries were most common (n=16), followed by lumbar (n=11) and cervical injuries (n=8). Motorcycle accidents accounted for 19 cases, while 16 cases resulted from automobile collisions. Traumatic brain injury accompanied TSCI in 14 cases. Baseline characteristics and pre-index healthcare utilization measures are summarized in Table 1.

Outcome Data

Because all count-based utilization variables showed significant deviation from normality (Supplementary Table 1), between-group comparisons were conducted using the Mann–Whitney U test. Compared with controls, individuals who later faced TSCI had significantly higher numbers of trauma-related ED visits ($p<0.001$; $r=0.45$), PD visits ($p=0.010$; $r=0.31$), and total trauma-related visits ($p=0.035$; $r=0.25$) during the 24 months preceding the index date. In contrast, trauma-related OTD visits did not differ between groups ($p=0.920$; $r=0.01$). Detailed comparisons are presented in Table 2.

Main Results

ROC analyses were performed for utilization variables that differed between groups to evaluate their discriminative abil-

Table 1. Participant characteristics and trauma-related healthcare utilization during the 24 months preceding the index date in TSCI cases and controls

	Control (n=35)	TSCI patients (n=35)
Age	31.97 (9.10)	31.37 (8.55)
Male (%)	29 (82.9)	29 (82.9)
Female (%)	6 (17.1)	6 (17.1)
Trauma-related ED visits	0 (0–0)	1 (0–1)
Trauma-related OTD visits	0 (0–0)	0 (0–0)
Total trauma-related visits	0 (0–1)	1 (0–2)
PD visits	0 (0–0)	0 (0–2)
Alcohol use documented (%)	3 (8.6)	1 (2.9)

Values are presented as mean (standard deviation) for age, median (Q1-Q3) for count variables, and n (%) for categorical variables. TSCI: Traumatic spinal cord injury, ED: Emergency department, OTD: Orthopedics/traumatology department, PD: Psychiatry department.

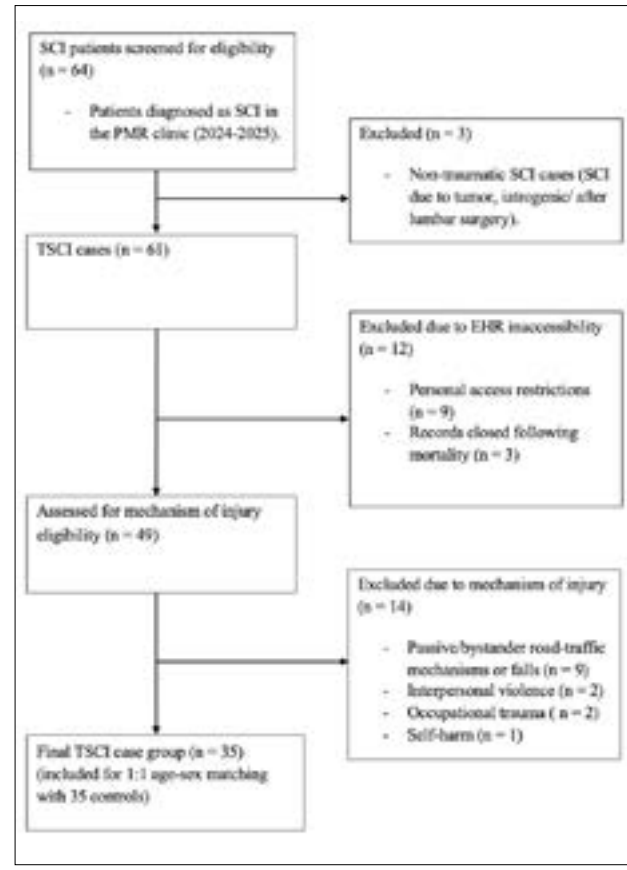

Figure 1. Strengthening the Reporting of Observational Studies in Epidemiology flow diagram. TSCI: Traumatic spinal cord injury; SCI: Spinal cord injury; HER: Electronic health records.

ity for TSCI within this case–control sample. Trauma-related ED visits demonstrated the highest discrimination (area under curve [AUC]=0.726, 95% CI 0.606–0.847; p<0.001). In this sample, the ≥1 versus 0 contrast provided sensitivity 60.0% and specificity 82.9%. PD visits showed modest discrimination (AUC=0.649, 95% CI 0.519–0.778; p=0.024). In this sample, the ≥1 versus 0 contrast provided sensitivity 45.7% and specificity 80.0%. For total trauma-related visits, the ≥2 versus <2 contrast showed limited discrimination (AUC=0.630, 95% CI 0.499–0.761; p=0.052). Performance metrics for selected contrasts are detailed in Table 3, and ROC curves are provided in Figure 2 for visualization of discriminative performance. ROC coordinate outputs are provided in Supplementary Table 2. These findings should be interpreted with caution, as discriminative performance estimates derived from case–control data may be subject to overestimation.

For interpretability, binary indicators (≥1 vs. 0) were defined for ED visits and psychiatry visits and used in subsequent analyses. Individuals who later sustained TSCI were significantly more likely to have had at least one trauma-related ED visit in the preceding 24 months compared with controls (60.0% vs. 17.1%, χ^2=13.6, p<0.001). A history of psychiatry visits was also more common among TSCI cases (45.7% vs. 20.0%), although the association was weaker (χ^2=5.25, p=0.022).

These binary risk flags were subsequently entered into a multivariable logistic regression model. Both pre-injury ED utilization and psychiatry visits were independently associated with subsequent TSCI. Individuals with at least one trauma-related ED visit had markedly higher odds of TSCI (OR=8.85,

Table 2. Between-group comparison of trauma-related healthcare utilization during the 24 months preceding the index date

	Control group median (Q1-Q3)	TSCI group median (Q1-Q3)	U value	p	Effect size (r)
Trauma-related ED visits	0 (0–0)	1 (0–1)	335.500	<0.001	0.45
Trauma-related OTD visits	0 (0–0)	0 (0–0)	606.500	0.920	0.01
Total trauma-related visits	0 (0–1)	1 (0–2)	453.000	0.035	0.25
PD visits	0 (0–0)	0 (0–2)	430.000	0.010	0.31

Values are presented as median (Q1–Q3); effect size (r) was calculated as |Z|/√N (n=70); p-values are two-tailed. TSCI: Traumatic spinal cord injury; ED: Emergency department; OTD: Orthopedics/traumatology department; PD: Psychiatry department.

Table 3. Discriminative performance of selected contrasts for pre-index utilization measures within the case–control sample

Predictor	AUC (95% CI)	p	Cut-off	Sensitivity (%)	Specificity (%)
Trauma-related ED visits	0.726 (0.606–0.847)	<0.001	≥1	60.0	82.9
Total traumatic visits	0.630 (0.499–0.761)	0.052	≥2	34.3	88.6
PD visits	0.649 (0.519–0.778)	0.024	≥1	45.7	80.0

Cut-offs were selected using Youden's index (J=sensitivity + specificity−1). TSCI: Traumatic spinal cord injury; AUC: Area under curve; CI: Confidence interval; ED: Emergency department; PD: Psychiatry department.

Table 4. Multivariable logistic regression for TSCI

Predictor	OR	95% CI	p
≥1 ED visit	8.85	2.68–29.23	<0.001
≥1 PD visit	4.52	1.34–15.20	0.015

Reference=no prior trauma-related ED visit and no prior psychiatric visit. OR: Odds ratio; CI: Confidence interval; ED: Emergency department; PD: Psychiatry department.

95% CI 2.68–29.23; p<0.001). A history of psychiatry visit was also independently associated with increased TSCI risk (OR=4.52, 95% CI 1.34–15.20; p=0.015). The model demonstrated acceptable explanatory performance (McFadden R2=0.21). Regression results are summarized in Table 4.

DISCUSSION

In this study employing national EHRs, we examined the disparities in healthcare utilization patterns between patients with TSCI among drivers/motorcyclists and control subjects. Individuals with TSCI exhibited a greater frequency of trauma-related ED visits, increased PD visits, and a higher overall count of trauma-related visits; however, trauma-related outpatient department visits did not show significant differences between the groups. These findings collectively validate our hypothesis that routinely collected health records may contain quantifiable pre-injury indicators associated with subsequent TSCI.

Key Results

Among the evaluated metrics, trauma-related ED visits exhibited the highest discrimination (AUC=0.726). In this sample, the ≥1 versus 0 contrast for trauma-related ED visits showed moderate sensitivity and high specificity, supporting its potential utility as a hypothesis-generating risk flag. PD visits demonstrated modest discrimination (AUC=0.649), suggesting that psychosocial vulnerability may contribute to elevated risk, although PD contacts are likely heterogeneous and may proxy multiple mechanisms (e.g., comorbidity, mental health, substance use, social adversity).

Importantly, when these binary risk flags were jointly evaluated in a multivariable model, both prior ED utilization and psychiatry visit remained independently associated with TSCI, indicating that their predictive value was not solely driven by shared exposure to healthcare services. Together, these findings support a multi-domain risk-flagging framework that integrates injury-related exposure and psychosocial vulnerability.

The absence of intergroup differences in OTD visits indicates that the most significant signals in our dataset were recorded at the ED level. The ED is the first place people go for acute injuries, and small injuries and dangerous exposures can add up. This pattern is theoretically consistent with a "prodromal" phase of significant trauma. Importantly, these findings should not be interpreted as predictive at the individual level but rather as hypothesis-generating signals that may help identify subgroups with relatively increased risk.

Comparison with Previous Research

Building on this risk-flagging interpretation, EHR-based identification of a higher-risk subgroup could be operationalized to deliver targeted, structured injury-prevention content, adapted from programs that have demonstrated effectiveness in improving safety behaviors such as seatbelt and helmet use.[18] A study identified high-risk adolescents using police input, field observations, and community reports; they then received a brief educational intervention on the risks of street racing and safer driving practices.[19] Although their identification method differs from ours, the underlying logic is similar: defining a high-risk subgroup first, then focusing preventive intervention where it is most needed.

More broadly, EHR-based risk flagging has been used for trauma in other clinical settings. For example, studies have shown that EHR data can distinguish patients at higher risk of in-hospital falls and fall-related outcomes.[20-22] These fall-risk models are different from our outpatient, pre-injury setting and TSCI outcome, but they show that it is possible to use health-record signals that are collected regularly to find higher-risk groups.

Our findings also align with trauma recidivism literature, where repetitive injury-related healthcare contacts are considered informative. In a trauma-center cohort of 954 operatively treated high-energy orthopedic trauma patients, Heimke et al.[11] reported that 14.3% returned to the ED with

a new, unrelated injury within a mean of 21 months, and recidivism was most strongly associated with pre-existing mental illness. Bauer et al.[12] similarly found that mental illness increased the likelihood of trauma recidivism. In addition, Strong et al.[14] reported that trauma recidivists had substantially higher long-term mortality after discharge, highlighting recidivism as a marker of a particularly vulnerable population. These studies collectively validate our findings by indicating that TSCI may develop following recurrent trauma-related healthcare interactions and impose a considerable mortality burden.

In addition, prior ED utilization has been proposed as an early warning signal in other injury domains, including suspected non-accidental trauma in children, where repeated healthcare contacts may precede formal recognition.[13] A broader EHR prediction and risk-stratification literature supports the general approach of leveraging routinely collected health data – demographics, diagnoses, labs, prescriptions, and utilization patterns – to identify higher-risk patients and support proactive interventions across multiple outcomes.[15] Other studies have also demonstrated that EHRs can be used to anticipate clinically important events before they occur, including mental health crises and relapse, suicidal behavior, multiple sclerosis relapse, inpatient acute kidney injury through continual updating, and even increased risk of acute myeloid leukemia years before diagnosis.[16,23-25] In this context, our findings position TSCI – an infrequent but clinically devastating event that can cause lifelong disability and markedly reduce productivity at a young age – within the same EHR-enabled risk-stratification paradigm, suggesting that routinely collected health-record data may be sufficient to generate pragmatic pre-injury risk flags.

Limitations

There are a few problems with this study. First, the sample was small and came from only one center, and the ROC-based thresholds were created using a case–control design. This means that the suggested cut-offs need to be tested and adjusted in larger, more prospective groups. The findings should be consistently interpreted as hypothesis-generating, given the small sample size and case–control design, and should not be considered confirmatory. In addition, discriminative performance measures derived from this case–control sample may be overestimated and should be interpreted with caution.

Second, a significant number of screened cases were excluded due to restricted or inaccessible EHRs, potentially leading to selection bias. Third, our cohort consists of TSCI patients who subsequently attended a PMR clinic; those managed solely through alternative pathways (e.g., neurosurgery, orthopedics) may not have been included. Fourth, alcohol consumption is probably not well-documented, and it was looked at as "documented vs. not documented." Furthermore, psychiatric data were limited by rules about privacy, which made it impossible to look at diagnostic detail or narrative content. Furthermore, individual behavioral traits (e.g., impulsivity, attention-deficit symptoms) and contextual factors (e.g., socioeconomic status, driving behaviors, and occupational hazards) could not be directly evaluated. Ultimately, we concentrated on a singular catastrophic outcome and did not assess the existence of analogous pre-injury utilization patterns for other significant trauma phenotypes (e.g., traumatic brain injury, multiple bone fractures), indicating a need for future research. Given the case–control design and sample size, ROC-based contrast findings should be interpreted as descriptive and hypothesis-generating; external validation is required before any operational use.

In addition, important behavioral and socioeconomic confounders – such as risk-taking behavior, driving patterns, and socioeconomic status – could not be assessed, which may have influenced the observed associations. Due to the retrospective case–control design, causal inference cannot be established, and the observed associations should be interpreted within this methodological constraint.

Despite these limitations, the study offers proof-of-concept evidence that routine pre-injury healthcare utilization – especially trauma-related ED visits and PD contacts – may harbor measurable indicators that could facilitate pragmatic risk identification. Although the analytic cohort was derived from a single center, pre-index healthcare utilization histories were obtained from a national longitudinal EHR system capturing encounters across multiple facilities. Future research must prospectively validate these signals, encompass wider risk domains, and evaluate the efficacy of trigger-based preventive outreach in mitigating severe trauma outcomes.

Interpretation

Individuals with at least one trauma-related ED visit and at least one psychiatry visit in the preceding 24 months constituted a subgroup with substantially higher odds of subsequent TSCI among drivers/motorcyclists. Because these visits are routinely documented, such individuals can be readily identified within existing EHR systems without additional screening burden.

Rather than implying deterministic prediction at the individual level, this pattern supports a pragmatic interpretation: Recurrent trauma-related ED utilization and psychiatry contact may function as early warning signals that enrich for risk. This creates an opportunity for timely, low-intensity preventive interventions – such as brief injury-prevention counseling, reinforcement of seatbelt and helmet use, and referral for psychosocial support – delivered at the point of care before catastrophic injury occurs. Therefore, these indicators should not be considered deterministic or predictive markers, nor are they clinically actionable; rather, they serve as pragmatic signals that may support targeted preventive strategies in appropriate contexts.

Generalizability

Generalizability may be highest in similar environments with

national longitudinal EHR coverage and analogous trauma-care pathways. Our cohort was limited to 18–45-year-old drivers/motorcyclists involved in traffic accidents, identified through subsequent PMR presentation; thus, the findings may not be generalizable to other age groups or non-driver mechanisms. In addition, given the small sample size and case–control design, the findings should be interpreted as hypothesis-generating, with limited generalizability. Before broader use, external validation in multi-center cohorts and across different healthcare entry points is needed.

CONCLUSION

Our data indicate that significant driver/motorcyclist-related trauma is not invariably a random event; it may be preceded by detectable patterns of prior healthcare utilization characterized by previous injuries and psychiatric interactions. By identifying these pre-injury warning signs in national EHRs, these findings support further research toward proactive, targeted prevention strategies. This could allow them to step in with high-risk drivers/motorcyclists before a serious TSCI happens. A potential implication, if validated, is that ED encounters could serve as opportunities for brief safety counseling and psychosocial support (e.g., seatbelt/helmet use and avoidance of distracted or impaired driving). These findings support the hypothesis that pre-injury healthcare utilization patterns may contain measurable signals worthy of further investigation.

In this sense, traffic-related TSCI may not be entirely unforeseeable and may be preceded by detectable patterns.

Ethics Committee Approval: This study was approved by the Ministry of Health Antalya City Hospital Ethics Committee (Date: 08.01.2026, Decision No: 20/176).

Informed Consent: The study was a retrospective case–control study matched for age and sex

Peer-review: Externally peer-reviewed.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Trafikle ilgili travmatik omurilik yaralanmalarından önce gözden kaçan uyarı sinyalleri var mı? Elektronik sağlık kayıtları kullanılarak yapılan keşifsel olgu-kontrol çalışması

AMAÇ: Travmatik omurilik yaralanması (OY), sıklıkla trafik kazaları sonucunda ortaya çıkan yıkıcı bir durumdur. Bu çalışmada, elektronik sağlık kayıtlarında (ESK) rutin olarak kaydedilen yaralanma öncesi sağlık hizmeti kullanım paternlerinin, sürücüler ve motosiklet kullanıcıları arasında travmatik OY için pratik uyarı sinyalleri olarak işlev görüp göremeyeceğini araştırdık.
GEREÇ VE YÖNTEM: Ulusal ESK verilerini kullanarak retrospektif, yaş ve cinsiyet açısından eşleştirilmiş bir olgu-kontrol çalışması gerçekleştirdik. Trafik kazasına bağlı travmatik OY gelişen, sürücü veya motosiklet kullanıcısı olan 18–45 yaş arası yetişkinler (2024–2025) 1: 1 oranında kontrol grubu ile eşleştirildi (her grupta n=35). İndeks tarihinden önceki 24 ay içinde yaralanma ile ilişkili acil servis (AS) başvuruları, ortopedi/travmatoloji departmanı (OTD) başvuruları, toplam travma ilişkili başvurular ve psikiyatri başvuruları değerlendirildi. Gruplar arası karşılaştırmalarda Mann–Whitney U testi kullanıldı. Ayırt edici performansı özetlemek amacıyla ROC analizleri yapıldı. İkili risk göstergeleri (≥1 ED başvurusu; ≥1 psikiyatri başvurusu) çok değişkenli lojistik regresyon ile değerlendirildi.
BULGULAR: Analize dahil edilen örneklem 70 katılımcıdan oluştu. Kontrollerle karşılaştırıldığında, travmatik OY olgularında travma ilişkili AS başvuruları (p<0.001; r=0.45), psikiyatri başvuruları (p=0.010; r=0.31) ve toplam travma ilişkili başvurular (p=0.035; r=0.25) daha yüksek bulundu; buna karşın OTD başvuruları açısından fark saptanmadı (p=0.920). AS başvuruları en yüksek ayırt edici performansı gösterdi (AUC=0.726). Bu örneklemde ≥1'e karşı 0 karşılaştırması için duyarlılık %60.0 ve özgüllük %82.9 idi. Psikiyatri başvuruları orta düzeyde ayırt edicilik gösterdi (AUC=0.649). Bu örneklemde ≥1'e karşı 0 karşılaştırması için duyarlılık %45.7 ve özgüllük %80.0 idi. Çok değişkenli analizde, ≥1 AS başvurusu (OR=8.85, %95 GA 2.68–29.23; p<0.001) ve ≥1 psikiyatri başvurusu (OR=4.52, %95 GA 1.34–15.20; p=0.015) travmatik OY ile bağımsız olarak ilişkili bulundu.
SONUÇ: Trafik ilişkili travmatik OY, rutin olarak toplanan ESK verilerinde yer alan ölçülebilir yaralanma öncesi paternlerle—özellikle travma ilişkili AS kullanımı ve psikiyatri başvuruları ile—önceden izlenebilir olabilir. Bu bulgular, hedefe yönelik önleyici eğitim, yaralanma riski danışmanlığı ve psikososyal risk azaltma girişimlerinden fayda görebilecek bireylerin belirlenmesine yardımcı olabilecek pragmatik bir risk işaretleme yaklaşımını desteklemektedir. Bu bulgular dikkatle yorumlanmalı ve daha büyük ölçekli prospektif çalışmalarla doğrulanmalıdır.

Anahtar sözcükler: Acil; elektronik sağlık kayıtları; psikiyatri; Spinal kord hasarı; trafik kazaları; travma.

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Supplementary Table 1. Normality test results for count-based healthcare utilization variables

Variable	Group	Kolmogorov-Smirnov statistic	df	p	Shapiro–Wilk statistic	df	p
Trauma-related ED visits	TSCI	0.271	35	<0.001	0.672	35	<0.001
Trauma-related OTD visits	TSCI	0.464	35	<0.001	0.495	35	<0.001
Total trauma-related visits	TSCI	0.258	35	<0.001	0.766	35	<0.001
PD visits	TSCI	0.306	35	<0.001	0.751	35	<0.001
Trauma-related ED visits	Control	0.492	35	<0.001	0.477	35	<0.001
Trauma-related OTD visits	Control	0.454	35	<0.001	0.457	35	<0.001
Total trauma-related visits	Control	0.394	35	<0.001	0.611	35	<0.001
PD visits	Control	0.477	35	<0.001	0.511	35	<0.001

TSCI: Traumatic spinal cord injury; ED: Emergency department; OTD: Orthopedics and traumatology department; PD: Psychiatry department. Notes: Kolmogorov–Smirnov p values use the Lilliefors significance correction. All variables showed significant deviation from normality in both groups (p<0.001), supporting the use of non-parametric comparisons.

Supplementary Table 2. Coordinates of the ROC curves for candidate predictors of TSCI within the case–control sample

Test result variable	Positive if ≥ (cut-off)*	Sensitivity	1 − specificity
Trauma-related ED visits	-1.0	1.000	1.000
	0.5	0.600	0.171
	1.5	0.229	0.029
	2.5	0.057	0.000
	5.0	0.029	0.000
	8.0	0.000	0.000
Total trauma-related visits	−1.0	1.000	1.000
	0.5	0.514	0.314
	1.5	0.343	0.114
	2.5	0.200	0.029
	3.5	0.086	0.029
	4.5	0.057	0.000
	6.0	0.029	0.000
	8.0	0.000	0.000
PD visits	−1.0	1.000	1.000
	0.5	0.457	0.200
	1.5	0.314	0.086
	2.5	0.200	0.000
	3.5	0.114	0.000
	5.0	0.029	0.000
	7.0	0.000	0.000

TSCI: Traumatic spinal cord injury; ED: Emergency department; PD: Psychiatry department. For discrete count variables (0,1,2,…), Statistical Package for the Social Sciences reports cut-offs as midpoints between ordered values; thus, 0.5 corresponds to ≥1, 1.5 to ≥2, etc.

ORIGINAL ARTICLE

Comparison of analgesic treatments used for ankle sprains in the emergency department

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ABSTRACT

BACKGROUND: Ankle sprains (ASs) account for approximately 5% of emergency department visits and 40% of all sports-related injuries, causing significant pain and restriction in the range of motion (ROM). This study aims to observe the clinical outcomes of early administration of intravenously administered paracetamol, ibuprofen, and dexketoprofen, which are frequently used in emergency department practice for ASs. For this purpose, pain monitoring and ROM measurements were performed to demonstrate the effectiveness of early functional analgesia.

METHODS: This prospective, randomized, double-blind study was conducted between December 2023 and May 2024 on patients diagnosed with grade 1–2 ASs in the emergency department. Patients were divided into three groups and received intravenous dexketoprofen (Group D, n=52), paracetamol (Group P, n=52), and ibuprofen (Group I, n=51). Pain assessment was performed using the numeric rating scale (NRS) and the Wong–Baker FACES Pain Scale (WBS). ROM was evaluated by measuring dorsiflexion ROM (d-ROM) and plantar flexion ROM (p-ROM) angles using a semicircular goniometer. Pre-treatment and 1-h post-treatment measurements were compared.

RESULTS: In the post-treatment pain assessment, no significant difference was observed between the groups in terms of NRS scores ($p=0.352$); however, Group I had the lowest WBS scores ($p<0.001$). Nevertheless, in all three groups, post-treatment pain scores (NRS and WBS) were significantly lower compared to pre-treatment values ($p<0.001$). Regarding ROM, pre-treatment d-ROM and p-ROM values were similar among the groups ($p=0.196$) and $p=0.287$, respectively). Post-treatment measurements revealed that d-ROM was lower in Group I ($p=0.034$), whereas p-ROM was higher ($p=0.011$). However, in all groups, ROM values significantly improved after treatment compared to baseline ($p<0.001$). When pre- and post-treatment changes (Δ) in pain scores and ROM values were compared, no statistically significant differences were found between the groups (ΔNRS $p=0.264$, ΔWBS $p=0.965$, Δd-ROM $p=0.099$, Δp-ROM $p=0.073$).

CONCLUSION: Paracetamol, ibuprofen, and dexketoprofen demonstrated similar efficacy in reducing pain and improving ankle joint ROM during the acute phase of ASs. These findings suggest that the early initiation of analgesic treatment in ASs contributes to clinical recovery.

Keywords: Ankle sprains; dexketoprofen; ibuprofen; pain; paracetamol; range of motion.

INTRODUCTION

Ankle sprain (AS) is one of the most common musculoskeletal injuries in the active population. It accounts for approximately 5% of emergency department visits and 40% of all sports-related injuries.[1] Sprains cause pain and restriction in the range of motion (ROM), which can lead to functional impairments, disability, and chronic ankle instability. Moreover, this condition can lead to recurrent injuries, balance-postural disorders, and joint degeneration, such as osteoarthritis. These symptoms may appear in 44% of patients within 1 year after the injury.[2] To reduce these risks, the proper and effective management

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of AS in emergency departments is crucial. The primary treatment goals are to alleviate pain and swelling while preserving the ROM before initiating exercise. Thus, in ASs that do not require surgery or immobilization, early mobilization can help reduce the risk of such morbidities.

Protection, rest, ice, compression, elevation, cryotherapy, pain management, elastic bandaging, physiotherapy exercises, supportive braces, and surgical intervention in severe injuries are among the available treatment options.[3] However, there is no consensus among physicians regarding the implementation of conservative treatment protocols.[4] However, pain control in the acute phase is known to be essential for both patient comfort and reducing the restriction of ankle ROM. For this purpose, oral, parenteral, and topical non-steroidal anti-inflammatory drugs (NSAIDs), paracetamol, and opioids are commonly used for pain management. Opioids, which are preferred more frequently in emergency applications due to their rapid and effective analgesic properties, should not be overlooked for their potential to cause serious side effects such as nausea, vomiting, dizziness, hypotension, respiratory depression, and dependence.[5] In recent years, clinicians have increasingly adopted multimodal approaches in pain management, favoring medications that provide maximum benefit with minimal side effects for patients. In emergency department practice, effective and rapid pain control in patients presenting with severe pain during the acute phase is crucial for early functional recovery. In this context, intravenous (IV) analgesics may offer clinical advantages due to their faster onset of action and higher bioavailability compared to oral agents. Specifically, the IV forms of ibuprofen and dexketoprofen, both NSAIDs as well as paracetamol, may be considered safe alternatives that can provide effective analgesia while potentially reducing the need for opioid use. However, studies comparing the efficacy of ibuprofen, dexketoprofen, and paracetamol simultaneously in AS remain limited in the literature.

This study aimed to evaluate the short-term effects of paracetamol, ibuprofen, and dexketoprofen on pain intensity and ankle ROM in patients presenting to the emergency department with grade 1 and 2 AS. In addition, the study aimed to observe the contribution of different IV analgesics, administered in accordance with clinical practice, to effective pain control and early functional recovery.

MATERIALS AND METHODS

Study Design

This study was conducted as a prospective, double-blind, randomized, and controlled trial. Patients who presented to the emergency department of Ankara Etlik City Hospital with an AS between December 1, 2023, and May 1, 2024, were included in the study. The study was initiated after obtaining approval from the Ankara Etlik City Hospital Ethics Committee (decision no: AEŞH-EK1-2023-666) and was conducted in accordance with the Declaration of Helsinki. All participants were informed about the purpose and procedures of the study, and written informed consent was obtained from all individuals before their inclusion in the study.

Patient Selection and Data Collection

Patients aged 18 years and older who presented to the emergency department within the first 48 h after a grade 1–2 AS, with no signs of fracture-dislocation, were included in the study. All patients were provided with detailed information about the study procedures. Written informed consent was obtained from those who voluntarily agreed to participate in the study. Patients with multiple trauma, those who were pregnant or suspected of being pregnant, those with fractures or dislocations of the foot or ankle, those with a history of ankle fracture or previous ankle surgery, those with a history of ankle trauma within the past 3 months, those with a known allergy or any adverse reaction to the agents used in the study, those who had used analgesics within 12 h before presenting to the emergency department, and those with a numeric rating scale (NRS) score <5 or a Wong–Baker FACES Pain Rating Scale (WBS) score <2 were excluded from the study. During the study, a total of 1553 patients presented to the emergency department with foot and ankle trauma. Based on the inclusion and exclusion criteria, 215 patients were randomized; 155 patients completed the study protocol and were included in the final analysis (Fig. 1).

The sociodemographic characteristics and vital parameters of the patients (age, sex, systolic and diastolic blood pressure, heart rate, respiratory rate, body mass index (BMI), dominant and injured foot, and mechanism of injury), as well as their pain scores at presentation and after treatment, were recorded. To exclude fractures and dislocations during the inclusion process, the Ottawa Ankle Rules were applied, and radiography was used when indicated.

The grading of AS is as follows:

• **Grade 1 (Mild):** Ligaments are stretched but not torn. Mild tenderness and edema are present. The patient can bear weight, and radiographs appear normal.

• **Grade 2 (Moderate):** Excessive stretching and partial ligament tears may occur. Moderate tenderness, edema, and significant pain on weight-bearing are observed. Standard radiographs appear normal, but stress radiographs may reveal an abnormal relationship between the talus and mortise.

• **Grade 3 (Severe):** Occurs when the ligaments are completely torn. Severe tenderness, edema, ecchymosis, and often joint deformity are present. The patient is unable to bear weight. Standard radiographs show abnormalities between the talus and mortise; stress radiographs are not required.

Randomization and Blinding

Eligible patients were randomly assigned to one of three groups in a 1:1:1 ratio using a computer-generated randomization table. The groups were created by a statistician who was not involved in the study. To minimize selection bias, al-

location concealment was ensured using an interactive web-based response system until the randomization process was completed by the computer. All medications were prepared by an independent individual and drawn into sealed syringes. To mask their appearance, each syringe was mixed with 150 mL of normal saline. This method ensured that the drugs assigned to each treatment group had a similar appearance and physical properties. No label containing information about the administered drugs was present. Thus, both patients and researchers were blinded to the treatment assignment. Group assignments were stored in sealed envelopes.

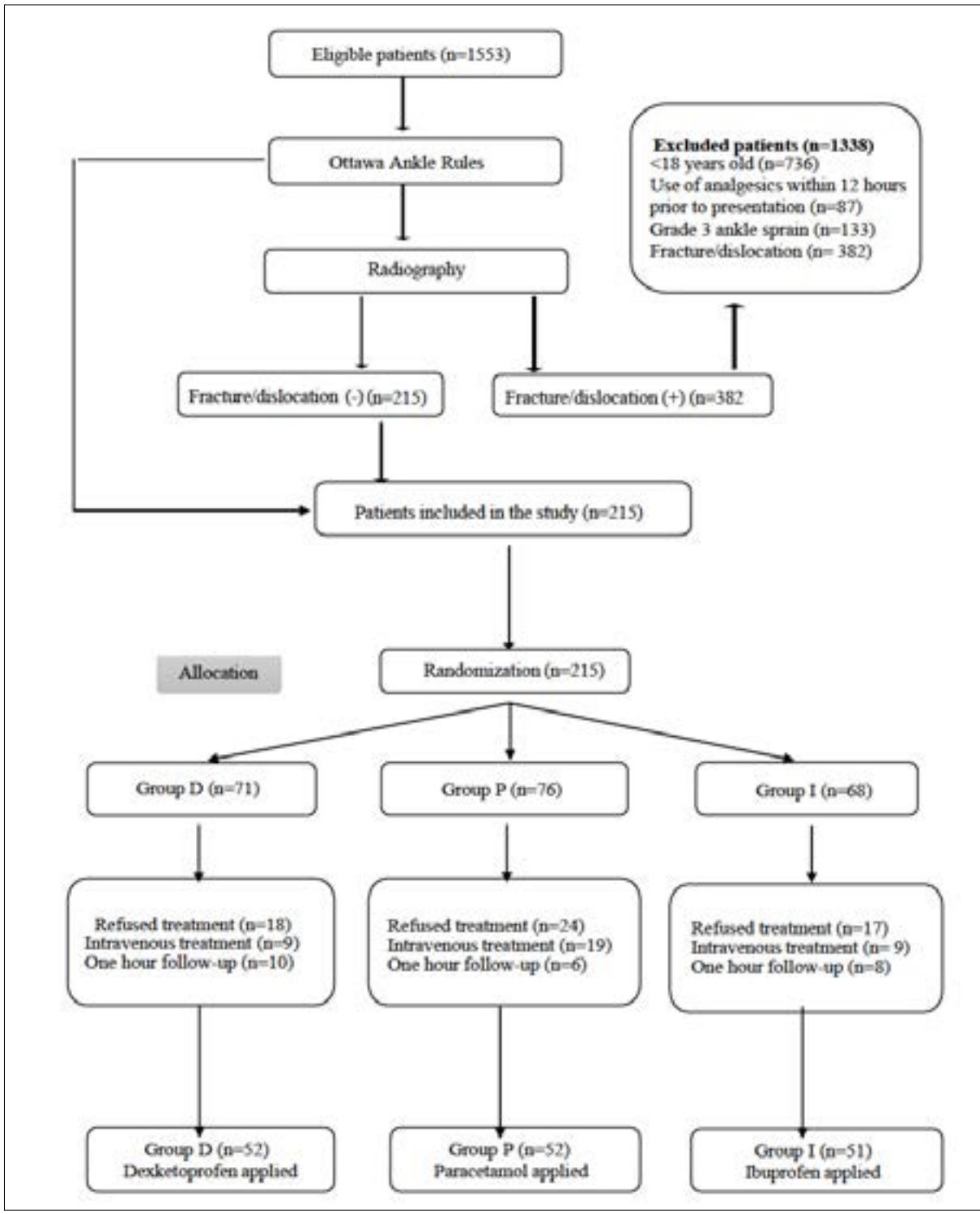

Figure 1. Flow chart.

