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Case Report - *Olgu Sunumu*

ORIGINAL ARTICLE

Outcomes of acute moderate cholecystitis management techniques: percutaneous transhepatic gallbladder drainage and early laparoscopic cholecystectomy

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ABSTRACT

BACKGROUND: Acute cholecystitis (AC) is a common hepatobiliary condition that requires surgical intervention. The Tokyo Guidelines 2018 (TG18) recommend early laparoscopic cholecystectomy (LC) for moderate AC (Grade II) and percutaneous transhepatic gallbladder drainage (PTGBD) for high-risk patients. However, the optimal timing for LC following PTGBD remains controversial.

METHODS: This retrospective study analyzed data from 432 patients with Grade II AC treated at a high-volume center between January 2022 and February 2024. Patients were divided into two groups: early LC (n=131) and delayed LC following PTGBD (n=43). Clinical outcomes, postoperative complications, and length of hospital stay were compared using statistical analyses, including linear regression modeling.

RESULTS: No significant differences were observed between the groups in conversion to open surgery (4.7% vs. 9.9%, p=0.27), postoperative bleeding (6.9% vs. 1.5%, p=0.006), or biliary tract complications (4.7% vs. 3%, p=0.638). However, postoperative systemic inflammatory response syndrome (SIRS) occurred significantly more frequently in the PTGBD group (23.3% vs. 6.9%, p=0.003). Linear regression analysis identified conversion to open surgery, postoperative SIRS, and biliary complications as independent predictors of prolonged hospital stay, whereas PTGBD itself was not associated with increased hospitalization duration (p=0.304).

CONCLUSION: Early LC is a feasible approach for most patients with Grade II AC, with outcomes comparable to those of PTGBD followed by delayed LC. PTGBD remains a valuable alternative for high-risk patients. Further large-scale prospective studies are needed to refine treatment strategies and determine the optimal timing for LC following PTGBD.

Keywords: Acute cholecystitis; percutaneous transhepatic cholecystostomy; laparoscopic cholecystectomy.

INTRODUCTION

Laparoscopic cholecystectomy (LC) is the standard surgical treatment for acute cholecystitis (AC), a common hepatobiliary condition requiring definitive surgical management. Since the introduction of the Tokyo Guidelines in 2007, the management of AC has been stratified according to disease severity, enabling clinicians to select more appropriate treatment strategies.[1] The Tokyo Guidelines 2018 (TG18) provide recommendations for the optimal management of AC and serve as an important reference for clinical decision-making.[2] According to TG18, patients with moderate AC and limited comorbidity may benefit from early LC, particularly when performed in centers with substantial laparoscopic expertise.[3-5] Furthermore, TG18 suggests that LC may also be considered in selected patients with severe AC (Grade III) who do

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not have unfavorable prognostic factors despite the presence of organ dysfunction.[6]

Since its introduction in the 1980s, percutaneous transhepatic gallbladder drainage (PTGBD) has been primarily used as a therapeutic option for patients who are poor surgical candidates and as a bridge to definitive surgery in severe AC. PTGBD remains an important component of treatment for moderate and severe (Grade II/III) AC because it can stabilize patients prior to surgery.[8,9] The Tokyo Guidelines 2018 provide an important framework for the management of acute cholecystitis and recommend percutaneous transhepatic gallbladder drainage followed by elective cholecystectomy in selected patients with Grade II/III AC who have poor general health status or do not respond adequately to antibiotic therapy.[10]

However, Grade III AC is associated with systemic illness and organ dysfunction and does not represent an indication for straightforward LC. For these patients, TG18 prioritizes prompt medical management and organ support. The decision to proceed with surgery should be based on comprehensive evaluation of the patient's clinical condition, including comorbidities and associated complications.[2]

When selecting between PTGBD and early LC for patients with Grade II and III AC, the presence of unfavorable risk factors and organ dysfunction plays a critical role. Careful perioperative management and mitigation of surgical risk are essential, particularly in patients considered for percutaneous transhepatic gallbladder drainage, who are often older and have substantial comorbidity burdens. In clinical practice, adherence to the TG18 recommendations for urgent or early cholecystectomy may be limited by constraints in institutional infrastructure and available medical resources. Clinicians often employ PTGBD as an initial treatment strategy for patients with Grade II and III AC to reduce inflammation before performing delayed cholecystectomy. However, this approach may result in the development of dense adhesions, increasing technical difficulty during subsequent laparoscopic cholecystectomy.

Treatment guidelines are periodically updated to incorporate emerging findings. In the initial management of patients with Grade III acute cholecystitis, the choice of surgical approach is generally secondary to systemic treatment and management of organ dysfunction. This study aimed to evaluate the outcomes of laparoscopic cholecystectomy following percutaneous transhepatic gallbladder drainage and to assess the feasibility of early laparoscopic cholecystectomy by comparing these two treatment strategies in patients with Grade II acute cholecystitis.

MATERIALS AND METHODS

This retrospective study was approved by the Local Ethics Committee of Training and Research Hospital (Approval No: 2024/04/04/041). All procedures were conducted in accordance with the principles of the Declaration of Helsinki.

Retrospective data were collected from patients diagnosed with acute cholecystitis and hospitalized for treatment at Bağcılar Training and Research Hospital. All surgical procedures were performed by teams with extensive experience in laparoscopic cholecystectomy. Our institution is a high-volume center, performing approximately 1,000–1,500 LC procedures and more than 100 PTGBD procedures annually. Data collected between January 2022 and February 2024 were systematically recorded in an electronic database.

Medical records of 470 patients who underwent surgical treatment for AC were reviewed. Complete data were available for 432 patients, who were subsequently classified according to the Tokyo Guidelines 2018. Patients classified as Grade I or Grade III were excluded. The remaining patients were divided into two groups: delayed LC following PTGBD (n=43) and early LC (n=131) (Fig. 1).

Statistical Analysis

All statistical analyses were performed using Python (Jupyter Notebook) with the SciPy and pandas libraries. Categorical variables are presented as number (percentage) and were compared using Fisher's exact test when expected cell counts were small; otherwise, the chi-square test was applied. Continuous variables were assessed for normality and, because distributions were non-normal, are presented as median and interquartile range (IQR) and compared using the Mann–Whitney U test.

To identify factors independently associated with postoperative systemic inflammatory response syndrome (SIRS), multivariable binary logistic regression analysis was performed. The model included treatment group (PTGBD vs. early LC), age (continuous), and preoperative white blood cell count (WBC) as an indicator of baseline inflammatory status. Because WBC demonstrated a skewed distribution, values were log-transformed before analysis. A composite comorbidity variable ("any major comorbidity") was included as an adjustment factor and defined as the presence of at least one of the following conditions: cardiovascular disease (CVD), chronic obstructive pulmonary disease (COPD), or chronic kidney disease (CKD). Results are reported as adjusted odds ratios (aOR) with 95% confidence intervals (CI).

Length of hospital stay (LOS) was analyzed as a continuous, right-skewed outcome. Accordingly, median (τ=0.5) quantile regression was used to evaluate the association between postoperative complications and LOS while adjusting for potential confounders. "Any postoperative complication" was defined as the occurrence of at least one of the following: conversion to open surgery, postoperative bleeding, biliary complication, or postoperative SIRS. Quantile regression results are reported as beta coefficients representing the estimated change in median LOS (days) with 95% CI. A two-sided p value <0.05 was considered statistically significant.

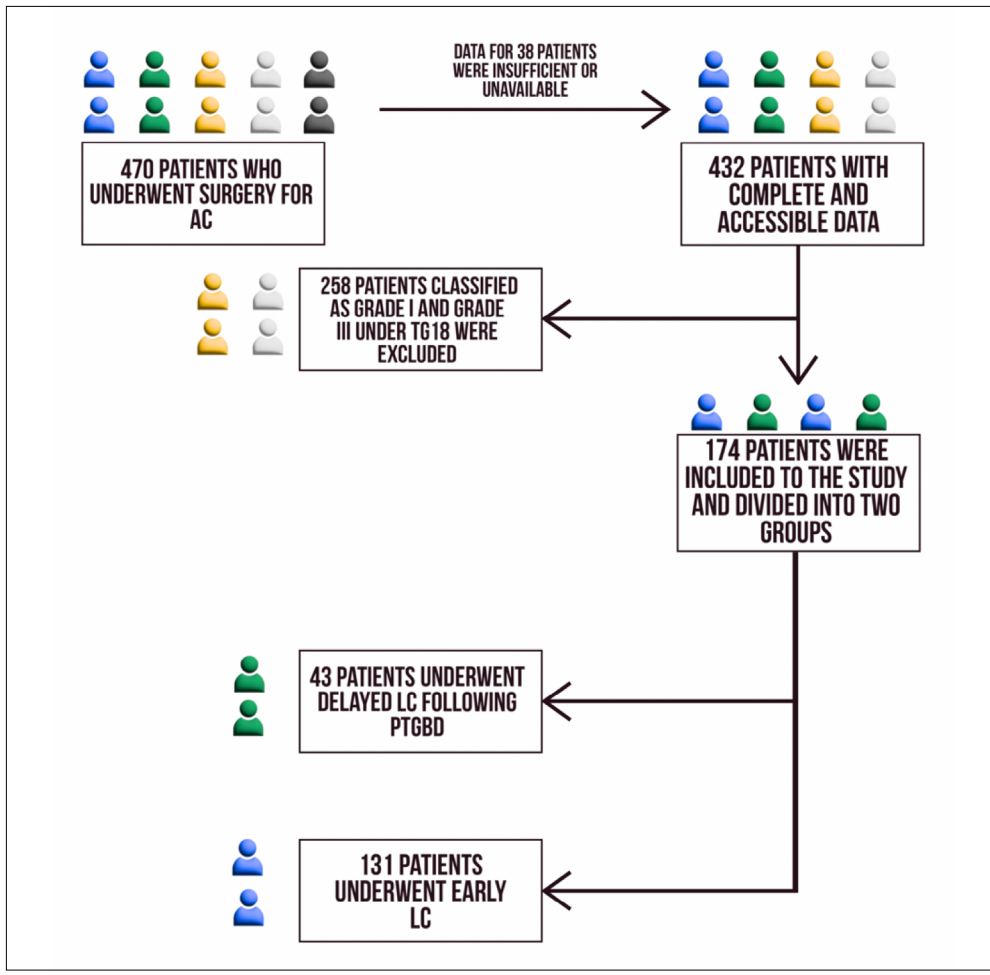

Figure 1. Flow diagram of patient selection and study inclusion.

RESULTS

Patients were divided into two treatment groups: PTGBD followed by delayed LC and early LC. The clinical and demographic characteristics of both groups are summarized in Table 1.

Postoperative outcomes were compared between patients undergoing PTGBD and those undergoing early LC while accounting for demographic and perioperative characteristics.

No significant differences were observed between the groups in rates of conversion to open surgery (relative risk [RR] 0.47, 95% CI 0.11–1.99; p=0.27), postoperative bleeding (7.0% vs. 1.5%; RR 4.57, 95% CI 0.79–26.45; p=0.06), or biliary tract complications (4.7% vs. 3%; p=0.638). A statistically significant difference was observed only in the incidence of postoperative SIRS, which occurred more frequently in the PTGBD group than in the early LC group (23.3% vs. 6.9%; RR 3.39, 95% CI 1.47–7.78; p=0.003) (Table 2).