Intervention

In this study, IV administration was preferred over oral formulations due to its faster onset of action and higher bioavailability. Since IV drugs bypass gastrointestinal absorption and first-pass metabolism, they achieve more rapid and predictable therapeutic plasma concentrations. These pharmacokinetic advantages are clinically important for ensuring timely analgesia and supporting functional recovery during the acute phase of musculoskeletal injuries. The following medications were used.

- In Group D, 50 mg of IV dexketoprofen was administered to 52 patients (Arveles, Menarini Pharmaceuticals, Spain; 50 mg/2 mL).
- In Group P, 1000 mg of IV paracetamol was administered to 52 patients (Parol, Atabay Kimya, Istanbul; 1000 mg vial).
- In Group I, 400 mg of IV ibuprofen was administered to 51 patients (Intrafen, GEN Pharmaceuticals, Turkey; 800 mg/8 mL).

All three medications were prepared in 150 mL of normal saline and administered over 15 min using an infusion pump. In emergency department settings, IV administration is often preferred over oral routes in cases where rapid and reliable analgesia is essential. This method ensures a faster onset of action and circumvents the variability in gastrointestinal absorption that may occur due to trauma-related stress, nausea, or other factors commonly encountered in acute care patients.

Two different scales were used to assess pain in patients. WBS: This scale is rated from 0 to 5, where "0" represents no pain, and "5" represents the most severe pain expression. Physicians introduced this scale to the patients by explaining each facial expression along with the accompanying "short word instructions" and asked them to circle the face that best represented their pain.[6] Immediately after obtaining WBS scores, patients were asked to indicate their pain levels using the NRS. NRS is an 11-point scale, where "0" represents no pain and "10" represents the most severe pain imaginable.[7] The purpose of using both pain scales together was to assess pain more objectively and comprehensively.

Measurements of ankle dorsiflexion ROM (d-ROM) and plantar flexion ROM (p-ROM) were performed by the same physiotherapist using a 360° manual Baseline semicircular goniometer. This goniometer is calibrated in accordance with the international standards for measurement system and is a reliable tool for assessing ankle ROM.[8] During the measurements, patients were positioned at the edge of a bed in a semi-seated position at approximately 45°. The knees were flexed to 20–30°, and a pillow was placed under the lower legs to elevate the heels off the bed surface. The initial position of the goniometer (pivot point) was placed approximately 1.5 cm below the lateral malleolus of the ankle. The stationary arm was aligned along the lateral aspect of the fibula, while the moving arm was positioned parallel to the lateral aspect of the 5th metatarsal bone. To ensure measurement accuracy, each position was assessed 3 times, and the results were recorded.

Outcomes

The primary outcome of this study is the reduction of early-stage pain and the improvement of joint ROM in patients with AS. The secondary outcome is to evaluate the effects of parenteral analgesic medications on ROM and compare them with each other.

Sample Size Estimation

For the power analysis of the study, G-Power 3.1 software was used to derive an effect size of 0.75 from the data of a reference study. With a significance level of 0.05, a power of 85%, and a confidence level of 95%, it was determined that at least 147 patients, equally divided with 49 participants per group, were required.[2]

Statistical Analysis

The data were analyzed using IBM Statistical Package for the Social Sciences Statistics for Windows, Version 27.0 (IBM Corp., Armonk, NY, USA). The normality of data distribution was determined by the Kolmogorov–Smirnov test. In descriptive statistics, normally distributed numerical data were presented as mean and standard deviation, non-normally distributed numerical data were presented as median (minimum–maximum), and nominal data were presented as number (n) and percentage (%). Group comparisons were performed using the Student's t-test for normally distributed numerical data and the Mann–Whitney U test for non-normally distributed numerical data. The Chi-square test was used for categorical data. One-way analysis of variance/Kruskal–Wallis tests were used for repeated measures. A $p<0.05$ was considered statistically significant.

RESULTS

Demographic and Descriptive Characteristics

A total of 155 patients were included in the study (Group D: n=52, Group P: n=52, Group I: n=51). Among the participants, 56.12% (n=87) were male. There was no statistically significant difference between the groups in terms of mean age and BMI (p=0.737, p=0.105). Regarding gender distribution, although the proportion of male patients was higher in Group I (62.7%), this difference was not statistically significant (p=0.312). When injury mechanisms were evaluated, the most common cause of injury was a fall from the same level, which was more frequently observed in Group D (61.5%, p=0.051). There was no statistically significant difference between the groups in terms of dominant foot distribution (p=0.095) and the right/left distribution of the injured foot (p=0.187) (Table 1). None of the groups experienced any adverse effects during the study.

Table 1. Demographic and background characteristics in the groups

	Sociodemographic data			
Variables	**Group D (n=52)**	**Group P (n=52)**	**Group I (n=51)**	**p***
Age (mean±SD)	33±12	35±11	35±14	0.737
Body mass index (mean±SD)	24.7±3.7	26.5±5.1	26.3±4.9	0.105
Gender				
Male (n, %)	25 (48.1)	30 (57.7)	32 (62.7)	0.312
Female (n, %)	27 (51.9)	22 (42.3)	19 (37.3)	
Mechanism of injury				
Fall from the same level (n, %)	32 (61.5)	17 (32.7)	22 (43.1)	0.051
Fall from a height (n, %)	11 (21.2)	24 (46.2)	18 (35.3)	
During sports (n, %)	9 (17.3)	11(21.2)	11 (21.6)	
Dominant foot				
Right	45 (86.5)	51 (98.1)	46 (90.2)	0.095
Left (n, %)	7 (13.5)	1 (1.9)	5 (9.8)	
Traumatic foot				
Right (n, %)	30 (57.7)	29 (55.8)	21 (41.2)	0.187
Left (n, %)	22 (42.3)	23 (44.2)	30 (58.8)	

*Comparison of the three groups using multiple Chi-square, One-way ANOVA/Kruskal-Wallis. SD: Standard deviation.

Pain Scores and ROM Changes

Pre-treatment NRS scores were found to be similar among the groups (p=0.787). However, pre-treatment WBS scores were significantly higher in Group D compared to the other groups (p=0.030). While there was no statistically significant difference in post-treatment NRS scores between the groups (p=0.352), Group I had the lowest WBS score (p<0.001). However, in all three groups, post-treatment pain scores were significantly reduced compared to pre-treatment values (p<0.001). When the ROM angles of the patients were evaluated, pre-treatment d-ROM and p-ROM angles were found

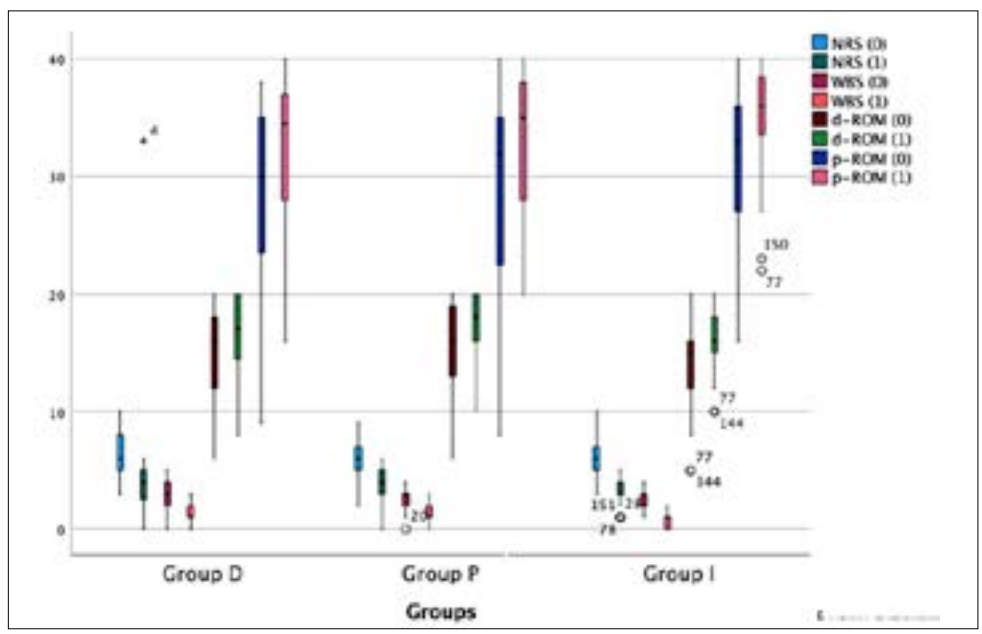

Figure 2. Changes in Pain Scores and Range of Motion with Treatment. 0: Pre-Treatment, 1: Post-Treatment (1st h), NRS: Numeric rating scale, WBS: Wong-Baker faces pain rating, d-ROM: Dorsiflexion range of motion, p-ROM: Plantar flexion range of motion.

Table 2. Pain scales and range of motion angles

	Pain scales and ROM angles			
	Group D	**Group P**	**Group I**	**p‡**
Numeric pain rating scale (0–1 h)				
NRS0	6 (5–8)	6 (5–7)	6 (5–7)	0.787
NRS1	4 (2.25–5)	4 (3–5)	3 (3–4)	0.352
p-value*	<0.001*	<0.001*	<0.001*	
Wong–Baker FACES Pain Rating (0–1 h)				
WBS0	3 (2–4)	3 (2–3)	3 (2–3)	0.030‡ Group D
WBS1	1 (1–2)	1 (1–2)	1 (0–1)	<0.001‡ Group I
p-value*	<0.001*	<0.001*	<0.001*	
d-ROM (°) (0–1 h)				
d-ROM0	16 (12–18)	16 (13–19.5)	15 (12–16)	0.196
d-ROM1	17 (14.2–20)	18 (16-20)	16 (15–18)	0.034‡ Group I
p-value*	<0.001*	<0.001*	<0.001*	
p-ROM (°) (0–1 h)				
p-ROM0	30 (23.2–35)	32 (22.2–35)	33 (27–36)	0.287
p-ROM1	34.5 (28–37)	35 (28–38)	36 (33-39)	0.011‡ Group I
p-value*	<0.001*	<0.001*	<0.001*	

*Pre- and post-treatment repeated measures: Paired t-test/Wilcoxon test. ‡Comparison of the three groups: One-way analysis of variance/Kruskal–Wallis. ROM: Range of motion, NRS: Numeric rating scale, WBS: Wong–Baker FACES Pain Scale, d-ROM: dorsiflexion range of motion, p-ROM: plantar flexion range of motion.

Table 3. Changes in pre- and post-treatment pain scores and range of motion angles (Δ: Delta)

	Group D	**Group P**	**Group I**	**p***
ΔNRS (mean±SD)	2±4.2	2.3±1.3	2.9±1.1	0.264
ΔWBS (mean±SD)	1.3±0.7	1.2±0.7	1.4±1.9	0.965
Δd-ROM (mean±SD)	1.9±1.9	1.9±2.1	1.9±1.8	0.099
Δp-ROM (mean±SD)	3.7±3.9	3.3±3.2	4.3±3.8	0.073

*Comparison of the three groups: One-way analysis of variance/Kruskal-Wallis. Δ=Delta: Changes in pain and ROM between 0 and 1 h; NRS: Numeric pain rating scale; WBS: Wong–Baker FACES Pain Rating; d-ROM: Dorsiflexion range of motion; p-ROM: Plantarflexion range of motion; SD: Standard deviation.

to be similar across all three groups (p=0.196 and p=0.287, respectively). Post-treatment, d-ROM was lower in Group I (p=0.034), while p-ROM was higher (p=0.011). However, in all three groups, post-treatment ROM angles showed a significant improvement compared to pre-treatment values (p<0.001) (Table 2 and Fig. 2).

Pre- and Post-Treatment Changes (Δ Values)

Changes in pain scores and ROM angles before and after treatment were analyzed using Δ (delta) values. The reduction levels in ΔNRS and ΔWBS pain scores were similar across all three groups (p=0.264, p=0.965). Likewise, there was no significant difference between the groups in terms

of the increase in Δd-ROM and Δp-ROM angles (p=0.099, p=0.073) (Table 3).

DISCUSSION

This study demonstrated that paracetamol, dexketoprofen, and ibuprofen were effective in reducing pain and improving ROM in the acute phase. These findings support that both NSAIDs and paracetamol are effective treatment options for acute pain management and functional recovery.

In the acute phase of AS, the goal of conservative treatment is to reduce pain and edema while promoting early mobilization. Pain and edema may lead to ROM restriction, which can result in permanent damage, such as chronic ankle instability, affecting ankle function. This condition may also lead to workforce loss in the physically active young population, where AS is more common. Successful early pain management can facilitate mobilization, thereby reducing these risks. Meta-analysis studies have concluded that early mobilization and exercise programs help reduce chronic ankle instability and recurrent ASs.[9,10] In this study, patients had similar sociodemographic characteristics. Two different pain assessment scales were used to evaluate patients' pain levels. NRS scores were found to be parallel to WBS values, indicating that pain measurement was more objective. There was no difference in pre-treatment NRS pain scores among the three groups; however, WBS scores were statistically higher in Group D. A statistically significant reduction in pain scores was observed in all three groups after treatment. Although the groups were different, the fact that the analgesic mechanisms led to similar outcomes suggests that these medications may have comparable analgesic efficacy. It is well known that NSAIDs achieve analgesia through cyclooxygenase enzyme inhibition, whereas paracetamol exerts its effect through multiple mechanisms, including serotonergic pathways and inhibition of prostaglandin synthesis.[11]

AS not only damages the ligaments but can also affect the muscles, tendons, and nerves within the ankle structure. Such injuries may lead to ligament laxity and muscle weakness, ultimately resulting in impaired joint proprioception, balance, and muscle strength. In addition, they may cause restricted ROM, particularly dorsiflexion.[12] Proper functioning of the surrounding ankle muscles and adequate ROM are essential for maintaining balance and preventing recurrent injuries.[13] To reduce such morbidities, the treatment goals for AS should include not only pain control but also the full restoration of ankle ROM. Several studies have shown that long-term application of certain physical activities and mobilization exercises improves ROM and ankle function.[13-15] The methods used in these studies included therapeutic procedures aimed at increasing the length of shortened soft-tissue structures following injury, as well as the isometric activation of passive tense muscles in the lower leg. In this study, analgesics were found to significantly increase d-ROM and p-ROM angles at the end of the 1st h. The activation of nociceptors in the joint capsule due to trauma may lead to hyperactivity of the muscle spindle and continuous muscle contraction, resulting in ischemia. This process causes the accumulation of inflammatory mediators in the affected area, contributing to pain. Furthermore, increased pain during the stretching of persistently contracted muscles, along with the shortening of muscle and soft tissue, may contribute to ROM restriction.[16] In this context, we suggest that the reduction of edema and inflammation in connective tissue by paracetamol and NSAIDs contributed to pain relief and muscle relaxation, ultimately improving joint ROM.

The most notable statistical finding in this study was the comparison of differences (delta = Δ) in pain and ROM measurements before and after treatment. When the delta (Δ) values of pain scores and ROM angles before and after treatment were compared, no statistically significant difference was found among the three groups. The reduction in pain and the increase in ROM angles contributed to early mobilization, even in the acute phase. It was also demonstrated through delta (Δ) values that paracetamol, dexketoprofen, and ibuprofen are effective analgesics and have comparable effects in improving ankle function. In a study conducted by Yilmaz et al.,[17] it was found that there was no significant difference between dexketoprofen and paracetamol in reducing pain scores in acute musculoskeletal trauma-related pain in the emergency department. Another study on traumatic isolated extremity pain in the emergency department demonstrated that the analgesic effects of paracetamol and morphine were nearly equivalent.[18] In a study conducted by Doğan et al.,[19] which evaluated the efficacy of paracetamol, dexketoprofen, and ibuprofen in the treatment of non-traumatic acute low back pain, it was found that there was no significant difference in the reduction of pain scores on the Visual Analog Scale among the three groups. In a comparative study by Dönmez et al.[20] examining the analgesic efficacy of ibuprofen and dexketoprofen in the pain management of long bone fractures, both NSAIDs demonstrated effective analgesic properties in the acute phase. Notably, ibuprofen 800 mg exhibited superior analgesic efficacy at 60 and 120 min compared to dexketoprofen, suggesting that the dosage and timing of NSAID administration may influence clinical outcomes in traumatic bone injuries. This finding aligns with our observation that NSAIDs can provide effective pain relief in acute musculoskeletal trauma, though the specific choice of agent and its pharmacokinetic profile may affect the magnitude and duration of analgesic response. Although these studies share similar findings with our study, there are also studies that have reported different results. The efficacy of paracetamol and dexketoprofen in reducing non-traumatic musculoskeletal pain, including neck, shoulder, back, hip, and knee pain, has been compared. It has been shown that dexketoprofen was statistically more effective than paracetamol in reducing Visual Analog Scale and NRS scores across all pain locations.[21] We believe that this difference is due to the use of these drugs in different chronic pain models rather than trauma-related conditions. While pain in trauma is primarily

caused by excessive stretching of muscle spindles in the injured area and subsequent ischemia, chronic musculoskeletal pain may be associated with different mechanisms, such as widespread hyperalgesia or allodynia.[22] This finding suggests that NSAIDs and paracetamol may exert their effects through different mechanisms in traumatic pain compared to other types of pain. The differential efficacy of NSAIDs in various acute pain conditions warrants careful consideration when selecting analgesic agents in emergency medicine. While the current study demonstrated comparable analgesic efficacy between ibuprofen and dexketoprofen in acute ASs, the literature reveals nuanced differences in their performance across different pain conditions. Similar effectiveness of ibuprofen and dexketoprofen has been documented in various non-traumatic acute pain states, including migraine and renal colic. This broad equivalence in efficacy across diverse pain pathophysiologies suggests that both NSAIDs share fundamental mechanisms of action through cyclooxygenase inhibition, resulting in comparable anti-inflammatory and analgesic effects in many clinical scenarios.[23,24]

In this study, no adverse effects were observed in any of the three groups during the acute phase. However, NSAIDs have not only mild side effects, such as dyspepsia and peptic ulcers, but also potentially serious adverse effects, including gastrointestinal bleeding, myocardial infarction, liver failure, and renal failure. Although paracetamol is generally considered a safer option, it carries a risk of hepatotoxicity, particularly with high doses and prolonged use. Therefore, the selection of analgesics should be individualized by taking into account the patient's clinical condition, comorbidities, and the potential side effects of the medications. Although there are studies in the literature comparing paracetamol and NSAIDs in different pain models, the number of studies specifically comparing these drugs in AS during the acute phase is extremely limited.[25]

Limitations

This study has several limitations. First, it was conducted at a single center, which may restrict the generalizability of the findings to broader populations. Future multi-center trials are needed to validate these results in diverse healthcare settings. Second, the follow-up period was limited to the early phase after treatment, and long-term outcomes such as persistent pain, recurrent sprains, and functional recovery were not evaluated. However, the primary aim of this study was to assess early analgesic efficacy and immediate functional improvement, which are clinically critical in emergency department practice. Nonetheless, the use of two validated pain scales in conjunction with objective ROM measurements strengthens the acute pain assessment compared to previous studies. Furthermore, the prospective, randomized, double-blind design, relatively large sample size, and meticulous data collection enhance the internal validity and reliability of our findings.

CONCLUSION

In this study, paracetamol and NSAIDs were found to have similar effects in reducing pain and improving ROM in the treatment of AS. Due to its lower cost, paracetamol may be considered a first-line option in appropriate patients. Regardless of the analgesic used, analgesic treatment holds an important place in clinical management to support early mobilization.

Ethics Committee Approval: This study was approved by the Ministry of Health Ankara Etlik City Hospital Ethics Committee (Date: 01.11.2023, Decision No: AEŞH-EK1-2023-666).

Informed Consent: Written informed consent was obtained from all individuals before their inclusion in the study.

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Acil serviste ayak bileği burkulmalarında kullanılan analjezik tedavilerin karşılaştırılması

AMAÇ: Ayak bileği burkulmaları, acil servise yapılan başvuruların yaklaşık %5'ini ve tüm sporla ilişkili yaralanmaların %40'ını oluşturmaktadır ve genellikle belirgin ağrı ile eklem hareket açıklığında (ROM) kısıtlılığa yol açmaktadır. Bu çalışma, acil servis pratiğinde yaygın olarak kullanılan intravenöz parasetamol, ibuprofen ve deksketoprofenin erken dönemde uygulanmasının klinik sonuçlarını değerlendirmeyi amaçlamaktadır. Bu amaçla, erken fonksiyonel analjezinin etkinliğini gösterebilmek için ağrı düzeyi takipleri ve ROM ölçümleri yapıldı.

GEREÇ VE YÖNTEM: Bu prospektif, randomize, çift kör çalışma Aralık 2023 ile Mayıs 2024 tarihleri arasında acil serviste Derece 1–2 ayak bileği burkulması tanısı alan hastalar üzerinde gerçekleştirildi. Hastalar üç gruba ayrıldı ve intravenöz deksketoprofen (Grup D, n=52), parasetamol (Grup P, n=52) ve ibuprofen (Grup I, n=51) uygulandı. Ağrı değerlendirmesi Sayısal Derecelendirme Ölçeği (NRS) ve Wong-Baker Yüz Ağrı Ölçeği (WBS) kullanılarak yapıldı. ROM, yarım daireli gonyometre ile dorsifleksiyon (d-ROM) ve plantar fleksiyon (p-ROM) açıları ölçülerek değerlendirildi. Tedavi öncesi ve tedaviden 1 saat sonraki ölçümler karşılaştırıldı.

BULGULAR: Tedavi sonrası ağrı değerlendirmesinde; NRS skorları açısından gruplar arasında anlamlı bir fark bulunmadı (p=0.352), ancak WBS skorları bakımından Grup I en düşük değere sahipti (p<0.001). Bununla birlikte, her üç grupta da tedavi sonrası ağrı skorlarının (NRS ve WBS) tedavi öncesine göre istatistiksel olarak anlamlı düzeyde azaldığı saptandı (p<0.001). ROM açıları incelendiğinde, tedavi öncesi d-ROM ve p-ROM değerleri gruplar arasında benzerdi (p=0.196). Tedavi sonrasında Grup I'da d-ROM daha düşük (p=0.034) ve p-ROM daha yüksek bulundu (p=0.011). Ancak, her üç grupta da tedavi sonrası ROM değerlerinde tedavi öncesine göre anlamlı iyileşme gözlendi (p<0.001). Ağrı skorları ve ROM açıları için tedavi öncesi-sonrası değişim (Δ) değerleri karşılaştırıldığında ise gruplar arasında istatistiksel olarak anlamlı fark saptanmadı (ΔNRS p=0.264, ΔWBS p=0.965, Δd-ROM p=0.099, Δp-ROM p=0.073).

SONUÇ: Parasetamol, ibuprofen ve deksketoprofen, ayak bileği burkulmalarının akut fazında ağrıyı azaltma ve ayak bileği eklem hareket açıklığını artırma açısından benzer etkinlik göstermiştir. Bu bulgular, ayak bileği burkulmalarında analjezik tedavinin erken başlanmasının klinik iyileşmeye katkı sağladığını göstermektedir.

Anahtar sözcükler: Ağrı; ayak bileği burkulmaları; deksketoprofen; hareket açıklığı; ibuprofen; parasetamol.

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ORIGINAL ARTICLE

Comparison of screw and suture-button techniques in the treatment of ankle syndesmotic injuries

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ABSTRACT

BACKGROUND: Syndesmotic disruption frequently accompanies ankle fractures and requires stable fixation to restore distal tibiofibular congruence and function. Cortical screw and suture-button constructs are widely used; however, their relative superiority, particularly with respect to early recovery versus long-term outcomes, remains uncertain.

METHODS: We conducted a single-center, retrospective, nonrandomized cohort study of adults with ankle fractures and radiographically confirmed syndesmotic injuries treated between 2017 and 2021. Patients underwent fixation according to surgeon preference using either screws (n=81) or suture-button constructs (n=25). The primary outcome was the American Orthopaedic Foot & Ankle Society (AOFAS) ankle-hindfoot score at 12 months. Secondary outcomes included AOFAS score at 3 months, Olerud–Molander Ankle Score (OMAS) at final follow-up, tibiofibular clear space (TFCS), tibiofibular overlap (TFO), medial clear space (MCS), and complication rates. Standardized anteroposterior (AP), mortise, and lateral radiographs were obtained preoperatively and postoperatively. Median follow-up was 14 months (range: 12–19). Treatment selection was at the operating surgeon's discretion, taking into account patient age and activity level, fracture pattern and instability (including initial subluxation or dislocation), soft-tissue condition, and implant availability.

RESULTS: Both groups demonstrated significant radiographic improvement in TFCS, TFO, and MCS from preoperative to postoperative assessment (all p<0.001). At three months, the suture-button group achieved higher AOFAS scores than the screw group (median, 75 vs. 70; p=0.009). However, the primary outcome of AOFAS score at 12 months and the final OMAS did not differ significantly between groups (p=0.161 and p=0.090, respectively). Interpretation of the findings is limited by baseline imbalances, including a younger patient population in the suture-button group (p=0.008) and unequal group sizes (81 vs. 25). Complication rates were low and comparable between groups.

CONCLUSION: Both cortical screw and suture-button fixation provided satisfactory long-term functional and radiographic outcomes in patients with ankle fractures and syndesmotic injuries. Although suture-button fixation was associated with superior early functional recovery, this apparent advantage should be interpreted cautiously given baseline differences and potential confounding. These hypothesis-generating findings support the need for prospective randomized trials with standardized rehabilitation protocols.

Keywords: Ankle syndesmosis; American Orthopaedic Foot & Ankle Society (AOFAS); Olerud–Molander Ankle Score (OMAS); screw fixation; suture-button.

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INTRODUCTION

Ankle fractures are common injuries that may be complicated by disruption of the distal tibiofibular syndesmosis, a key stabilizer that contributes substantially to ankle stability and load transmission.[1,3-7] Syndesmotic injuries commonly occur in association with rotational ankle fractures and may be accompanied by posterior malleolar involvement or Maisonneuve-type injury patterns.[1,2,4,5] Accurate reduction and stable fixation are essential for the successful treatment of unstable syndesmotic injuries. Although syndesmotic screw fixation provides reliable rigid stabilization, it may be associated with implant loosening or breakage and often requires subsequent hardware removal.[11-13] Dynamic fixation with a suture-button device was developed to permit more physiologic motion while maintaining syndesmotic reduction. Systematic reviews, randomized trials, and meta-analyses have generally reported comparable radiographic outcomes between screw and suture-button fixation, with evidence suggesting improved early functional recovery and fewer implant-related reoperations in patients treated with suture-button constructs.[4,14-19] However, long-term findings remain inconsistent across studies with differing fracture patterns and follow-up durations.[15-17]

Accordingly, we compared the clinical and radiographic outcomes of cortical screw fixation and suture-button fixation in patients with ankle fractures and associated syndesmotic injuries.

This single-center, retrospective, nonrandomized cohort study compared functional and radiographic outcomes between patients treated with cortical screw fixation and those treated with suture-button fixation for ankle fractures with syndesmotic injury, with a particular focus on early functional recovery and longer-term outcomes.

MATERIALS AND METHODS

Study Design, Setting, and Patient Selection

This retrospective, single-center, nonrandomized cohort study was conducted at a tertiary trauma center between October 2017 and October 2021. Adult patients (≥18 years) with acute ankle fractures presenting within three weeks of injury and radiographically confirmed syndesmotic disruption were screened for eligibility. Treatment allocation (cortical screw or suture-button fixation) was based on surgeon preference, and no randomization was performed. In our institution, suture-button fixation was more commonly selected for younger, higher-demand patients and for injuries associated with marked initial subluxation or dislocation, with the aim of permitting physiologic micromotion while maintaining syndesmotic reduction and facilitating earlier rehabilitation. Screw fixation was more frequently used for routine injury patterns and when implant availability favored screw fixation.

Inclusion criteria were: (1) age ≥18 years; (2) ankle fracture associated with syndesmotic injury requiring operative fixation; (3) surgery performed within three weeks of injury; and (4) availability of preoperative and postoperative radiographs and a minimum clinical follow-up of 12 months.

Exclusion criteria were: (1) open fractures; (2) polytrauma; (3) pathological or bilateral injuries; (4) combined screw and suture-button fixation; and (5) incomplete follow-up data.

A total of 143 patients were screened for eligibility. Thirty-seven patients were excluded, including five who died from coronavirus disease 2019-related (COVID-19–related) causes during follow-up, nine who were lost to follow-up, 19 with incomplete data, and four who underwent combined screw and suture-button fixation. The final analytic cohort comprised 106 patients, including 81 treated with cortical screw fixation and 25 treated with suture-button fixation. Baseline demographic and injury characteristics (age, sex, injured side, fracture pattern, and dislocation/subluxation status) are summarized in Table 1.

Surgical Technique

Following anatomic fracture reduction, syndesmotic stabilization was performed under fluoroscopic guidance. For screw fixation, a 3.5-mm fully threaded cortical screw was inserted 2–3 cm proximal to the tibial plafond and directed ~20°–30° anteriorly across three or four cortices while maintaining anatomic reduction (Figs. 1, 2). Routine screw removal was scheduled 8–10 weeks postoperatively.

For dynamic fixation, a commercially available suture-button device (e.g., TightRope®, Arthrex Inc.) was implanted according to the manufacturer's instructions. The transosseous tunnel was created at a level and orientation corresponding to the native syndesmotic axis. Reduction was confirmed fluoroscopically using both neutral and stress views. Preoperative computed tomography (CT) was obtained at the surgeon's discretion for complex fracture patterns.

Postoperative Rehabilitation

A standardized rehabilitation protocol was applied to both groups, with differences in weight-bearing progression based

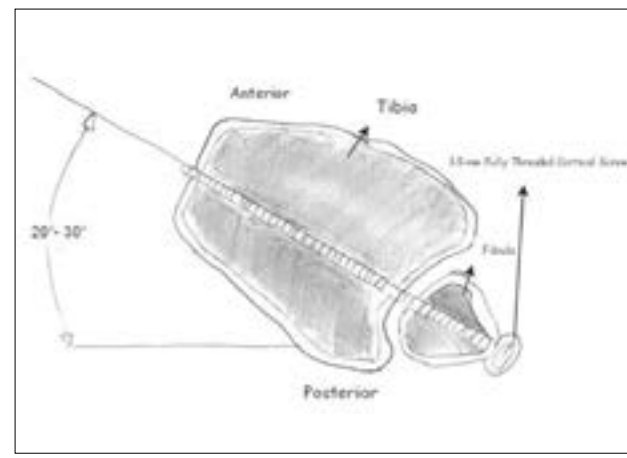

Figure 1. Flow diagram illustrating patient screening, exclusions, and final cohort allocation.

Table 1. Baseline characteristics of the study cohort

Variable	Cortical screw (n=81)	Suture-button (n=25)	Total (n=106)	p
Age, years (mean±SD; range)	45.61±16.28 [19-91]	35.52±16.16 [19-77]	43.22±16.74 [19-91]	0.008
Male sex, n (%)	40 (49.4)	15 (60.0)	55 (51.9)	0.353
Female sex, n (%)	41 (50.6)	10 (40.0)	51 (48.1)	
Left-sided injury, n (%)	28 (34.6)	14 (56.0)	42 (39.6)	0.055
Right-sided injury, n (%)	53 (65.4)	11 (44.0)	64 (60.4)	
Fracture pattern at presentation, n (%)				0.001
Isolated distal fibula fracture	29 (35.8)	0 (0.0)	29 (27.4)	
Bimalleolar fracture (medial malleolus + distal fibula)	45 (55.6)	24 (96.0)	69 (65.1)	
Pilon fracture + distal fibula fracture	6 (7.4)	0 (0.0)	6 (5.7)	
Trimalleolar fracture	1 (1.2)	1 (4.0)	2 (1.9)	
Dislocation or subluxation at presentation, n (%)				<0.001
No dislocation	66 (81.5)	5 (20.0)	71 (67.0)	
Subluxation	12 (14.8)	19 (76.0)	31 (29.2)	
Dislocation	3 (3.7)	1 (4.0)	4 (3.8)	

Values are presented as mean ± standard deviation (SD) (range), median [interquartile range (IQR)], or n (%), as appropriate. P values were calculated using the Student's t-test or Mann–Whitney U test for continuous variables and the chi-square test or Fisher's exact test for categorical variables, as appropriate, for overall group comparisons.

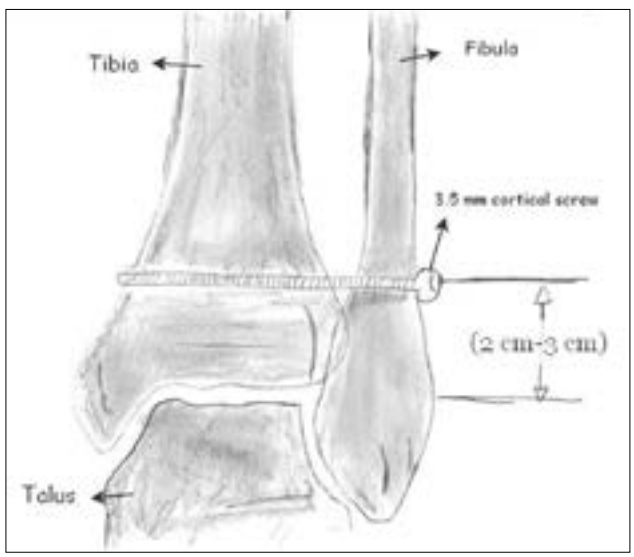

Figure 2. Image demonstrating syndesmotic fixation with a 3.5-mm fully threaded cortical screw inserted 2–3 cm proximal to the tibial plafond and angled approximately 30° anteriorly.

on the fixation method. Patients treated with screw fixation remained non-weight-bearing for two weeks, progressed to partial weight-bearing at 3–4 weeks, and commenced full weight-bearing after screw removal, typically at 8–10 weeks postoperatively. Patients treated with suture-button fixation were permitted weight-bearing as tolerated beginning in the third postoperative week. All patients participated in a standardized physiotherapy program emphasizing restoration of ankle range of motion, proprioception, and progressive strengthening.

Radiographic Assessment

Standardized anteroposterior, mortise, and lateral ankle radiographs were obtained preoperatively and at 3 months, 12 months, and final follow-up. Syndesmotic reduction was evaluated using the following radiographic parameters:

• Tibiofibular clear space (TFCS): the distance between the lateral border of the posterior tibial malleolus and the medial border of the fibula, measured approximately 1 cm proximal to the plafond on anteroposterior (AP) and mortise radiographs.

• Tibiofibular overlap (TFO): the degree of overlap between the distal tibia and fibula on AP and mortise radiographs.

• Medial clear space (MCS): the distance between the lateral border of the medial malleolus and the medial border of the talar dome on mortise radiographs.

All radiographic measurements were independently performed by two fellowship-trained orthopedic surgeons using standardized ankle radiographs. In cases of disagreement, measurements were reviewed jointly to achieve consensus, and the final agreed value was used for analysis.

Clinical Outcomes

Outcome measures were prespecified. The primary outcome

Table 2. Functional outcome scores (OMAS and AOFAS) during follow-up

Outcome	Cortical screw (n=81) median [min–max]	Suture-button (n=25) median [min–max]	p
AOFAS at 3 months	70 [60-75]	75 [65-75]	0.009
AOFAS at 12 months	85 [65-95]	85 [75-85]	0.161
OMAS at final follow-up	80 [65-95]	80 [75-90]	0.090

P values were calculated using the Mann–Whitney U test. AOFAS: American Orthopaedic Foot & Ankle Society Ankle-Hindfoot Score; OMAS: Olerud–Molander Ankle Score.

was the American Orthopaedic Foot & Ankle Society (AOFAS) ankle–hindfoot score at 12 months postoperatively. Secondary outcomes included the AOFAS score at three months, the Olerud–Molander Ankle Score (OMAS) at final follow-up, longitudinal changes in TFCS, TFO, and MCS, and complication rates, including superficial infection, hardware irritation, pain during prolonged ambulation, and a composite endpoint of any complication. The median follow-up duration for the overall cohort was 14 months (range, 12–19).

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 24.0 (IBM Corp., Armonk, NY, USA) and R software (R Foundation for Statistical Computing, Vienna, Austria). Normality was assessed using the Shapiro–Wilk test. Continuous variables are presented as mean ± standard deviation (SD) for normally distributed data and median (interquartile range [IQR]) for non-normally distributed data. Categorical variables are presented as n (%). Between-group comparisons were performed using the independent-samples t-test or the Mann–Whitney U test, as appropriate. Within-group comparisons over time were assessed using paired t-tests, Wilcoxon signed-rank tests, or Friedman tests. Categorical variables were compared using the chi-square test.

To account for baseline differences between groups, multivariable linear regression analyses were performed for functional outcomes (AOFAS and OMAS scores), and logistic regression was used for complications. Models were adjusted for age, sex, fracture pattern (Weber and Lauge–Hansen classifications), and the presence of initial dislocation. Results are reported as adjusted mean differences (β) or odds ratios (OR) with 95% confidence intervals (CIs). To control for multiple comparisons among secondary endpoints, the false discovery rate was adjusted using the Benjamini–Hochberg procedure, and q-values are reported alongside p-values. Because of the retrospective study design, no a priori sample size calculation was performed; therefore, all findings should be considered exploratory and hypothesis-generating. A two-sided $p<0.05$ was considered statistically significant.

Ethics

Ataturk University Faculty of Medicine Institutional Clinical Research Ethics Committee (Approval No. B.30.2.ATA.0.01.00/273; Meeting No. 3; Date: March 31, 2022). The requirement for informed consent was waived because of the retrospective design and use of de-identified data. The study was conducted in accordance with the principles of the Declaration of Helsinki.

RESULTS

Patient Selection and Baseline Characteristics

Of the 143 patients screened, 37 were excluded: five died from COVID-19–related causes, nine were lost to follow-up, 19 had incomplete data, and four were treated with combined screw and suture-button fixation. The final cohort comprised 106 patients, including 81 in the cortical screw group and 25 in the suture-button group (Fig. 1). Table 1 summarizes the baseline characteristics, including fracture pattern distribution ($p=0.001$) and initial dislocation/subluxation status ($p<0.001$). Patients in the suture-button group were younger than those in the cortical screw group (35.52±16.16 vs. 45.61±16.28 years, $p=0.008$). Sex distribution ($p=0.353$) and injured side ($p=0.055$) were similar between groups.

Radiographic Outcomes

Both treatment groups demonstrated significant radiographic improvement from the preoperative assessment to final follow-up. TFCS and MCS decreased, whereas TFO increased in both groups (all $p<0.001$). Changes in TFCS over time are illustrated in Figure 3. At final follow-up, no significant between-group differences were observed in TFCS, TFO, or MCS (all $p>0.05$).

Functional Outcomes

Functional scores are presented in Table 2. At 3 months postoperatively, the suture-button group demonstrated higher AOFAS scores than the screw fixation group (median 75 vs. 70; $p=0.009$). However, no significant difference was observed in the primary outcome of AOFAS score at 12 months ($p=0.161$). Similarly, OMAS at final follow-up did not differ significantly between groups ($p=0.090$). The median follow-up duration was 14 months (range, 12–19). A representative case of a 37-year-old male patient treated with suture-button fixation, including preoperative and postoperative radio-

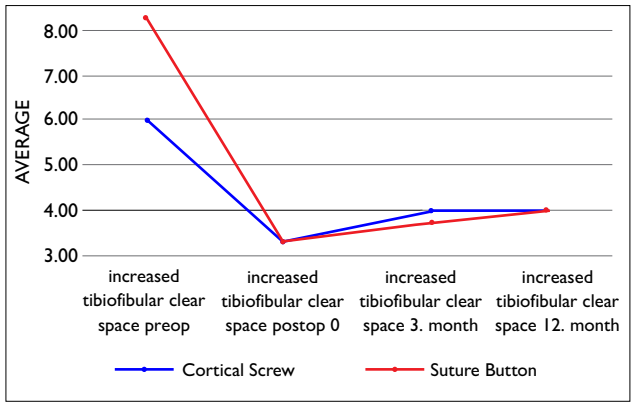

Figure 3. Changes in tibiofibular clear space (TFCS) from the preoperative assessment to final follow-up in the cortical screw and suture-button fixation groups.

Figure 4. Preoperative and postoperative radiographs of a representative case treated with suture-button fixation.

graphs, is shown in Figure 4.

Complications

Complication rates were low and comparable between groups (all p>0.05). The most common complications were intermittent pain during prolonged walking and mild ankle swelling. No cases of deep infection, syndesmotic synostosis, or hardware failure requiring revision surgery were observed.

Adjusted Analyses (Multivariable Regression)

Multivariable models adjusting for age, sex, fracture pattern, and initial dislocation/subluxation status are summarized in Table 3. After adjustment, no significant between-group difference was observed in 12-month AOFAS scores (adjusted β=3.21; 95% CI: −0.25 to 6.68; p=0.069; q=0.276). The difference in 3-month AOFAS scores was no longer significant after adjustment (adjusted β=1.18; 95% CI: −1.56 to 3.91; p=0.395; q=0.426), and final OMAS scores were similarly comparable between groups (adjusted β=1.81; 95% CI: −1.51 to 5.13; p=0.282; q=0.426). Likewise, the odds of experiencing any complication did not differ between fixation methods (adjusted OR=1.68; 95% CI: 0.47 to 6.09; p=0.426; q=0.426).

DISCUSSION

In this retrospective cohort of patients with operatively treated ankle fractures and associated syndesmotic disruption, both cortical screw and suture-button fixation resulted in satisfactory functional outcomes, significant radiographic improvement, and low complication rates.[18,19] Although patients treated with suture-button fixation demonstrated higher AOFAS scores at three months, no significant differences were observed in the primary outcome of 12-month AOFAS scores or in final OMAS. These findings suggest that any potential advantage of dynamic fixation may be limited to the early postoperative period and may not translate into superior mid-term outcomes.

A potential biomechanical explanation for the observed early (three-month) functional advantage is that suture-button fixation permits controlled physiologic micromotion of the distal tibiofibular joint while maintaining reduction. This may reduce stiffness and facilitate earlier progression of weight-bearing and rehabilitation compared with rigid screw fixation.[11]

However, after adjustment for baseline differences, no significant between-group differences were observed for 3-month AOFAS, 12-month AOFAS, OMAS, or complication rates

Table 3. Multivariable regression analysis of group differences

Outcome	Model	Estimate (suture-button vs. screw)	95% CI	p	q (BH-FDR)
AOFAS at 12 months (primary outcome)	Linear regression	β=3.21	−0.25 to 6.68	0.069	0.276
AOFAS at 3 months	Linear regression	β=1.18	−1.56 to 3.91	0.395	0.426
OMAS at final follow-up	Linear regression	β=1.81	−1.51 to 5.13	0.282	0.426
Any complication (yes/no)	Logistic regression	OR=1.68	0.47 to 6.09	0.426	0.426

β: Adjusted mean difference; OR: Odds ratio; CI: Confidence interval. All models were adjusted for age, sex, fracture pattern, and initial dislocation status. q values were calculated using the Benjamini–Hochberg false discovery rate procedure. Sample sizes were n=106 for the AOFAS outcomes and complication analysis and n=105 for the OMAS analysis.

(Table 3). These findings indicate that the apparent early functional advantage of suture-button fixation observed in the unadjusted analyses may have been influenced by selection factors, including differences in fracture pattern and initial dislocation or subluxation severity. Nevertheless, the direction of effect for 12-month AOFAS favored suture-button fixation, indicating that larger prospective studies with balanced cohorts are needed to determine whether a modest long-term benefit exists.[19]

Prior randomized trials and meta-analyses comparing dynamic and static fixation have reported similar findings. Andersen et al.[14] reported superior clinical outcomes at two years following suture-button stabilization compared with a single quadricortical screw, whereas another randomized trial comparing a suture-button device with a single tricortical 3.5-mm screw demonstrated largely equivalent outcomes at similar follow-up.[16] In a longer-term study, Raeder et al.[15] found superior clinical scores and lower rates of osteoarthritis at five years among patients treated with suture-button fixation. Conversely, a trial with a minimum follow-up of 6 years in patients with pronation–external rotation fractures reported comparable maintenance of reduction and functional outcomes between fixation methods.[17] Taken together, the available evidence suggests that suture-button fixation provides at least equivalent clinical outcomes to screw fixation, with a potential reduction in implant-related complications, particularly implant breakage and the need for routine implant removal.[18,19]

From a practical perspective, rigid screw fixation can constrain physiologic micromotion at the distal tibiofibular joint and may loosen or break, particularly in the setting of premature weight-bearing. Screw configuration (tricortical vs. quadricortical) and the optimal level of screw placement remain subjects of debate in the literature.[8-10] The necessity and timing of routine screw removal also remain controversial. Although retained screws may be associated with loosening, breakage, synostosis, or peri-implant osteolysis, elective removal entails the cost and morbidity of a second procedure and may increase the risk of infection associated with reoperation.[11-13] In our series, the few screw failures occurred primarily in patients who did not adhere to postoperative weight-bearing restrictions, underscoring the importance of patient compliance when static fixation is used.

This study has limitations inherent to its retrospective, nonrandomized design, including the potential for selection bias and baseline differences between groups. Notably, the suture-button group was younger and exhibited a different distribution of initial dislocation/subluxation status, which may reflect surgeon preference and confound comparisons of early functional outcomes. Accordingly, the observed three-month AOFAS scores should be interpreted with caution and cannot be attributed solely to the fixation method. Radiographic assessment relied on standard radiographic measurements rather than routine postoperative CT, which is more sensitive for detecting subtle malreduction and axial translation or rotation malalignment. Finally, the duration of follow-up may have been insufficient to capture late degenerative changes.

Despite these limitations, our findings support the growing body of evidence indicating that both cortical screw and suture-button fixation can provide reliable syndesmotic stabilization when anatomic reduction is achieved. Suture-button fixation may be particularly attractive when earlier mobilization and avoidance of planned hardware removal are priorities, whereas screw fixation remains a reliable and widely available alternative.[18,19]

CONCLUSION

Both cortical screw and suture-button fixation achieved satisfactory radiographic restoration and functional outcomes in patients with ankle fractures and associated syndesmotic injuries. Although suture-button fixation was associated with higher three-month AOFAS scores, 12-month AOFAS scores (primary endpoint) and final OMAS scores were comparable between groups, with similarly low complication rates. Given the retrospective, single-center, nonrandomized design, the group-size imbalance (81 vs. 25), and the younger age of the suture-button cohort, these comparisons should be interpreted as exploratory. Technique selection should therefore be individualized, taking into account patient characteristics, surgeon preference, resource availability, and rehabilitation logistics. Future prospective randomized studies, or rigorously propensity-adjusted multicenter cohort studies, with standardized rehabilitation protocols, longer-term clinical and structural outcomes, comprehensive patient-reported outcome measures, and cost-effectiveness analyses are needed to determine whether any early functional advantage of dynamic fixation translates into a durable clinical benefit.

Ethics Committee Approval: This study was approved by the Ataturk University Faculty of Medicine Institutional Clinical Research Ethics Committee (Date: 31.03.2022, Decision No: B.30.2.ATA.0.01.00/273, Meeting No: 3).

Informed Consent: The requirement for individual informed consent was waived due to the retrospective study design and the use of de-identified data. Written informed consent for publication was obtained from any patient whose potentially identifiable images or data were included.

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Conflict of Interest: The authors declare no competing financial or personal interests related to this work.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Ayak bileği sindezmoz yaralanmalarında vida ve sütür-buton tekniği sonuçlarının karşılaştırılması

AMAÇ: Sindezmotik yaralanma, ayak bileği kırıklarıyla sıkça birlikte görülür ve distal tibiofibular uyum ile fonksiyonun yeniden sağlanması için stabil fiksasyon gerektirir. Kortikal vida ve sütür buton yapıları yaygın olarak kullanılmakta olup, özellikle erken iyileşme ile uzun dönem sonuçlar açısından karşılaştırmalı üstünlükleri belirsizliğini korumaktadır.

GEREÇ VE YÖNTEM: Bu çalışmada, 2017–2021 yılları arasında ayak bileği kırığı ve radyografik olarak doğrulanmış sindezmotik yaralanması olan erişkin hastalar retrospektif, tek merkezli, randomize olmayan bir kohort çalışması kapsamında değerlendirildi. Tedavi yöntemi cerrah tercihiyle belirlendi (vida n=81; sütür butonu n=25). Birincil sonuç 12. ayda AOFAS skoru idi. İkincil sonuçlar; 3. ayda AOFAS, son kontrolde OMAS, tibiofibular aralık (TFCS), tibiofibular örtüşme (TFO), medial aralık (MCS) ve komplikasyonlardı. Tüm hastalara standart AP/mortis/lateral grafiler çekildi. Ortanca takip süresi 14 [12–19] ay idi. Tedavi seçimi; hastanın yaşı/aktivite düzeyi, kırık paterni ve instabilite (ilk subluksasyon/dislokasyon dahil), yumuşak doku durumu ve implant bulunabilirliği göz önüne alınarak ameliyatı yapan cerrahın takdirine göre yapıldı.

BULGULAR: Her iki grupta TFCS, TFO ve MCS ölçümlerinde anlamlı radyografik düzelme görüldü (tüm p<0.001). Üçüncü ay AOFAS puanı sütür butonu lehineydi (medyan 75 vs 70; p=0.009). On ikinci ay AOFAS (birincil sonuç) ve son OMAS skorları ise benzerdi (p=0.161 ve p=0.090). Sütür butonu grubunun daha genç olması (p=0.008) ve grup büyüklüklerindeki dengesizlik (81:25) nedensel çıkarımı sınırlamaktadır. Komplikasyon oranları her iki grupta da düşüktü ve benzerdir.

SONUÇ: Kortikal vida ve sütür buton fiksasyonu, uzun dönemde tatmin edici fonksiyonel ve radyografik sonuçlar sağlamıştır. Sütür buton ile görülen erken fonksiyonel avantaj, başlangıçtaki grup farklılıkları ve olası karıştırıcı faktörler göz önünde bulundurularak temkinli yorumlanmalıdır. Bu hipotez oluşturucu bulgular, standart rehabilitasyon ile yürütülecek prospektif randomize çalışmalara ihtiyaç olduğunu göstermektedir.

Anahtar sözcükler: Ayak bileği sindesmozu; Amerikan Ortopedik Ayak ve Ayak Bileği Derneği (AOFAS); Olerud-Molander Ayak Bileği Skoru (OMAS); sütür butonu; vida fiksasyonu.

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ORIGINAL ARTICLE

Nailing approach and residual fracture gap: A comparative study of antegrade versus retrograde fixation in distal femoral shaft fractures

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ABSTRACT

BACKGROUND: The optimal nailing approach for simple distal femoral shaft fractures located below the isthmus remains controversial. A critical factor that may affect union is the residual fracture gap created during intramedullary nail insertion. This study aimed to compare antegrade and retrograde nailing techniques in terms of residual fracture gap, time to union, and functional outcomes.

METHODS: This retrospective study included 50 patients (21 antegrade, 29 retrograde) with transverse or short oblique femoral shaft fractures distal to the isthmus. Residual fracture gap, union time, modified radiographic union scale for tibial fractures scores, Visual Analog Scale scores, and lower extremity functional scale were evaluated. Radiographic measurements were performed by two independent blinded observers, and statistical comparisons were conducted using appropriate parametric and non-parametric tests.

RESULTS: The residual fracture gap was significantly larger in the retrograde group compared with the antegrade group on both the anteroposterior view (4.8±2.6 mm vs. 2.1±1.4 mm; p=0.006) and the lateral view (5.6±2.9 mm vs. 2.6±1.8 mm; p<0.0001). Time to radiographic union was significantly longer in the retrograde group (20.2±5.2 weeks vs. 16.0±4.6 weeks; p=0.030). However, there were no significant differences in non-union rates, functional scores, or complications.

CONCLUSION: In distal femoral shaft fractures located below the isthmus, retrograde nailing was associated with larger residual fracture gaps and longer time to union. Although both techniques remain viable, attention should be directed toward minimizing distraction during retrograde nail placement to optimize healing.

Keywords: Antegrade nailing; distal femoral shaft fracture; residual fracture gap; retrograde nailing; time to union.

INTRODUCTION

Distal femoral shaft fractures constitute a subset of diaphyseal femur fractures and pose unique challenges owing to their proximity to the metaphyseal region and the joint surface.[1] Intramedullary nailing (IMN) has become the gold standard for the treatment of femoral shaft fractures, providing biomechanical stability, minimal invasiveness, and the potential for early mobilization.[2]

Both antegrade and retrograde approaches are commonly used for IMN fixation; however, the optimal entry point for fractures located in the distal femoral shaft remains a subject of ongoing debate.[3] Multiple factors influence the choice of approach, including the patient's general condition, associated injuries, surgical accessibility, and anatomical constraints.[4]

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Particularly in transverse and short oblique fractures, minimizing the residual fracture gap is critical, as persistent gapping may impede bone healing and increase the risk of delayed union or non-union.[5] Although several surgical techniques have been proposed to reduce fracture gaps, a potentially underappreciated factor is the spatial relationship between the fracture site and the nail entry point.[6] In a recent study on tibial shaft fractures, it was reported that when fractures are located distal to the isthmus, the isthmus moves together with the nail during insertion, creating a compressive effect at the fracture site and resulting in a decrease in the residual fracture gap.[7] This relationship may substantially affect the ability to achieve and maintain reduction during nail insertion.

To the best of our knowledge, no previous studies have specifically evaluated the association between nailing approach and residual fracture gap in distal femoral shaft fractures or its subsequent impact on healing and functional outcomes. The aim of this study was to investigate whether the choice of nailing approach – antegrade or retrograde – in distal femoral shaft fractures influences the residual fracture gap and to explore how this relates to union rates and clinical and functional results.

MATERIALS AND METHODS

Ethical Information

This study was approved by the University of Health Sciences Baltalimani Bone Diseases Training and Research Hospital (Date: 18.06.2025, Decision no: 284) and was conducted in accordance with the principles of the Declaration of Helsinki. Informed consent was obtained from all patients.

Patients

This retrospective study analyzed distal femoral shaft fractures treated between 2014 and 2022 using data prospectively collected in a hospital database. During the same period, 232 patients underwent IMN for unilateral femoral shaft fractures. The inclusion criteria were as follows: Femoral shaft fractures located distal to the isthmus, simple transverse or short oblique fracture patterns, and patient age between 18 and 60 years.

To ensure homogeneity of the study population, strict exclusion criteria were applied. The exclusion criteria were as follows:

(1) Open fractures, (2) comminuted or segmental fractures, (3) neurovascular deficits, (4) previous surgery on the same extremity, (5) inadequate soft tissue coverage, (6) diagnosis of rheumatological disease or diabetes, and (7) patients lost to follow-up.

After applying these criteria, 50 patients remained eligible and were included in the study. Patients were divided into two groups based on the femoral nail entry point: Group 1 (antegrade nailing, n=21) and Group 2 (retrograde nailing, n=29).

A fracture gap was defined as a separation of greater than 2 mm between the fracture fragments on either anteroposterior (AP) or lateral radiographs. The femoral isthmus was defined as the narrowest segment of the medullary canal on anteroposterior radiographs, located proximal to the supracondylar flare of the distal femur. This region has a narrow and uniform morphology, unlike the remaining femoral anatomy that expands proximally and distally, and no distraction or compression is expected as the nail advances through this segment.[7] Consequently, fractures located within the isthmus region were excluded from the analysis. The rationale for including only patients with fractures distal to the isthmus was to observe the effects of compression and distraction between fragments during nail placement (Fig. 1).

Data Collection

Pre-operative patient characteristics, including age, sex, injury side, body mass index (BMI), trauma mechanism, associated injuries, time from injury to surgery, and comorbidities, were documented and compared between the antegrade and retrograde nailing groups. Fracture-related variables, including fracture type (transverse or short oblique), fracture location, nail diameter and length, post-operative residual gap, time to union, angulation between proximal and distal fragments, occurrence of malunion or non-union, and the distance from the fracture site to the isthmus, were measured and evaluated.

All radiographic measurements were performed retrospectively by two orthopedic surgeons who were blinded to clinical data and were not involved in the treatment or follow-up of the patients. Assessments were performed using pre-operative and post-operative femoral radiographs obtained at 1, 2, 3, and 4 months postoperatively, as well as at the final follow-up (>6 months). The residual fracture gap was measured on the first post-operative radiograph. All radiological evaluations were performed using the Infinitt PACS System (Infinitt Healthcare Co., Seoul, South Korea), which provides a measurement accuracy of 0.1 mm for linear dimensions and 0.1° for angular measurements.

Radiological fracture healing was assessed using the modified radiographic union scale for tibial fractures (RUST) adapted for femoral fractures, based on radiographs obtained at 0, 1, 2, 3, and 4 months postoperatively.[8] Pain and functional outcomes were evaluated using the Visual Analog Scale (VAS) at post-operative months 0, 1, 2, 3, and 4, and the lower extremity functional scale (LEFS) at 1-year follow-up.[9] The LEFS comprises 20 items, each scored from 0 to 4, with a maximum score of 80. The final score is calculated as a percentage, with higher values indicating better functional capacity.

Post-operative complications were recorded and compared between the antegrade and retrograde nailing groups.

Surgical Technique

Both surgical procedures were performed under combined spinal-epidural anesthesia by an orthopedic trauma surgeon

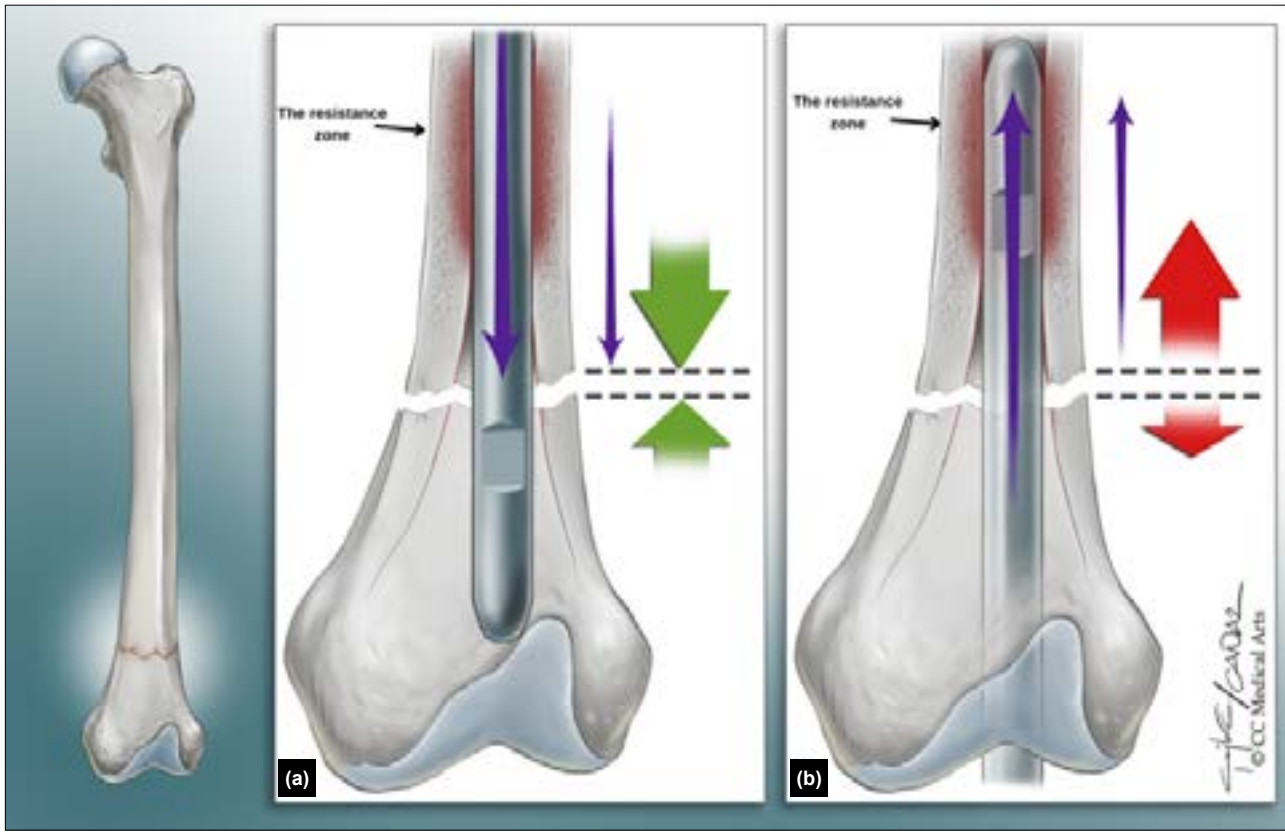

Figure 1. (a) Illustration showing the compressive effect exerted by the antegrade intramedullary nail on the fracture gap during nail placement, **(b)** Illustration showing the distractive effect exerted by the retrograde intramedullary nail on the fracture gap during nail placement.

with a minimum of 5 years of experience. A single nail system was used in all cases (Tasarim Medikal, Istanbul, Turkey). All nails were inserted after sequential reaming in 0.5 mm increments until the desired nail diameter was achieved. Static locking was performed in all patients. No adjunctive reduction techniques, such as blocking screws, percutaneous clamps, or reduction tools, were used. Postoperatively, all patients were allowed partial weight-bearing with crutches from the early post-operative period until the 1st post-operative month, after which full weight-bearing was permitted as tolerated.

For antegrade nailing, patients were positioned in the lateral decubitus position. A guidewire was inserted through the trochanteric entry point. A skin incision was made around the guidewire using the lateral hip approach. Closed reduction was performed under fluoroscopy. After the nail entry point was opened, the guidewire was advanced to 3 cm above the knee joint line with the knee in full extension. Subsequently, reaming was performed using reamers selected preoperatively based on the anteroposterior and lateral diameters of the intramedullary canal at the isthmus. An appropriately sized femoral antegrade intramedullary nail was then inserted. The maximum number of distal locking screws was placed. Following distal locking, two or three proximal locking screws were inserted after applying back hammering to reduce any remaining fracture gap.

For retrograde nailing, patients were positioned supine with a bolster placed under the knee. A skin incision was made using the medial parapatellar approach. A guidewire was placed through the intercondylar notch as the entry point. After the nail entry point was opened, the guidewire was advanced proximally in the femoral canal with the hip maintained in the neutral position. Reaming was performed using reamers selected preoperatively based on AP and lateral intramedullary canal diameters at the isthmus level. A retrograde femoral intramedullary nail was then inserted. After placing proximal locking screws, two or three distal locking screws were inserted following back hammering to minimize the fracture gap. As all fractures were located in the femoral shaft, blocking screws were not required. Metaphyseal fractures were excluded from the study.

Representative post-operative radiographs of both treatment groups are presented in Figure 2 (antegrade nailing) and Figure 3 (retrograde nailing) to illustrate typical implant positioning and residual fracture gap appearance after nail placement.

Statistical Analysis

Descriptive statistics are presented as mean, standard deviation, median, minimum and maximum values, frequency, and

Figure 2. Representative radiographic series of a patient treated with antegrade intramedullary nailing for a distal femoral shaft fracture.

Figure 3. Representative radiographic series of a patient treated with retrograde intramedullary nailing for a distal femoral shaft fracture.

ratios. The Kolmogorov–Smirnov test was used to assess the distribution of variables. For independent quantitative data, the independent samples t-test and the Mann–Whitney U test were used, while independent qualitative data were analyzed using the Chi-square test and Fisher's exact test. To explore the relationship between fracture and patient characteristics and the fracture gap, Spearman and Pearson correlation analyses were performed. The intraclass correlation coefficient (ICC) and Fleiss' kappa (κ) coefficient were used to determine interobserver agreement, and Cronbach's alpha was used to assess intraobserver reliability for measurement parameters and union assessment. Statistical significance was set at $p<0.05$. All statistical analyses were performed using IBM Statistical Package for the Social Sciences Statistics for Windows, version 22.0 (IBM Corp., Armonk, NY, USA).

RESULTS

A total of 50 patients who underwent IMN for distal femoral shaft fractures met the inclusion criteria and were included in the final analysis. Of these, 21 patients were treated with antegrade nailing (Group 1) and 29 patients with retrograde nailing (Group 2). The patient selection flowchart is shown in Figure 4.

Patient Characteristics

Table 1 summarizes the demographic and clinical characteristics of both groups. No statistically significant differences were observed between the antegrade and retrograde groups in terms of age ($p=0.821$), sex distribution ($p=1.000$), BMI ($p=0.850$), injury side ($p=0.778$), time from injury to surgery ($p=0.188$), or fracture type ($p=0.773$). Nail size was also comparable between the groups ($p=0.249$).

Fracture Gap and Union Outcomes

On initial post-operative radiographs, the residual fracture gap was significantly larger in the retrograde group than in the antegrade group. The mean residual gap on the anteroposterior view was 4.8±2.6 mm in the retrograde group and 2.1±1.4 mm in the antegrade group ($p=0.006$), while on the lateral view, it was 5.6±2.9 mm versus 2.6±1.8 mm, respectively ($p<0.0001$) (Table 2). The mean time to ra-

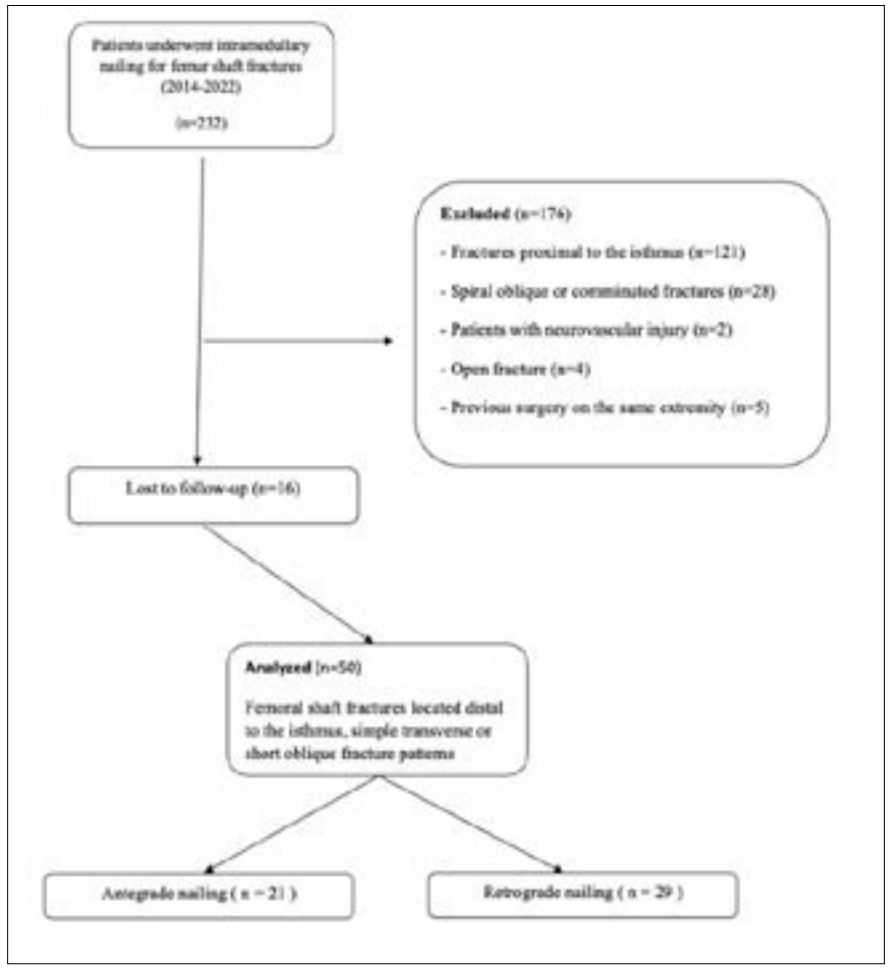

Figure 4. Study flowchart.

diographic union was significantly longer in the retrograde group (20.2±5.2 weeks) compared with the antegrade group (16.0±4.6 weeks) (p=0.030).