The median interval between PTGBD and subsequent LC was 60 days. Factors associated with length of hospital stay were evaluated using linear regression models. In univariable analyses, several factors were significantly associated with prolonged length of hospital stay across both treatment groups. Postoperative complications—including conversion to open surgery, postoperative bleeding, biliary complications, and SIRS—were each associated with significantly longer hospital stays (Table 3). Preoperative PTGBD was not significantly associated with length of hospital stay in either univariable or multivariable linear regression models (p=0.304 and p=0.638, respectively). In median quantile regression analysis, the occurrence of any postoperative complication was independently associated with a three-day increase in median length of hospital stay (β=3.0 days, 95% CI 2.36–3.64; p<0.001), after adjustment for treatment group, age, baseline WBC level, and major comorbidity status.

Multivariable logistic regression demonstrated that PTGBD remained independently associated with postoperative SIRS after adjustment for age, preoperative WBC (log-transformed), and major comorbidity status (aOR 5.27, 95% CI 1.78–15.65; p=0.003) (Table 4).

Table 1. Clinical characteristics

Variable	PTGBD (n=43)	Early LC (n=131)	p
Age	61 (56–64)	55 (45–64)	0.010
Preoperative WBC, $\times 10^9$/L	16.94 (12.18–18.07)	15.38 (12.89–18.01)	0.298
Total bilirubin	0.8 (0.1–3.4)	1.0 (0.1–4.8)	0.177
INR	1.2 (0.9–2.0)	1.2 (0.2–1.7)	0.697
History of abdominal surgery	14 (32.5%)	21 (16.0%)	0.027
CVD	18 (41.9%)	38 (29.0%)	0.134
COPD	8 (18.6%)	7 (5.3%)	0.012
CKD	5 (11.6%)	13 (9.9%)	0.775
Any major comorbidity (CVD/COPD/CKD)	25 (58.1%)	50 (38.2%)	0.032

Values are presented as median (IQR) or n (%). Continuous variables were compared using the Mann–Whitney U test. Categorical variables were compared using the Fisher's exact test when expected cell counts were small. PTGBD: Percutaneous transhepatic gallbladder drainage; LC: Laparoscopic cholecystectomy; WBC: White blood cell count; INR: International Normalized Ratio; CVD: Cardiovascular disease; COPD: Chronic obstructive pulmonary disease; CKD: Chronic kidney disease.

Table 2. Postoperative outcomes

Variable	PTGBD	Early LC	RR (95% CI)	OR (95% CI)	p
Interval from PTGBD to surgery (days)	60 (20–152)				0.123
Postoperative SIRS	10 (23.3%)	9 (6.9%)	3.39 (1.47–7.78)	4.11 (1.54–10.94)	0.003
Biliary complications					
	2 (4.7%)	4 (3.0%)	1.52 (0.29–8.03)	1.55 (0.27–8.77)	0.638
Postoperative bleeding					
	3 (6.9%)	2 (1.5%)	4.57 (0.79–26.45)	4.84 (0.78–29.98)	0.006
Conversion to open surgery	2 (4.7%)	13 (9.9%)	0.47 (0.11–1.99)	0.44 (0.10–2.05)	0.27
Length of hospital stay (days)	3.53 (1–20)	3.5 (2–11)			0.814

Values are presented as n (%). Relative risks (RR) and odds ratios (OR) are reported with 95% confidence intervals (CI). Group comparisons were performed using the chi-square test. Statistical significance was defined as $p<0.05$. PTGBD: Percutaneous transhepatic gallbladder drainage; LC: Laparoscopic cholecystectomy.

Table 3. Length of hospital stay according to postoperative complications

Complication	PTGBD – no complication LOS, median (IQR)	PTGBD – complication LOS, median (IQR)	p	Early LC – no complication LOS, median (IQR)	Early LC – complication LOS, median (IQR)	p
Conversion to open surgery	3 (2–4)	8 (6–11)	<0.001	3 (2–4)	6 (4–8)	0.003
Postoperative bleeding	3 (2–4)	6 (5–8)	0.02	3 (2–4)	5 (4–7)	0.04
Biliary complications	3 (2–4)	8 (6–10)	0.006	3 (2–4)	6 (4–9)	0.01
Postoperative SIRS	3 (2–4)	6 (4–8)	<0.001	3 (2–4)	5 (4–7)	<0.001

Values are presented as median (interquartile range). Length of hospital stay was compared between patients with and without each complication within treatment groups using the Mann–Whitney U test. PTGBD: Percutaneous transhepatic gallbladder drainage; LC: Laparoscopic cholecystectomy; LOS: Length of hospital stay; IQR: Interquartile range.

Table 4. Multivariable logistic regression analysis for postoperative systemic inflammatory response syndrome (SIRS)

Predictor	aOR	95% CI	p
PTGBD (vs. Early LC)	5.27	1.78–15.65	0.003
Age (per one-year increase)	0.99	0.94–1.04	0.637
ln(WBC) (per 1 ln-unit increase)	0.18	0.05–0.66	0.010
Any major comorbidity	1.76	0.58–5.29	0.316

aOR: Adjusted odds ratios; CI: Confidence intervals; PTGBD: Percutaneous transhepatic gallbladder drainage; WBC: White blood cell count.

DISCUSSION

For high-risk patients with AC, PTGBD represents a less invasive therapeutic strategy that may reduce the need for emergency surgery. LC remains the definitive treatment following stabilization. However, the optimal timing of LC after PTGBD remains controversial, with observational studies reporting heterogeneous findings.

Surgical treatment of Stage II/III AC carries risks including bleeding, bile duct injury, and prolonged hospitalization. The Tokyo Guidelines provide recommendations supporting earlier surgical intervention under appropriate conditions to improve outcomes.[2] Nevertheless, as with previous versions of the guidelines, these recommendations remain a subject of ongoing debate. Based on these recommendations, we evaluated the feasibility of early surgery in patients with Grade II AC. In our study, postoperative complications and length of hospital stay did not differ significantly between the early LC and PTGBD groups. These findings support the feasibility of early surgical intervention in appropriately selected patients and are consistent with the recommendations of the TG18. Additionally, our results demonstrated that patients who underwent LC following PTGBD achieved surgical outcomes comparable to those of patients undergoing early LC despite a greater burden of comorbidities and more challenging operative conditions.

In current clinical practice, delayed surgery following PTGBD is often considered a safe strategy for patients with increased perioperative risk related to comorbidities and general anesthesia.[12] PTGBD is generally regarded as an adjunctive treatment for AC rather than definitive therapy. However, several studies have suggested that PTGBD may improve survival and reduce postoperative complications in patients with AC. Additionally, elective LC following PTGBD in high-risk patients with Grade II/III AC has demonstrated outcomes comparable to those of early LC.[13] However, another study reported that patients undergoing early LC had higher rates of postoperative mortality, intraoperative and postoperative complications, and conversion to open surgery compared with those treated with PTGBD.[14,15] These findings suggest that elective LC following PTGBD may provide clinical benefit compared with early LC. Notably, studies involving older patients and those with multiple comorbidities have demonstrated improved postoperative outcomes in these patient groups.[16,17] A decision-tree algorithm proposed by previous authors incorporates readily available clinical parameters, including C-reactive protein (CRP) level, gallbladder wall thickness, and age, to preoperatively predict complicated acute cholecystitis. Incorporating low-cost and accessible risk-stratification tools may help clinicians individualize treatment decisions between PTGBD and early LC, particularly in resource-limited settings.[18] Additionally, a recent meta-analysis highlighted substantial heterogeneity and lack of consensus regarding the definition of high-risk patients suitable for PTGBD, emphasizing the need for standardized predictive models.[19]

Another study reported that preoperative PTGBD before planned LC significantly reduced operative duration, intraoperative blood loss, postoperative length of hospital stay, conversion to open surgery, and postoperative complications in elderly patients with AC. These findings suggest that PTGBD followed by planned LC may be the optimal treatment strategy.[20]

Consistent with current guideline recommendations, our findings demonstrated that surgical outcomes in the PTGBD group were not substantially inferior to those in the early LC group. Furthermore, our results suggest that early LC may be safely performed in clinically stable patients without routinely delaying surgery for 6–8 weeks after PTGBD.

Therefore, the timing of surgery should not be determined solely by prior PTGBD status but should also consider patient comorbidities, physiologic reserve, and operative tolerance. Collectively, these findings support a personalized, risk-based approach to optimize treatment timing and modality in moderate to severe acute cholecystitis.

There is currently no consensus regarding the optimal interval between PTGBD and LC, with previous studies reporting heterogeneous findings. Some studies have demonstrated that LC performed within one week after PTGBD achieves comparable intraoperative outcomes, postoperative complication rates, and conversion rates to open cholecystectomy, suggesting that early intervention is feasible and safe.[21,22] In contrast, other studies have proposed that the optimal timing for LC ranges from 7 to 26 days after PTGBD and have suggested that surgery performed within 216 hours may be technically more challenging.[23-25] Future revisions of the Tokyo Guidelines and incorporation of emerging evidence may help clarify the optimal timing of surgical intervention.

Recent studies have continued to expand treatment approaches beyond current guideline recommendations for moderate to severe AC. Specifically, a recent study of patients with moderate to severe AC reported that a more aggressive surgical strategy, including subtotal cholecystectomy following PTGBD, was associated with a higher rate of

successful laparoscopic completion. The authors concluded that laparoscopic partial cholecystectomy is a feasible and safe treatment option in selected patients.[26] Another study evaluated the association between a predictive scoring system and perioperative complications and developed a model to estimate the likelihood of requiring additional emergency interventions and conversion to open surgery during LC following PTGBD. The authors concluded that this scoring system may be a useful tool for identifying patients at increased risk of conversion and additional surgical intervention and for predicting perioperative outcomes.[27]

Several recent studies have investigated emerging approaches for the management of AC. One study evaluated the use of PTGBD-guided cholangiography to improve preoperative delineation of biliary anatomy.[28] This approach may facilitate surgical planning and optimize outcomes in patients undergoing subsequent procedures. Another investigation examined the impact of improving gallstone mobility after PTGBD in patients with AC caused by impacted gallstones.[29] Collectively, these studies advance our understanding of AC management and its potential treatment approaches. Their findings may contribute to future refinements of clinical recommendations and support improvements in patient care and decision-making. However, additional validation and further investigation are necessary before broader implementation and incorporation into clinical guidelines.

Supplementary Figures 1–3 provide descriptive visual summaries of outcome prioritization and the relationship between postoperative complications and length of hospital stay. These figures are intended for descriptive purposes only and do not replace inferential statistical analyses.

When interpreting the results, it is important to consider the limitations of this study. First, the retrospective design and investigation of a single-center cohort limit the generalizability of the findings. Therefore, large-scale prospective studies are required to confirm our results. Second, this study demonstrated a lower incidence of biliary complications than is generally reported in the literature, which may be explained by the relatively small overall sample size.

Due to the limited number of cases and the inclusion of multiple variables in the regression analysis, there are some limitations regarding the interpretation of these analyses. A larger sample size is needed to obtain more robust and reliable results. Small sample sizes may lead to unstable and less reliable estimates, emphasizing the need for larger studies to strengthen the statistical findings. Lastly, the broad interval between PTGBD and LC in the PTGBD group may have introduced variability that affected the accuracy of the results. Despite these limitations, we believe this study provides valuable clinical insights.

Our study contributes to the ongoing discussion by directly comparing early LC and LC following PTGBD in patients with Grade II acute cholecystitis and by incorporating detailed analyses of postoperative complications, length of hospital stay, and patient comorbidity burden.