Modified RUST scores were comparable between the two groups during the early follow-up periods (months 1–3; all p>0.05); however, the antegrade group had significantly higher final RUST scores at the end of follow-up (15.4±2.5 vs. 14.6±3.0; p=0.043) (Table 3).

To assess the reliability of radiographic measurements and union evaluations, interobserver and intraobserver agree-

Table 1. Patient demographics and baseline characteristics

Variable	Antegrade (n=21)	Retrograde (n=29)	p
Age (years, mean±SD)	29.1±7.8	30.6±8.5	0.821
Sex (m/f)	15/6	20/9	1
BMI (kg/m2, mean±SD)	23.8±2.8	24.1±3.2	0.850
Side (right/left)	12/9	15/14	0.778
Time from injury to surgery (days)	2.1±0.4	2.4±0.6	0.188
Fracture type (transverse/oblique)	13/8	16/13	0.773
Nail size (mm)	10.4±0.9	10.8±0.6	0.249
Distance from knee joint line (mm)	166±20.4	172±26	0.970

SD: Standard deviation; BMI: Body mass index.

Table 2. Post-operative residual fracture gap and time to union

Outcome	Antegrade (n=21)	Retrograde (n=29)	p
Residual fracture gap on AP view (mm)	2.1±1.4	4.8±2.6	0.006
Residual fracture gap on lateral view (mm)	2.6±1.8	5.6±2.9	<0.0001
Time to union (weeks, mean±SD)	16.0±4.6	20.2±5.2	0.030
Post-operative knee pain (n, %)	1 (4)	6 (17)	0.215
Malunion (n, %)	0 (0)	0 (0)	1
Non-union (n, %)	1 (4)	2 (6)	1

SD: Standard deviation.

Table 3. Modified RUST scores at follow-up

Time point	Antegrade (mean±SD) (n=21)	Retrograde (mean±SD) (n=29)	p
Post-operative month 1	4.0±0	4.0±0	1
Post-operative month 2	5.3±1.2	5.2±1.4	0.364
Post-operative month 3	7.8±2.9	7.1±2.2	0.595
Post-operative month 4	10.2±3.1	9.4±3.3	0.100
Final score	15.4±2.5	14.6±3.0	0.043

SD: Standard deviation; RUST: Radiographic union scale for tibial.

Table 4. Clinical and functional outcomes

Outcome	Antegrade (n=21)	Retrograde (n=29)	p
VAS score – month 1	2.8±1.6	2.7±1.4	0.175
VAS score – month 2	2.3±1.8	2.2±1.6	0.383
VAS score – month 3	2.0±1.2	1.9±1.4	0.349
VAS score – month 4	1.4±1.1	1.4±1.4	0.447
LEFS score at 1 year (mean±SD)	72.4±6.6	70.2±8.2	0.429
Hardware-related complaints (n, %)	2 (9)	1 (3)	0.565

SD: Standard deviation; VAS: Visual Analog Scale; LEFS: Lower extremity functional scale.

ment analyses were performed. All quantitative analyses were based on the mean of two independent, blinded observers' measurements to minimize individual measurement bias. The ICC for continuous variables such as the residual fracture gap demonstrated almost perfect agreement between observers (ICC=0.89). Similarly, the Fleiss' kappa (κ) value for categorical assessments based on the modified RUST score was 0.82, also indicating almost perfect agreement. Intraobserver reliability was also assessed using Cronbach's alpha, which yielded a value of 0.979, indicating excellent internal consistency. These findings confirm the reproducibility and consistency of the radiological evaluations performed in this study.

Clinical and Functional Outcomes

Post-operative pain levels, as assessed by VAS scores at months 1 through 4, were similar between groups with no statistically significant differences (all p>0.05). Functional outcomes assessed using the LEFS at 1-year follow-up were also comparable (72.4±6.6 in the antegrade group vs. 70.2±8.2 in the retrograde group; p=0.429) (Table 4).

Complications

Delayed union was observed in one patient (4%) in the antegrade group and two patients (6%) in the retrograde group (p=1.000). Non-union developed in one patient (4%) in the

antegrade group and two patients (6%) in the retrograde group (p=1.000). No malunion was reported in either group. Post-operative knee pain was more frequently reported in the retrograde group (6 patients, 17%) compared with the antegrade group (1 patient, 4%); however, this difference did not reach statistical significance (p=0.215). Hardware-related complaints were noted in two patients (9%) in the antegrade group and one patient (3%) in the retrograde group (p=0.565). No infections, neurovascular injuries, or implant failures were recorded in either group during the follow-up period.

DISCUSSION

The most important finding of this study is that retrograde nailing is associated with a larger residual fracture gap than antegrade nailing in the treatment of distal femoral shaft fractures. This finding is clinically relevant, as the fracture gap is directly related to union, with gaps greater than 4.14 mm potentially having a negative impact on healing outcomes.[5] Our results suggest that the choice of nail entry point may be a critical factor for minimizing residual fracture gaps, particularly in distal shaft fractures.

There is no clear consensus regarding the effect of antegrade versus retrograde nailing on union time in femoral shaft fractures. Ostrum et al.[10] reported that antegrade nailing resulted in shorter union times. Similarly, Moed and Watson suggested that retrograde nailing should not be used routinely for isolated femoral shaft fractures owing to higher non-union rates.[11] However, our findings of increased fracture gaps with retrograde nailing in distal shaft fractures support these previous observations and may partially explain the variability in the results reported across different studies.

Conversely, many authors have concluded that retrograde and antegrade nailing are comparable in terms of union time, suggesting that retrograde nailing can be safely used when antegrade nailing is not suitable for the patient.[6,12] Supporting this perspective, Ricci et al.[4] found no significant difference between the two methods with regard to healing outcomes, although they noted that retrograde nailing, particularly without reaming, reduced blood loss and avoided hip pain commonly associated with antegrade nail entry sites. In addition, retrograde nailing may be associated with residual patellofemoral pain, and the potential consequences of intra-articular nail placement must also be considered.

In their 2022 study, Rodriguez-Fontan et al.[13] compared antegrade and retrograde techniques in proximal femoral shaft fractures and found that both surgical time and healing time were shorter in the retrograde group. Unlike our study, their cohort included only proximal femoral shaft fractures. One possible reason for the shorter fracture healing time with retrograde nailing in their study, consistent with our hypothesis, may be that during nail placement, the retrograde nail moves together with the distal fragment, thereby leaving a smaller residual fracture gap.

Nino et al.[14] demonstrated that retrograde nailing may be a viable alternative for extremely proximal femoral shaft fractures, with high union rates and low complication rates. Retrograde nailing in proximal femoral shaft fractures would be expected to have a gap-reducing effect, which supports our hypothesis.

Although most previous studies have not evaluated site-specific fracture union in femoral fractures, Kim et al.[15] found that while no significant difference was observed based on intramedullary nail type, a shorter working length distal to the fracture showed a strong association with non-union. Our findings of increased residual fracture gaps with retrograde nailing in distal shaft fractures appear to be inconsistent with some studies in the literature. Although retrograde nailing may offer certain biomechanical advantages, such as better control of the fractured fragments, our observations suggest that it creates a disadvantage in terms of residual fracture gap. A smaller fracture gap may enhance primary bone healing and accelerate the consolidation process in these specific fracture configurations.

Practical advantages of retrograde nailing include the ability to use a tourniquet, which reduces blood loss, and less need for position changes during surgery, which shortens operative time.[16] The ease of fluoroscopy use in the supine position is an additional advantage. Our study suggests a possible biomechanical disadvantage of retrograde nailing in distal shaft fractures, where antegrade nailing appears to create more favorable conditions for bone contact and subsequent healing. This may be related to the direction of nail entry relative to the natural expansion of the medullary canal in the distal femur. The greater grip of the nail at the isthmus during placement may push the proximal fragment more proximally, creating a residual gap that sometimes cannot be compensated for by back hammering.

The results of our study demonstrated that retrograde nailing resulted in larger residual fracture gaps compared with antegrade nailing and was associated with longer healing times. However, no statistically significant difference was found in non-union rates or functional outcomes at final follow-up. This study highlights the importance of paying particular attention to minimizing the residual fracture gap when performing retrograde nailing.

This study has several limitations. First, its retrospective design inherently limits the ability to control for all confounding variables despite the application of strict inclusion and exclusion criteria. Second, the choice between antegrade and retrograde nailing was based entirely on the operating surgeon preference, which introduces potential selection bias and may have influenced group allocation in a non-randomized fashion. Third, although radiographic measurements were performed by two independent, blinded observers, the absence of advanced imaging (e.g., computed tomography) may have re-

duced the precision of fracture gap and alignment evaluations. Fourth, although the distance from the knee joint line to the fracture site was recorded and was comparable between groups, the direct distance from the fracture site to the isthmus was not measured; this measurement would have more directly supported the biomechanical hypothesis underlying the study and should be addressed in future investigations. Fifth, the relatively small sample size and single-center nature of the study may limit the generalizability of the results.

Nevertheless, a key strength of this study is the strict standardization of fracture type (transverse or short oblique) and fracture level (distal to the isthmus), which allowed for a more focused and valid comparison of the mechanical effects of antegrade versus retrograde nailing on the residual fracture gap and healing outcomes.

CONCLUSION

In this study of patients with simple distal femoral shaft fractures treated with IMN, retrograde nailing was associated with a significantly larger residual fracture gap and longer time to radiographic union compared with antegrade nailing. Despite these differences, non-union rates, malunion rates, and functional outcomes were comparable between the two approaches. These findings suggest that, particularly in fractures located distal to the isthmus, careful attention should be paid to minimizing the residual fracture gap during retrograde nailing, as it may influence the biological environment for healing. Although both techniques remain viable, future prospective studies are warranted to guide optimal entry point selection based on fracture geometry, patient factors, and long-term joint function.

Ethics Committee Approval: This study was approved by the University of Health Sciences Baltalimani Bone Diseases Training and Research Hospital Ethics Committee (Date: 18.06.2025, Decision No: 284).

Informed Consent: Informed consent was obtained from all patients.

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Distal femur şaft kırıklarında çivileme yaklaşımı ve rezidüel kırık aralığı ilişkisi: Antegrad ve retrograd fiksasyonun karşılaştırılması

AMAÇ: İstmusun inferiorundaki basit distal femur şaft kırıkları için en uygun çivileme yaklaşımı hâlâ tartışmalıdır. Kaynamayı etkileyebilecek kritik faktörlerden biri de intramedüller çivileme sonrası kırık uçları arasında oluşan rezidüel boşluktur. Bu çalışma, rezidüel kırık boşluğu, kaynama süresi ve fonksiyonel sonuçlar açısından antegrad ve retrograd çivileme tekniklerini karşılaştırmayı amaçlamaktadır.

GEREÇ VE YÖNTEM: Bu retrospektif çalışmaya, istmus distalinde transvers veya kısa oblik femur şaft kırığı olan 50 hasta (21 antegrad, 29 retrograd) dahil edilmiştir. Rezidüel kırık boşluğu, kaynama süreleri, modifiye RUST skorları, VAS skorları ve LEFS değerlendirilmiştir. Radyografik ölçümler iki bağımsız kör gözlemci tarafından yapılmış ve istatistiksel karşılaştırmalar uygun parametrik ve parametrik olmayan testler kullanılarak gerçekleştirilmiştir.

BULGULAR: Rezidüel kırık boşluğu, retrograd grupta (AP grafide: 4.8±2.6 mm; lateral grafide: 5.6±2.9 mm) antegrad gruba (AP grafide: 2.1±1.4 mm; lateral grafide: 2.6±1.8 mm) kıyasla anlamlı olarak daha büyüktü (sırasıyla, AP için $p=0.006$ ve lateral için $p<0.0001$). Radyografik kaynama süresi retrograd grupta anlamlı olarak daha uzundu (20.2±5.2 hafta vs. 16.0±4.6 hafta; $p=0.030$). Ancak kaynamama oranları, fonksiyonel skorlar veya komplikasyonlar açısından anlamlı bir fark yoktu.

SONUÇ: İstmusun altında bulunan distal femur şaft kırıklarında retrograd çivileme, daha büyük rezidüel kırık boşlukları ve daha uzun kaynama süresi ile ilişkiliydi. Her iki teknik de uygulanabilir olmakla birlikte, iyileşmeyi optimize etmek için retrograd çivi yerleştirme sırasında distraksiyonun en aza indirilmesine dikkat edilmelidir.

Anahtar sözcükler: Antegrad çivileme; distal femur şaft kırığı; fonksiyonel sonuç; kaynama süresi; rezidüel kırık boşluğu; retrograd çivileme.

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ORIGINAL ARTICLE

Serum 25-hydroxyvitamin D levels in children with distal radius torus fractures: A case–control analysis

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ABSTRACT

BACKGROUND: Vitamin D influences bone mineralization, yet its relationship with distal radius torus fractures in children is uncertain. This study aims to investigate the relationship between serum Vitamin D levels and distal radial torus fracture.

METHODS: We compared serum 25-hydroxyvitamin D (25[OH]D) levels between children with radiographically confirmed isolated distal radius torus fractures (n=236) and laboratory-tested pediatric outpatient controls (n=505). Controls underwent serum 25(OH)D testing during routine pediatric outpatient health evaluations and were not selected because of fracture, bone pain, suspected metabolic bone disease, or delayed fracture healing. In the fracture cohort, 25(OH)D was measured at the 3rd week after injury during outpatient follow-up. Group comparisons were performed using the Mann–Whitney U and Chi-square tests. Multivariable logistic regression assessed associations with age and sex. An exploratory subgroup analysis was additionally performed.

RESULTS: Median 25(OH)D was 23.0 (interquartile range [IQR] 16.8–30.3) ng/mL in the fracture patients versus 18.4 (IQR=13.1–26.6) ng/mL in controls (p<0.001). Vitamin D deficiency (<20 ng/mL) occurred of the fracture group and 55.6% of the control group, respectively. After adjustment, 25(OH)D was not independently associated with torus fracture (adjusted OR/10 ng/mL 1.08, 95% CI=0.95–1.23; p=0.262), whereas male sex strongly predicted torus fracture (adjusted OR=3.35, 95% CI=2.41–4.66; p<0.001).

CONCLUSION: In this laboratory-selected case–control cohort, children with distal radius torus fractures did not have lower measured 25(OH)D levels than outpatient controls. These findings do not support routine Vitamin D testing solely on the basis of an isolated torus fracture, but screening should remain guided by individual clinical risk factors.

Keywords: 25-Hydroxyvitamin D; Buckle fracture; distal radius; pediatric; torus fracture; vitamin D.

INTRODUCTION

Distal radius torus (buckle) fractures are common pediatric injuries encountered in trauma and emergency settings. These stable, low-energy fractures typically result from axial loading with compressive failure of the metaphyseal cortex, and they are generally managed non-operatively.[1]

Vitamin D is central to calcium homeostasis and bone mineralization. Although severe deficiency causes rickets, the clinical significance of milder hypovitaminosis D in otherwise healthy children remains debated, and recent guidance varies regarding screening and optimal thresholds.[2,3] Prior pediatric studies have reported inconsistent associations between serum 25-hydroxyvitamin D (25[OH]D) levels and fracture risk, with heterogeneity across populations and fracture types.[4,5] Several pediatric fracture cohorts, including studies focusing on

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torus fractures, have reported a high prevalence of Vitamin D insufficiency or deficiency with variable clinical implications for recovery and outcomes.[6,7]

Distal radius torus fractures represent a relevant phenotype because they often occur after minor trauma and are frequent in active children. Clarifying whether measured Vitamin D status differs between children with torus fractures and appropriate comparison groups may inform pragmatic screening decisions in orthopedic and emergency care.[8]

The aim of this study was to compare serum 25(OH)D levels between children with distal radius torus fractures and pediatric outpatient controls, and to evaluate whether Vitamin D status is independently associated with torus fracture status after adjustment for age and sex. Because Vitamin D was measured after injury in the fracture cohort, the analysis was designed to assess association rather than incidence or causality.

MATERIALS AND METHODS

Study Design and Data Source

This retrospective case–control analysis used two de-identified datasets provided as spreadsheets. The case dataset included children with a distal radius torus fracture. The control dataset included pediatric outpatient controls with available serum 25(OH)D measurements. For each child, age (years), sex, and serum 25(OH)D level (ng/mL) were available.

Eligibility Criteria and Fracture Definition

Eligible fracture patients were children who sustained a low-energy injury and were diagnosed with an isolated distal radius torus fracture. Fracture diagnoses were based on radiographic evaluation documented in orthopedic records. Inclusion further required the availability of a laboratory-measured serum 25(OH)D level obtained within 1 month following the date of fracture diagnosis.

Patients were excluded if they were older than 15 years, sustained high-energy trauma, had a known metabolic or systemic disease affecting bone metabolism, presented with multiple fractures, or had associated distal ulna involvement. Children with radiographic patterns other than isolated distal radius torus fractures were not included.

Control Group Selection

The control group was derived from children who underwent serum 25(OH)D testing during routine pediatric outpatient health evaluations. In our institution, serum 25(OH)D measurement is frequently included in pediatric outpatient assessments because hypovitaminosis D is common in the local pediatric population. Controls were not selected because of fracture, bone pain, suspected metabolic bone disease, delayed skeletal development, or delayed fracture healing.

Children were excluded from the control group if they had a history of fracture at the time of assessment, chronic systemic disease, endocrine disorder, malabsorption, renal or hepatic disease, known metabolic bone disease, clinical or radiographic evidence of bone fragility, or medication use known to affect bone metabolism or Vitamin D status. Therefore, although the control cohort was laboratory-selected rather than population-based, we attempted to reduce clinically relevant selection bias by excluding conditions directly related to fracture susceptibility or Vitamin D metabolism.

Vitamin D Sampling Timing

In the fracture group, serum 25(OH)D was obtained at the 3rd week after injury during the routine outpatient follow-up visit. The control group reflected outpatient measurements obtained during routine pediatric evaluation. Because fracture-group measurements were obtained after injury rather than before fracture occurrence, the measured 25(OH)D values cannot be assumed to represent pre-injury baseline Vitamin D status with certainty.

Vitamin D Status Definitions

We defined Vitamin D deficiency as 25(OH)D <20 ng/mL and insufficiency as 20–29 ng/mL, consistent with commonly used clinical thresholds in pediatric practice and recent guidance. Because optimal cut-points vary by population, season, assay, and age, we also analyzed 25(OH)D as a continuous variable.[2,3]

Statistical Analysis

Continuous variables are reported as median with interquartile range (IQR) and mean with standard deviation. Categorical variables are reported as counts and percentages. Between-group comparisons used the Mann–Whitney U test for continuous variables and the Chi-square test for categorical variables. Multivariable logistic regression analysis was performed to eliminate the potential confounding effects of age and sex while assessing the association between Vitamin D levels and torus fracture status.

In response to the observed sex imbalance between groups, an exploratory post hoc sex-stratified subgroup analysis was performed. Within boys and girls separately, serum 25(OH)D levels were compared between fracture patients and controls using the Mann–Whitney U test. Age-adjusted logistic regression models were also fitted within each sex stratum using serum 25(OH)D as a continuous variable. These subgroup analyses were intended as sensitivity analyses to evaluate the robustness and direction of the main finding rather than to establish causality. Statistical significance was defined as $p<0.05$ (two-sided). All analyses were performed using IBM Statistical Package for the Social Sciences Statistics version 22 software for Windows (IBM Corp., NY, USA).

Ethics

This study was approved by the Institutional Review Board of Metin Sabanci Baltalimani Bone Diseases Training and Research Hospital (IRB approval number: 44-359, date: November 26, 2025). All procedures were conducted in accordance with the principles of the Declaration of Helsinki.

RESULTS

Study Population

A total of 741 children were analyzed: 236 with distal radius torus fractures and 505 pediatric outpatient controls. Age did not differ significantly between groups (median 11.0 years [IQR=8.0–13.0] in fracture patients versus median 10.0 years [IQR=7.0–14.0] in controls; p=0.448). Sex distribution differed markedly, with a higher proportion of males in the fracture group (64.4%) compared with controls (34.7%) (p<0.001) (Table 1).

Serum 25(OH)D Comparisons

Median serum 25(OH)D was higher in the torus fracture group than in controls (23.0 [IQR=16.8–30.3] vs. 18.4 [IQR=13.1–26.6] ng/mL; p<0.001). Vitamin D deficiency (<20 ng/mL) was present in 35.6% of fracture patients and 55.6% of controls, whereas sufficiency (≥30 ng/mL) was present in 28.4% and 19.0%, respectively (Table 1).

Multivariable Analysis

In the adjusted continuous model, serum 25(OH)D was not independently associated with torus fracture status (adjusted odds ratio [OR]/10 ng/mL 1.08, 95% CI=0.95–1.23; p=0.262). Male sex was strongly associated with torus fracture (adjusted OR=3.35, 95% CI=2.41–4.66; p<0.001), whereas age was not significant (adjusted OR=0.98, 95% CI=0.94–1.02; p=0.289).

In the adjusted categorical model using Vitamin D deficiency as the reference, both insufficiency and sufficiency were associated with higher odds of being a fracture case (insufficient: Adjusted OR=2.22, 95% CI=1.52–3.26; p<0.001; sufficient: adjusted OR=1.95, 95% CI=1.28–2.95; p=0.002) (Table 2). This direction was opposite to the hypothesis that Vitamin D deficiency increases torus fracture susceptibility and was therefore interpreted cautiously as likely reflecting residual confounding, control-group selection, and categorization effects rather than a biologically causal effect of higher Vitamin D status.

Exploratory Sex-Stratified Subgroup Analysis

Because sex distribution differed substantially between groups, exploratory sex-stratified analyses were performed. Among boys, median 25(OH)D was 23.2 (IQR=17.3–30.3) ng/mL in fracture patients and 19.5 (IQR=12.1–32.8) ng/mL in controls (p=0.067). Vitamin D deficiency was observed in

Table 1. Baseline demographic characteristics and Vitamin D status of the study groups

Variable	Torus fracture (n=236)	Outpatient controls (n=505)	p
Age (years), median (IQR)	11.0 (8.0–13.0)	10.0 (7.0–14.0)	0.448
Male sex, n (%)	152 (64.4)	175 (34.7)	<0.001
25(OH)D (ng/mL), median (IQR)	23.0 (16.8–30.3)	18.4 (13.1–26.6)	<0.001
Vitamin D deficient (<20 ng/mL), n (%)	84 (35.6)	281 (55.6)	
Vitamin D insufficient (20–29.9 ng/mL), n (%)	85 (36.0)	128 (25.3)	
Vitamin D sufficient (≥30 ng/mL), n (%)	67 (28.4)	96 (19.0)	<0.001

IQR: Interquartile range.

Table 2. Multivariable logistic regression analysis for predictors of distal radius torus fracture. Model A analyzes serum 25(OH)D as a continuous variable. Model B analyzes Vitamin D categories with deficiency as the reference category. The categorical model is presented for transparency and should be interpreted cautiously because the direction of association likely reflects residual confounding and control-group selection rather than a causal effect of higher Vitamin D status

Model	Predictor	Adjusted OR	95% CI	p
Model A: Continuous 25(OH)D	25(OH)D, per 10 ng/mL increase	1.08	0.95–1.23	0.262
Model A: Continuous 25(OH)D	Male sex	3.35	2.41–4.66	<0.001
Model A: Continuous 25(OH)D	Age, per 1 year	0.98	0.94–1.02	0.289
Model B: categorical Vitamin D	Insufficient versus deficient	2.22	1.52–3.26	<0.001
Model B: Categorical Vitamin D	Sufficient versus deficient	1.95	1.28–2.95	0.002
Model B: Categorical Vitamin D	Male sex	3.34	2.40–4.66	<0.001
Model B: Categorical Vitamin D	Age, per 1 year	0.98	0.94–1.02	0.392

CI: Confidence interval; OR: Odds ratio.

Table 3. Exploratory sex-stratified subgroup analysis. Within each sex stratum, serum 25(OH)D levels were compared between fracture patients and outpatient controls. Age-adjusted ORs are reported per 10 ng/mL increase in serum 25(OH)D

Sex	Group	n	25(OH)D median (IQR), ng/mL	Deficiency <20 ng/mL, n (%)	Between-group p	Age-adjusted OR/ 10 ng/mL (95% CI)	p
Boys	Torus fracture	152	23.2 (17.3–30.3)	52 (34.2)	0.067	1.01 (0.87–1.18)	0.889
Boys	Outpatient controls	175	19.5 (12.1–32.8)	90 (51.4)			
Girls	Torus fracture	84	20.2 (16.3–30.5)	32 (38.1)	0.004	1.38 (1.06–1.81)	0.018
Girls	Outpatient controls	330	18.0 (13.7–24.9)	191 (57.9)			

CI: Confidence interval; OR: Odds ratio.

52 of 152 boys with fractures (34.2%) and 90 of 175 male controls (51.4%). In an age-adjusted logistic regression model limited to boys, 25(OH)D was not associated with fracture status (adjusted OR/10 ng/mL 1.01, 95% CI=0.87–1.18; p=0.889).

Among girls, median 25(OH)D was 20.2 (IQR=16.3–30.5) ng/mL in fracture patients and 18.0 (IQR=13.7–24.9) ng/mL in controls (p=0.004). Vitamin D deficiency was observed in 32 of 84 girls with fractures (38.1%) and 191 of 330 female controls (57.9%). In an age-adjusted logistic regression model limited to girls, higher 25(OH)D was associated with higher odds of being a fracture case (adjusted OR/10 ng/mL 1.38, 95% CI=1.06–1.81; p=0.018). This subgroup finding was opposite to a Vitamin D deficiency risk hypothesis and was interpreted as further evidence that the observed differences should not be considered causal, particularly given the laboratory-selected control cohort (Table 3).

DISCUSSION

In this study, children with distal radius torus fractures did not demonstrate lower measured 25(OH)D concentrations than pediatric outpatient controls. The unadjusted comparison showed higher median 25(OH)D in the fracture group; however, 25(OH)D as a continuous variable was not an independent predictor of torus fracture after adjustment for age and sex. These data should therefore be interpreted as an association analysis within a laboratory-selected cohort.

The broader pediatric literature suggests that low Vitamin D may be associated with certain fracture outcomes, although causality and fracture-specific effects remain debated. A recent systematic review and meta-analysis reported an association between lower 25(OH)D and fracture risk in children and adolescents, but with heterogeneity across populations, fracture types, and study designs.[4] Separately, prospective work during fracture healing has documented a high prevalence of deficiency or insufficiency at injury presentation and suggests that supplementation can normalize levels over follow-up, with uncertain implications for healing quality in routine low-risk fractures.[6]

The validity of the control group is central to interpretation. Although the controls were selected from routine pediatric outpatient evaluations and children with fracture history, metabolic bone disease, chronic systemic illness, and medication use affecting Vitamin D metabolism were excluded, the control group was not population-based. Since serum 25(OH)D testing is itself a selection process, the lower 25(OH)D values observed in controls may partly reflect laboratory-selection effects rather than true differences between the background pediatric population and children with torus fractures. This limitation is important and precludes causal inference.

The exploratory sex-stratified analyses were added to address the marked sex imbalance between groups. These analyses did not show lower Vitamin D levels among fracture patients in either boys or girls. Among boys, the age-adjusted association between 25(OH)D and fracture status was null. Among girls, fracture cases had higher measured 25(OH)D than controls, again in the opposite direction to the clinical hypothesis that Vitamin D deficiency increases susceptibility to torus fracture. This pattern supports a cautious interpretation: the paradoxical categorical model and subgroup findings are more plausibly explained by residual confounding, laboratory-selected controls, and unmeasured determinants of Vitamin D status than by a protective effect of deficiency or a harmful effect of higher Vitamin D levels.

Timing of sampling is another major methodological constraint. In the fracture cohort, Vitamin D was measured at the 3rd week after injury rather than at presentation or before injury. This timing may reduce the influence of any immediate acute-phase response but does not eliminate uncertainty regarding baseline Vitamin D status. Post-injury behavioral changes, temporary supplementation, reduced outdoor activity, altered diet, or family and clinician recommendations may influence measured 25(OH)D concentrations. In addition, Vitamin D may behave as a negative acute-phase reactant in some contexts, so values obtained after trauma may not perfectly represent pre-injury exposure.[9,10]

Our findings may also reflect the biology of torus fractures. These injuries represent stable compressive failures at the metaphyseal cortex and typically occur after low-energy falls

on an outstretched hand in children with otherwise normal bone. In contrast to fragility fractures or fractures associated with chronic disease, a torus fracture does not necessarily signal impaired mineralization.[11] Accordingly, current evidence supports minimalist treatment pathways for buckle fractures, emphasizing comfort-based immobilization and rapid return to function.[12-14]

Clinically, Vitamin D testing may still be appropriate in selected scenarios: recurrent fractures, low-energy fractures disproportionate to the trauma mechanism, history suggestive of nutritional deficiency, limited sun exposure, obesity, malabsorption, chronic inflammatory disease, anticonvulsant use, or radiographic signs of osteopenia. In such cases, identifying and correcting deficiencies is consistent with musculoskeletal health optimization and may be particularly relevant when fracture healing is delayed or when operative fixation is contemplated.[2,3,6,15]

An additional consideration is background vitamin D status in the local pediatric population. Contemporary Turkish datasets demonstrate that suboptimal 25(OH)D is common and varies by age and sex, with lower values in adolescents and in girls in several cohorts.[16-18] This high baseline prevalence increases the likelihood that low vitamin D will be encountered incidentally in both injured and non-injured children, underscoring the importance of interpreting 25(OH)D in a clinical context rather than attributing causality to a stable minor fracture pattern. Although this approach ensured methodological consistency within the same healthcare system, the control cohort may not fully represent a population-based pediatric sample.[19,20]

The retrospective design of the study and reliance on de-identified laboratory spreadsheets precluded adjustment for important determinants of serum 25(OH)D, including season of sampling, latitude, sun exposure, body mass index, dietary intake, supplementation status, socioeconomic factors, and ethnicity are also crucial limitations. These are non-trivial confounders in Vitamin D research, and their absence limits causal interpretation.

Although controls were selected from routine pediatric outpatient evaluations and children with conditions directly affecting bone or vitamin D metabolism were excluded, the control group was not population-based. Therefore, residual selection bias cannot be excluded. Moreover, fracture-group 25(OH)D levels were measured at the 3rd week after injury, and pre-injury baseline Vitamin D status could not be confirmed. Fourth, the sex-stratified analyses were exploratory and post hoc; they were intended to evaluate robustness and direction of effect rather than to provide definitive subgroup-specific causal estimates. Fifth, detailed information regarding injury mechanisms was unavailable beyond the exclusion of high-energy trauma and multiple fractures. Finally, the analysis was limited to isolated distal radius torus fractures, and the findings may not be generalizable to other pediatric fracture patterns, particularly those associated with higher-energy mechanisms or underlying bone pathology.

CONCLUSION

In this laboratory-selected retrospective case–control cohort, children with isolated distal radius torus fractures did not have lower measured serum 25(OH)D levels than outpatient controls, and 25(OH)D as a continuous variable was not independently associated with torus fracture status after adjustment for age and sex. These results do not support routine Vitamin D testing solely on the basis of an isolated torus fracture in an otherwise healthy child, but screening remains appropriate when clinical risk factors for Vitamin D deficiency or metabolic bone disease are present.

Ethics Committee Approval: This study was approved by the Institutional Review Board of Metin Sabanci Baltalimani Bone Diseases Training and Research Hospital (Date: 26.11.2025, Decision No: 44-359).

Informed Consent: This study retrospective case–control analysis.

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: S.G., K.F.G.; Design: S.G., G.P.; Supervision: G.P.; Resource: B.G.; Materials: M.M.Ç., C.B.Ö.; Data collection and/or processing: M.M.Ç., C.B.Ö., S.G.; Analysis and/or interpretation: S.G.; Literature review: B.G.; Writing: S.G.; Critical review: G.P.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Çocuk distal radius torus kırıklarında serum 25-hidroksivitamin D düzeyleri: Bir olgu-kontrol çalışması

AMAÇ: D vitamini kemik mineralizasyonunda önemli roy oynar; ancak çocuklarda distal radius torus kırıkları ile ilişkisi belirsizdir. Bu çalışmada D vitamini düzeyleri ile distal radius torus kırıkları arasındaki ilişki incelenecektir.

GEREÇ VE YÖNTEM: Distal radius torus kırığı olan çocuklar (n=236) ile pediatrik ayaktan hasta kontrol grubu (n=505) serum 25-hidroksivitamin D [25(OH)D] düzeyleri karşılaştırıldı. Analizler; yaş, cinsiyet ve 25(OH)D (ng/mL) verileri üzerinden yapıldı. Kontrol grubundaki bireylerde serum 25(OH)D ölçümü, rutin pediatrik ayaktan sağlık değerlendirmeleri sırasında gerçekleştirilmiş olup; bu bireyler kırık, kemik ağrısı, metabolik kemik hastalığı şüphesi veya gecikmiş kırık iyileşmesi dışlanarak dahil edilmişlerdir. Kırık hastaları grubunda ise 25(OH)D düzeyi, yaralanmadan sonraki üçüncü haftada ayaktan takip sürecinde ölçülmüştür. Gruplar arası karşılaştırmalarda Mann–Whitney U ve ki-kare testleri kullanıldı. Yaş ve cinsiyet ile ilişkilerin değerlendirilmesi amacıyla çok değişkenli lojistik regresyon analizi uygulanmıştır. Ayrıca, ek olarak keşifsel bir alt grup analizi gerçekleştirilmiştir.

BULGULAR: Medyan 25(OH)D düzeyi kırık hastalarında 23.0 (IQR 16.8–30.3) ng/mL, kontrollerde 18.4 (IQR 13.1–26.6) ng/mL idi (p<0.001). D vitamini eksikliği (<20 ng/mL) sırasıyla %35.6 ve %55.6 oranında saptandı. Düzeltme sonrası 25(OH)D düzeyi torus kırığı ile bağımsız olarak ilişkili değildi (10 ng/mL artış için düzeltilmiş OR 1.08, %95 GA 0.95–1.23; p=0.262). Buna karşılık erkek cinsiyet torus kırığı için güçlü bir öngördürücüydü (düzeltilmiş OR 3.35, %95 GA 2.41–4.66; p<0.001).

SONUÇ: Bu çalışmada, distal radius torus kırığı bulunan çocukların ölçülen 25(OH)D düzeylerinin ayaktan hasta kontrol grubuna kıyasla daha düşük olmadığı saptanmıştır. Elde edilen sonuçlar, izole bir torus kırığı varlığına dayanılarak rutin vitamin D testinin yapılmasını desteklememektedir; ancak tarama yaklaşımı bireysel klinik risk faktörleri doğrultusunda sürdürülmelidir.

Anahtar sözcükler: 25-hidroksivitamin D; D vitamini; distal radius; pediatri; torus kırığı.

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ORIGINAL ARTICLE

Three-year emergency department analysis of clavicle fractures: Age- and sex-dependent patterns and associated injuries

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ABSTRACT

BACKGROUND: This study aimed to evaluate the demographic and clinical characteristics of adult patients presenting to the emergency department (ED) with clavicle fractures, describe the distribution of concomitant thoracic injuries, and identify factors independently associated with rib fracture and hemothorax/pneumothorax.

METHODS: This single-center retrospective observational study included consecutive adult patients presenting to the ED with acute traumatic clavicle fractures between January 1, 2022, and January 1, 2025. Patients were identified through the Hospital Medical Record System using the ICD-10 code S42.0, and 687 of 828 screened ED encounters were included in the final analysis. Demographic characteristics, injury mechanisms, fracture patterns, associated injuries, treatment approaches, and ED outcomes were retrospectively reviewed. Trauma mechanisms were classified as low-energy or high-energy. Multivariable logistic regression analyses were performed to identify factors associated with rib fracture and hemothorax/pneumothorax.

RESULTS: Of the 687 patients, 85.2% (n=585) were younger than 65 years. High-energy trauma mechanisms and midshaft fractures were more common in younger patients, whereas low-energy trauma with medial/lateral fractures predominated in older patients (p<0.001). Rib fracture (19.7% vs. 7.6%, p=0.005) and hemothorax/pneumothorax (12.4% vs. 3.3%, p=0.009) were significantly more frequent in male patients. Multivariable analysis revealed that increasing age (adjusted odds ratio [aOR]: 1.02, 95% confidence interval [CI]: 1.01–1.03, p<0.001), male sex (aOR: 3.08, 95% CI: 1.29–7.33, p=0.011), high-energy trauma (aOR: 3.28, 95% CI: 1.89–5.70, p<0.001), and medial (sternal) fracture location (aOR: 2.81, 95% CI: 1.11–7.10, p=0.029) were independently associated with rib fracture. For hemothorax/pneumothorax, increasing age (aOR: 1.03, 95% CI: 1.02–1.05, p<0.001) and high-energy trauma (aOR: 8.51, 95% CI: 3.53–20.49, p<0.001) were independently associated.

CONCLUSION: Clavicle fractures demonstrated varying clinical and traumatic characteristics across different age and sex groups. Increasing age, male sex, high-energy trauma, and medial clavicle fractures were associated with rib fractures, whereas increasing age and high-energy trauma were associated with hemothorax/pneumothorax. Combined evaluation of trauma mechanism, patient characteristics, and fracture pattern may help identify patients at increased risk for concomitant thoracic injuries in the ED.

Keywords: Clavicle fracture; emergency department; pneumothorax; rib fracture; risk factors; thoracic trauma.

INTRODUCTION

Clavicle fractures account for approximately 44% of all shoulder girdle fractures and 2.6–3.3% of all orthopedic fractures.[1,2] Due to their high frequency in both adult and pediatric populations, these fractures represent a common injury encountered in orthopedic and emergency medicine practice.[3-5] The most common mechanisms include motor vehicle ac-

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cidents, falls, and sports-related injuries.[5-7]

Clavicle fractures are generally isolated injuries; however, they may occur in association with trauma to adjacent anatomical structures such as the thorax, major vascular structures, or the brachial plexus.[8] Previous studies have reported that thoracic injuries frequently accompany clavicle fractures and may complicate clinical management.[8,9] Injuries such as rib fractures, pneumothorax, and hemothorax may reflect greater trauma severity and may also increase the need for additional imaging, close monitoring, and hospital admission.[9-11]

Although clavicle fractures are often managed as isolated injuries in the emergency department (ED), associated thoracic injuries may have significant clinical consequences. Thoracic trauma has been associated with higher morbidity, prolonged hospitalization, and increased complication rates, particularly in older patients.[10-12] However, real-world data regarding associated injury patterns and clinical factors related to thoracic injuries in patients with clavicle fractures remain limited.[4,9] Most previous studies have primarily focused on specific complications or surgical treatment outcomes.[9]

Early recognition of thoracic injuries is clinically important for imaging strategies, patient monitoring, and disposition decisions in the ED.[8,13,14] This study aimed to evaluate the demographic and clinical characteristics of adult patients presenting to the ED with clavicle fractures, assess the distribution of concomitant thoracic injuries, and identify factors associated with rib fractures and pneumothorax/hemothorax.

MATERIALS AND METHODS

Study Design and Setting

This single-center retrospective observational study was conducted on patients diagnosed with clavicle fractures who presented to the ED of Bakırköy Dr. Sadi Konuk Training and Research Hospital between January 1, 2022, and January 1, 2025. Adult patients diagnosed with clavicle fractures in the ED were identified through the electronic medical record system. Bakirkoy Dr. Sadi Konuk Training and Research Hospital Non-Interventional Scientific Research Ethics Committee ethics committee approval was obtained for the study (Date: 23.07.2025, Decision no: 2025-13-31). Due to the retrospective nature of the study, individual informed consent was not obtained. All data were anonymized before analysis, collected using a standardized data collection form, and patient confidentiality was maintained in accordance with the Declaration of Helsinki.

Participants

Patients were identified through the hospital information management system using the International Classification of Diseases, 10th Revision (ICD-10) code S42.0 for clavicle fracture. Eligible participants were adults aged 18 years or older who were diagnosed with acute traumatic clavicle fractures in the ED. Diagnoses were confirmed by correlating clinical records with radiological reports, including plain radiography and/or computed tomography (CT). In cases of repeated presentations related to the same injury, only the index ED visit was included in the analysis. Of 828 screened ED encounters, 687 (83.0%) met the inclusion criteria and were analyzed. A total of 128 (15.5%) encounters involving patients younger than 18 years, 1 (0.1%) case with pathological/iatrogenic fracture, and 12 (1.4%) records with missing essential data were excluded (Fig. 1). Records with missing essential data were excluded from the analysis, and a complete-case analysis approach was used.

Data Collection

All study data were systematically obtained using a standardized data collection form. Recorded variables included age, sex, date and time of presentation, mode of admission (ambulance or self-presented), trauma mechanism, clavicle fracture characteristics (comminution, displacement status, and anatomical localization), associated injuries, treatment approach (conservative or surgical), and ED outcomes such as hospitalization and discharge.

Trauma mechanisms were predefined as low-energy trauma (ground-level falls) and high-energy trauma (bicycle/scooter and sports-related injuries, motor vehicle accidents, motorcycle accidents, pedestrian injuries, assault, and falls from a height of ≥1 m).

Associated thoracic injuries were identified using radiology

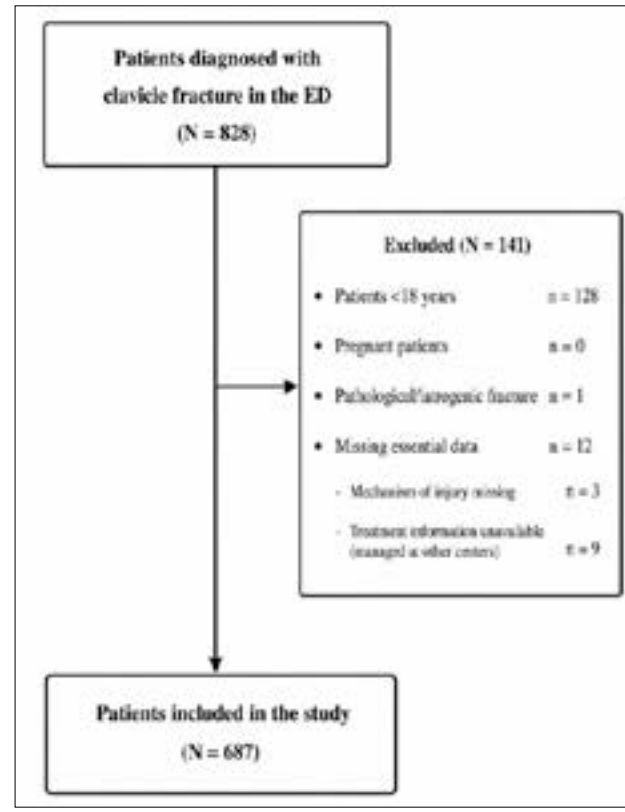

Figure 1. Study selection flow diagram.

reports generated during the index ED visit. Initial imaging assessment was generally performed using plain radiography, whereas thoracic CT was ordered based on the clinical judgment of the attending emergency physician, particularly in patients with high-energy trauma or suspected thoracic injury. Diagnoses of rib fracture, pneumothorax, and/or hemothorax were confirmed based on official radiology reports. Only radiologically confirmed thoracic injuries were included in the analysis. Associated injuries also included long bone fractures, craniofacial fractures, neurological injuries, and visceral injuries. Pathological and iatrogenic fractures were excluded based on clinical evaluation and radiology/oncology records.

Study Outcomes

The primary aim of the study was to evaluate the demographic and clinical characteristics of patients presenting to the ED with clavicle fractures. Secondary aims were to examine the distribution of associated injuries according to age group and sex, and to identify clinical and trauma-related factors associated with rib fractures and pneumothorax/hemothorax.

Statistical Analysis

Statistical analyses were performed using IBM Statistical Package for the Social Sciences Statistics for Windows version 25.0 (IBM Corp., Armonk, NY, USA) and R version 4.5.1 (R Foundation for Statistical Computing, Vienna, Austria). Con-

Table 1. Demographic, clinical, and injury characteristics by age group

Variable	<65 years (n=585)	≥65 years (n=102)	p
Sex			<0.001#
Female	48 (8.2)	44 (43.1)	
Male	537 (91.8)	58 (56.9)	
Mode of admission			<0.001#
Self-presented	261 (44.6)	24 (23.5)	
EMS	324 (55.4)	78 (76.5)	
Triage category			0.007#
ESI 1	46 (7.9)	3 (2.9)	
ESI 2	116 (19.8)	33 (32.4)	
ESI 3	423 (72.3)	66 (64.7)	
Mechanism of injury			<0.001#
Low-energy trauma†	162 (27.7)	75 (73.5)	
High-energy trauma‡	423 (72.3)	27 (26.5)	
Occupational accident	57 (9.7)	6 (5.9)	0.212#
Domestic accident	60 (10.3)	30 (29.4)	<0.001#
Fracture displacement	423 (72.3)	66 (64.7)	0.118#
Comminuted fracture	297 (50.8)	63 (61.8)	0.040#
Fracture location			0.012#
Medial (sternal)	14 (2.4)	13 (12.7)	
Midshaft	420 (71.8)	43 (42.2)	
Lateral (acromial)	151 (25.8)	46 (45.1)	
Treatment method			0.018#
Conservative	525 (89.7)	99 (97.1)	
Surgical	60 (10.3)	3 (2.9)	
ED outcomes			0.037#
Discharged from ED	444 (75.9)	87 (85.3)	
Hospitalized*⁂	141 (24.1)	15 (14.7)	

Values are presented as n (%) unless otherwise indicated. p-values were calculated using Pearson's Chi-square (#) or Fisher's exact test (*), as appropriate. †Low-energy trauma was defined as ground-level falls. ‡High-energy trauma included fall from height, motor-vehicle accident, motorcycle accident, bicycle/scooter accident, sports injury, assault, and crush injury. ⁂Includes ward and ICU admissions. EMS: Emergency medical services; ED: Emergency department; ESI: Emergency severity index.

tinuous variables were presented as mean±standard deviation or median (interquartile range), as appropriate. Categorical variables were expressed as numbers and percentages. For between-group comparisons, Pearson's chi-square test or Fisher's exact test was used for categorical variables, while the independent samples t-test or Mann–Whitney U test was applied for continuous variables, as appropriate. Comparative analyses were performed according to age group (<65 and ≥65 years) and sex. Multivariable logistic regression analyses using the ENTER method were performed to identify factors independently associated with rib fracture and pneumothorax/hemothorax. Variables were selected based on clinical relevance and previously reported associations in the literature. Adjusted odds ratios (aORs) and 95% confidence intervals (CIs) were calculated. To assess the potential impact of differential imaging utilization on the study findings, a sensitivity analysis restricted to patients who underwent thoracic CT was performed using the same multivariable logistic regression models as in the primary analysis. In addition, to evaluate the potential influence of sparse-data bias, Firth's penalized-likelihood logistic regression analyses were performed for both multivariable models. The events-per-variable ratio was approximately 17.7 for rib fracture and 11.0 for pneumothorax/hemothorax. A two-sided p<0.05 was considered statistically significant.

RESULTS

During the 3-year study period, a total of 687 adult patients presenting to the ED with clavicle fractures were evaluated. The majority of patients were younger than 65 years (n=585, 85.2%). Older patients had a higher proportion of females

Table 2. Demographic, clinical, and injury characteristics of patients aged <65 years by sex

Variable	Female (n=48)	Male (n=537)	p
Age, years	48.5 (21.5–54.0)	31.0 (22.0–42.0)	<0.001§
Mode of admission			0.433#
Self-presented	24 (50.0)	237 (44.1)	
EMS	24 (50.0)	300 (55.9)	
Triage category			0.231#
ESI 1	4 (8.3)	42 (7.8)	
ESI 2	5 (10.4)	111 (20.7)	
ESI 3	39 (81.3)	384 (71.5)	
Mechanism of injury			<0.001
Low-energy trauma†	30 (62.5)	132 (24.6)	
High-energy trauma‡	18 (37.5)	405 (75.4)	
Occupational accident	0	57 (10.6)	0.010*
Domestic accident	12 (25.0)	48 (8.9)	0.002*
Fracture displacement	36 (75.0)	387 (72.1)	0.664#
Comminuted fracture	30 (62.5)	267 (49.7)	0.090#
Fracture location			0.383
Medial (sternal)	0 (0.0)	14 (2.6)	
Midshaft	33 (68.8)	387 (72.1)	
Lateral (acromial)	15 (31.3)	136 (25.3)	
Treatment method			0.460*
Conservative	45 (93.8)	480 (89.4)	
Surgical	3 (6.3)	57 (10.6)	
ED outcomes			0.365#
Discharged from ED	39 (81.3)	405 (75.4)	
Hospitalized⁂	9 (18.7)	132 (24.6)	

Values are presented as n (%) unless otherwise indicated. P-values were calculated using Pearson's Chi-square test (#), Fisher's exact test (*), and Mann-Whitney U test (§), as appropriate. †Low-energy trauma was defined as ground-level falls. ‡High-energy trauma included fall from height, motor-vehicle accident, motorcycle accident, bicycle/scooter accident, sports injury, assault, and crush injury. ⁂Includes ward and ICU admissions. EMS: Emergency medical services, ED: Emergency department; ESI: Emergency severity index.

and were more frequently admitted via emergency medical services (both p<0.001). Thoracic CT was performed in 510 patients (74.2%), whereas 177 patients (25.8%) were evaluated using plain radiography alone. Regarding trauma mechanisms, low-energy trauma predominated among older patients, whereas high-energy trauma was more common in younger patients (p<0.001). In addition, domestic accidents were more common in older patients than in younger patients (29.4% vs. 10.3%, p<0.001).

Fracture characteristics differed significantly between age groups. Comminuted fractures were more common in older patients (61.8% vs. 50.8%, p=0.040), whereas midshaft clavicle fractures were more prevalent among younger patients. In contrast, medial and lateral fracture patterns were observed more frequently in older patients (p=0.012). Regarding treatment approach, conservative management was preferred more often in older patients, whereas surgical treatment was more common among younger patients (p=0.018). Hospitalization rates were higher in younger patients than in older patients (24.1% vs. 14.7%, p=0.037) (Table 1).

Among patients aged <65 years, female patients were significantly older than male patients (median age: 48.5 vs. 31.0 years, p<0.001). Low-energy trauma was more common among females, whereas high-energy trauma predominated in males (p<0.001). Occupational accidents were observed exclusively in male patients (10.6%, p=0.010), while domestic accidents were more frequent among female patients (25.0% vs. 8.9%, p=0.002). No significant sex-related differences were observed regarding fracture characteristics, treatment approach, or ED dispositions in this age group (Table 2). In

Table 3. Demographic, clinical, and injury characteristics of patients aged ≥65 years by sex

Variable	Female (n=45)	Male (n=57)	p
Age, years	76 (74–80)	76 (74–84)	0.361§
Mode of admission			<0.001
Self-presented	3 (6.7)	21 (36.8)	
EMS	42 (93.3)	36 (63.2)	
Triage category			0.295#
ESI 1	0 (0.0)	3 (5.2)	
ESI 2	15 (34.1)	18 (31.0)	
ESI 3	29 (65.9)	37 (63.8)	
Mechanism of injury			0.010#
Low-energy trauma†	38 (86.4)	37 (63.8)	
High-energy trauma‡	6 (13.6)	21 (36.2)	
Occupational accident	3 (6.8)	3 (5.2)	>0.99*
Domestic accident	8 (18.2)	22 (37.9)	0.030#
Fracture displacement	24 (54.5)	42 (72.4)	0.061#
Comminuted fracture	27 (61.4)	36 (62.1)	0.942#
Fracture location			0.183#
Medial (sternal)	6 (13.6)	6 (10.3)	
Midshaft	14 (31.8)	29 (50.0)	
Lateral (acromial)	24 (54.5)	23 (39.7)	
Treatment method			0.257*
Conservative	43 (97.7)	55 (94.8)	
Surgical	1 (2.3)	3 (5.2)	
ED outcomes			0.050#
Discharged from ED	41 (93.2)	46 (79.3)	
Hospitalized⁂	3 (6.8)	12 (20.7)	

Values are presented as n (%) unless otherwise indicated. P-values were calculated using Pearson's Chi-square test (#), Fisher's exact test (*), and Mann-Whitney U test (§), as appropriate. †Low-energy trauma was defined as ground-level falls. ‡High-energy trauma included fall from height, motor-vehicle accident, motorcycle accident, bicycle/scooter accident, sports injury, assault, and crush injury. ⁂Includes ward and ICU admissions. EMS: Emergency medical services, ED: Emergency department; ESI: Emergency severity index.

Table 4. Distribution of associated injuries according to age group and sex in adult patients with clavicle fractures

Variable	<65 years, n (%)	≥65 years, n (%)	p	Female, n (%)	Male, n (%)	p
Skull fracture	21 (3.6)	1 (1.0)	0.229*	4 (4.3)	18 (3.0)	0.520*
Facial fracture	30 (5.1)	2 (2.0)	0.070*	4 (4.3)	28 (4.7)	>0.99*
Hemo/pneumothorax	66 (11.3)	11 (10.8)	0.883#	3 (3.3)	74 (12.4)	0.009#
Sternal fracture	3 (0.5)	0 (0.0)	>0.99*	0 (0.0)	3 (0.5)	>0.99*
Rib fracture	108 (18.5)	16 (15.7)	0.501#	7 (7.6)	117 (19.7)	0.005#
Scapula fracture	36 (6.2)	6 (5.9)	0.916#	2 (2.2)	40 (6.7)	0.090#
Upper extremity fracture†	33 (5.6)	6 (5.9)	0.923#	6 (6.5)	33 (5.5)	0.707#
Lower extremity fracture‡	15 (2.6)	3 (2.9)	0.145*	4 (4.3)	12 (2.0)	0.267*
Spine fracture†	60 (10.3)	8 (7.8)	0.451#	7 (7.6)	61 (10.3)	0.429#
Intracranial hemorrhage	12 (2.1)	0 (0.0)	0.231#	0 (0.0)	12 (2.0)	0.385*
Intra-abdominal visceral injury	12 (2.1)	3 (2.9)	0.477*	3 (3.3)	12 (2.0)	0.438*

Tests were Pearson's chi-square (#) or Fisher's exact (*) as appropriate. Exact counts are given as n (%).†Includes humerus and forearm fractures. ‡Includes femur and tibia/fibula fractures.

Table 5. Sensitivity analysis restricted to patients who underwent thoracic CT (n=510)

Variable	Rib fracture aOR (95% CI)	p	PNX/HMX aOR (95% CI)	p
Age	1.02 (1.01–1.04)	0.001	1.04 (1.02–1.06)	<0.001
Male sex	3.68 (1.54–8.77)	0.003	3.95 (1.13–13.89)	0.032
Comminuted fracture	0.92 (0.55–1.54)	0.757	0.73 (0.39–1.37)	0.320
Fracture displacement	0.98 (0.53–1.81)	0.937	1.25 (0.56–2.76)	0.590
High-energy trauma	2.26 (1.20–4.24)	0.012	8.06 (2.98–21.74)	<0.001
Fracture localization	–	0.105	–	0.037
Sternal versus acromial	2.63 (1.04–6.62)	0.041	0.45 (0.05–3.70)	0.456
Shaft versus acromial	1.39 (0.82–2.37)	0.223	2.22 (1.11–4.44)	0.025

Reference categories were female sex, low-energy trauma, absence of comminution, absence of fracture displacement, and acromial fracture localization. aOR: Adjusted odds ratio; CI: Confidence interval; PNX: Pneumothorax; HMX: Hemothorax; CT: Computed tomography.

the ≥65-year age group, domestic accidents were more frequent among older male patients (37.9% vs. 18.2%, p=0.030). Hospitalization rates were also higher in older male patients (20.7% vs. 6.8%, p=0.050). No significant sex-related differences were observed regarding other demographic, clinical, or fracture-related characteristics (Table 3).

Thoracic injuries were among the most common associated injuries accompanying clavicle fractures. Rib fractures were identified in 18.5% of patients aged <65 years and 15.7% of those aged ≥65 years (p=0.501). Hemothorax/pneumothorax rates were 11.3% and 10.8% in younger and older patients, respectively (p=0.883). In sex-based analyses, rib fractures (19.7% vs. 7.6%, p=0.005) and hemothorax/pneumothorax (12.4% vs. 3.3%, p=0.009) were significantly more common in male patients than in female patients. Other associated injury patterns were similar across age groups and between sexes (Table 4).

Multivariable logistic regression analyses identified several clinical and trauma-related factors independently associated with rib fracture and hemothorax/pneumothorax (Fig. 2). Increasing age (aOR: 1.02, 95% CI: 1.01–1.03, p<0.001), male sex (aOR: 3.08, 95% CI: 1.29–7.33, p=0.011), high-energy trauma (aOR: 3.28, 95% CI: 1.89–5.70, p<0.001), and medial (sternal) fracture location (aOR: 2.81, 95% CI: 1.11–7.10, p=0.029) were independently associated with rib fracture. For hemothorax/pneumothorax, increasing age (aOR: 1.03, 95% CI: 1.02–1.05, p<0.001) and high-energy trauma (aOR: 8.51, 95% CI: 3.53–20.49, p<0.001) were identified as independent risk factors. No independent association was observed between hemothorax/pneumothorax and male sex,

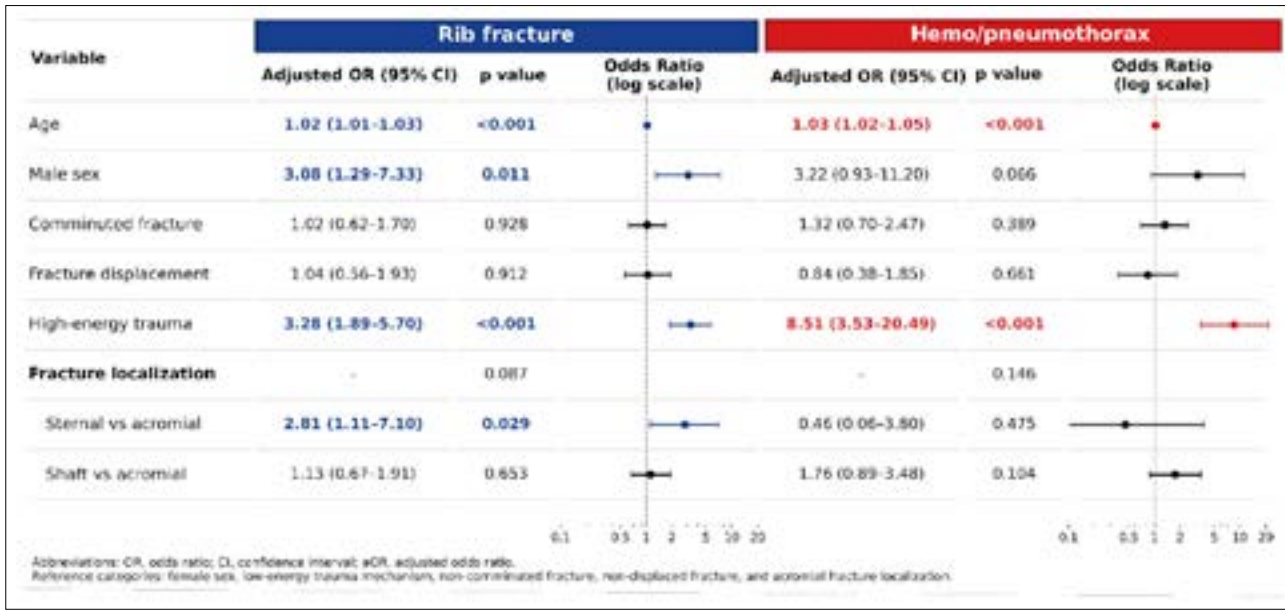

Figure 2. Adjusted odds ratios for rib fracture and pneumothorax/hemothorax according to clinical and trauma characteristics.

Table 6. Firth penalized logistic regression analyses for factors associated with rib fracture and pneumothorax/hemothorax

Variable	Rib fracture aOR (95% CI)	p	PNX/HMX aOR (95% CI)	p
Age	1.02 (1.01–1.03)	<0.001	1.03 (1.02–1.05)	<0.001
Male sex	2.89 (1.32–7.22)	0.007	2.82 (0.99–10.85)	0.053
Comminuted fracture	1.02 (0.62–1.70)	0.946	1.30 (0.71–2.46)	0.409
Fracture displacement	1.04 (0.56–1.92)	0.911	0.84 (0.38–1.85)	0.654
High-energy trauma	3.19 (1.88–5.61)	<0.001	7.83 (3.54–19.86)	<0.001
Sternal versus acromial	2.80 (1.10–6.82)	0.031	0.66 (0.07–2.98)	0.630
Shaft versus acromial	1.12 (0.67–1.90)	0.673	1.72 (0.89–3.45)	0.106

Reference categories were female sex, low-energy trauma, absence of comminution, absence of fracture displacement, and acromial fracture localization. aOR: Adjusted odds ratio; CI: Confidence interval; PNX: Pneumothorax; HMX: Hemothorax.

fracture displacement, comminuted fracture pattern, or fracture location (Fig. 2). To assess the potential impact of differential imaging utilization, a sensitivity analysis restricted to patients who underwent thoracic CT was performed using the same multivariable models. The findings were generally consistent with those of the primary analysis (Table 5). Additional analyses using Firth's penalized-likelihood logistic regression yielded results that were largely consistent with those of the primary multivariable models (Table 6).

DISCUSSION

This single-center, 3-year study demonstrated age- and sex-related differences in the clinical characteristics, fracture patterns, and concomitant thoracic injuries of adult patients presenting to the ED with clavicle fractures. Our findings suggest that clavicle fractures may not always represent isolated upper extremity injuries and may indicate a broader trauma burden, particularly following high-energy trauma. High-energy trauma mechanisms and midshaft fractures were more common in younger patients, whereas low-energy trauma and medial or lateral fracture patterns were more prevalent among older patients. These findings suggest that both the mechanism of injury and age-related changes in bone structure may influence clavicle fracture patterns.[7,15]

A strength of our study is the combined evaluation of age- and sex-stratified findings and factors independently associated with thoracic injuries in a real-world ED cohort. Previous studies have similarly reported that concomitant thoracic injuries are more common following high-energy trauma in patients with clavicle fractures. Amer et al.[8] reported associated thoracic injuries in 23.6% of patients with clavicle fractures, whereas Lewis et al.[9] reported pneumothorax rates

ranging from 15% to 25%, particularly following high-energy trauma.[8,9] Consistent with these studies, our findings indicate that high-energy trauma is associated with a greater likelihood of concomitant thoracic injuries. However, because thoracic CT was performed selectively, these associations should be interpreted with appropriate caution.

Increasing age, male sex, and medial fracture location were identified as independent factors associated with rib fractures. Despite the predominance of low-energy trauma among older patients, the occurrence of thoracic injuries in this population may be related to age-related bone fragility and structural changes in the thoracic wall.[16-18] Even relatively low-energy trauma may result in thoracic injury in patients with osteoporotic or otherwise fragile bone structure. The higher frequency of thoracic injuries observed among male patients may partly reflect the greater prevalence of high-energy trauma mechanisms in males.[4,7] However, these interpretations are limited by the absence of data on bone mineral density, frailty, and objective trauma severity.

Thoracic injuries represented one of the most frequent categories of associated trauma in our study. Rib fractures occurred in approximately one in six patients, while hemothorax/pneumothorax also occurred at clinically relevant rates. These findings highlight the importance of systematic thoracic assessment, particularly following high-energy trauma.[13,14] In ED practice, the integrated evaluation of trauma mechanism, patient age, and fracture location may help identify patients who could benefit from more detailed thoracic imaging. Because thoracic CT was selectively performed according to clinical judgment, we conducted a sensitivity analysis restricted to patients who underwent thoracic CT. The findings were generally consistent with those of the primary analysis, supporting the robustness of the observed associations. Nevertheless, because CT utilization was not standardized, residual detection bias cannot be completely excluded, and the findings should therefore be interpreted cautiously.

The treatment strategy in our study was predominantly conservative, while surgical intervention was more frequently performed in younger patients. This finding is partially discordant with reports from high-income countries showing an increasing trend toward operative management, particularly for displaced midshaft fractures.[19,20] Although surgical fixation may reduce the risk of non-union and facilitate earlier functional recovery in selected patients, evidence supporting its long-term functional superiority remains limited.[21,22] Accordingly, current guidelines recommend individualized treatment decisions based on fracture pattern, patient expectations, comorbidities, functional requirements, and the risk of complications.[23] Our findings indicate that conservative management remains the predominant treatment approach, particularly among older patients presenting after low-energy trauma.

Several limitations of this study warrant consideration. First, the retrospective and single-center design precludes the complete exclusion of selection bias and missing data. Furthermore, because thoracic CT was not routinely performed in all patients and was instead obtained according to clinical judgment, some small pneumothoraces or non-displaced rib fractures may have been underdetected. Although sensitivity analyses restricted to patients who underwent thoracic CT yielded findings generally consistent with the primary analyses, the possibility of residual detection bias cannot be completely excluded. The unavailability of trauma severity scores, osteoporosis status, and frailty assessments constitutes an additional important limitation. Moreover, because the study was conducted at a tertiary care hospital, selection bias toward patients with more severe trauma may have occurred, potentially limiting the generalizability of our findings. Finally, although additional Firth penalized regression analyses produced results comparable to those of the primary models, some degree of sparse-data bias may still persist.

CONCLUSION

In this study, clavicle fractures demonstrated varying clinical and traumatic characteristics across different age and sex groups. High-energy trauma and midshaft fractures were more common in younger patients, whereas low-energy trauma and medial clavicle fracture patterns were more frequently observed in older patients. In addition, increasing age, male sex, high-energy trauma, and medial clavicle fractures were associated with rib fractures, while increasing age and high-energy trauma were associated with hemothorax/pneumothorax. These findings suggest that the combined evaluation of trauma mechanism, patient characteristics, and fracture pattern may help identify patients at increased risk for concomitant thoracic injuries in the ED.

Ethics Committee Approval: This study was approved by the Bakirkoy Dr. Sadi Konuk Training And Research Hospital Non-Interventional Scientific Research Ethics Committee (Date: 23.07.2025, Decision No: 2025-13-31).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Klavikula kırıklarının acil serviste üç yıllık analizi: Yaş ve cinsiyete bağlı kalıplar ve ilişkili yaralanmalar

AMAÇ: Bu çalışmanın amacı, acil servise klavikula kırığı ile başvuran erişkin hastaların demografik ve klinik özelliklerini değerlendirmek, eşlik eden torasik yaralanmaların dağılımını tanımlamak ve kaburga kırığı ile hemotoraks/pnömotoraks ile bağımsız ilişkili faktörleri belirlemektir.

GEREÇ VE YÖNTEM: Bu tek merkezli retrospektif gözlemsel çalışma, 1 Ocak 2022 ile 1 Ocak 2025 tarihleri arasında akut travmatik klavikula kırığı ile acil servise başvuran ardışık erişkin hastaları içermektedir. Hastalar, ICD-10 S42.0 kodu kullanılarak Hastane Tıbbi Kayıt Sistemi üzerinden belirlendi ve taranan 828 acil servis başvurusunun 687'si nihai analize dahil edildi. Demografik özellikler, yaralanma mekanizmaları, kırık paternleri, eşlik eden yaralanmalar, tedavi yaklaşımları ve acil servis sonlanımları retrospektif olarak değerlendirildi. Travma mekanizmaları düşük enerjili veya yüksek enerjili olarak sınıflandırıldı. Kaburga kırığı ve hemotoraks/pnömotoraks ile ilişkili faktörleri belirlemek amacıyla çok değişkenli lojistik regresyon analizleri yapıldı.