CONCLUSION

Our findings suggest that early laparoscopic cholecystectomy is a feasible treatment strategy for most patients with Grade II AC. For patients with substantial comorbidity burden or increased perioperative risk related to general anesthesia, PTGBD may serve as an alternative initial treatment approach. Additional large-scale prospective studies are needed to determine the optimal interval between PTGBD and LC. Continued evaluation of management approaches may improve patient outcomes and long-term prognosis.

Ethics Committee Approval: This study was approved by the The Bagcilar Trainıng And Research Hospıtal Non-Interventıonal Clınıcal Research Ethics Committee (Date: 29.04.2024, Decision No: 2024/04/04/041).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Akut orta dereceli kolesistitte tedavi yöntemlerinin sonuçları: Perkütan transhepatık safra kesesi drenajı ve erken laparoskopik kolesistektomi

AMAÇ: Akut kolesistit (AK), cerrahi müdahale gerektiren yaygın bir hepatobiliyer rahatsızlıktır. Tokyo 2018 Kılavuzu (TG18), orta dereceli AK (Derece II) için erken laparoskopik kolesistektomi (LK) ve yüksek riskli hastalar için perkütan transhepatik safra kesesi drenajı (PTGBD) önermektedir. Ancak, PTGBD sonrası LK'nin optimal zamanlaması hala tartışmalıdır.

GEREÇ VE YÖNTEM: Bu retrospektif çalışmada, Ocak 2022 ile Şubat 2024 tarihleri arasında yüksek hacimli bir merkezde tedavi edilen Derece II AK'li 432 hastanın verileri analiz edilmiştir. Hastalar iki gruba ayrılmıştır: erken LK (n=131) ve PTGBD sonrası gecikmiş LK (n=43). Klinik sonuçlar, postoperatif komplikasyonlar ve hastanede kalış süresi, doğrusal regresyon modellemesi de dahil olmak üzere istatistiksel analizler kullanılarak karşılaştırılmıştır.

BULGULAR: İki grup arasında açık cerrahiye geçiş (%4.7-%9.9, p=0.27), postoperatif kanama (%6.9-%1.5, p=0.097) veya safra yolu komplikasyonları (%4.7-%3, p=0.638) açısından anlamlı bir fark gözlenmemiştir. Ancak, postoperatif sistemik inflamatuar yanıt sendromu (SIRS), PTGBD grubunda anlamlı derecede daha yüksek saptanmıştır (%23.3-%6.9, p=0.003). Doğrusal regresyon analizi, açık cerrahiye geçiş, postoperatif SIRS ve safra yolu komplikasyonlarını hastanede kalış süresinin uzaması için risk faktörleri olarak belirlerken, PTGBD'nin kendisi daha uzun hastanede kalış süresiyle ilişkili görülmemiştir (p=0.304).

SONUÇ: Erken LK, çoğu Evre II AK vakası için uygulanabilir bir yaklaşımdır ve sonuçlar PTGBD ve ardından gelen gecikmiş LK ile karşılaştırılabilir düzeydedir. PTGBD, yüksek riskli hastalar için değerli bir alternatif olmaya devam etmektedir. Tedavi stratejilerini geliştirmek ve PTGBD sonrası LC için optimal zamanlamayı belirlemek için daha geniş ölçekli prospektif çalışmalara ihtiyaç vardır.

Anahtar sözcükler: Akut kolesistit; perkütan transhepatik kolesistostomi; laparoskopik kolesistektomi.

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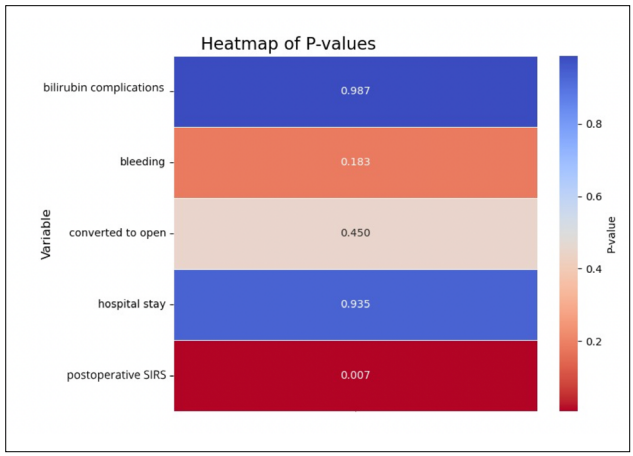
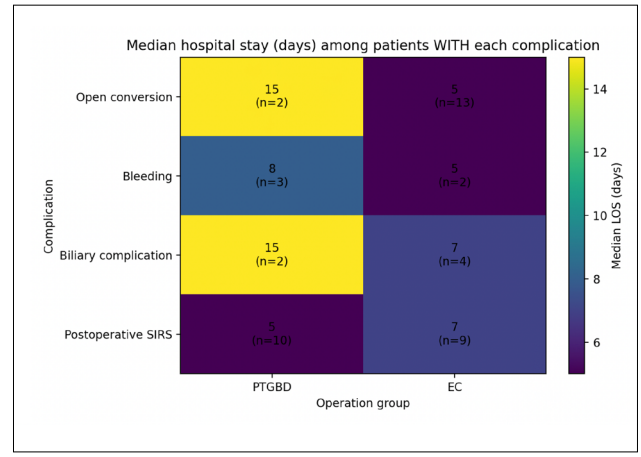
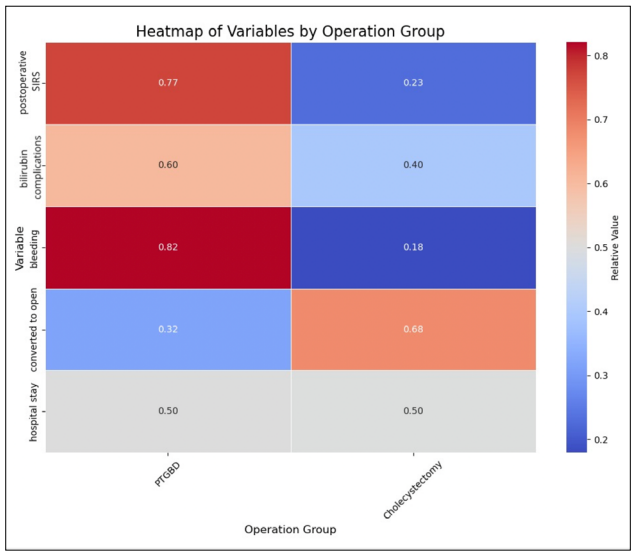


Supplementary Figure 1. Heatmap summarizing p-values for comparisons between treatment groups across postoperative outcomes. Color intensity reflects longer duration of hospitalization. These figures are intended for descriptive visual interpretation only and do not represent effect sizes or inferential statistical analyses.



Supplementary Figure 2. Heatmap illustrating the median length of hospital stay according to individual postoperative complications, stratified by treatment group (percutaneous transhepatic gallbladder drainage [PTGBD] vs. early laparoscopic cholecystectomy [LC]). Color intensity reflects longer duration of hospitalization. This figure is intended for descriptive visualization.



Supplementary Figure 3. HHeatmap illustrating the relative distribution of variables between the two treatment groups. For continuous variables, mean values were calculated, whereas categorical variables are presented as percentages. To ensure comparability, variables were reindexed across both groups.

ORIGINAL ARTICLE

Prognostic value of the HALP score in patients undergoing emergency surgery for gastroduodenal perforation

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ABSTRACT

BACKGROUND: Gastroduodenal perforation is a life-threatening surgical emergency associated with substantial postoperative morbidity and mortality. In the emergency setting, rapid and objective preoperative risk stratification remains challenging. This study aimed to evaluate the prognostic value of the hemoglobin, albumin, lymphocyte, and platelet (HALP) score for predicting postoperative outcomes in patients undergoing emergency surgery for gastroduodenal perforation.

METHODS: This retrospective cohort study included 115 adults who underwent emergency surgery for gastroduodenal perforation at a tertiary referral center between January 2021 and December 2025. The HALP score was calculated using laboratory values obtained at admission before surgery. The primary endpoint was a composite adverse outcome defined as postoperative mortality, reoperation, or prolonged hospital stay (≥8 days). Clinical, laboratory, and operative variables were compared between patients with and without the composite outcome. Predictive performance was assessed using receiver operating characteristic (ROC) curve analysis.

RESULTS: Postoperative mortality occurred in five patients (4.3%). Non-survivors were older and had higher American Society of Anesthesiologists (ASA) classification than survivors ($p<0.05$). Patients who experienced the composite adverse outcome had significantly lower HALP and prognostic nutritional index (PNI) values and higher inflammatory indices on univariate analysis ($p<0.05$). In ROC analysis, the HALP score demonstrated modest discriminatory ability for predicting the composite adverse outcome (area under the curve [AUC] 0.619, 95% confidence interval [CI]: 0.511–0.719). Increasing age was associated with adverse outcomes, whereas a multivariable model incorporating age, ASA classification, and HALP score demonstrated improved discrimination (AUC 0.748).

CONCLUSION: The HALP score is an inexpensive and readily available preoperative marker that reflects both inflammatory and nutritional status. In this cohort, lower HALP values were associated with adverse postoperative outcomes on univariate analysis. Although HALP was not identified as an independent predictor in multivariable analysis, it may provide complementary information regarding patients' immunonutritional vulnerability when interpreted alongside established clinical risk factors. Further prospective multicenter studies are needed to validate its prognostic utility and establish clinically relevant cutoff values.

Keywords: Emergency surgery; gastroduodenal perforation; HALP score; prognostic factors; postoperative outcomes.

INTRODUCTION

Despite advances in perioperative care, gastroduodenal perforation remains a critical surgical emergency associated with substantial morbidity and mortality. Most cases are related to peptic ulcer disease and typically present with sudden-onset generalized peritonitis, a pronounced systemic inflammatory response, and a high risk of postoperative complications and death. Although early diagnosis and prompt surgical intervention are essential, surgical outcomes vary considerably and are influenced by several patient-related factors, including age, comorbidities, and overall physiological reserve.[1]

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Various clinical scoring systems, including the American Society of Anesthesiologists (ASA) classification and several sepsis-related indices, have been proposed to assess perioperative risk in patients with gastrointestinal perforation. However, many of these tools require intraoperative findings, incorporate variables that may not be immediately available at admission, or involve complex calculations, limiting their practicality in emergency settings where rapid and objective assessment is essential. In particular, traditional risk scores have demonstrated variable accuracy and practical limitations in emergency gastrointestinal surgery, highlighting the need for simpler and more readily available biomarkers for early risk stratification.[2]

Inflammation- and nutrition-based indices derived from routine laboratory parameters have increasingly been investigated as prognostic tools across a variety of clinical settings, including oncology and acute illness.[3] Among these, the hemoglobin, albumin, lymphocyte, and platelet (HALP) score combines markers of nutritional status, immune competence, and systemic inflammation into a single composite index.[4] Although initially developed in oncological populations, emerging evidence suggests that the HALP score may also have prognostic relevance in non-malignant acute conditions, supporting its potential applicability in emergency surgical patients.[5]

Patients with gastroduodenal perforation commonly present with acute inflammation, catabolic stress, and impaired nutritional status, factors that are collectively reflected by the HALP score, a composite index of systemic inflammatory and nutritional status. The HALP score has demonstrated prognostic value across a wide range of clinical conditions, including critical illness and surgical populations, where lower scores have been associated with adverse outcomes such as increased morbidity and mortality.[6] Despite this theoretical relevance, data specifically evaluating the role of the HALP score in predicting postoperative outcomes after emergency surgery for gastroduodenal perforation remain limited, and large-scale studies in this patient population are lacking.[7] Furthermore, because mortality alone is often infrequent in single-center cohorts, composite outcome measures that incorporate morbidity and clinically meaningful complications may provide a more comprehensive assessment of postoperative risk in this patient population.[8]

Therefore, the present study aimed to investigate the prognostic value of the HALP score in patients undergoing emergency surgery for gastroduodenal perforation. We hypothesized that lower preoperative HALP scores would be associated with adverse postoperative outcomes, defined as a composite of mortality, reoperation, and prolonged hospital stay. The HALP score is a composite biomarker derived from hemoglobin, albumin, lymphocyte, and platelet levels that reflects both inflammatory and nutritional status. Previous studies have demonstrated associations between the HALP score and clinical outcomes across a variety of patient populations, including both oncological and non-oncological settings.[9] In particular, lower HALP values have been associated with increased mortality and adverse clinical outcomes in non-oncological cohorts, such as patients with cardiovascular disease and other acute medical conditions.[10] By evaluating this readily available index, we sought to determine its utility as a practical tool for early risk stratification and perioperative decision-making in patients with acute gastroduodenal perforation.