BULGULAR: Altı yüz seksen yedi hastanın %85.2'si (n=585) 65 yaşın altındaydı. Yüksek enerjili travma mekanizmaları ve midshaft kırıklar genç hastalarda daha sık görülürken, düşük enerjili travma ile birlikte medial/lateral kırıklar yaşlı hastalarda daha baskındı ($p<0.001$). Kaburga kırığı (%19.7'ye karşı %7.6, $p=0,005$) ve hemotoraks/pnömotoraks (%12.4'e karşı %3.3, $p=0.009$) erkek hastalarda anlamlı olarak daha sık görüldü. Çok değişkenli analizde artan yaş (aOR: 1.02, %95 GA: 1.01–1.03, $p<0.001$), erkek cinsiyet (aOR: 3.08, %95 GA: 1.29–7.33, $p=0.011$), yüksek enerjili travma (aOR: 3.28, %95 GA: 1.89–5.70, $p<0.001$) ve medial (sternal) kırık lokalizasyonu (aOR: 2.81, %95 GA: 1.11–7.10, $p=0.029$) kaburga kırığı ile bağımsız ilişkili bulundu. Hemotoraks/pnömotoraks için ise artan yaş (aOR: 1.03, %95 GA: 1.02–1.05, $p<0.001$) ve yüksek enerjili travma (aOR: 8.51, %95 GA: 3.53–20.49, $p<0.001$) bağımsız ilişkili bulundu.

SONUÇ: Klavikula kırıkları farklı yaş ve cinsiyet gruplarında değişken klinik ve travmatik özellikler göstermiştir. Artan yaş, erkek cinsiyet, yüksek enerjili travma ve medial klavikula kırıkları kaburga kırıkları ile ilişkili bulunurken, artan yaş ve yüksek enerjili travma hemotoraks/pnömotoraks ile ilişkiliydi. Travma mekanizması, hasta özellikleri ve kırık paterninin birlikte değerlendirilmesi, acil serviste eşlik eden torasik yaralanma riski yüksek olan hastaların belirlenmesine yardımcı olabilir.

Anahtar sözcükler: Acil servis; kaburga kırığı; klavikula kırığı; pnömotoraks; risk faktörleri; toraks travması.

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ORIGINAL ARTICLE

Clinical and radiological outcomes of surgical treatment using a posterolateral approach based on computed tomography-based fracture morphology in posterior malleolar fractures: A single-center retrospective analysis

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ABSTRACT

BACKGROUND: The aim of this study was to evaluate the clinical and radiological outcomes of posterior malleolar fractures (PMFs) treated surgically via a posterolateral approach and to investigate the prognostic value of Bartoníček–Rammelt fracture morphology in predicting functional outcome, reduction quality, and osteoarthritis development.

METHODS: In this single-center retrospective study, 61 patients with PMFs who were treated surgically via a posterolateral approach between January 2020 and December 2023 and had a minimum follow-up of 24 months were included. Fractures were classified according to the Bartoníček–Rammelt classification (BRC). Clinical outcomes were assessed using the Olerud-Molander Ankle Score (OMAS), while radiological outcomes were evaluated based on articular step-off and the Kellgren–Lawrence osteoarthritis grade. Multivariable linear regression analysis was performed to identify independent predictors of functional outcome.

RESULTS: The mean follow-up duration was 38.2±8.8 months. The mean OMAS was 89.9±10.2. Articular step-off was <1 mm in 82.0% of the patients. OMAS scores differed significantly among the BRC fracture types (p=0.039), with lower scores observed in more complex fracture patterns. In the adjusted multivariable regression model including fracture morphology, articular step-off, osteoarthritis grade, syndesmotic fixation, and post-operative complications, articular step-off (p<0.001) and osteoarthritis grade (p<0.001) remained independent predictors of OMAS, whereas fracture morphology was not independently associated with functional outcome.

CONCLUSION: Bartoníček–Rammelt fracture morphology was associated with functional outcome in unadjusted analyses. However, after adjustment for articular reduction quality, osteoarthritis grade, syndesmotic fixation, and post-operative complications, fracture morphology was not independently associated with OMAS. Articular reduction quality and osteoarthritis grade were the strongest independent determinants of functional outcome, emphasizing the importance of achieving anatomical reduction in PMFs.

Keywords: Ankle fractures; fracture fixation; posterior malleolar fractures; posterolateral surgical approach.

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INTRODUCTION

Posterior malleolar fractures (PMFs) are observed in approximately 30–40% of ankle fractures and have significant implications for ankle stability, articular congruity, and long-term functional outcomes.[1-3] The posterior malleolar fragment not only constitutes a portion of the tibial plafond but also plays a critical role in syndesmotic stability, as it serves as the insertion site of the posterior inferior tibiofibular ligament (PITFL). Therefore, accurate evaluation and appropriate management of PMFs are essential to prevent the development of post-traumatic osteoarthritis and to achieve optimal functional outcomes.[2,3]

Conventionally, surgical indication was based on the criteria that the posterior fragment involved more than 25% of the tibial articular surface or that fragment displacement exceeded 2 mm.[1,2] However, with the widespread use of computed tomography (CT), it has become evident that, in addition to fragment size, factors such as fracture morphology, extension into the articular surface, involvement of the fibular incisura, and its effect on syndesmotic stability may be decisive determinants of clinical outcomes.[3-5] Accordingly, CT-based classification systems have enabled a more detailed morphological assessment of PMFs. The Bartoníček–Rammelt classification (BRC), described by Bartoníček et al.[2] and widely used in current practice, categorizes PMFs into five types based on anatomical localization of the fragment, involvement of the incisura, and fracture morphology, and is regarded as a guiding system for surgical planning.[5] This classification has also been shown to demonstrate high interobserver and intraobserver reliability.[4,5]

In PMFs, morphological characteristics may influence not only the choice of surgical approach but also the quality of reduction and long-term joint health. Achieving anatomical reduction – particularly maintaining minimal articular step-off – is a critical factor in improving functional outcomes. The literature indicates that limiting post-operative articular step-off to <1 mm is associated with superior clinical outcomes, whereas step-off of 1–2 mm or greater significantly increases the risk of post-traumatic osteoarthritis.[6-9] Therefore, in the evaluation of PMFs, not only fragment size but also fracture morphology and the quality of reduction achieved should be considered important prognostic factors.

In the surgical management of PMFs, the posterolateral approach is widely preferred because it allows direct visualization and anatomical reduction of the posterior fragment. This approach provides direct access to the posterolateral aspect of the tibia and the fibula, thereby facilitating anatomical reduction and stable fixation. The literature reports that, compared with indirect reduction and anteroposterior screw fixation, the posterolateral approach achieves superior articular congruity, reduces articular step-off, and improves functional outcomes.[10-15]

In recent years, increasing emphasis has been placed on individualized surgical planning based on CT-derived morphological classification in the management of PMFs.[2-5] In particular, the BRC has been recognized as an important guide in determining surgical strategy, as it enables a detailed assessment of fracture morphology.[2,5] However, clinical studies directly evaluating the impact of the morphological fracture types defined by this classification on reduction quality, functional outcomes, and the development of osteoarthritis following treatment with a posterolateral approach remain limited.[3,15] Although CT-based classification systems are increasingly used in surgical decision-making for PMFs, the extent to which fracture morphology influences post-operative functional recovery and radiological outcomes remains incompletely understood. Establishing this relationship may improve prognostic assessment, support morphology-based surgical planning in clinical practice, and provide additional evidence regarding the clinical utility of the BRC.[3,14,15] Therefore, further clarification of the prognostic role of fracture morphology on clinical and radiological outcomes is warranted. In this context, the aim of the present study was to evaluate the clinical and radiological outcomes of PMFs treated surgically via a posterolateral approach and to investigate the prognostic value of Bartoníček–Rammelt fracture morphology in predicting functional outcome, reduction quality, and osteoarthritis development.

MATERIALS AND METHODS

Patient Selection and Data Collection

This single-center retrospective study included patients who underwent surgical treatment for PMFs between January 2020 and December 2023 at the University of Health Sciences, Diyarbakır Gazi Yaşargil Training and Research Hospital. The study protocol was approved by the Ethics Committee of the University of Health Sciences Gazi Yaşargil Training and Research Hospital (Decision No: 6, Date: January 09, 2026) and was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all patients.

A total of 61 patients aged 18 years and older were included in the study. The decision for surgical treatment was based on the CT-based BRC rather than fragment size or displacement thresholds alone. BRC Type 2, Type 3, and Type 4 fractures were considered to require anatomical reduction and stable fixation and were therefore treated surgically. BRC Type 1 fractures were not considered to have a surgical indication and were excluded from the study cohort. No BRC Type 5 fractures were identified during the study period. Patients who underwent surgical treatment during the study period were retrospectively reviewed, and those who met the inclusion criteria and had complete clinical and radiological data were included in the analysis. Patients with open fractures, pathological fractures, or incomplete clinical and/or radiological follow-up data were excluded from the study.

Demographic and clinical data included sex, age, affected side, mechanism of injury, follow-up duration, fixation meth-

ods applied, and syndesmotic stabilization. Associated medial and lateral malleolar fractures and syndesmotic injuries were also evaluated using pre-operative radiographs and CT imaging and were managed according to AO/OTA principles. Follow-up duration was calculated as the time interval between the date of surgery and the date of the last clinical and radiological evaluation. PMFs were classified according to the CT-based BRC.[2]

The classification was performed independently by two orthopedic surgeons experienced in ankle surgery; in cases of disagreement, a final decision was reached by consensus. Functional outcomes were assessed at the final follow-up using the Olerud-Molander Ankle Score (OMAS). Radiographic osteoarthritis was graded on standard anteroposterior and lateral ankle radiographs according to the Kellgren–Lawrence (KL) classification. Ankle dorsiflexion and plantarflexion ranges of motion were measured using a goniometer and compared with the contralateral side to calculate the limb symmetry index (LSI) (LSI=[affected side/contralateral side]×100).

Surgical Technique

All surgical procedures were performed in the prone position using a posterolateral approach.[2,16] Following the posterolateral skin incision, the sural nerve and the small saphenous vein were identified and protected during superficial dissection. The dissection was deepened through the anatomical interval between the peroneal tendons and the flexor hallucis longus (FHL) muscle. The FHL muscle was retracted medially to expose the posterolateral cortex of the tibia and the posterior malleolar fragment. At this stage, adequate surgical visualization was achieved while preserving the PITFL and the surrounding soft tissues as much as possible.[2,17]

The posterior malleolar fragment was primarily reduced under direct visualization to achieve anatomical alignment. Reduction was assessed intraoperatively using fluoroscopy to evaluate articular step-off and intra-articular separation, and temporary stabilization was achieved with Kirschner wires. The adequacy of anatomical reduction was confirmed fluoroscopically (Fig. 1a and b).

In the present study, definitive fixation of the posterior malleolar fragment was achieved using a buttress plate in all cases.[16,17] Following stabilization of the posterior fragment, concomitant fibular and medial malleolar fractures were treated with internal fixation according to the AO/OTA principles.[18]

Syndesmotic stability was assessed intraoperatively using the Cotton hook test and the external rotation stress test. In patients with detected syndesmotic instability, stabilization was performed with a syndesmotic screw after achieving anatomical reduction.[19] Reduction and implant positioning were verified using fluoroscopy. Pre-operative CT images and post-operative radiographs of representative cases corresponding to different BRC types are presented in Fig. 2a-l.

Post-operative Protocol and Rehabilitation

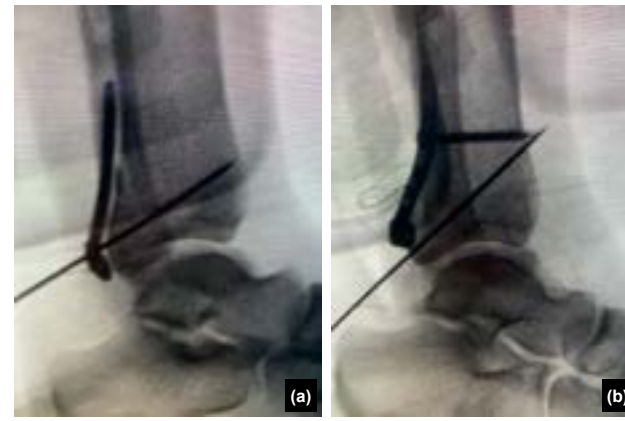

Figure 1. Intraoperative fluoroscopic assessment of the posterior malleolar fragment. **(a)** Intraoperative fluoroscopic image demonstrating articular step-off before implant placement following the posterolateral approach. **(b)** Intraoperative fluoroscopic image showing restoration of the anatomical articular surface after reduction.

In the post-operative period, limb elevation and edema control were implemented, and early active toe motion was initiated. Following soft tissue healing, active and passive ankle range-of-motion exercises were commenced. Partial weight-bearing was allowed at 3–4 weeks postoperatively, based on fixation stability and clinical assessment, with gradual progression to full weight-bearing. Rehabilitation included muscle strengthening and proprioceptive exercises. Complications were retrospectively evaluated based on patient records, clinical examination findings, and radiographic assessments.

Outcome Assessment

Post-operative articular step-off was evaluated at the final follow-up using a digital measurement method on standard lateral ankle radiographs. All measurements were performed independently by two experienced orthopedic surgeons who were blinded to the clinical outcomes, and interobserver agreement was assessed using intraclass correlation coefficient (ICC) analysis. Articular step-off was defined as the perpendicular distance between the posterior malleolar fragment and the main tibial plafond articular surface, using the tibial plafond as the reference. It was categorized as <1 mm, 1–2 mm, and >2 mm. In cases where radiographic evaluation was insufficient, measurements were completed using CT images.

Statistical Analysis

Statistical analyses were performed using IBM Statistical Package for the Social Sciences Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA). The normality of continuous variables was assessed using the Shapiro–Wilk test. For variables demonstrating normal distribution, one-way analysis of variance was applied, whereas the Kruskal–Wallis test was used for variables not conforming to a normal distribution. Categorical variables were compared using the Chi-square test or Fisher's exact test, as appropriate. Holm correction was applied for post hoc analyses.

Figure 2. Representative images of different Bartoníček–Rammelt classification (BRC) types. (a-d) BRC Type 2 posterior malleolar fractures (PMF): **(a)** Pre-operative axial computed tomography (CT) slice, **(b)** Pre-operative sagittal CT slice, **(c)** Post-operative lateral radiograph, **(d)** Post-operative anteroposterior radiograph. **(e-h)** BRC Type 3 PMF: **(e)** Pre-operative axial CT slice, **(f)** Pre-operative sagittal CT slice, **(g)** Post-operative lateral radiograph, **(h)** Post-operative anteroposterior radiograph. **(i-l)** BRC Type 4 PMF: Pre-operative axial CT slice, **(j)** Pre-operative sagittal CT slice, **(k)** Post-operative lateral radiograph, **(l)** Post-operative anteroposterior radiograph.

To identify independent predictors of functional outcome (OMAS score), a multivariable linear regression analysis was performed. Bartoníček–Rammelt fracture type, post-operative articular step-off, KL osteoarthritis grade, syndesmotic fixation, and post-operative complications were included in the model as independent variables. Categorical variables were entered into the model as dummy variables. Regression coefficients (β), 95% confidence intervals (CIs), and p values were reported. Statistical significance was set at $p<0.05$. In the regression analysis, Bartoníček–Rammelt Type 2 was used as the reference category.

To evaluate the potential influence of associated injuries and post-operative complications on functional outcomes, additional analyses were performed. OMAS scores were compared according to the presence of syndesmotic fixation and post-operative complications using the Mann–Whitney U test. Post-operative complications were defined as the occurrence of infection, sural nerve neuropathy, or revision surgery. A sensitivity analysis was conducted after excluding patients with post-operative complications.

RESULTS

Demographic, Injury, and Surgical Characteristics

The mean age of the 61 patients was 43.9±13.2 years. Of the patients, 31 (50.8%) were female and 30 (49.2%) were male. Fractures occurred on the right side in 43 cases (70.5%). The most common mechanism of injury was a twisting injury, observed in 53 patients (86.9%). Fifty-five patients (90.2%) were operated on within the first 24 h after injury. The mean follow-up duration was 38.2±8.8 months (range, 24–56 months).

According to the BRC, fracture distribution was as follows: Type 2 in 35 patients (57.4%), Type 3 in 15 patients (24.6%), and Type 4 in 11 patients (18.0%). During the study period, BRC Type 1 fractures were not included in the cohort due to the absence of a surgical indication, and no BRC Type 5 fractures were identified. Definitive fixation of the posterior malleolar fragment was performed using a buttress plate in all cases. Syndesmotic stabilization was applied in 16 patients (26.2%). The demographic and clinical characteristics of the groups are presented in Table 1.

Overall Clinical and Radiological Outcomes

At the final follow-up, the mean OMAS was 89.92±10.19 (median, 95; range, 55–100). The distribution of post-operative articular step-off was as follows: <1 mm in 50 patients (82.0%), 1–2 mm in 9 patients (14.8%), and >2 mm in 2 patients (3.3%). According to the KL osteoarthritis grading, 55.7% of the cases were classified as KL grade 0, 23.0% as KL grade 1, 19.7% as KL grade 2, and 1.6% as KL grade 3.

Interobserver agreement was evaluated for BRC classification, articular step-off, and KL grading. The ICC values were excellent for BRC (0.91; 95% CI: 0.85–0.95), good for articular step-off (0.88; 95% CI: 0.80–0.93), and good for KL grading (0.75; 95% CI: 0.66–0.83).

In the range-of-motion symmetry analysis, the median dorsiflexion LSI was 75% (range, 25%–100%), whereas the mean plantarflexion LSI was 100% (range, 33%–100%).

Table 1. Comparison of demographic and clinical characteristics according to the BRC

BRC	Type 2 (n=35) (%)	Type 3 (n=15) (%)	Type 4 (n=11) (%)	Total (n=61) (%)	p
Age (years)	43.34±11.49	43.33±11.02	46.64±20.35	43.90±13.20	0.761
Sex				0.059	
Male	13 (37.1)	11 (73.3)	6 (54.5)	30 (49.2)	
Female	22 (62.9)	4 (26.7)	5 (45.5)	31 (50.8)	
Side				0.588	
Left	12 (34.3)	3 (20.0)	3 (27.3)	18 (29.5)	
Right	23 (65.7)	12 (80.0)	8 (72.7)	43 (70.5)	
Mechanism of injury					0.574
Twisting injury	29 (82.9)	15 (100.0)	9 (81.8)	53 (86.9)	
Fall from height	2 (5.7)	0 (0.0)	2 (18.2)	4 (6.6)	
Fall from stairs	1 (2.9)	0 (0.0)	0 (0.0)	1 (1.6)	
Scooter accident	2 (5.7)	0 (0.0)	0 (0.0)	2 (3.3)	
Motorcycle accident	1 (2.9)	0 (0.0)	0 (0.0)	1 (1.6)	
Weber classification					0.279
Weber B	30 (85.7)	10 (66.7)	8 (72.7)	48 (78.7)	
Weber C	5 (14.3)	5 (33.3)	3 (27.3)	13 (21.3)	
Syndesmotic Stabilization					0.682
Yes	9 (25.7)	5 (33.3)	2 (18.2)	16 (26.2)	
No	26 (74.3)	10 (66.7)	9 (81.8)	45 (73.8)	
Follow-up duration (months)	38.7±8.8	38.5±6.9	36.3±11.4	38.2±8.8	0.741

BRC: Bartoníček–Rammelt classification; SD: Standard deviation.

Table 2. Comparison of radiological and functional outcomes according to the Bartoníček–Rammelt classification

BRC	Type 2 (n=35)	Type 3 (n=15)	Type 4 (n=11)	Total (n=61)	p
Articular step-off (%)					0.005*
<1 mm	32 (91.4)	10 (66.7)	8 (72.7)	50 (82.0)	
1–2 mm	3 (8.6)	5 (33.3)	1 (9.1)	9 (14.8)	
>2 mm	0 (0.0)	0 (0.0)	2 (18.2)	2 (3.3)	
OMAS score (Mean±SD)	92.71±7.11	88.00±11.77	83.64±13.43	89.92±10.19	0.039*
KL grade (%)					0.009*
KL 0	22 (62.9)	9 (60.0)	3 (27.3)	34 (55.7)	
KL 1	10 (28.6)	0 (0.0)	4 (36.4)	14 (23.0)	
KL 2	3 (8.6)	6 (40.0)	3 (27.3)	12 (19.7)	
KL 3	0 (0.0)	0 (0.0)	1 (9.1)	1 (1.6)	
Dorsiflexion LSI (%) (median, range)	100 (40–100)	100 (50–100)	71 (25–100)	75 (25–100)	0.106
Plantarflexion LSI (%) (median, range)	100 (56–100)	100 (40–100)	89 (33–100)	100 (33–100)	0.056

BRC: Bartoníček–Rammelt classification; OMAS: Olerud-Molander ankle score; SD: Standard deviation; KL: Kellgren-Lawrence; LSI: Limb symmetry index.

Comparisons According to BRC Types

No significant differences were observed among the groups in terms of age, affected side, mechanism of injury, Weber classification, or syndesmotic stabilization. Follow-up duration did not differ significantly between groups (p=0.741).

Radiological reduction quality differed significantly across BRC types (p=0.005); articular step-off >2 mm was observed exclusively in the Type 4 group (2/11; 18.2%). The OMAS demonstrated a decreasing trend with increasing fracture type severity (Type 2: 92.71±7.11; Type 3: 88.00±11.77; Type 4: 83.64±13.43; p=0.039). The difference between Type 2 and Type 4 remained statistically significant after Holm correction (adjusted p=0.020; effect size r=0.38).

The development of osteoarthritis differed significantly among the fracture types (p=0.009); KL grade 3 was observed exclusively in the Type 4 group (1/11; 9.1%). Radiological reduction quality, functional outcomes, and the distribution of osteoarthritis according to BRC types are summarized in Table 2.

Relationship Between Articular Step-Off, KL Grade, and OMAS

OMAS scores decreased significantly as articular step-off increased (Kruskal–Wallis, p<0.001). The mean OMAS was 93.70±5.61 in the <1 mm group, 75.56±5.83 in the 1–2 mm group, and 60.00±7.07 in the >2 mm group. A significant association was observed between step-off categories and KL grades (p<0.001). OMAS scores also decreased significantly with increasing KL grade (p<0.001).

Multivariable Regression Analysis

In the expanded multivariable linear regression analysis including Bartoníček–Rammelt fracture type, articular step-off, KL osteoarthritis grade, syndesmotic fixation, and post-operative complications, articular step-off and osteoarthritis grade remained independent predictors of OMAS scores.

Using Type 2 as the reference category, neither Type 3 fractures (β=−0.46; 95% CI: −3.25 to 2.33; p=0.743) nor Type 4 fractures (β=−1.18; 95% CI: −4.49 to 2.13; p=0.477) were independently associated with OMAS scores.

Compared with patients with an articular step-off of <1 mm, those with a step-off of 1–2 mm demonstrated significantly lower OMAS scores (β = −9.44; 95% CI: −13.65 to −5.23; p<0.001), while a step-off >2 mm was associated with an even greater reduction in OMAS scores (β=−21.05; 95% CI: −28.68 to −13.41; p<0.001).

Each increase in KL osteoarthritis grade was independently associated with lower OMAS scores (β=−5.80; 95% CI: −7.75 to −3.85; p<0.001). Syndesmotic fixation (β=−1.05; p=0.434) and post-operative complications (β=−2.02; p=0.274) were not independently associated with functional outcome.

Detailed results of the multivariable regression analysis are presented in Table 3.

Additional Analyses Addressing Associated Injuries and Complications

Additional analyses were performed to evaluate whether associated injuries or post-operative complications influenced functional outcomes. Patients with post-operative complications had lower mean OMAS scores than those without complications; however, this difference did not reach statistical significance (85.0±10.8 vs. 90.6±10.0; p=0.066). Similarly, patients who underwent syndesmotic fixation had lower mean OMAS scores than those without syndesmotic fixation, but the difference was not statistically significant (86.9±11.9 vs. 91.0±9.5; p=0.124).

Table 3. Multivariable linear regression analysis for OMAS scores

Variable	β	95% CI	p
BRC type 3 (Reference: Type 2)	−0.46	−3.25–2.33	0.743
BRC type 4 (Reference: Type 2)	−1.18	−4.49–2.13	0.477
Articular step-off 1–2 mm (reference: <1 mm)	−9.44	−13.65–−5.23	<0.001
Articular step-off >2 mm (reference: <1 mm)	−21.05	−28.68–−13.41	<0.001
Kellgren–Lawrence grade (per+1 increase)	−5.80	−7.75–−3.85	<0.001
Syndesmotic fixation	−1.05	−3.72–1.62	0.434
Post-operative complication	−2.02	−5.69–1.65	0.274

BRC: Bartoníček–Rammelt classification; CI: Confidence interval; OMAS: Olerud-Molander Ankle score. Reference categories: BRC Type 2 and articular step-off <1 mm.

A sensitivity analysis was performed after excluding the seven patients with post-operative complications. In this analysis, OMAS scores continued to differ significantly among Bartoníček–Rammelt fracture types (Kruskal–Wallis test, p=0.032), suggesting that the observed difference in functional outcome according to fracture morphology was not solely explained by post-operative complications.

Complications and Revision Surgery

Complications occurred in 7 of the 61 patients (11.5%). One patient (1.6%) developed a deep infection and underwent surgical debridement three times. After infection control and fracture union, the implants were removed.

Superficial infection was observed in two patients (3.3%). One of these patients fully recovered with conservative treatment, while the other required skin grafting by the plastic surgery team due to the development of skin necrosis.

Two patients (3.3%) developed sural nerve neuropathy. Both showed progressive clinical improvement during follow-up, and no additional surgical intervention was required.

Revision surgery was required in two patients (3.3%) during the early post-operative period. In one patient, inadequate syndesmotic reduction was identified, and in the other, inadequate reduction of the posterior malleolar fragment was observed. Anatomical reduction and stable fixation were achieved in both cases through revision surgery.

Overall, the rate of major complications was low. Fracture union was achieved in all cases, and no permanent implant-related complications were observed.

DISCUSSION

CT-based morphological classification systems are considered essential tools in the assessment of PMFs, guiding surgical planning, reduction strategies, and evaluation of fracture complexity. The BRC provides a detailed description of the morphological spectrum of PMFs based on fragment location, involvement of the incisura, and fracture morphology, offering a reliable framework for surgical decision-making.[2-5] Current literature emphasizes that PMF morphology may influence articular reduction quality, syndesmotic stability, and long-term functional outcomes.[3,9,20]

The main finding of this study is that Bartoníček–Rammelt fracture morphology was associated with both functional outcomes and radiological degenerative changes in unadjusted analyses. OMAS scores progressively decreased with increasing fracture complexity, and more advanced fracture types demonstrated higher rates of osteoarthritic changes. However, after adjustment for articular step-off, osteoarthritis grade, syndesmotic fixation, and post-operative complications, fracture morphology was no longer independently associated with functional outcome. Instead, residual articular incongruity and osteoarthritis grade emerged as the strongest independent predictors of OMAS. These findings suggest that the relationship between fracture morphology and functional outcome may be mediated through the difficulty of achieving anatomical reduction and the subsequent development of degenerative joint changes rather than fracture morphology itself.[6-8,14,20-22]

In the expanded multivariable regression model, increasing articular step-off and higher KL grades were independently associated with worse functional outcomes, whereas fracture morphology, syndesmotic fixation, and post-operative complications were not significant independent predictors. These findings emphasize that restoration of articular congruity remains the most important modifiable factor affecting clinical recovery after PMFs. Therefore, CT-based fracture morphology should primarily be considered a tool for surgical planning and assessment of reduction difficulty rather than an independent determinant of long-term functional outcome.[3,6-8,20,22]

Moreover, articular reduction quality was identified as the strongest independent predictor of functional outcome. The significant decrease in OMAS scores with increasing articular step-off supports the notion that preserving anatomical joint

congruity should be a primary goal in the treatment of PMFs. These findings are consistent with studies reporting that long-term outcomes are determined by joint congruity regardless of fragment size and that residual step-off increases the risk of osteoarthritis.[6-8,22]

The significant association between BRC types and reduction quality indicates that fracture morphology may influence the success of anatomical reduction. This observation may explain why fracture morphology was associated with OMAS scores in unadjusted analyses but lost statistical significance after adjustment for reduction quality and osteoarthritis grade. The higher rates of residual articular step-off observed in more advanced morphological types suggest that achieving anatomical reduction may be technically more challenging in these cases. This finding aligns with the approach proposed by Cho et al.,[20] emphasizing that different surgical strategies may be required for different morphological fracture types.

The posterolateral approach facilitates direct visualization of the posterior fragment, allowing reliable anatomical reduction, and has been associated with improved joint congruity.[10-15] This approach enables the posterior malleolar fragment to be reduced and fixated early in the surgical procedure, supporting anatomical restoration of the articular surface.[17,23] In our study, the high rate of <1 mm articular step-off and generally high OMAS scores support the effectiveness and reliability of the posterolateral approach in achieving anatomical reduction within morphology-based surgical planning.

In our study, the rate of syndesmotic stabilization was 26.2%. The literature reports syndesmotic fixation rates ranging from 20% to 50% in PMF.[15,22-24] The rate observed in our cohort is consistent with previously reported rates in the literature. In the present study, syndesmotic fixation was not independently associated with functional outcome after adjustment for fracture morphology, reduction quality, osteoarthritis grade, and post-operative complications.

Regarding the development of osteoarthritis, higher rates were observed in more advanced morphological fracture types in our study. Although osteoarthritis is multifactorial, residual articular step-off has been strongly highlighted in the literature as one of its most important determinants.[7,8,22] Therefore, achieving anatomical reduction is critical not only for short-term functional recovery but also for the preservation of long-term joint health.

Limitations

This study has several limitations. Its retrospective design may introduce selection bias and the influence of uncontrolled variables. The small sample size in certain morphological fracture subtypes, particularly in the subgroup with articular step-off >2 mm, may have limited the statistical power and generalizability of the analyses for these subgroups. Articular reduction quality was primarily assessed using radiographs, and post-operative CT was not performed in all cases. Although the follow-up duration was sufficient for mid-term evaluation, longer-term prospective studies are needed to more clearly assess the progression of osteoarthritis. Associated medial and lateral malleolar fractures, syndesmotic injuries, and post-operative complications may influence functional outcomes after ankle fractures. To address these potential confounders, additional analyses including sensitivity analysis and adjusted multivariable regression models were performed. Nevertheless, residual confounding cannot be completely excluded because of the retrospective design and the relatively limited sample size. Furthermore, the high prevalence of associated malleolar injuries in the present cohort limited the ability to perform meaningful subgroup analyses for these injury patterns.

CONCLUSION

This study demonstrates that Bartoníček–Rammelt fracture morphology is associated with functional outcome in unadjusted analyses in PMFs treated via the posterolateral approach. However, after adjustment for articular step-off, osteoarthritis grade, syndesmotic fixation, and post-operative complications, fracture morphology itself was not identified as an independent predictor of OMAS. Instead, residual articular step-off and radiographic osteoarthritis grade were the strongest independent determinants of functional outcome. These findings suggest that although CT-based fracture morphology remains important for surgical planning, restoration of articular congruity appears to be the key modifiable factor associated with functional recovery.

Ethics Committee Approval: This study was approved by the Ethics Committee of the University of Health Sciences Gazi Yaşargil Training and Research Hospital (Date: 09.01.2026, Decision No: 6).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Posterior malleol kırıklarında BT-temelli morfolojiye dayalı posterolateral yaklaşım ile cerrahi tedavinin klinik ve radyolojik sonuçları: Tek merkezli retrospektif analiz

AMAÇ: Bu çalışmanın amacı, posterolateral yaklaşım ile cerrahi olarak tedavi edilen posterior malleol kırıklarının (PMK) klinik ve radyolojik sonuçlarını değerlendirmek ve Bartoníček–Rammelt kırık morfolojisinin fonksiyonel sonuçlar, redüksiyon kalitesi ve osteoartrit gelişimi açısından prognostik değerini araştırmaktır.

GEREÇ VE YÖNTEM: Bu tek merkezli retrospektif çalışmaya, Ocak 2020-Aralık 2023 tarihleri arasında posterolateral yaklaşım ile cerrahi olarak tedavi edilen ve en az 24 ay takip edilen 61 PMK hastası dahil edildi. Kırıklar Bartoníček-Rammelt sınıflamasına (BRS) göre sınıflandırıldı. Klinik sonuçlar Olerud-Molander Ayak Bileği Skoru (OMAS) ile, radyolojik sonuçlar ise artiküler basamaklanma ve Kellgren–Lawrence osteoartrit evresi ile değerlendirildi. Fonksiyonel sonucun bağımsız belirleyicilerini belirlemek amacıyla çok değişkenli lineer regresyon analizi yapıldı.

BULGULAR: Ortalama takip süresi 38.2±8.8 ay idi. Ortalama OMAS skoru 89.9±10.2 olarak bulundu. Artiküler basamaklanma hastaların %82.0'ında <1 mm idi. OMAS skorları BRS tipleri arasında anlamlı farklılık gösterdi (p=0.039) ve daha kompleks kırık paternlerinde daha düşük skorlar gözlendi. Kırık morfolojisi, artiküler basamaklanma, osteoartrit evresi, sindezmoz tespiti ve postoperatif komplikasyonları içeren düzeltilmiş çok değişkenli regresyon modelinde, artiküler basamaklanma (p<0.001) ve osteoartrit evresi (p<0.001) OMAS skorunun bağımsız belirleyicileri olarak saptanırken, kırık morfolojisinin fonksiyonel sonuç ile bağımsız ilişkisi gösterilemedi.

SONUÇ: Bartoníček-Rammelt kırık morfolojisi düzeltilmemiş analizlerde fonksiyonel sonuç ile ilişkili bulunmuştur. Ancak artiküler redüksiyon kalitesi, osteoartrit evresi, sindezmoz tespiti ve postoperatif komplikasyonlar için düzeltme yapıldığında, kırık morfolojisinin OMAS üzerinde bağımsız bir etkisi gösterilememiştir. Artiküler redüksiyon kalitesi ve osteoartrit evresi fonksiyonel sonucun en güçlü bağımsız belirleyicileri olup, posterior malleol kırıklarında anatomik redüksiyonun sağlanmasının önemini vurgulamaktadır.

Anahtar sözcükler: Ayak bileği kırıkları; kırık fiksasyonu; posterior malleol kırıkları; posterolateral cerrahi yaklaşım.

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ORIGINAL ARTICLE

Radiographic and clinical factors associated with open reduction in pediatric supracondylar humerus fractures

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ABSTRACT

BACKGROUND: The aim of this study was to evaluate demographic and radiographic factors associated with the likelihood of open reduction in pediatric supracondylar humerus fractures (SCHF).

METHODS: A total of 294 pediatric patients with SCHFs treated operatively between 2016 and 2025 were retrospectively reviewed. Patients were divided into two groups: Open reduction (OR, n=128) and closed reduction (CR, n=166). Demographic variables, including age, sex, side of injury, and surgeon experience, were recorded. Radiographic parameters assessed on preoperative anteroposterior and lateral elbow radiographs included fracture type, displacement direction, rotational deformity, diaphyseal involvement, coronal fracture pattern, sagittal fracture pattern, and coronal alignment. Variables with $p<0.05$ in univariate analysis were included in a multivariable logistic regression model using a backward stepwise method.

RESULTS: The mean age was significantly higher in the OR group compared to the CR group (6.94±2.85 vs. 5.58±2.64 years, $p<0.001$). Flexion-type fractures were more frequent in the OR group (24.2% vs. 10.2%, $p=0.012$). Posterolateral displacement and rotational deformity were also significantly associated with open reduction. Coronal alignment differed significantly between groups, with varus and valgus malalignment more common in the OR group ($p=0.003$). Multivariable logistic regression analysis identified increasing age (OR=1.127, 95% confidence interval [CI]: 1.029–1.236; $p=0.010$), flexion-type fractures (OR=1.807, 95% CI: 1.261–2.590; $p=0.001$), and posterolateral displacement (OR=1.39, 95% CI: 1.010–1.926; $p=0.043$) as independent predictors of open reduction. In contrast, neutral coronal alignment was associated with a lower likelihood of open reduction (OR=0.681, 95% CI: 0.510–0.909; $p=0.009$).

CONCLUSION: Several demographic and fracture-related characteristics were independently associated with the likelihood of open reduction in pediatric SCHFs. Among these, fracture-related characteristics, particularly displacement pattern and coronal alignment, showed the strongest associations with open reduction. Recognition of these associated factors may assist preoperative planning and help surgeons anticipate technically challenging reductions.

Keywords: Closed reduction; coronal alignment; fracture displacement; open reduction; supracondylar humerus fracture.

INTRODUCTION

Supracondylar humerus fractures (SCHFs) represent one of the most common elbow injuries in the pediatric population and account for a substantial proportion of pediatric orthopedic trauma.[1] These injuries most commonly occur following a fall onto an outstretched hand, typically resulting in extension-type fractures, whereas flexion-type injuries are relatively uncommon and are often associated with direct trauma to the elbow.[2,3] The primary goal of treatment is to achieve and maintain anatomical reduction to restore alignment and pre-

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vent long-term complications such as malunion, neurovascular compromise, and functional limitation.

Closed reduction and percutaneous pinning (CRPP) is widely accepted as the standard treatment for displaced SCHFs.[4] However, in certain cases, satisfactory reduction cannot be achieved or maintained with closed techniques, necessitating conversion to open reduction.[5] Open reduction is generally associated with increased soft-tissue dissection, longer operative time, and a potentially higher risk of complications.[6] Therefore, identifying factors that may predict the need for open reduction is of considerable clinical importance for preoperative planning and surgical decision-making.

A considerable number of studies have investigated predictors of open reduction in pediatric SCHFs. Various quantitative and qualitative parameters have been reported in the literature, including clinical, demographic, and radiographic factors.[7-11] Among these, fracture displacement pattern, rotational deformity, and instability have been suggested to influence the difficulty of achieving and maintaining closed reduction (CR).[12] However, despite the growing body of evidence, the findings remain heterogeneous, and no clear consensus has been established regarding which radiographic features reliably predict the need for open reduction.

The aim of the present study was to evaluate the demographic and radiographic factors associated with the need for open reduction in pediatric SCHFs. We hypothesized that increasing fracture instability as reflected by radiographic features and fracture patterns would be associated with a higher likelihood of requiring open reduction.

MATERIALS AND METHODS

Patients and Study Design

This retrospective study included pediatric patients with SCHFs who underwent either CRPP or open reduction between January 2016 and December 2025. The study protocol was approved by the institutional review board (IRB approval no: 9-2026), and all procedures were conducted in accordance with the ethical standards of the Declaration of Helsinki. Demographic characteristics, clinical data, fracture classification, and radiographic findings were obtained from hospital databases and patient charts. Radiographic evaluations were performed using images retrieved from the picture archiving and communication system. The inclusion criteria for this study were as follows: (1) Pediatric patients diagnosed with SCHFs treated with either CRPP or open reduction, including Gartland type III extension and flexion-type fractures and (2) availability of adequate preoperative and postoperative radiographs, including anteroposterior and lateral views, suitable for measurement and evaluation. The exclusion criteria were (1) patients managed nonoperatively, (2) delayed surgery due to external referral or medical reasons, (3) history of prior trauma or surgery involving the affected elbow, (4) inadequate radiographic quality for accurate measurements, and (5) neurovascular injuries requiring immediate open reduction.

A total of 574 pediatric patients with SCHFs were initially assessed for eligibility. Of these, 280 patients were excluded for the following reasons: Conservative (nonoperative) manage-

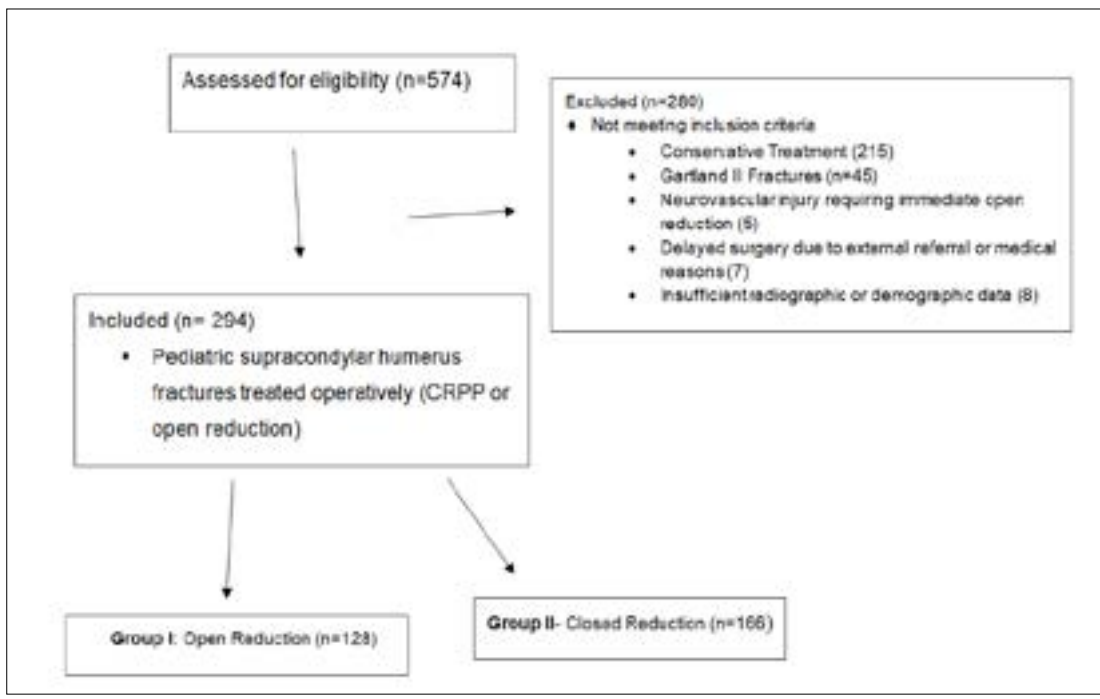

Figure 1. Flow diagram of the study.

ment (n=215), Gartland type II fractures (n=45), neurovascular injury requiring immediate open reduction (n=5), delayed surgery due to external referral or medical reasons (n=7), and insufficient radiographic or demographic data (n=8). After applying the inclusion and exclusion criteria, 294 patients who underwent operative treatment were included in the study. These patients were divided into two groups based on the surgical technique: Group I consisted of patients treated with open reduction (n=128) and Group II included those treated with CRPP (n=166) (Fig. 1).

Surgical Technique and Postoperative Management

All operations were carried out under general anesthesia with the patient in the supine position. Intravenous cefazolin (30 mg/kg) was administered preoperatively for antibiotic prophylaxis. Fracture reductions and fixations were performed under fluoroscopic guidance. CR was attempted as the initial treatment in all cases. Gentle longitudinal traction was first applied to restore coronal alignment, followed by rotational correction according to the direction of fracture displacement. Sagittal alignment was then achieved by elbow flexion for extension-type fractures or extension for flexion-type fractures. The elbow was maintained in hyperflexion and pronation (Jones position), and reduction was assessed fluoroscopically using anteroposterior and lateral views. Acceptable reduction was defined as restoration of coronal alignment without residual varus or valgus malalignment on the anteroposterior view and satisfactory sagittal alignment, with the anterior humeral line intersecting the middle third of the capitellum on the lateral view. If acceptable reduction could not be achieved or maintained after several attempts at gentle manipulation or if persistent varus or valgus malalignment, rotational deformity, or failure of the anterior humeral line to intersect the middle third of the capitellum remained, conversion to open reduction was performed. Once satisfactory alignment was obtained, fracture fixation was completed using percutaneous Kirschner wires.

In our institution, open reduction was typically carried out using medial, lateral or combined approaches, depending on fracture characteristics and surgeon choice. Following open reduction, fixation was again performed with percutaneous Kirschner wires under fluoroscopic control. Postoperatively, the extremity was immobilized in a long-arm splint with the elbow maintained at approximately 90° of flexion. Patients were followed in the outpatient clinic with regular wound care, clinical assessment, and radiographic evaluation. The long-arm splint was removed at approximately the 4th postoperative week, and gradual elbow range-of-motion exercises were initiated. In the absence of delayed union or other complications, Kirschner wires were removed at the 5th postoperative week in the outpatient setting.

Outcome Measurements

Demographic and radiological parameters

Demographic data, including patient age, sex, side of injury, and the operating surgeon's level of experience, were obtained retrospectively from hospital records and operative reports. Surgeon experience was categorized based on years of clinical practice. The operating surgeon's experience was stratified into three categories according to years of clinical practice: ≤5 years, 5–10 years, and >10 years.

Radiographic parameters were assessed on preoperative anteroposterior and lateral elbow radiographs, including fracture type (extension or flexion), diaphyseal involvement, rotational deformity, and the direction of fracture displacement. Displacement patterns were categorized as posterior (without coronal translation), posteromedial (posterior and medial translation), posterolateral (posterior and lateral translation), or anterior (flexion type), according to the classification of Novais et al.[13]

Coronal plane fracture patterns were classified as high transverse, low transverse, medial oblique, or lateral oblique, whereas sagittal plane fracture types were categorized as high or low as originally defined by Bahk et al.[14] Coronal alignment was further assessed on anteroposterior radiographs and categorized as varus, valgus, or neutral. These coronal plane assessments were performed in accordance with previously described methods.[7,14] Radiographic measurements were independently performed by two senior orthopedic trauma surgeons who were blinded to the treatment allocation (open or CR). Interobserver reliability was assessed using intraclass correlation coefficients (ICCs).

Statistical analysis

Statistical analyses were performed using IBM Statistical Package for the Social Sciences Statistics (Version 27.0; IBM Corp., Armonk, NY, USA). The normality of continuous variables was assessed using the Kolmogorov–Smirnov test. Continuous variables were presented as mean±standard deviation and compared using the independent samples t-test or Mann–Whitney U test, as appropriate. Categorical variables were expressed as frequencies and percentages and analyzed using the Chi-square test or Fisher's exact test. Radiographic measurements were independently performed by two senior orthopedic trauma surgeons who were blinded to the treatment allocation (open or CR). Interobserver reliability was assessed using ICCs based on a two-way mixed-effects model with absolute agreement. The ICCs for the evaluations made by the two observers demonstrated values of 0.83 or higher across all radiographic measurements, indicating good interobserver reliability.

Variables found to be significant in univariate analyses ($p<0.05$) were entered into a multivariable logistic regression model using a backward stepwise (likelihood ratio) method to identify independent predictors of open reduction. Given the presence of multiple correlated categorical subgroups (e.g., displacement patterns and coronal alignment), the stepwise approach was used to reduce potential collinearity and identify the most relevant independent variables. Results were

reported as odds ratios (ORs) with 95% confidence intervals (CIs). A p<0.05 was considered statistically significant.

RESULTS

A total of 294 patients were included in the study, comprising 128 patients in the open reduction (OR) group and 166 patients in the CR group. The mean age was significantly higher in the OR group compared to the CR group (6.94±2.85 vs. 5.58±2.64 years, p<0.001). There was no significant difference between the groups in terms of side of injury, with right-sided involvement observed in 64 patients (52.9%) in the OR group and 82 patients (50.0%) in the CR group (p=0.91). Similarly, sex distribution was comparable between the groups, with females accounting for 34.4% of the OR group and 36.7% of the CR group (p=0.74). The distribution of operating surgeon experience did not differ significantly between the groups (p=0.251). Surgeons with more than 10 years of experience performed the majority of procedures in both groups (53.1% in OR vs. 40.4% in CR) (Table 1).

Radiographic evaluation revealed significant differences between the groups in terms of fracture type, displacement pattern, rotational deformity, and coronal alignment. Flexion-type fractures were significantly more common in the OR group compared to the CR group (24.2% vs. 10.2%, p=0.012). The distribution of displacement patterns differed significantly between the groups (p<0.001). Posterolateral and anterior displacements were more frequently observed in the OR group, whereas posterior and posteromedial displacements predominated in the CR group. Rotational deformity was significantly more frequent in the OR group compared to the CR group (75% vs. 59%, p=0.038). Diaphyseal involvement tended to be more common in the OR group (25.8% vs. 19.3%); however, this difference was not statistically significant (p=0.183). Coronal fracture pattern and sagittal fracture pattern were comparable between the groups (p=0.075 and p=0.363, respectively). In contrast, coronal alignment differed significantly between the groups (p=0.003), with varus and valgus malalignment observed more frequently in the OR group while neutral alignment predominated in the CR group. Variables identified as significant in the univariate analyses (p<0.05) were entered into a multivariable logistic regression model, and a backward stepwise (likelihood ratio) method was applied to obtain the final model (Table 2). The results of this analysis are summarized in Table 3. Multivariable logistic regression analysis demonstrated that increasing age was significantly associated with a higher likelihood of open reduction (OR=1.127, 95% CI: 1.029–1.236, p=0.010). Similarly, flexion-type fractures were identified as an independent predictor of open reduction, showing increased odds compared to extension-type fractures (OR=1.807, 95% CI: 1.261–2.590, p=0.001). Posterolateral displacement was also significantly associated with a greater likelihood of requiring open reduction (OR=1.39, 95% CI: 1.010–1.926, p=0.043). In contrast, neutral coronal alignment was associated with reduced odds of open reduction, indicating a protective effect (OR=0.681, 95% CI: 0.510–0.909, p=0.009).

Table 1. Demographic characteristics of the patient

Age (years)			
Mean±SD	6.94±2.85	5.58±2.64	p<0.001
Min-Max	(1.5–13)	(1–14)	
Side (%)			
Right (R)	64 (52.9)	82 (50)	p=0.91
Left (L)	64 (47.1)	84 (50)	
Sex (%)			
Female	44 (34.4)	61 (36.7)	p=0.74
Male	88 (65.6)	105 (63.3)	
Operating surgeon (%)			
Experience (years) (%)			
≤5	32 (25)	53 (31.9)	p=0.251
5–10	28 (21.9)	46 (27.7)	
≥10 years	68 (53.1)	67 (40.4)	

OR: Open reduction; CR: Closed reduction; SD: Standard deviation.

DISCUSSION

In the present study, patient- and fracture-related factors associated with the need for open reduction in pediatric SCHFs were systematically evaluated. It was demonstrated that increasing age, flexion-type fractures, and posterolateral displacement were independently associated with a higher likelihood of open reduction, whereas neutral coronal alignment was found to exert a protective effect. Furthermore, although certain variables, including rotational deformity and displacement characteristics, were found to be significant in univariate analyses, these associations did not persist following multivariable adjustment. Taken together, these findings suggest that the requirement for open reduction is influenced by a complex interplay of patient-specific and radiographic factors rather than a single determinant.

In this context, numerous studies have investigated factors associated with the need for open reduction in pediatric SCHFs, identifying a broad range of potential risk factors. Among patient-related variables, age has emerged as a frequently discussed factor; however, the findings regarding its influence on open reduction remain controversial. Oguzkaya et al.[9] reported that increasing age was an independent predictor of failed CR, demonstrating that each 1-year increase in age was associated with approximately a 40% increase in risk (OR≈1.40, p≈0.01). In contrast, Thirakulpakdi et al.[15] reported that patients younger than 8 years of age had a higher likelihood of requiring open reduction, suggesting an inverse relationship between age and reduction success. These conflicting findings indicate that the effect of age may not be

Table 2. Comparison of radiographic parameters between groups

	Group 1 (OR) (n=128) (%)	Group 2 (CR) (n=166) (%)	p
Fracture type			
Extension	97 (75.8)	149 (89.2)	p=0.012
Flexion	31 (24.2)	17 (10.2)	
Displacement pattern			
Anterior	27 (21.1)	14 (8.4)	p<0.001
Posterior	27 (21.1)	70 (42..2)	
Posterolateral	41 (32)	26 (15.7)	
Posteromedial	33 (25.8)	56 (33.7)	
Rotation			
Present	96 (75)	98 (59)	p=0.038
Absent	32 (25)	68(41)	
Diaphyseal ınvolvement			
Present	33 (25.8)	32 (19.3)	p=0.183
Absent	95 (74.2)	134 (80.7)	
Coronal fracture pattern			
High transverse	23	30	p=0.075
Low transverse	72	108	
Medial oblique	16	12	
Lateral oblique	17	16	
Sagittal fracture pattern			
Low	66 (51.6)	101 (60.8)	p=0.363
High	62 (48.4)	65 (39.2)	
Coronal alignment			
Varus	43 (33.6)	39 (23.5)	p=0.003
Neutral	36 (28.1)	78 (47)	
Valgus	49 (38.3)	49 (29.5)	

OR: Open reduction; CR: Closed reduction.

Table 3. Results of backward stepwise (likelihood ratio) logistic regression analysis. Only the final step of the model is presented for clarity

Variable	B	SE	OR	95% CI	p
Age	0.120	0.047	1.127	1.029–1.236	0.010
Flexion type	0.592	0.184	1.807	1.261–2.590	0.001
Posterolateral displacement	0.333	0.165	1.39	1.010–1.926	0.043
Neutral alignment	−0.384	0.148	0.681	0.510–0.909	0.009

SE: Standard error; OR: Odds Ratio; CI: Confidence interval.

linear and could vary depending on fracture characteristics and study populations. In the present study, increasing age emerged as an independent predictor of open reduction, with each additional year associated with a higher likelihood of requiring open reduction, suggesting that older children may experience greater reduction difficulty.

Beyond patient-related variables, fracture-specific characteristics have been shown to play a critical role in determining the need for open reduction. Among these, fracture type was

identified as one of the most important determinants. Flexion-type fractures have been widely reported in the literature to be associated with a higher likelihood of open reduction, largely due to their inherent instability. In a recent study, Kolac et al.[11] demonstrated that flexion-type fractures were significantly more common in the open reduction group than in the CR group, indicating a strong association between fracture configuration and the need for open reduction. Similarly, Oguzkaya et al.[9] reported that flexion-type fracture configuration was an independent predictor of failed CR (OR=2.644, 95% CI: 1.085–6.440; p=0.032). Furthermore, Latario et al.[10] demonstrated that flexion-type injuries increased the risk of conversion to open reduction more than tenfold (relative risk =10.2). However, recent meta-analytic evidence has yielded more heterogeneous findings, suggesting that although extension-type Gartland IV fractures are strongly associated with open reduction, flexion-type injuries may not independently predict the need for open reduction (OR=2.354, p=0.251). Consistent with several previous studies, flexion-type fractures remained an independent predictor of open reduction in our cohort (OR=1.807), further supporting the concept that fracture instability plays a major role in reduction difficulty.

The direction of fracture displacement is another important factor that may significantly influence reduction success and the likelihood of open reduction. The direction of fracture displacement is another important factor that may significantly influence reduction success and the likelihood of open reduction. In this context, previous studies have suggested that lateral displacement patterns, particularly those corresponding to posterolateral translation, are associated with increased reduction difficulty and a higher likelihood of open reduction. Wang et al.[16] reported that distal fragment displacement toward the radial side was an independent risk factor for failed CR, indirectly supporting the clinical importance of posterolateral displacement patterns. More directly, Ondina et al.[4] demonstrated that posterolateral displacement was present in 65.9% of patients who required open reduction and identified it as a key factor associated with conversion to open reduction. In addition, a recent meta-analysis by Transtrum et al.[8] demonstrated that medially displaced fractures were significantly less likely to require open reduction (OR=0.35; 95% CI: 0.15–0.78; p=0.011), indirectly supporting the notion that lateral and posterolateral displacement patterns are associated with an increased risk of open reduction. Consistent with these studies, posterolateral displacement was identified as a factor associated with an increased likelihood of open reduction in our study, with a 1.39-fold higher risk of requiring open reduction. When fracture patterns were considered in our study, both flexion- and extension-type fractures, particularly those with posterolateral displacement corresponding to Gartland type IIIb injuries, were more frequently managed with open reduction, likely due to their inherently unstable nature. These findings further emphasize that instability plays a key role in determining the need for open reduction and should be carefully considered during preoperative planning.[17] In addition, the experience level of the operating surgeon was evaluated to determine whether it influenced the choice between open and CR; however, no significant association was found. This observation is consistent with findings from a recent meta-analysis suggesting that fracture characteristics rather than surgeon-related factors primarily dictate the need for open reduction.[8] Although the decision to proceed with open reduction is ultimately made intraoperatively, it is primarily based on the inability to achieve or maintain an acceptable reduction despite appropriate CR maneuvers. Therefore, the need for open reduction represents a clinically meaningful surrogate of reduction difficulty rather than surgeon preference alone. Nevertheless, surgeon-related factors and intraoperative judgment may still have contributed to the final treatment decision. Accordingly, our findings should be interpreted as identifying fracture characteristics associated with an increased likelihood of open reduction rather than absolute indications for conversion.

Among the evaluated variables, coronal fracture alignment emerged as a key independent factor influencing the likelihood of open reduction. In our analysis, preoperative neutral coronal alignment (neither varus nor valgus) was associated with a lower likelihood of requiring open reduction (OR=0.681, 95% CI: 0.510–0.909; p=0.009). This finding indicates that fractures without coronal malalignment are more likely to be successfully managed with CR. Similarly, the importance of coronal alignment has been emphasized in the literature. Colak et al.[7] demonstrated that varus fracture orientation was significantly associated with an increased likelihood of open reduction (OR=3.848, 95% CI: 1.506–9.831; p=0.005). Taken together, these findings highlight that coronal malalignment, particularly varus deformity, increases fracture instability and the likelihood of requiring open reduction.

This study has several limitations that should be acknowledged. First, due to its retrospective design, the study is inherently subject to selection and information bias. Second, certain potentially relevant variables, such as injury mechanism severity and soft tissue status, could not be fully evaluated due to limitations in the available records. Furthermore, patients with associated neurovascular injuries were excluded to obtain a more homogeneous study cohort. Consequently, our findings may not be generalizable to patients with more severe injury patterns, and a degree of selection bias cannot be excluded. Third, although radiographic measurements were performed by two experienced trauma surgeons and demonstrated good interobserver reliability, measurement-related variability cannot be completely excluded. Furthermore, although the operating surgeon's level of experience was evaluated, procedures performed within the study period were conducted by multiple surgeons, which may have introduced heterogeneity in reduction techniques. Variations in surgical experience, technical approach, and individual thresholds for conversion to open reduction may have influenced

intraoperative decision-making and introduced potential bias. Finally, as this was a single-center study, the generalizability of the findings may be limited. Nevertheless, the relatively large sample size, the balanced distribution of patients between groups, and the comprehensive assessment of both demographic and radiographic variables strengthen the validity and robustness of our findings.

CONCLUSION

Several patient and fracture-related characteristics were found to be independently associated with the likelihood of open reduction in pediatric SCHFs. Increasing age, flexion-type fractures, and posterolateral displacement were independently associated with a higher likelihood of open reduction, whereas neutral coronal alignment was associated with a lower likelihood of requiring open reduction. Among these, fracture-related characteristics, particularly those reflecting fracture instability and displacement pattern, showed the strongest associations with open reduction. Recognition of these associated factors may assist preoperative planning and help surgeons anticipate technically challenging reductions.

Ethics Committee Approval: This study was approved by the Haseki Training and Research Hospital Non-Interventional Clinical Research Ethics Committee (Date: 25.02.2026, Decision No: 51-2026).

Informed Consent: Written informed consent was obtained from all patients or their legal guardians

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Pediatrik suprakondiler humerus kırıklarında açık redüksiyon ile ilişkili klinik ve radyolojik faktörler

AMAÇ: Bu çalışmanın amacı, pediatrik suprakondiler humerus kırıklarında (SKHK) açık redüksiyon gereksinimi ile ilişkili demografik ve radyografik faktörleri değerlendirmektir.

GEREÇ VE YÖNTEM: 2016–2025 yılları arasında cerrahi olarak tedavi edilen toplam 294 pediatrik SKHK olgusu retrospektif olarak incelendi. Hastalar açık redüksiyon (OR, n=128) ve kapalı redüksiyon (CR, n=166) olmak üzere iki gruba ayrıldı. Yaş, cinsiyet, yaralanma tarafı ve cerrah deneyimi gibi demografik veriler kaydedildi. Preoperatif ön-arka ve lateral dirsek grafilerinde kırık tipi, deplasman yönü, rotasyonel deformite, diafizer uzanım, koronal kırık paterni, sagittal kırık paterni ve koronal dizilim değerlendirildi. Tek değişkenli analizde anlamlı bulunan değişkenler ($p<0.05$), backward stepwise yöntemi kullanılarak çok değişkenli lojistik regresyon analizine dahil edildi.

BULGULAR: OR grubunda ortalama yaş, CR grubuna göre anlamlı olarak daha yüksekti (6.94±2.85 yıla karşılık 5.58±2.64 yıl, $p<0.001$). Fleksiyon tipi kırıklar OR grubunda daha sık gözlendi (%24.2'ye karşılık %10.2, $p=0.012$). Posterolateral deplasman ve rotasyonel deformite de açık redüksiyon ile anlamlı olarak ilişkili bulundu. Koronal dizilim açısından gruplar arasında anlamlı fark saptandı; varus ve valgus maldizilimi OR grubunda daha sık izlendi ($p=0.003$). Çok değişkenli lojistik regresyon analizinde artan yaş (OR=1.127, %95 GA: 1.029–1.236; $p=0.010$), fleksiyon tipi kırık (OR=1.807, %95 GA: 1.261–2.590; $p=0.001$) ve posterolateral deplasman (OR=1.39, %95 GA: 1.010–1.926; $p=0.043$) açık redüksiyon için bağımsız belirleyiciler olarak saptandı. Buna karşın, koronal planda nötral dizilim, açık redüksiyon olasılığını azaltan bağımsız bir faktör olarak bulundu (OR=0.681, %95 GA: 0.510–0.909; $p=0.009$).

SONUÇ: Pediatrik SKHK'larda çeşitli demografik ve kırığa ait özellikler açık redüksiyon gereksinimi ile bağımsız olarak ilişkili bulunmuştur. Özellikle deplasman paterni ve koronal dizilim ile ilişkili kırık özellikleri, açık redüksiyon gereksinimi ile en güçlü ilişkiyi göstermiştir. Bu faktörlerin preoperatif dönemde değerlendirilmesi, cerrahi planlamaya katkı sağlayabilir ve teknik olarak güç redüksiyonların öngörülmesine yardımcı olabilir.

Anahtar sözcükler: Açık redüksiyon; kapalı redüksiyon; koronal dizilim; kırık deplasmanı; suprakondiler humerus kırığı.

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ORIGINAL ARTICLE

Epidemiology and injury patterns of high-energy pediatric pelvic and acetabular fractures: A retrospective study with comparative outcomes

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ABSTRACT

BACKGROUND: This study aimed to evaluate the epidemiological characteristics, injury mechanisms, fracture patterns, associated injuries, and early hemoglobin (Hb) changes and physiological response in pediatric patients with pelvic fractures. In addition, clinical and injury-related variables were compared according to skeletal maturity status and treatment modality.

METHODS: This retrospective single-center study included 52 consecutive patients younger than 18 years who were treated for pelvic fractures between September 2022 and March 2025. Skeletal maturity was determined based on triradiate cartilage status. Fractures were classified using Torode-Zieg, Young-Burgess, and Letournel-Judet systems. Early physiological response was assessed using serial Hb measurements at admission, 24 h, and 48 h. Comparative analyses were performed according to skeletal maturity and treatment modality.

RESULTS: The median age was 14 years, and 55.8% of patients were female. Pelvic ring injuries were observed in 76.9% of patients, and associated injuries were present in 67.3%. Non-operative treatment was performed in 65.4% of patients. Hb levels decreased from 12.3±1.8 g/dL at admission to 11.1±2.0 g/dL at 24 h and 10.5 g/dL at 48 h. No significant differences in Hb decline were observed according to skeletal maturity ($p>0.05$). Patients who underwent operative treatment had significantly lower Hb levels at 24 and 48 h ($p=0.006$ and $p=0.005$, respectively); however, the magnitude of Hb decrease did not differ significantly between treatment groups ($p>0.05$).

CONCLUSION: Pediatric pelvic fractures are uncommon injuries typically associated with high-energy trauma and multiple concomitant injuries. Early Hb decline was modest and did not differ according to skeletal maturity. Lower Hb levels in surgically treated patients may reflect overall injury severity rather than pelvic fracture-related hemorrhage. Careful evaluation of associated injuries and close monitoring of Hb levels are essential in pediatric pelvic trauma.

Keywords: Acetabulum; hemoglobin; pediatric; pelvic fractures; skeletal maturity.

INTRODUCTION

Pediatric pelvic fractures are uncommon injuries, accounting for <0.2% of all fractures in children and occurring at an estimated incidence of approximately 1/100,000 children.[1] In contrast to adults, the pediatric pelvis has distinct anatomical and biomechanical characteristics, including a higher proportion of cartilage, thicker periosteum, and greater elasticity, which allow the pelvic ring to absorb higher levels of force before fracturing.[2,3] Due to these structural differences, frac-

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ture patterns in children may differ from those seen in adults, and incomplete or isolated pelvic ring injuries may occur more frequently.[4,5]

The mechanisms responsible for pediatric pelvic fractures typically involve high-energy trauma such as falls from height or traffic accidents, and isolated pelvic fractures are uncommon.[3,6] Because the force required to fracture the pediatric pelvis is substantial, energy is frequently transmitted to other body regions, resulting in associated injuries involving the head, spine, extremities, thorax, or abdominal organs.[2,7] Previous studies have reported associated injuries in more than half of pediatric pelvic trauma cases, highlighting the importance of careful systemic evaluation.[7,8] Consequently, although mortality directly attributable to pelvic fracture itself is generally lower in children than in adults, overall morbidity and mortality are often determined by the severity of associated injuries rather than the fracture alone.[9,10]

Management strategies for pediatric pelvic fractures are influenced by fracture pattern, skeletal maturity, and the presence of associated injuries. Historically, most pelvic fractures in children have been treated non-operatively because many injuries are stable and the pediatric pelvis has considerable healing potential.[11,12] Nevertheless, recent evidence suggests that pelvic remodeling capacity may be more limited than previously assumed, and displaced or unstable fractures may require operative stabilization to restore pelvic symmetry and prevent long-term complications.[3,11,13] In addition, the status of the triradiate cartilage is considered one of the most reliable indicators of skeletal maturity and helps guide both fracture classification and treatment strategy.[14] Although life-threatening hemorrhage is a well-recognized concern in adults with pelvic fractures, exsanguinating bleeding appears to be considerably less common in children due to more effective vasoconstriction and the tamponading effect of the intact periosteum.[2,4] Nevertheless, early blood loss and hemoglobin (Hb) decline may still reflect injury severity and overall trauma burden in pediatric patients sustaining pelvic fractures. However, data describing the relationship between skeletal maturity, treatment strategy, and trauma-related early Hb changes and physiological response in pediatric pelvic fractures remain limited in the current literature.

In this study, early Hb changes were used as an indirect marker of early physiological response rather than a direct measure of hemorrhage. The aim of this study was to evaluate the epidemiological characteristics, injury mechanisms, fracture patterns, associated injuries, and early Hb changes and physiological response in pediatric patients presenting with pelvic fractures at a single tertiary center. In addition, we sought to compare clinical and injury-related variables according to skeletal maturity status and treatment modality in order to better characterize injury patterns and early Hb changes in this patient population.

MATERIALS AND METHODS

This retrospective study was performed in accordance with the principles of the Declaration of Helsinki and was approved by the Institutional Ethics Committee Etlik City Hospital (Approval No:AEŞH-BADEK1-2026-144, Date: 18.02.2026). As this study was designed as a retrospective analysis using anonymized patient data, the requirement for informed consent to participate was waived by the institutional ethics committee.

This retrospective single-center study was conducted at a tertiary referral hospital and included pediatric patients who presented to the emergency department with pelvic injuries between September 2022 and March 2025 and were treated by our orthopedic department. Patients younger than 18 years with radiologically confirmed pelvic fractures were eligible for inclusion. A total of 52 consecutive patients met the inclusion criteria and were analyzed. Patients older than 18 years, those transferred after initial treatment elsewhere, patients with pelvic avulsion fractures, which are usually caused by low-energy mechanisms, and those with incomplete radiological or laboratory data were excluded.

Demographic and clinical data were obtained from electronic medical records. Recorded variables included age, sex, mechanism of injury, skeletal maturity status, fracture pattern, associated injuries, treatment modality, and serial Hb measurements. Mechanisms of injury were categorized as fall from height, traffic accident (including both in-vehicle and pedestrian injuries), crush injury, or other causes.