MATERIALS AND METHODS

Study Design and Patient Selection

This retrospective cohort study included adult patients (≥18 years) who underwent emergency surgery for gastroduodenal perforation at a tertiary referral center between January 2021 and December 2025. Patients with a confirmed diagnosis of gastroduodenal perforation and complete preoperative clinical and laboratory data were eligible for inclusion. Patients with missing laboratory parameters required for calculation of the HALP score were excluded.

The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the local Institutional Ethics Committee (Approval No. E-30785963-020-373119). Given the retrospective nature of the study, the requirement for informed consent was waived.

Data Collection

Demographic characteristics (age and sex), preoperative risk status assessed using the ASA classification, laboratory parameters, operative details, and postoperative outcomes were extracted from electronic medical records. Preoperative laboratory tests obtained at admission before surgery included white blood cell count, hemoglobin level, platelet count, neutrophil count, lymphocyte count, C-reactive protein (CRP), and serum albumin level. For reproducibility, laboratory units used in index calculations were standardized as follows: hemoglobin (g/dL), albumin (g/dL), lymphocyte count (10³/μL), and platelet count (10³/μL). These units were applied consistently across all calculations.

HALP Score and Other Inflammatory Indices

The HALP score was calculated for all patients using admission laboratory values according to the following formula:

HALP = hemoglobin (g/dL) × albumin (g/dL) × lymphocyte count (10³/μL) / platelet count (10³/μL)

In addition to the HALP score, several inflammation- and nutrition-based indices were calculated for comparative analyses, including the neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), prognostic nutritional index (PNI), and C-reactive protein-to-albumin ratio (CAR). The PNI was calculated using the following formula:

PNI = (10 × serum albumin (g/dL)) + (0.005 × total lymphocyte count (10³/μL))

To ensure consistency and reproducibility, lymphocyte and

platelet counts were used in units of $10^3/\mu L$, as reported by the institutional laboratory system.

Surgical Management

All patients underwent emergency surgical intervention following the diagnosis of gastroduodenal perforation. The surgical approach (open, laparoscopic, or conversion to open surgery) was selected by the attending surgeon according to the patient's clinical condition and intraoperative findings. Postoperative care was provided in accordance with institutional protocols.

Outcome Measures

The primary outcome was a composite adverse endpoint defined as the occurrence of at least one of the following: postoperative mortality, reoperation, or prolonged hospital stay. Prolonged hospital stay was defined as a length of stay of ≥8 days, exceeding the cohort median of 7 days, consistent with previous studies evaluating composite outcomes in emergency surgery. Because length of stay may be influenced by both clinical and system-level factors, it was included to capture the overall postoperative burden.

Statistical Analysis

Continuous variables were reported as mean ± standard deviation or median with interquartile range (IQR), depending on the type of distribution. Categorical variables were presented as counts and percentages. Comparisons between patients with and without the composite adverse outcome were performed using the Mann–Whitney U test for continuous variables and the chi-square test or Fisher's exact test for categorical variables, as appropriate. Receiver operating characteristic (ROC) curve analysis was used to evaluate the predictive performance of the HALP score and other indices for the composite endpoint. A two-sided p-value <0.05 was considered statistically significant. Multivariable logistic regression analysis was additionally performed to identify independent predictors of the composite adverse outcome. Age, ASA classification, and HALP score were entered into the model. Adjusted odds ratios (OR) with 95% confidence intervals (CI) were calculated. Model discrimination was assessed using ROC curve analysis, and the optimal cutoff value was determined using the Youden index. Variables included in the multivariable analysis were selected a priori according to their clinical relevance. All analyses were performed using IBM SPSS Statistics version 26 (IBM Corp., Armonk, NY, USA).

Methodological Considerations

Given the limited number of mortality events, multivariable regression analyses focusing exclusively on mortality were not prioritized. Consequently, findings were interpreted primarily on the basis of univariate analyses and exploratory multivariable modeling of the composite endpoint. This approach was adopted to better capture clinically relevant postoperative risk in this single-center cohort.

RESULTS

Patient Characteristics

During the study period, 115 patients who underwent emergency surgical treatment for gastroduodenal perforation were included in the analysis. The median age was 44 years (IQR, 33.5–57.5 years), and the majority of patients were male (85.2%). According to the ASA classification, most patients were categorized as ASA II or III. Open surgery was the most commonly performed procedure (83.5%), followed by laparoscopic surgery (14.8%), whereas conversion to open surgery was required in only a small proportion of cases (1.7%) (Table 1).

Postoperative Outcomes

Postoperative mortality occurred in five patients (4.3%), and reoperation was required in two patients (1.7%). The median length of hospital stay was 7 days (IQR, 6–9 days). Based on the predefined criterion, prolonged hospital stay was defined

Table 1. Baseline demographic and clinical characteristics

Variable	Survivors (n=110)	Non-survivors (n=5)	p
Age, median (IQR)	43.5 (33–56)	71 (65–78)	0.028
Male sex, n (%)	96 (87.3)	2 (40.0)	0.023†
ASA classification, median (IQR)	2 (2–3)	3 (3–4)	0.003
Open surgical approach, n (%)	92 (83.6)	4 (80.0)	1.000†
Length of hospital stay, median (days), IQR	7 (6–9)	8 (6–9)	0.41
Reoperation, n (%)	1 (0.9)	1 (20.0)	0.085†

ASA: American Society of Anesthesiologists; IQR: Interquartile range. Data are presented as median (IQR) or number (%), as appropriate. Continuous variables were compared using the Mann–Whitney U test. Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate. †Fisher's exact test.

Table 2. Inflammation- and nutrition-based indices according to composite adverse outcome

Variable	No adverse outcome (median, IQR)	Adverse outcome (median, IQR)	p
HALP score	42 (19–70)	23 (9–44)	0.028
PNI	50.5 (46–55)	44.8 (40–49)	0.014
NLR	7.13 (4.6–10.8)	9.49 (6.2–14.1)	0.114
PLR	160.1 (120–210)	218.8 (160–300)	0.064
CAR	0.05 (0.02–0.11)	0.20 (0.08–0.35)	<0.001

HALP: Hemoglobin–albumin–lymphocyte–platelet score; PNI: Prognostic nutritional index; NLR: Neutrophil-to-lymphocyte ratio; PLR: Platelet-to-lymphocyte ratio; CAR: C-reactive protein–to–albumin ratio; IQR: Interquartile range. Data are presented as median (IQR). Comparisons between groups were performed using the Mann–Whitney U test.

Table 3. Multivariable logistic regression analysis for the composite adverse outcome

Variable	Adjusted OR	95% CI	p
Age (per 1-year increase)	1.05	1.02–1.08	0.0008
ASA classification	1.30	0.72–2.34	0.38
HALP score (per 10- unit increase)	0.96	0.86–1.07	0.48

OR: Odds ratio; CI: Confidence interval; ASA: American Society of Anesthesiologists; HALP: Hemoglobin–albumin–lymphocyte–platelet score. Multivariable logistic regression analysis was performed to identify independent predictors of the composite adverse outcome. Adjusted odds ratios and 95% confidence intervals are presented.

as ≥8 days. The composite adverse outcome (postoperative mortality, reoperation, or prolonged hospital stay) occurred in 53 patients (46.1%).

Comparison According to Outcomes

When patients were stratified according to postoperative mortality, non-survivors were significantly older than survivors (median age, 71 vs. 43.5 years, p=0.028) and had higher ASA classifications (p=0.003). Sex distribution also differed between groups; however, given the small number of mortality events, the clinical significance of this finding should be interpreted cautiously. No significant association was observed between surgical approach and mortality (p>0.05).

Prognostic Value of the HALP Score in Gastroduodenal Perforation

The HALP score was successfully calculated for all patients using preoperative laboratory values. Patients who experienced adverse outcomes had significantly lower HALP scores than those without adverse outcomes (median, 23 vs. 42, p=0.028). Similarly, PNI values were significantly lower (p=0.014), whereas CAR values were significantly higher (p<0.001) in the adverse outcome group. These univariate findings suggest a potential association between impaired immunonutritional status and increased postoperative risk (Table 2).

Predictive Performance of the HALP Score

Receiver operating characteristic curve analysis demonstrated that the HALP score had modest discriminatory ability for predicting the composite adverse outcome, with an area under the curve (AUC) of 0.619 (95% CI: 0.511–0.719) (Fig. 1). Lower HALP values were more frequently observed among patients who developed adverse outcomes, consistent with

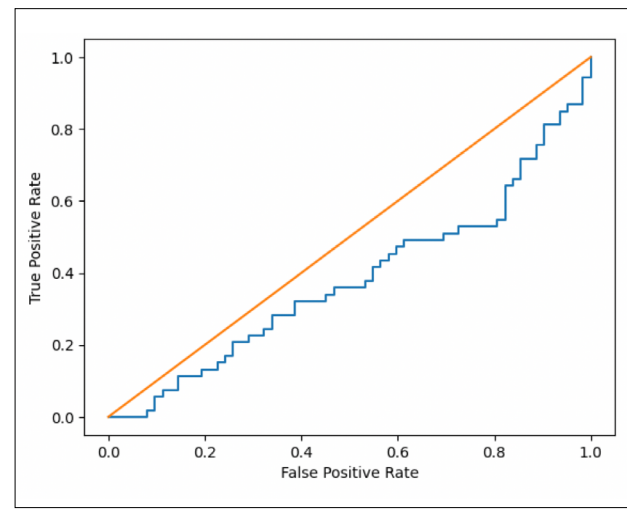

Figure 1. Receiver operating characteristic (ROC) curve of the HALP score for predicting composite adverse outcomes.

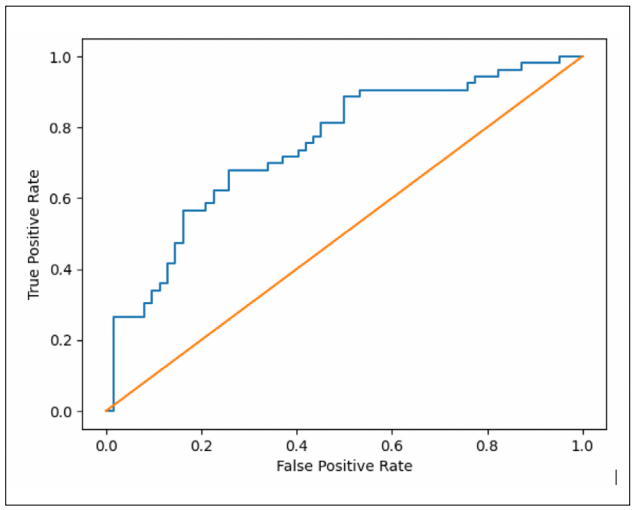

Figure 2. Receiver operating characteristic (ROC) curve of the multivariable model for predicting composite adverse outcomes. The multivariable model (age, ASA, and HALP) demonstrated improved discrimination (AUC 0.748).

the expected direction of the association. The optimal HALP cutoff value, determined using the Youden index, was 19.9, corresponding to a sensitivity of 47.2% and a specificity of 80.6%.

In multivariable logistic regression analysis, increasing age remained an independent predictor of the composite adverse outcome (OR, 1.05 per year increase; 95% CI: 1.02–1.08; p=0.0008). In contrast, neither ASA classification (OR, 1.30; 95% CI: 0.72–2.34; p=0.38) nor HALP score (OR, 0.96 per 10-unit increase; 95% CI: 0.86–1.07; p=0.48) was independently associated with the composite endpoint. The Hosmer–Lemeshow goodness-of-fit test indicated adequate calibration of the multivariable model (χ^2=7.70, df=8, p=0.464).

ROC analysis of the multivariable model demonstrated improved discriminatory performance (AUC 0.748) (Fig. 2). The optimal predicted probability cutoff for the multivariable model, determined using the Youden index, was 0.45, yielding a sensitivity of 67.9% and a specificity of 74.2%. The cutoff value corresponds to the predicted probability derived from the multivariable logistic regression model.

DISCUSSION

Gastroduodenal perforation is widely recognized as a critical surgical emergency associated with substantial morbidity and mortality despite advances in diagnostic and therapeutic strategies.[11] Early identification of high-risk patients is essential for optimizing perioperative management and clinical decision-making. However, practical and reliable prognostic tools that can be readily applied in emergency settings are still limited.[12] In the present study, we evaluated the prognostic value of the HALP score, a simple inflammation- and nutrition-based index, in patients undergoing emergency surgery for gastroduodenal perforation. Previous studies have suggested that the HALP score may provide prognostic information across diverse surgical and critically ill populations, with lower scores generally associated with worse outcomes, including increased morbidity and mortality.[13]

Several key findings emerged from this study. First, postoperative mortality was relatively low (4.3%), although advanced age and higher ASA classification were significantly associated with mortality, supporting their established role as major determinants of outcome after gastroduodenal perforation.[14] Second, patients who experienced adverse postoperative outcomes (composite endpoint) had lower HALP and PNI values and higher inflammatory indices. In the present cohort, patients who experienced composite adverse outcomes had significantly lower HALP and PNI values and significantly higher CAR levels, suggesting a potential association between impaired immunonutritional status and increased postoperative risk.[15] Finally, ROC analysis showed that the HALP score had modest discriminatory value for predicting the composite adverse outcome (AUC, 0.619; 95% CI 0.511–0.719), suggesting that it may provide limited but potentially valuable additional prognostic information when interpreted alongside established clinical predictors.[16] As a stand-alone marker, however, HALP showed limited ability to discriminate between patients with and without adverse outcomes. The relatively low sensitivity (47.2%) observed at the optimal cutoff value suggests that HALP may be more useful for identifying a subset of patients at particularly high risk (high specificity), rather than serving as a broad screening tool.

Multivariable analysis identified age as the only independent predictor of the composite adverse outcome, reinforcing the well-established importance of physiological reserve and baseline health status in determining surgical prognosis.[17] Although ASA classification was associated with mortality in univariate analysis, it did not remain independently significant after adjustment, suggesting that chronological age may better capture overall vulnerability in this cohort. The loss of statistical significance for ASA classification in the multivariable model may be partly explained by collinearity with age, as older patients frequently have higher ASA classification and reduced physiological reserve. The multivariable model consistently demonstrated improved discriminatory performance (AUC 0.748) (Fig. 2), underscoring the value of integrating clinical and laboratory variables rather than relying on individual biomarkers alone. Although the odds ratio for HALP was calculated per 10-unit increase, interpretation across clinically meaningful ranges may be more informative given the wide distribution of HALP values within the cohort.

The HALP score integrates hemoglobin, albumin, lymphocyte count, and platelet count into a single index reflecting nutritional status and immune competence, and has recently gained attention as a potential biomarker of immunonutritional status.[18,19] Previous studies have suggested that the HALP score may serve as a practical indicator of mortality risk in older adults with low muscle mass[20] and as a promis-

ing prognostic biomarker in patients with digestive system malignancies.[21] Patients with gastroduodenal perforation frequently present with acute inflammation, catabolic stress, and impaired nutritional status, making HALP a biologically plausible preoperative risk marker. Furthermore, related immunonutritional indices have demonstrated prognostic value across a variety of medical and surgical populations.[22] Consistent with these observations, lower HALP values were associated with adverse postoperative outcomes in the present study. However, this association did not persist after adjustment for age and ASA classification, suggesting that HALP may primarily reflect overall physiological vulnerability rather than function as an independent risk factor.

The modest predictive performance of HALP observed in ROC analysis warrants careful interpretation. Although lower HALP values were associated with worse outcomes, the observed AUC indicates only limited discrimination between patients with and without adverse events, consistent with findings from other non-oncological populations in which HALP has provided incremental rather than definitive prognostic information.[23] Furthermore, the composite endpoint included prolonged hospital stay, defined as a length of stay exceeding the cohort median, which may reflect not only postoperative complications but also healthcare utilization and variability in recovery patterns. Consequently, HALP should be regarded as a complementary marker rather than a stand-alone prognostic tool. Its greatest clinical utility may lie in combination with established clinical risk factors. The cohort-derived HALP cutoff value of 19.9, identified using the Youden index, demonstrated moderate specificity but limited sensitivity, suggesting that very low HALP values may identify patients at increased risk. Nevertheless, this threshold is exploratory and requires external validation.

The inclusion of prolonged hospital stay as a component of the composite endpoint may have influenced overall predictive performance, as length of stay can be affected by both clinical severity and local healthcare system factors. However, given the low mortality rate observed in this single-center cohort, use of a composite outcome was considered methodologically appropriate to improve statistical power and capture a broader spectrum of clinically relevant postoperative burden.

Compared with traditional risk assessment tools, the HALP score offers several practical advantages. It can be calculated rapidly from routine admission laboratory tests and does not require intraoperative variables or complex calculations, both of which may limit the applicability of other prognostic models in emergency general surgery.[24] Accordingly, HALP may serve as a useful adjunct during initial assessment to support early triage decisions, such as identifying patients who may benefit from closer monitoring, more aggressive resuscitation, or early intensive care evaluation.[25] Future studies integrating HALP with other scoring systems, such as the National Early Warning Score (NEWS), may further improve risk stratification in this patient population and help guide more targeted perioperative management strategies.[26]

The relatively low postoperative mortality rate (4.3%) observed in this cohort may reflect early surgical intervention and standardized perioperative management at our institution. Nevertheless, the small number of mortality events limited statistical power and may have contributed to the lack of an independent association between HALP and adverse outcomes.

Limitations

Several limitations should be acknowledged. First, the retrospective, single-center design may limit the generalizability of the findings. Second, the low number of mortality events restricted robust multivariable modeling for mortality-specific outcomes and reduced statistical power. Third, although the composite endpoint was selected to capture overall postoperative risk in a cohort with low mortality, it may have been influenced by prolonged length of stay, which can reflect both clinical and non-clinical factors. Finally, dynamic changes in laboratory parameters over time were not assessed, and potential confounding related to disease severity, including time to surgery, perforation characteristics, and physiologic derangement at presentation, could not be fully accounted for. Despite these limitations, the study provides preliminary evidence regarding the role of the HALP score in an understudied emergency surgical population and may serve as a basis for future prospective investigations.

CONCLUSION

In this retrospective cohort of patients undergoing emergency surgery for gastroduodenal perforation, lower preoperative HALP scores were significantly associated with adverse postoperative outcomes in univariate analysis. However, HALP did not retain independent prognostic significance after adjustment for age and ASA classification. Although the HALP score demonstrated modest discriminatory performance, it may provide complementary information regarding patients' immunonutritional status when interpreted alongside established clinical risk factors. Prospective multicenter studies are needed to validate these findings and establish clinically relevant cutoff values.

Ethics Committee Approval: This study was approved by the Malatya Turgut Ozal University Ethics Committee (Date: 30.01.2025, Decision No: 2026/59).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: O.G.G.; Design: O.G.G.; Data collection and/or processing: O.G.G., S.A.K.; Analysis and/or interpretation: O.G.G.; Writing: O.G.G.; Critical review: S.A.K.

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Gastroduodenal perforasyon nedeniyle acil cerrahi uygulanan hastalarda halp skorunun prognostik değeri

AMAÇ: Gastroduodenal perforasyon, önemli derecede postoperatif morbidite ve mortalite ile ilişkili, yaşamı tehdit eden bir cerrahi acildir. Acil durumlarda hızlı ve objektif preoperatif risk sınıflandırması yapmak hâlen zorluk oluşturmaktadır. Bu çalışmanın amacı, gastroduodenal perforasyon nedeniyle acil cerrahi uygulanan hastalarda postoperatif sonuçları öngörmede hemoglobin, albümin, lenfosit ve trombositten oluşan HALP skorunun prognostik değerini değerlendirmektir.

GEREÇ VE YÖNTEM: Bu retrospektif kohort çalışmasına, Ocak 2021 ile Aralık 2025 tarihleri arasında üçüncü basamak bir merkezde gastroduodenal perforasyon nedeniyle acil cerrahi uygulanan 115 yetişkin hasta dahil edildi. HALP skoru, ameliyat öncesinde hastaneye başvuru sırasında elde edilen laboratuvar değerlerinden hesaplandı. Birincil sonlanım noktası; postoperatif mortalite, yeniden ameliyat gereksinimi veya uzamış hastanede yatış süresi (≥8 gün olarak tanımlandı) durumlarından en az birinin görülmesi şeklinde tanımlanan bileşik olumsuz sonuç idi. Klinik, laboratuvar ve operatif değişkenler, bileşik sonlanım gelişen ve gelişmeyen hastalar arasında karşılaştırıldı. Prediktif performans receiver operating characteristic (ROC) analizi kullanılarak değerlendirildi.

BULGULAR: Postoperatif mortalite 5 hastada (%4.3) görüldü. Hayatta kalmayan hastalar, hayatta kalanlara göre daha ileri yaşta olup daha yüksek American Society of Anesthesiologists (ASA) sınıflamasına sahipti ($p<0.05$). Bileşik olumsuz sonlanım gelişen hastalarda tek değişkenli analizde HALP ve prognostik beslenme indeksi (PNI) değerleri anlamlı derecede daha düşük, inflamatuvar indeksler ise daha yüksek bulundu ($p<0.05$). ROC analizinde HALP skoru, bileşik olumsuz sonlanımı öngörmede sınırlı ayırt edici güç gösterdi (AUC 0.619; %95 GA: 0.511–0.719). Yaş olumsuz sonuçlarla ilişkili bulunurken, çok değişkenli model (yaş, ASA ve HALP) daha iyi ayırt edici performans gösterdi (AUC 0.748).