Skeletal maturity was determined based on the status of the triradiate cartilage evaluated on initial pelvic radiographs and computed tomography scans. The status of the triradiate cartilage and fracture classifications was independently assessed by an orthopedic surgeon and a radiologist who were blinded to the clinical data. Discrepancies between the two reviewers were resolved by consensus. Patients were classified as skeletally immature if the triradiate cartilage was open and skeletally mature if it was closed.

Fractures were classified using established classification systems appropriate to skeletal maturity. In skeletally immature patients, pelvic fractures were categorized according to the Torode-Zieg classification system. In skeletally mature patients with pelvic ring injuries, fractures were classified using the Young-Burgess system. Acetabular fractures were classified according to the Letournel-Judet classification system. For descriptive and comparative purposes, fractures were also grouped anatomically as pelvic ring injuries or isolated acetabular fractures.

Associated injuries were identified through clinical examination and imaging findings on admission and categorized as thoracic injuries, spine fractures, extremity fractures, maxillofacial and/or intracranial injuries, and intra-abdominal injuries. In addition, a composite variable defined as the presence of any associated injury was recorded.

Treatment modality was documented as operative or non-operative. Indications for operative treatment included fracture displacement, instability, and inability to maintain alignment with conservative management. All operative interventions were performed after the first 48 hours of admission. Therefore, Hb changes observed within the initial 48-h period were considered to represent trauma-related blood loss rather than surgical bleeding.

Early physiological response was assessed using serial Hb measurements obtained from routine complete blood counts at admission (Hb0), at 24 h (Hb24), and at 48 h (Hb48). To quantify early Hb decline, the decrease within the first 24 h (ΔHb24/0=Hb0−Hb24), the decrease between 24 and 48 h (ΔHb48/24=Hb24−Hb48), and the total decrease within the first 48 h (ΔHb48/0=Hb0−Hb48) were calculated. Since all operative interventions were performed after 48 h, these Hb changes were considered to reflect early trauma-related hemorrhage. No patient received a blood transfusion within the first 48 h. Hb values were interpreted with caution, as

Table 1. Baseline characteristics and injury patterns of the population (n=52)

Variable	Overall (n=52)
Age, years [median (min–max)]	14 (4–18)
Sex, n (%)	
Female	29 (55.8)
Male	23 (44.2)
Skeletal maturity (triradiate cartilage), n (%)	
Open	26 (50)
Closed	26 (50)
Injury mechanism, n (%)	
Fall from height	22 (42.3)
Traffic accident (in-vehicle+pedestrian)	19 (36.5)
Crush injury	7 (13.5)
Other	4 (7.7)
Fracture pattern, n (%)	
Pelvic ring injury	40 (76.9)
Isolated acetabular fracture	12 (23.1)
Associated injuries, n (%)	
Any associated injury	35 (67.3)
Thoracic injury	22 (42.3)
Spine fracture	18 (34.6)
Extremity fracture	14 (26.9)
Maxillofacial and/or intracranial injury	12 (23.1)
Intra-abdominal injury	5 (9.6)
Treatment, n (%)	
Non-operative	34 (65.4)
Operative	18 (34.6)
Hemoglobin change	
Hb at admission, Hb0 (g/dL) (mean± SD)	12.3±1.8
Hb at 24 h, Hb24 (g/dL) (mean±SD)	11.1±2.0
Hb at 48 h, Hb48 (g/dL) [median (min–max)]	10.5 (6.1–15.2)
Hb decrease within first 24 h, ΔHb24/0=Hb0–Hb24 (g/dL) [median (min–max)]	1 (−2.3–4.6)
Hb decrease within second 24 h, ΔHb48/24=Hb24−Hb48 (g/dL) [median (min–max)]	0.3 (−1.7–2.3)
Hb decrease within first 48 h, ΔHb48/0=Hb0−Hb48 (g/dL) [median (min–max)]	1.05 (−2.2–5.3)

Hb: Hemoglobin; SD: Standard deviation.

they may be influenced by factors such as fluid resuscitation and hemodilution.

Comparative analyses were performed according to skeletal maturity status (open vs. closed triradiate cartilage) and treatment modality (operative vs non-operative).

Descriptive statistics are presented as number (n) and percentage (%) for qualitative data. For quantitative data, mean and standard deviation are given for normally distributed data, and median and minimum–maximum values are given for non-normally distributed data. Comparison of categorical variables was performed using the Pearson Chi-square test. Fisher's exact test was used when the number of cells where the expected value was less than five exceeded 20% of the total number of cells. For comparing continuous variables in two independent groups, the independent samples t-test was used if the continuous variable followed a normal distribution in both groups, and the Mann–Whitney U test was used if it did not follow a normal distribution in at least one group. The Type I error margin (alpha) was accepted as 0.05. The Statistical Package for the Social Sciences version 31.0 was used for data analysis.

RESULTS

A total of 52 pediatric patients with pelvic fractures were included in the study. The median age was 14 years (range, 4–18 years), and 29 patients (55.8%) were female. The triradiate cartilage was open in 26 patients (50%) and closed in 26 patients (50%). The most common mechanism of injury was a fall from height (42.3%), followed by traffic accidents (36.5%). Pelvic ring injuries were observed in 40 patients (76.9%), whereas isolated acetabular fractures were present in 12 patients (23.1%). Associated injuries were identified in 35 patients (67.3%), with thoracic injuries being the most frequent (42.3%), followed by spine fractures (34.6%) and extremity fractures (26.9%). Non-operative treatment was performed in 34 patients (65.4%), while 18 patients (34.6%) underwent operative management. The mean Hb level at admission was 12.3±1.8 g/dL, which decreased to 11.1±2.0 g/dL at 24 h and to a median of 10.5 g/dL (range, 6.1–15.2) at 48 h. The median Hb decrease within the first 48 h was 1.05 g/dL (range, −2.2–5.3) (Table 1).

According to fracture classification, among skeletally immature patients, Torode-Zieg type III fractures were the most common (57.6%), followed by type II (26.9%) and type IV injuries (15.3%). Among skeletally mature pelvic ring injuries, Young-Burgess LC1 fractures predominated (71.4%). Acetabular fractures were evenly distributed between transverse and posterior wall types (33.3% each), with both-column and anterior column fractures each accounting for 16.7% (Table 2).

When patients were compared according to skeletal maturity, the median age was significantly higher in the skeletally mature group than in the immature group (16 vs. 12.5 years, p<0.001). No significant differences were observed between the groups regarding sex distribution, injury mechanisms, associated injuries, or operative treatment rates. Hb values at admission, 24 h, and 48 h were similar between groups. Likewise, Hb decreases within the first 24 h, between 24 and 48 h, and within the first 48 h did not differ significantly according to skeletal maturity status (all p>0.05) (Table 3).

Table 2. Fracture classification

Classification	n (%)
Torode-Zieg classification (n=26)	
Type II	7 (26.9)
Type III	15 (57.6)
Type IV	4 (15.3)
Young-Burgess classification (n=14)	
LC1	10 (71.4)
LC2	3 (21.4)
LC3	1 (7.1)
Letournel-Judet classification (n=12)	
Transverse	4 (33.3)
Posterior wall	4 (33.3)
Both column	2 (16.7)
Anterior column	2 (16.7)

Comparison according to treatment modality showed no significant differences between operative and non-operative groups in terms of age, sex, skeletal maturity, injury mechanisms, or associated injuries. Admission Hb levels were also similar between groups (p=0.072). However, Hb levels at 24 h and 48 h were significantly lower in the operative group compared to the non-operative group (median Hb24: 10.0 vs. 11.7 g/dL, p=0.006; median Hb48: 9.4 vs. 11.6 g/dL, p=0.005). Despite these differences, Hb decreases within the first 24 h, between 24 and 48 h, and within the first 48 h were not statistically different between operative and non-operative patients (all p>0.05) (Table 4). In an additional analysis, Hb values at admission, 24 h, and 48 h, as well as Hb changes, were comparable between patients with pelvic ring injuries and those with isolated acetabular fractures (all p>0.05).

DISCUSSION

The most important finding of the present study was that patients who underwent operative treatment had significantly lower Hb levels at 24 and 48 h, whereas the magnitude of Hb decline within the first 48 h did not differ significantly between operative and non-operative groups. This observation suggests that lower Hb levels in surgically treated patients may be associated with overall injury severity; however, this interpretation should be considered speculative in the absence of objective injury severity scores. Although pelvic fractures in adults are commonly associated with life-threatening

Table 3. Comparison according to skeletal maturity

Variable	Open triradiate-Immature (n=26)	Closed triradiate-Mature (n=26)	p
Age, years [median (min-max)]	12.5 (4–14)	16 (14–18)	<0.001[a]
Female sex, n (%)	15 (57.7)	14 (53.8)	0.780[b]
Injury mechanism, n (%)			0.197[c]
Fall from height	11 (42.3)	11 (42.3)	
Traffic accident (all MVC combined)	8 (30.8)	11 (42.3)	
Crush	6 (23.1)	1 (3.8)	
Other	1 (3.8)	3 (11.5)	
Associated injuries, n (%)			
Any associated injury	18 (69.2)	17 (65.4)	0.768[b]
Thoracic injury	10 (38.5)	12 (46.2)	0.575[b]
Spine fracture	8 (30.8)	10 (38.5)	0.560[b]
Extremity fracture	7 (26.9)	7 (26.9)	1.000[b]
Maxillofacial and/or intracranial injury	7 (26.9)	5 (19.2)	0.510[b]
Intra-abdominal injury	3 (11.5)	2 (7.7)	1.000[c]
Operative treatment, n (%)	7 (26.9)	11 (42.3)	0.244[b]
Hb change			
Hb at admission, Hb0 (g/dL) (mean±SD)	12.0±1.7	12.5±1.9	0.312[d]
Hb at 24 h, Hb24 (g/dL) (mean±SD)	10.6±1.7	11.6±2.1	0.061[d]
Hb at 48 h, Hb48 (g/dL) (mean±SD)	10.4±1.8	11.3±2.2	0.093[d]
Hb decrease within first 24 h, ΔHb24/0=Hb0–Hb24 (g/dL) (mean±SD)	1.4±1.3	0.9±1.3	0.170[d]
Hb decrease within second 24 h, ΔHb48/24=Hb24−Hb48 (g/dL) (mean±SD)	0.3±1.0	0.3±0.8	0.792[d]
Hb decrease within first 48 h, ΔHb48/0=Hb0−Hb48 (g/dL) [median (min–max)]	1.1 (−1.6–4.6)	1.0 (−2.2–5.3)	0.197[a]

[a]Mann–Whitney U test; [b]Pearson Chi-square test; [c]Fisher exact test; [d]Independent samples t test; Hb: Hemoglobin; SD: Standard deviation; MVC: Motor vehicle crash.

hemorrhage, exsanguinating bleeding appears to be less frequent in children due to the tamponading effect of the intact periosteum and the more reactive vasculature in the pediatric population.[2,4] Our findings support this concept and indicate that early Hb decline in pediatric pelvic trauma may be influenced more by overall trauma severity than by pelvic injury alone. Previous studies have also demonstrated that lower Hb levels are associated with increased injury severity and a higher likelihood of operative intervention in pediatric pelvic trauma.[15] Hb levels should be interpreted as indirect markers of physiological response rather than direct indicators of hemorrhage, as they may be influenced by factors such as fluid resuscitation and hemodilution, potentially limiting their ability to accurately reflect true blood loss in the early trauma period.

Another notable finding was that skeletal maturity did not significantly affect early Hb change. Despite a significant age difference between skeletally immature and mature patients, Hb levels and Hb decline within the first 48 h were comparable between groups. The pediatric pelvis differs structurally from the adult pelvis, with a higher cartilage content, thicker periosteum, and greater elasticity, which may limit displacement and reduce bleeding.[2-4] Previous studies have also emphasized that skeletally immature pelvic fractures represent a distinct injury entity; however, our results suggest that these anatomical differences may not translate into meaningful differences in early hemorrhagic response when pelvic fractures occur.[3,14]

Pediatric pelvic fractures typically result from high-energy trauma and are frequently accompanied by multiple associated injuries. In the present study, associated injuries were identified in more than two-thirds of patients, with thoracic and spinal injuries being the most common. These findings are consistent with previous reports demonstrating that pediatric pelvic fractures rarely occur in isolation and that energy transfer during trauma often results in injuries involving multiple organ systems.[6,7,16] The high rate of concomitant injuries observed in our cohort supports earlier studies report-

Table 4. Comparison according to treatment

Variable	Non-operative (n=34)	Operative (n=18)	p
Age, years [median (min–max)]	14 (4–18)	15 (8–18)	0.444[a]
Female sex, n (%)	17 (50.0)	12 (66.7)	0.250[b]
Closed triradiate cartilage, n (%)	15 (44.1)	11 (61.1)	0.244[b]
Injury mechanism, n (%)			
Fall from height	15 (44.1)	7 (38.9)	
Traffic accident	13 (38.2)	6 (33.3)	
Crush	3 (8.8)	4 (22.2)	0.630[c]
Other	3 (8.8)	1 (5.6)	
Associated injuries, n (%)			
Any associated injury	21 (61.8)	14 (77.8)	0.242[b]
Thoracic injury	12 (35.3)	10 (55.6)	0.159[b]
Spine fracture	11 (32.4)	7 (38.9)	0.637[b]
Extremity fracture	7 (20.6)	7 (38.9)	0.197[c]
Maxillofacial and/or intracranial injury	7 (20.6)	5 (27.8)	0.731[c]
Intra-abdominal injury	3 (8.8)	2 (11.1)	1.000[c]
Hb change			
Hb at admission, Hb0 (g/dL) (mean±SD)	12.6±1.8	11.6±1.7	0.072[d]
Hb at 24 h, Hb24 (g/dL) [median (min–max)]	11.7 (7.4–15.9)	10.0 (7.9–14.6)	0.006[a]
Hb at 48 h, Hb48 (g/dL) [median (min-max)]	11.6 (7.2–15.2)	9.4 (6.1–14.0)	0.005[a]
Hb decrease within first 24 h, ΔHb24/0=Hb0–Hb24 (g/dL) [median (min–max)]	0.5 (−2.3–4.6)	1.3 (−0.5–3.6)	0.303[a]
Hb decrease within second 24 h, ΔHb48/24=Hb24−Hb48 (g/dL) (mean±SD)	0.2±0.8	0.4±1.0	0.394[d]
Hb decrease within first 48 h, ΔHb48/0=Hb0−Hb48 (g/dL) (mean±SD)	1.2±1.5	1.9±1.6	0.125[d]

[a]Mann–Whitney U test; [b]Pearson Chi-square test; [c]Fisher Exact test; dIndependent samples t test.

ing associated injuries in 58–100% of pediatric pelvic fracture cases.[7,16] Furthermore, previous literature has indicated that morbidity and mortality in pediatric pelvic trauma are more closely related to associated injuries than to the pelvic fracture itself,[9,10] which is consistent with our findings. Recent studies have further emphasized that, in pediatric pelvic trauma, hemorrhagic burden is more often related to associated injuries rather than the pelvic fracture itself.[17]

Historically, most pediatric pelvic fractures have been managed non-operatively, as many injuries are stable and the pediatric pelvis has considerable healing potential.[11,12] In our series, approximately two-thirds of patients were treated conservatively, which aligns with previous reports indicating that the majority of pediatric pelvic fractures do not require surgical stabilization.[18] However, recent studies suggest that pelvic remodeling potential may be limited, particularly in displaced or unstable fractures, and operative stabilization may be required to restore pelvic symmetry and prevent long-term deformity.[3,11,13] In the present study, although operative treatment was more frequent in skeletally mature patients, this difference did not reach statistical significance. This finding highlights that treatment decisions in pediatric pelvic trauma depend on multiple factors, including fracture pattern, skeletal maturity, and the presence of associated injuries.[19]

The fracture patterns observed in our study also reflect known characteristics of pediatric pelvic trauma. Pelvic ring injuries constituted the majority of cases, whereas isolated acetabular fractures were less common. The elasticity of the pediatric pelvis and the relative strength of ligamentous structures may allow deformation without complete disruption of the pelvic ring, leading to different injury patterns compared to adults.[2,5] In addition, the status of the triradiate cartilage has been reported as one of the most reliable indicators of skeletal maturity and plays an important role in determining injury pattern and management strategy.[14] Our findings are consistent with this concept, although skeletal maturity did not influence early hemorrhagic changes.

The present study has several limitations. First, the retrospective design may introduce selection bias, particularly in the comparison between operative and non-operative groups,

as treatment decisions were based on clinical judgment and underlying injury characteristics. Second, the relatively small sample size may limit statistical power for subgroup analyses. Third, formal injury severity scores were not available, which limits the ability to objectively assess overall trauma burden. Finally, data regarding intensive care unit admission and length of hospital stay were not available. Despite these limitations, the strengths of this study include the evaluation of early Hb changes, blinded radiologic assessment, and comparative analyses according to skeletal maturity and treatment modality.

CONCLUSION

In conclusion, pediatric pelvic fractures are rare injuries typically resulting from high-energy trauma and frequently associated with additional injuries. Early Hb decline was modest overall and did not differ according to skeletal maturity. Although surgically treated patients demonstrated lower Hb levels during early follow-up, the degree of Hb decline was similar, suggesting that overall injury severity rather than pelvic fracture-related hemorrhage may influence early hematologic changes. Careful assessment of associated injuries and close monitoring of Hb levels, with consideration of potential confounding factors, remain essential in the management of pediatric pelvic trauma.

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Ethics Committee Approval: This study was approved by the Institutional Ethics Committee Etlik City Hospital (Date: 18.02.2026, Decision No: AEŞH-BADEK1-2026-144).

Informed Consent: As this study was designed as a retrospective analysis using anonymized patient data, the requirement for informed consent to participate was waived by the institutional ethics committee.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Yüksek enerjili pediatrik pelvik ve asetabulum kırıklarının epidemiyolojisi ve yaralanma paternleri: Karşılaştırmalı sonuçları içeren retrospektif bir çalışma

AMAÇ: Bu çalışmanın amacı, pelvik kırığı olan pediatrik hastalarda epidemiyolojik özellikleri, yaralanma mekanizmalarını, kırık paternlerini, eşlik eden yaralanmaları ve erken dönemde hemoglobin değişikliklerini ve fizyolojik yanıtı değerlendirmektir. Ayrıca, klinik ve yaralanmaya bağlı değişkenler iskelet matürite durumu ve tedavi modalitesine göre karşılaştırıldı.

GEREÇ VE YÖNTEM: Bu retrospektif tek merkezli çalışmaya, Eylül 2022 ile Mart 2025 tarihleri arasında pelvik kırık nedeniyle tedavi edilen 18 yaş altı 52 ardışık hasta dahil edildi. İskelet matüritesi triradiat kıkırdak durumuna göre değerlendirildi. Kırıklar Torode–Zieg, Young–Burgess ve Letournel–Judet sınıflama sistemlerine göre sınıflandırıldı. Erken fizyolojik yanıt, başvuru, 24. saat ve 48. saatte ölçülen seri hemoglobin değerleri ile değerlendirildi. Karşılaştırmalı analizler iskelet matüritesi ve tedavi modalitesine göre yapıldı.

BULGULAR: Medyan yaş 14 olup hastaların %55.8'i kadındı. Pelvik halka yaralanmaları hastaların %76.9'unda izlenirken, eşlik eden yaralanmalar %67.3 oranında mevcuttu. Hastaların %65.4'ü konservatif olarak tedavi edildi. Hemoglobin düzeyi başvuruda 12.3±1.8 g/dL iken 24. saatte 11.1±2.0 g/dL'ye ve 48. saatte 10.5 g/dL'ye geriledi. İskelet matüritesine göre hemoglobin düşüşü açısından anlamlı fark saptanmadı ($p>0.05$). Cerrahi tedavi uygulanan hastalarda 24. ve 48. saat hemoglobin düzeyleri anlamlı olarak daha düşük bulundu (sırasıyla $p=0.006$ ve $p=0.005$); ancak hemoglobin düşüş miktarı açısından gruplar arasında anlamlı fark yoktu ($p>0.05$).

SONUÇ: Pediatrik pelvik kırıklar genellikle yüksek enerjili travmalarla ilişkili nadir yaralanmalar olup sıklıkla çoklu eşlik eden yaralanmalarla birlikte-dir. Erken dönemde hemoglobin düşüşü sınırlı olup iskelet matüritesine göre farklılık göstermemektedir. Cerrahi uygulanan hastalarda daha düşük hemoglobin düzeyleri, pelvik kırığa bağlı kanamadan ziyade genel yaralanma şiddetini yansıtıyor olabilir. Pediatrik pelvik travma yönetiminde eşlik eden yaralanmaların dikkatli değerlendirilmesi ve hemoglobin düzeylerinin yakın takibi önemlidir.

Anahtar sözcükler: Asetabulum; hemoglobin; iskelet matüritesi pediatrik; pelvik kırıklar.

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CASE REPORT

Penetrating maxillofacial trauma with transmaxillary migration of a metallic foreign body to the sphenoid sinus: A rare case

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ABSTRACT

This case report details a rare and potentially life-threatening injury of an initially overlooked maxillofacial trauma sustained during agricultural activity. A 19-year-old male presented to the emergency department with a headache and fatigue, 2 days following a right malar injury that had been previously sutured without advanced evaluation. A thorough clinical examination was conducted, which revealed the presence of periorbital swelling on both sides, accompanied by a right subconjunctival hemorrhage and chemosis. Radiographic imaging revealed the presence of a substantial, crescent-shaped metallic foreign body with its tip lodged just beneath the anterior skull base, penetrating the sphenoid sinus and lying inferior to the hypophysis. The base of the foreign body extended horizontally into the region adjacent to the middle nasal concha. Multislice computed tomography with angiography revealed its close proximity to critical neurovascular structures, including branches of the maxillary artery. Surgical removal was performed under general anesthesia via an extra-nasal transmaxillary approach, utilizing the trauma incision. Following meticulous dissection, the foreign body was reached and carefully extracted through an executed outward rotation technique. This case emphasizes the vital necessity for thorough clinical evaluation, detailed history-taking, and advanced imaging in the context of facial trauma, where superficially innocuous wounds may harbor latent complications. Primary closure of laceration without full diagnostic clarity risks sealing the patient in danger just millimeters from vital neurovascular structures. A detailed history, systematic examination and proper investigations are needed before primary closure of traumatic facial lacerations.

Keywords: Agricultural injury; foreign bod; midface trauma.

INTRODUCTION

Agriculture is considered to be one of the most hazardous economic sectors. It accounts for a significant number of accidents and occupational diseases on an annual basis.[1] It is for this reason that agriculture continues to be categorized as one of the most hazardous occupational sectors. Those engaged in agricultural activities are exposed to a high rate of injury and risk. Injuries sustained in agricultural areas remain a significant cause of morbidity and mortality on a global scale. The aforementioned injuries are frequently the consequence of abrupt mechanical or environmental forces that surpass the physiological limits of the human body, thereby compromising its structural integrity. From an epidemiological perspective, only injuries severe enough to require medical attention, cause functional impairment, or lead to loss of consciousness are systematically recorded.[2] It is important to note that this approach may lead to an underestimation of the true scope of the problem, especially in distant and rural areas.

It is an established fact that those engaged in agricultural pursuits are routinely exposed to a range of potential hazards, including but not limited to the utilization of heavy machinery, the employment of pesticides, and physically demanding la-

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bor.[3] These factors have been shown to result in long-term disability and a significant economic burden on the affected individuals and communities. Despite growing awareness and prevention efforts, agricultural injuries remain a pressing public health issue.[4] In addition to the long-term damage and health problems associated with agricultural labor, injuries that require acute and urgent intervention are also prevalent.[5] In the case of agricultural injuries presenting to primary care after an acute trauma, it is imperative that healthcare professionals recognize that such injuries may be more serious than they appear at first glance. This case report aims to present such a scenario: A simple facial laceration, seemingly harmless and occurring during agricultural work, has been observed to conceal a metallic crescentic-shaped foreign body extending beneath the skull base. Institutional review board approval was not required for this single-patient case report in accordance with local regulations. Written informed consent was obtained from the patient for including study.

CASE REPORT

A 19-year-old male patient presented to the emergency department with complaints of headache and fatigue. The patient reported that he had sustained a traumatic injury 2 days earlier while working in the fields as a result of a steel tow rope used to pull agricultural products behind a tractor becoming taut and striking the right side of his face. The patient's initial treatment was administered at a primary health center, where the laceration in the right malar region was sutured without the use of advanced imaging or specialist consultation. The patient was admitted to the emergency department 2 days later, owing to a deterioration in his symptoms, and was referred to the plastic reconstructive and aesthetic surgery department. A detailed examination of the sutured laceration revealed signs of inflammation, manifesting as hyperemia, edema, and non-purulent discharge (Fig. 1). At the time of presentation, the patient displayed symptoms consistent with a subfebrile fever, and vital signs, including heart rate, blood pressure, and oxygen saturation, remained within normal range. A neurological examination was conducted, which revealed intact extraocular movements in all directions, normal facial nerve function, and an absence of sensory deficits except decreased sensation in the region extending from the right malar area to the upper lip. The additional findings included the presence of bilateral periorbital edema, right subconjunctival hemorrhage, and chemosis. A radiographic evaluation was deemed necessary in order to accurately ascertain the patient's injury, taking into account the results of the examination, signs and the patient's trauma history. Radiographic imaging revealed the presence of a large, crescent-shaped metallic foreign body measuring approximately 34.8 mm in length and 10.0 mm in width (Fig. 2). Multislice computed tomography (CT) with angiography was performed subsequently, and this revealed that the foreign body penetrated the sphenoid sinus, with its tip located just

Figure 1. Pre-operative suture line and postoperative 6-month scar within the palpebral groove.

Figure 2. Direct head graphy displays a crescent-shaped metallic foreign body (lateral view).

inferior to the anterior skull base beneath the hypophysis, and its base lying horizontally near the middle nasal concha. The foreign object was found to be in close proximity to branches of the maxillary artery; however, no active bleeding or cerebrospinal fluid (CSF) leak was observed. The patient was admitted and hospitalized immediately. Under general anesthesia, the previously sutured malar laceration was me-

Figure 3. The foreign body, which measured 5.5 cm in width, was removed using a transmaxillary approach.

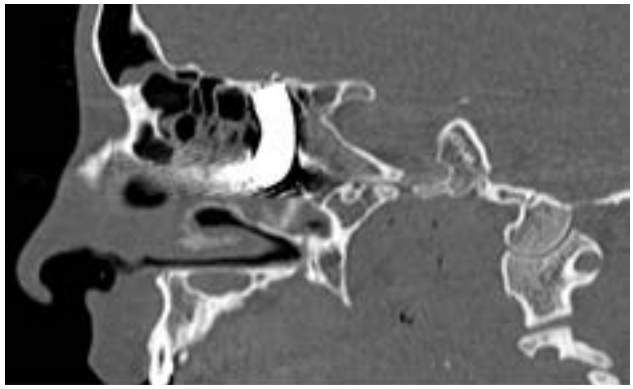

Figure 4. A metallic foreign body is seen in the sagittal section of computed tomography scan, breaking through the ethmoid bone and penetrating into the anterior wall of the sphenoid sinus.

ticulously dissected. A transmaxillary approach was used to reach the foreign body, which was trapped within the posterior aspect of the maxillary sinus and extended into the sphenoid sinus. The metallic foreign body was extracted through a controlled reverse rotational maneuver. This allowed for safe and complete removal along its insertion axis without causing injury to the surrounding tissues (Figs. 3 and 4).

Consequently, the anatomical location after removal was meticulously debrided and irrigated. The maxillary sinus mucosa was meticulously debrided, and the anterior wall of the maxillary sinus was restored. An endonasal tampon was strategically placed, along with bilateral nasal septal splints, to provide support for mucosal healing and to ensure the maintenance of structural alignment. The patient was admitted to the hospital for a period of 5 days to facilitate close post-operative monitoring, with particular attention to signs of CSF leakage.

To prevent the onset of meningitis, prophylactic broad-spectrum antibiotics, including vancomycin and meropenem, were administered. Post-operative complications were not observed. The nasal splints were removed on the 5th day, and the patient was discharged in good condition with no neurological deficit or residual symptoms.

The patient was scheduled to attend follow-up visits once a month for 6 months postoperatively. A comprehensive clinical evaluation and endoscopic examination were performed on the patient during each visit, and it was ascertained that the wound was healing adequately. There were no indications of infection, neurological deficit, or functional impairment. A CT scan was performed to ascertain the complete healing of the patient, and no residual fragments or secondary complications were observed during the 6-month follow-up. As demonstrated in Figure 1, the patient continued to demonstrate no symptoms at the 6-month evaluation, and no long-term sequelae were identified.

DISCUSSION

Penetrating cranio-facial injuries resulting from farm machinery injuries are a rarity, yet when such injuries do occur, they pose grave threats to vital anatomical structures such as the ocular, cerebral and vasculo-nervous structures.[6] In this case, a crescent-shaped metallic hook was observed in close proximity to the pituitary and maxillary artery branches, passing through the maxillary and sphenoid sinuses. It is evident that, due to this foreign body's absence of visibility from external observation, it went undetected during the primary care evaluation. As a result, the patient remained unaware of the severity of his condition for 2 days until he sought further medical attention. This case demonstrates the pivotal role of radiological assessment following the initial evaluation. As the literature indicates, comparable cases of penetrating craniofacial trauma involving metallic foreign bodies have been documented, frequently resulting from objects such as knives or blades that traverse profound anatomical corridors and reach the skull base.[7] The type of foreign body and agricultural machine-related injury observed in this case has not been previously documented in the extant literature. It is therefore a noteworthy exemplar with regard to diagnosis, treatment and follow-up. The injury was effectively managed with a multidisciplinary approach, including the use of endoscopic assistance. In conclusion, the use of the endoscope as a diagnostic and therapeutic tool is of great importance, as demonstrated in the literature.[8]

Although persistent CSF leakage is rare, CSF leakage in the first 2–7 days is a well-known complication of craniofacial trauma, especially involving damage to the anterior cranial fossa, cribriform plate, and ethmoid air cells.[9] In such cases, anterior skull base fractures, particularly those affecting the

ethmoid and sphenoid regions, are of particular clinical significance due to their proximity to the dura and the potential for communication with the nasal cavity. In our case, we were fortunate that the anterior skull base was preserved, and the removal of the foreign body, as well as adequate debridement, irrigation and obliteration, prevented CSF leakage. It is vital to emphasize that, in this instance, our case underscores the importance of close post-operative monitoring for the leakage of CSF, even in the absence of overt dural injury during trauma and surgery.

Furthermore, as demonstrated in the relevant literature, the utilization of antibiotics during the perioperative period has been shown to promote healing in cases of meningitis, sinusitis and soft-tissue infections.[10] Considering this situation, broad-spectrum antibiotics were administered prophylactically in our patient, and no infectious condition was observed, although the patient presented to us on the 2nd day after the injury.

Recent literature highlights the severity and complexity of injuries to farm machinery and craniofacial trauma, particularly in low-resource rural areas.[11] The study revealed that the mechanisms of injury encompass a wide spectrum of severity, from mild to severe injuries. In addition, late presentation to tertiary hospitals has been shown in another study to contribute significantly to morbidity due to farm-related injuries in low-income countries.[12] The similarities that can be identified between both experience and our case are of paramount importance in emphasizing the clinical significance of treating even seemingly minor agricultural facial injuries with a high level of suspicion, employing a multidisciplinary approach, and utilizing available resources.

CONCLUSION

This case demonstrates the critical importance of comprehensive clinical evaluation, detailed history, and advanced imaging in the maxillofacial trauma patient due to farm machinery injury. It also serves to highlight the necessity for caution when assessing penetrating injuries, as their initial appearance may be misleading. In rural areas, where access to advanced diagnostic facilities may be delayed, physicians should be alert for occult injuries and other underlying pathologies.

Ethics Committee Approval: This is a single case report, and therefore ethics committee approval was not required in accordance with institutional policies.

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

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

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OLGU SUNUMU - *ÖZ*

Transmaksiller yoldan sfenoid sinüse saplanan metalik yabancı cisim ile penetran maksillofasiyal travma: Nadir bir olgu

Bu olgu raporunda, tarımsal faaliyet sırasında meydana gelen ve başlangıçta gözden kaçan bir maksillofasiyal travmanın nadir görülen ve potansiyel olarak hayatı tehdit edebilecek bir yaralanması sunulmaktadır. On dokuz yaşında bir erkek, daha önce ileri değerlendirme yapılmadan dikilen sağ malar bölgedeki yaralanmasından iki gün sonra baş ağrısı ve halsizlik şikayetiyle acil servise başvurmuştur. Yapılan kapsamlı klinik muayenede her iki tarafta periorbital ödem, sağ subkonjonktival hemoraji ve kemozis tespit edildi. Radyografik görüntülemede, ucu ön kafa tabanının hemen altına yerleşmiş, sfenoid sinüsü penetre eden ve hipofizin inferiorunda uzanan, hilal şeklinde metalik bir yabancı cismin varlığı tespit edildi. Yabancı cismin tabanı yatay olarak orta burun konkasına bitişik bölgeye doğru uzanıyordu. Anjiyografi ile çok kesitli bilgisayarlı tomografi tetkik ettirilerek, maksiller arter dalları da dahil olmak üzere kritik nörovasküler yapılara yakınlığı ortaya koydu. Acil ameliyata alınan hastanın yaralanmasına genel anestezi altında, travma insizyonu kullanılarak ekstra nazal transmaksiller yaklaşıldı. Titiz, dikkatli diseksiyonun ardından metalik yabancı cisme ulaşıldı ve ekseni etrafında dışa döndürme tekniği uygulanarak dikkatlice çıkarıldı. Bu olgu, yüzeysel olarak zararsız görünen kesi ve yaraların içerisinde yabancı cisim barındırabileceği ve maksillofasiyal travma hastalarında kapsamlı klinik değerlendirme, ayrıntılı öykü alma ve ileri görüntülemenin hayati gerekliliğini vurgulamaktadır. Travmatik yüz laserasyonlarının primer olarak kapatılmasından önce ayrıntılı bir öykü, sistematik muayene ve uygun incelemeler gereklidir.

Anahtar sözcükler: Orta yüz travması; tarımsal yaralanma; yabancı cisim.

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