SONUÇ: HALP skoru, inflamatuvar ve beslenme durumunu yansıtan, ucuz ve kolay erişilebilir bir preoperatif belirteçtir. Bu kohortta düşük HALP değerleri tek değişkenli analizde olumsuz postoperatif sonuçlarla ilişkili bulunmuştur. Her ne kadar çok değişkenli analizde HALP bağımsız bir prediktör olarak belirlenmemiş olsa da, yerleşik klinik risk faktörleri ile birlikte değerlendirildiğinde hastaların immünnütrisyonel kırılganlığı hakkında tamamlayıcı bilgi sağlayabilir. HALP skorunun prognostik değerinin daha iyi ortaya konulabilmesi ve klinik olarak anlamlı kesim noktalarının belirlenebilmesi için prospektif ve çok merkezli araştırmalar gereklidir.

Anahtar sözcükler: Acil cerrahi; Gastroduodenal perforasyon; HALP skoru, prognostik faktörler; postoperatif sonuçlar.

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ORIGINAL ARTICLE

Emergency department evaluation of immature granulocytes for complicated acute appendicitis: a retrospective cohort study

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ABSTRACT

BACKGROUND: Preoperative identification of complicated acute appendicitis (CAA) is important for reducing morbidity. We assessed the diagnostic value of immature granulocyte (IG) count and percentage (IG%) for predicting CAA and histopathologically confirmed perforation in adults presenting to the emergency department.

METHODS: We retrospectively reviewed consecutive adults (≥18 years) with histopathologically confirmed appendicitis admitted to a tertiary care center between January 1, 2025 and January 1, 2026. Cases were classified as CAA or non-complicated acute appendicitis (NAA). Perforation was analyzed as a separate secondary endpoint. Diagnostic performance was assessed using receiver operating characteristic (ROC) analysis, the Youden index, and multivariable logistic regression.

RESULTS: A total of 891 patients were included (58.6% male; median age, 35 years [IQR 25–47]); 466 (52.3%) had CAA and 105 (11.8%) had perforation. For discrimination of CAA, the highest area under the curve (AUC) was observed for the neutrophil-to-lymphocyte ratio (NLR) (0.547; 95% confidence interval [CI]: 0.508–0.586), whereas the AUC for IG% was 0.519 (95% CI: 0.479–0.556). Among patients with perforation, lymphocyte counts were lower (p=0.032) and NLR values were higher (p=0.018). Although IG% was numerically higher and demonstrated a small-to-moderate effect size (Cohen's d=0.257), the difference did not reach statistical significance (p=0.116). In multivariable analysis, IG% did not reach independent statistical significance for perforation (adjusted odds ratio [aOR]=1.66; 95% CI: 0.99–2.76; p=0.053), although the point estimate suggested a possible positive association.

CONCLUSION: IG count and IG% did not provide clinically meaningful discrimination between CAA and NAA. The non-significant association observed for IG% in the multivariable perforation model should be considered hypothesis-generating rather than confirmatory. These findings challenge the high diagnostic performance reported in previous smaller studies and do not support the use of IG count or IG% as standalone preoperative biomarkers in adult acute appendicitis.

Keywords: Acute appendicitis; biomarker; complicated appendicitis; emergency department; immature granulocytes; perforation.

INTRODUCTION

Acute appendicitis, an inflammation of the vermiform appendix, remains the most common cause of acute abdomen worldwide and continues to be the most frequently performed emergency surgical procedure. The lifetime cumulative risk is approximately 7%–9%, and its incidence has increased steadily over the past three decades.[1,2] In a systematic review, Ferris et al.[2] reported a 21st-century incidence of acute appendicitis/appendectomy ranging from 100 to 206 cases per 100,000 person-years. Likewise, the Global Burden of Disease study by Stewart et al.[3] identified acute appendicitis as one of the leading contributors to the workload of emergency surgical services worldwide. In Türkiye, appen-

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dectomy is among the most commonly performed emergency general surgical procedures.

The clinical spectrum of acute appendicitis ranges from simple catarrhal inflammation to transmural necrosis and free perforation. Complicated acute appendicitis (CAA) encompasses phlegmonous or gangrenous inflammation, localized or generalized peritonitis, periappendicular abscess, and perforation. Published series report CAA rates of approximately 20%–30% among all cases, increasing to as high as 50% in older adults.[1,4] CAA is associated with longer hospital stays, higher healthcare costs, and an increased risk of intra-abdominal abscess, surgical-site infection, paralytic ileus, and mortality.[1,5] Consequently, accurate preoperative prediction of CAA is a key component of clinical decision-making, influencing operative planning, antibiotic selection, and the consideration of non-operative management in selected patients.[5,6]

The pathophysiological cascade of acute appendicitis is initiated by luminal obstruction, leading to increased intraluminal pressure, mucosal ischemia, bacterial translocation across the compromised mucosa, and neutrophilic infiltration of the appendiceal wall. Progression to transmural necrosis and uncontrolled inflammation ultimately results in perforation.[1,4] Numerous laboratory markers—including white blood cell count (WBC), C-reactive protein (CRP), neutrophil-to-lymphocyte ratio (NLR), procalcitonin, and bilirubin—have been investigated as indicators of disease severity. However, none has demonstrated sufficient accuracy to reliably distinguish CAA from non-complicated acute appendicitis (NAA) when used in isolation.[7,8] Consistent with these findings, the systematic review by Acharya et al.,[8] which evaluated 65 laboratory tests, concluded that no single biomarker currently provides adequate discriminative performance for this purpose.

Immature granulocytes (IGs)—including myelocytes, metamyelocytes, and promyelocytes—are granulocytic precursor cells released from the bone marrow into the peripheral circulation before reaching full maturity. They are rarely detected in the peripheral blood of healthy individuals. In contrast, severe infection, sepsis, and marked systemic inflammation stimulate bone marrow activity and increase their release into the circulation.[9,10] The widespread adoption of automated hematology analyzers, particularly the Sysmex XN series, has enabled routine measurement of IG count and IG% as part of the complete blood count without additional cost or workload. This accessibility has generated interest in IGs as potential biomarkers in busy emergency department settings.[10,11]

Evidence regarding the role of IGs in acute appendicitis has expanded considerably over the past five years, but findings remain inconsistent. In a retrospective study of 438 adult patients, Ünal reported significantly higher IG% values in patients with CAA and an exceptionally high area under the curve (AUC) of 0.979.[12] In a prospective cohort of 252 patients, Yazla et al.[11] suggested that an IG% cut-off of 0.6% could aid in identifying CAA, with a specificity of 92%.In a pediatric cohort of more than 80 patients, Doğan and Gürleyen[13] reported that IG% was a significant predictor of perforation, with a sensitivity of 81.8%, a specificity of 85.2%, and an AUC of 0.83. However, most available studies are limited by relatively small sample sizes, and reported AUC values vary widely from 0.55 to 0.98. This variability underscores the need for validation in larger and more homogeneous adult emergency department cohorts.

The present study had two primary objectives. First, we evaluated the association of preoperative IG count and IG% with (i) complicated acute appendicitis and (ii) histopathologically confirmed perforation in adult patients presenting to the emergency department of a tertiary care hospital with acute appendicitis. Second, we compared the diagnostic performance of these markers with that of commonly used inflammatory markers, including WBC, absolute neutrophil count, NLR, and CRP. We hypothesized that IG% would demonstrate discriminatory performance at least comparable to that of established inflammatory markers.

MATERIALS AND METHODS

Study Design and Ethics

This single-center retrospective observational cohort study was conducted and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. The study protocol was approved by the Ankara Etlik City Hospital Scientific Research Evaluation and Ethics Committee (decision no. AEŞH-BADEK1-2026-403, date: 15/04/2026). All procedures were performed in accordance with the ethical standards of the 1964 Declaration of Helsinki and its subsequent amendments, as well as the Good Clinical Practice Guideline issued by the Republic of Türkiye Ministry of Health and implemented on February 1, 2024. Owing to the retrospective design and use of anonymized data, the requirement for informed consent was waived by the Ethics Committee.

Patient Selection

We included consecutive adult patients who presented to the emergency department of a tertiary care hospital between January 1, 2025 and January 1, 2026 with abdominal pain, received an initial diagnosis of acute appendicitis, underwent appendectomy at the same institution, and subsequently had acute appendicitis confirmed histopathologically. Eligibility criteria were: (i) age ≥18 years; (ii) availability of complete blood count and CRP measurements obtained during the initial emergency department visit; and (iii) histopathological confirmation of acute appendicitis. Patients were excluded if they met any of the following criteria: pregnancy; transfer from another institution or initial laboratory testing performed elsewhere; known immunodeficiency or hematological disorder; immunosuppressive or steroid therapy; blood transfusion within the preceding three months; hematological malignancy; or incomplete data. Negative appendectomies, defined as cases in which histopathological examination yield-

ed a diagnosis other than appendicitis, were also excluded.

Sample size was estimated a priori using G*Power version 3.1. Assuming a medium effect size (Cohen's d=0.5), α=0.05, and 1−β=0.95, a minimum of 105 patients per group (210 total) was required for comparison of means between two independent groups. Allowing for a 20% data-loss rate, the target sample size was increased to 252 patients. Because all consecutive eligible patients during the study period were included, the final cohort comprised approximately three times the target sample size. Although the sample size calculation was based on comparison of means, the achieved cohort of 891 patients, including 466 CAA cases and 105 perforation events, provided acceptable precision for diagnostic accuracy analyses, with 95% confidence interval half-widths of ≤0.06 for AUC estimates, consistent with Hanley–McNeil sample size considerations.

Data Collection and Laboratory Analysis

Demographic characteristics, clinical assessment records, imaging findings, operative reports, and pathology reports were extracted from the hospital electronic medical record system. Each patient was assigned a unique code independent of personal identifiers, and all data were entered into a standardized data collection form. Complete blood count and CRP measurements were obtained from venous blood samples collected during the initial emergency department evaluation. Hematological parameters were analyzed using an automated Sysmex XN-series analyzer (Sysmex Corporation, Kobe, Japan) according to the manufacturer's instructions. WBC, absolute neutrophil count, absolute lymphocyte count, IG count ($\times 10^9$/L), and IG percentage (%) were recorded directly from the analyzer output. The NLR was calculated by dividing the absolute neutrophil count by the absolute lymphocyte count. CRP concentrations were measured using an immunoturbidimetric method.

Endpoints

The primary endpoint was histopathologically confirmed complicated acute appendicitis. Cases were classified as CAA if the pathology report documented at least one of the following findings: perforation, gangrenous inflammation, phlegmonous inflammation, localized or generalized peritonitis, plastron, or periappendicular abscess. Cases lacking any of these findings and reported as catarrhal acute appendicitis alone were classified as non-complicated acute appendicitis. The secondary endpoint was histopathologically confirmed perforation. Because perforation represents the most severe manifestation within the spectrum of complicated appendicitis, it was analyzed separately in the overall cohort.

Statistical Analysis

Most statistical analyses were performed using IBM SPSS Statistics for Windows, version 27 (IBM Corp., Armonk, NY, USA). Receiver operating characteristic (ROC) analyses requiring bootstrap confidence intervals and permutation testing were conducted in R version 4.3 (R Foundation for Statistical Computing, Vienna, Austria) using the pROC and boot packages. Normality of continuous variables was assessed using the Shapiro–Wilk test and visual inspection of histograms and quantile–quantile (Q–Q) plots. For non-normally distributed variables, data are presented as both mean ± standard deviation and median (interquartile range [IQR]). Categorical variables are presented as n (%).

Continuous variables were compared using the Mann–Whitney U test, whereas categorical variables were compared using Pearson's χ^2 test or Fisher's exact test, as appropriate. Effect sizes for pairwise comparisons were expressed as Cohen's d, calculated from raw means and standard deviations to facilitate comparison with previous studies. Cohen's d values were interpreted as small (0.2), medium (0.5), and large (≥0.8). When applied alongside non-parametric tests, Cohen's d should be considered an approximate measure of effect size. Diagnostic performance was evaluated using the AUC with corresponding 95% confidence intervals. Confidence intervals were derived from 2,000 bootstrap resamples, and p-values for the null hypothesis of AUC=0.5 were obtained using 2,000 permutation iterations. Pairwise comparisons of AUCs were performed using the paired bootstrap method. Optimal cut-off values were identified using the Youden index (J = sensitivity + specificity − 1). For each cut-off, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated.

Variables associated with the outcome at p<0.20 in univariable analyses, together with prespecified clinically relevant covariates (age, sex, WBC, absolute neutrophil count, CRP, and IG%), were entered simultaneously into two separate multivariable logistic regression models: one evaluating CAA and the other evaluating perforation. Results are reported as adjusted odds ratios (aOR) with 95% confidence intervals. Goodness-of-fit was assessed using the Hosmer–Lemeshow test and McFadden's pseudo-R^2. Multicollinearity was assessed using variance inflation factors (VIF), all of which were <2.0. All statistical tests were two-sided, and p<0.05 was considered statistically significant.

RESULTS

Patient Flow and Baseline Characteristics

During the study period, 915 consecutive adult patients admitted to the general surgery service with a preliminary diagnosis of acute appendicitis were screened. Twenty-four patients (2.6%) were excluded because histopathological endpoint data were unavailable, leaving 891 patients for analysis. Of these, 522 (58.6%) were male, and the median age was 35 years (IQR 25–47). Histopathological examination classified 466 patients (52.3%) as having CAA and 425 (47.7%) as having NAA. Perforation, a subset of CAA, was identified in 105 patients (11.8%). All continuous variables deviated from normality according to the Shapiro–Wilk test (all p<0.001); therefore, the Mann–Whitney U test was used for group comparisons.

Baseline demographic characteristics are presented in Table 1. Sex distribution was similar between groups (p=0.947). Patients with CAA were slightly older than those with NAA (36 vs. 33 years; p=0.035), although the effect size was small (Cohen's d=0.144), suggesting limited clinical relevance.

Primary Endpoint: CAA Versus NAA

Comparisons of inflammatory markers between groups are shown in Table 2. WBC, absolute neutrophil count, lymphocyte count, and CRP did not differ significantly between patients with CAA and NAA (p=0.125, 0.063, 0.142, and 0.756, respectively), and effect sizes for all markers were small (0.15). The study variables of primary interest, IG and IG%, were nearly identical between groups (p=0.103 and p=0.318, respectively), with effect sizes of only 0.070 and 0.084, respectively. Although the NLR was slightly higher in the CAA group (p=0.015), the effect size was negligible (Cohen's d=0.048).

Diagnostic performance for CAA is summarized in Table 3 and Figure 1A. The AUCs of all six markers clustered near the line of no discrimination (0.5). The lowest AUC was observed for CRP (0.506; 95% confidence interval [CI]: 0.467–0.545), whereas the highest was observed for NLR (0.547; 95% CI: 0.508–0.586). The AUCs for IG count and IG% were 0.531 (95% CI: 0.492–0.569) and 0.519 (95% CI: 0.479–0.556), respectively. Using the Youden index, the optimal IG% cut-off was ≥0.7%, yielding a specificity of 93.9%, but a sensitivity of only 9.7%. All pairwise comparisons of AUCs were non-significant in the paired bootstrap analysis (all p>0.10), indicating that no marker demonstrated superior discriminatory performance for CAA.

Secondary Endpoint: Perforation

The perforation subgroup analysis yielded somewhat different findings from those observed for the overall CAA endpoint (Table 4). Lymphocyte count was significantly lower in patients with perforation (p=0.032; Cohen's d=0.250), whereas NLR was significantly higher in this group (p=0.018), although the corresponding effect size was minimal (d=0.044), and the statistical significance should be interpreted in the context of the large sample size. IG% was numerically higher in patients with perforation and demonstrated a small-to-moderate effect size (Cohen's d=0.257), although the difference did not reach statistical significance (p=0.116). In contrast, CRP, WBC, absolute neutrophil count, and age did not differ

Table 1. Sociodemographic characteristics of the patients

	NAA (n=425; 47.7%)	CAA (n=466; 52.3%)	p	Cohen's d
Sex, n (%)				
Male	248 (58.4%)	274 (58.8%)	0.947	—
Female	177 (41.6%)	192 (41.2%)		—
Age (years), median (IQR)	33 (24–46)	36 (25–49)	0.035	0.144

NAA: Non-complicated acute appendicitis; CAA: Complicated acute appendicitis; IQR: Interquartile range. Sex was compared with Pearson's χ^2 test and age with the Mann–Whitney U test.

Table 2. Comparison of laboratory parameters between the CAA and NAA groups

Parameter	NAA (n=425)	CAA (n=466)	p	Cohen's d
WBC ($\times 10^9$/L)	13.49±4.39	13.93±4.16	0.125	0.102
Absolute neutrophils ($\times 10^9$/L)	10.43±4.34	10.91±4.10	0.063	0.115
Lymphocytes ($\times 10^9$/L)	2.07±0.94	1.96±0.83	0.142	0.123
NLR	6.83±6.08	7.10±5.12	0.015	0.048
IG ($\times 10^9$/L)	0.059±0.075	0.064±0.065	0.103	0.070
IG (%)	0.41±0.32	0.43±0.32	0.318	0.084
CRP (mg/L)	47.03±51.03	51.54±63.22	0.756	0.078

Data are presented as mean ± standard deviation for ease of comparability with the existing literature; all continuous variables were non-normally distributed on the Shapiro–Wilk test (p<0.001), and group comparisons were performed with the Mann–Whitney U test on the raw distributions. Cohen's d was reported as an approximate effect size and should be interpreted alongside the non-parametric p-values. WBC: White blood cell count; NLR: Neutrophil-to-lymphocyte ratio; IG: Immature granulocytes; CRP: C-reactive protein.

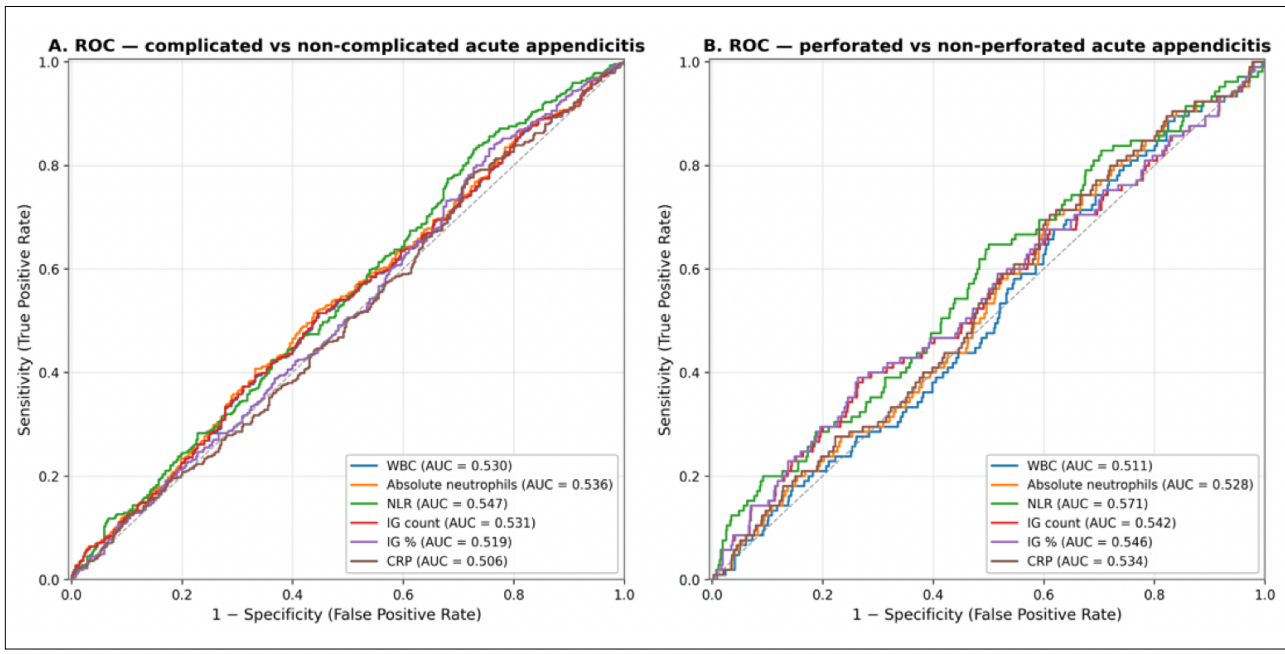

Figure 1. Receiver operating characteristic (ROC) curves for six laboratory markers in the prediction of (A) complicated versus non-complicated acute appendicitis and (B) perforated versus non-perforated acute appendicitis. Area under the curve (AUC) values were estimated using 2,000 bootstrap resamples, and pairwise comparisons were performed using the paired bootstrap method. The diagonal dashed line represents the line of no discrimination (AUC=0.500). WBC: White blood cell count; NLR: Neutrophil-to-lymphocyte ratio; IG: Immature granulocytes; CRP: C-reactive protein.

Table 3. Receiver-operating-characteristic (ROC) analysis of laboratory parameters in the diagnosis of CAA.

Marker	AUC (95% CI)	p	Cut-off	Sensitivity	Specificity	PPV	NPV
WBC (×10^9/L)	0.530 (0.491–0.568)	0.123	11.27	74.2%	33.0%	55%	54%
Absolute neutrophils	0.536 (0.496–0.575)	0.057	7.73	78.8%	29.7%	55%	56%
NLR	0.547 (0.508–0.586)	0.016	3.34	78.1%	32.1%	56%	57%
IG (×10^9/L)	0.531 (0.492–0.569)	0.095	0.04	76.4%	30.2%	55%	54%
IG (%)	0.519 (0.479–0.556)	0.311	0.70	9.7%	93.9%	63%	49%
CRP (mg/L)	0.506 (0.467–0.545)	0.746	224.49	3.7%	99.5%	89%	48%

The 95% CIs for AUC were obtained from 2 000 bootstrap resamples; p-values relative to the null hypothesis of AUC=0.5 were obtained from 2 000 permutation iterations. Cut-offs were determined with the Youden index. WBC: White blood cell count; PPV: Positive predictive value; NPV: Negative predictive value.

significantly between perforated and non-perforated patients (all p≥0.17), and sex distribution was similar between the two groups (p=0.401).

Diagnostic performance for perforation is shown in Table 5 and Figure 1B. NLR demonstrated the highest discriminatory ability (AUC 0.571; 95% CI: 0.519–0.621), followed by IG% (AUC 0.546; 95% CI: 0.490–0.603) and IG count (AUC 0.542; 95% CI: 0.486–0.599). The AUC of NLR was significantly greater than that of WBC (ΔAUC=+0.060; 95% CI: +0.005 to +0.119; p=0.035). The Youden-derived cut-off for IG% (≥0.5%) yielded a sensitivity of 33.3%, specificity of 73.8%, and an NPV of 89.2%. For IG count, a cut-off of ≥0.10 ×10^9/L produced a specificity of 89.8% and an NPV of 89.0%. The high NPVs observed across markers (89.0%–92.9%) largely reflect the relatively low prevalence of perforation in the study population (11.8%).

Multivariable Analysis

Results of the multivariable logistic regression models are presented in Table 6. Both models included age, sex, WBC, absolute neutrophil count, CRP, and IG%. In the model evaluating CAA, none of the inflammatory markers independently predicted the outcome. For IG%, the aOR was 1.12 (95% CI: 0.70–1.78; p=0.642). The McFadden pseudo-R^2 of the model

Table 4. Comparison of demographic and laboratory parameters according to perforation status

	Non-perforated (n=786)	Perforated (n=105)	p	Cohen's d
Sex, n (%)				
Male	456 (58.0%)	66 (62.9%)	0.401	—
Female	330 (42.0%)	39 (37.1%)		—
Age (years), median (IQR)	34 (25–47)	38 (25–51)	0.171	0.143
WBC (×10^9/L)	13.71±4.31	13.82±4.02	0.714	0.026
Absolute neutrophils (×10^9/L)	10.65±4.28	10.92±3.77	0.358	0.066
Lymphocytes (×10^9/L)	2.04±0.90	1.82±0.72	0.032	0.250
NLR	6.94±5.76	7.19±4.23	0.018	0.044
IG (×10^9/L)	0.060±0.067	0.072±0.089	0.154	0.160
IG (%)	0.41±0.30	0.49±0.47	0.116	0.257
CRP (mg/L)	48.12±56.15	58.94±68.14	0.258	0.188

Data are presented as mean ± standard deviation for ease of comparability with the existing literature; all continuous variables were non-normally distributed on the Shapiro–Wilk test (p<0.001), and group comparisons were performed with the Mann–Whitney U test on the raw distributions. Cohen's d was reported as an approximate effect size and should be interpreted alongside the non-parametric p-values. WBC: White blood cell count; NLR: Neutrophil-to-lymphocyte ratio; IG: Immature granulocytes; CRP: C-reactive protein.

Table 5. Receiver-operating-characteristic (ROC) analysis of laboratory parameters in the diagnosis of perforation

Marker	AUC (95% CI)	p	Cut-off	Sensitivity	Specificity	PPV	NPV
WBC (×10^9/L)	0.511 (0.452–0.565)	0.709	9.61	88.6%	17.6%	13%	92%
Absolute neutrophils	0.528 (0.470–0.580)	0.360	7.11	87.6%	21.7%	13%	93%
NLR	0.571 (0.519–0.621)	0.014	4.21	77.1%	39.5%	15%	93%
IG (×10^9/L)	0.542 (0.486–0.599)	0.162	0.10	17.1%	89.8%	18%	89%
IG (%)	0.546 (0.490–0.603)	0.121	0.50	33.3%	73.8%	15%	89%
CRP (mg/L)	0.534 (0.474–0.597)	0.242	62.23	41.0%	70.8%	16%	90%

Cut-offs were determined with the Youden index. The 95% CIs for AUC were obtained from 2 000 bootstrap resamples and p-values relative to the null hypothesis of AUC=0.5 from 2 000 permutation iterations. WBC: White blood cell count; NLR: Neutrophil-to-lymphocyte ratio; IG: Immature granulocytes; CRP: C-reactive protein; PPV: Positive predictive value; NPV: Negative predictive value.

Table 6. Multivariable logistic-regression analysis for the prediction of CAA and perforation

Variable	CAA aOR	95% CI	p	Perforation aOR	95% CI	p
Age	1.008	1.000–1.017	0.061	1.005	0.992–1.019	0.420
Female sex	1.001	0.761–1.316	0.996	0.786	0.511–1.209	0.273
WBC	0.980	0.866–1.110	0.753	0.862	0.707–1.052	0.143
Absolute neutrophils	1.042	0.919–1.182	0.518	1.150	0.941–1.406	0.173
CRP	1.001	0.999–1.003	0.451	1.002	0.999–1.006	0.137
IG (%)	1.116	0.702–1.775	0.642	1.656	0.995–2.757	0.053

CAA model: n=885, events=465; perforation model: n=885, events=105. All variables were entered into the model simultaneously. aOR: Adjusted odds ratio; CI: Confidence interval; WBC: White blood cell count; IG: Immature granulocytes; CRP: C-reactive protein; CAA: complicated acute appendicitis.

was 0.006, indicating that the model explained little of the variation in complications. In the perforation model, which included the same covariates, IG% did not reach statistical significance (aOR=1.66 per 1% increase; 95% CI: 0.99–2.76; p=0.053). Although the point estimate suggested a positive association, this finding should be interpreted as a non-significant trend and considered hypothesis-generating. None of the other variables included in the perforation model reached statistical significance. The Hosmer–Lemeshow goodness-of-fit test indicated acceptable calibration for both models (p=0.38 and p=0.42, respectively), and VIF values were <2.0 for all predictors.

Figure 1 jointly presents ROC curves for WBC, absolute neutrophil count, NLR, IG, IG%, and CRP in the prediction of CAA (Fig. 1A) and perforation (Fig. 1B). In both analyses, the curves remained close to the line of no discrimination; however, in the perforation analysis, the NLR and IG% curves showed modest separation from the others.

DISCUSSION

In this cohort of 891 adults with histopathologically confirmed appendicitis, we evaluated the diagnostic performance of preoperative IG and IG%. Contrary to the findings of several smaller studies, neither marker demonstrated clinically meaningful discrimination between CAA and NAA. The perforation analysis yielded somewhat different findings, although these should be interpreted cautiously. In the multivariable model, IG% showed a non-significant trend toward an association with perforation (p=0.053; 95% CI: 0.99–2.76, encompassing unity), whereas lymphopenia and elevated NLR emerged as the most consistent laboratory correlates of perforation.

The absence of significant differences in traditional acute-phase markers (WBC, absolute neutrophil count, lymphocyte count, and CRP) between CAA and NAA may appear unexpected. However, this finding likely reflects the inherent heterogeneity of CAA as a pathologically defined entity. CAA encompasses a broad spectrum of disease, ranging from phlegmonous inflammation to free perforation. Patients at the less advanced end of this spectrum, such as those with phlegmonous inflammation or localized peritonitis, may undergo surgery before a substantial systemic inflammatory response develops. Consequently, although the designation of "complicated" is pathologically appropriate, it may not correspond to clear separation from NAA at the laboratory level. This interpretation is supported by the more consistent findings observed in the perforation analysis, which represents the most advanced stage of the disease spectrum. Lymphopenia and elevated NLR, both markers of a more pronounced systemic inflammatory response, differed significantly between perforated and non-perforated patients. These findings further support the methodological importance of evaluating more homogeneous subgroups of CAA, such as perforation, gangrene, and abscess formation, in biomarker studies.[8,14]

The observation that IG appeared to be associated with perforation but not with CAA overall is biologically plausible. Immature granulocytes represent the peripheral blood manifestation accelerated bone marrow granulopoiesis in response to systemic inflammatory stimuli ("left shift").[9,10] Mechanistically, this process involves emergency granulopoiesis driven by elevations in granulocyte colony-stimulating factor (G-CSF) induced by lipopolysaccharide and inflammatory cytokines such as tumor necrosis factor-α (TNF-α) and interleukin-6 (IL-6), leading to the early release of granulopoietic precursors into the circulation.[15] Band neutrophilia and the immature cell fraction can be objectively measured using automated hematology analyzers, enabling clinical monitoring of this response.[16,17] When the integrity of the appendiceal wall is breached (that is, when perforation or transmural necrosis develops), the magnitude of bacterial translocation and the severity of systemic inflammation increase, potentially leading to higher circulating IG levels. In earlier forms of complicated appendicitis in which mucosal integrity is preserved, this threshold may not be reached; consequently, the degree of systemic inflammation may overlap substantially with that observed in NAA, limiting the discriminatory ability of an early marker such as IG%.

Our findings are consistent with some aspects of the existing literature but differ from others. Yazla et al.[11] reported a specificity of 92% for IG% at a cut-off of 0.6% in a prospective cohort of 252 adult patients. Similarly, high IG% cut-offs yielded a similar specificity profile (93.9% at ≥0.7%). However, this specificity came at the expense of low sensitivity (9.7%), and overall discrimination remained poor (AUC 0.519). Together with the absence of pairwise AUC superiority over any other marker, this profile does not support a clinically meaningful role for IG% as a rule-in adjunct, as the specificity of the Youden-derived cut-off was accompanied by very poor sensitivity and limited overall discrimination. A more striking contrast is provided by the retrospective study by Ünal, which reported a markedly higher AUC (0.979) for IG% in predicting CAA in a cohort of 438 patients.[12] Differences in patient selection, CAA definitions, laboratory platforms, reference ranges, and center-specific practices may account for these divergent results. Likewise, the perforation AUC reported by Doğan and Gürleyen[13] in a pediatric cohort (0.83) substantially exceeded that observed in our adult population (0.546). Differences in comorbidity burden, disease characteristics, and perforation rates between pediatric and adult populations may partially explain this discrepancy.

The identification of NLR as the most consistent marker in both the CAA and perforation analyses is consistent with previous literature. The meta-analysis by Hajibandeh et al.,[18] which included 17 studies, found that NLR demonstrated statistically significant but individually modest performance for diagnosing acute appendicitis and distinguishing complicated from uncomplicated disease. Single-center data from an adult Turkish cohort reported by Kahramanca et al.[19] also sup-

port these findings. In our study, NLR achieved the highest AUC among the evaluated biomarkers, although its overall discriminatory performance remained limited. These findings are entirely consistent with the literature. The lack of significant performance of CRP for either endpoint is likewise consistent with the mixed findings reported in the literature. CRP levels typically rise 8-12 hours after the onset of inflammation; therefore, variability in the timing of patients' presentation to the emergency department may reduce the discriminatory performance of this marker.[1,7]

From a clinical perspective, the principal message is straightforward. Neither IG count nor IG% should be used as a standalone preoperative marker for predicting complicated appendicitis in adults. Moreover, the performance observed in our cohort does not support their routine use as adjunctive biomarkers. Whether IG% provides incremental value when integrated with validated clinical scoring systems, such as the Alvarado score and the Appendicitis Inflammatory Response (AIR) score, together with imaging findings and other laboratory parameters for identifying patients at high risk of perforation, is a question that our retrospective study was not designed to address. This remains a hypothesis to be tested in future studies rather than a basis for clinical recommendation. This interpretation is consistent with the imaging-priority and clinicoradiological approach advocated by the World Society of Emergency Surgery (WSES) Jerusalem 2020 guidelines and further underscores the limitations of diagnostic strategies that rely on a single biomarker.[5]

The major strengths of this study include its large sample size, use of a single laboratory platform (Sysmex XN), endpoint definitions validated against the histopathological gold standard, prespecified statistical analyses, and reporting of effect sizes and bootstrap-based ROC comparisons. These features strengthen the study's internal validity and enhance the reliability of the findings.

Some limitations should also be acknowledged. First, the retrospective design precludes causal inference and introduces the potential for selection bias. However, the inclusion of consecutive patients meeting the eligibility criteria may have mitigated this bias. Second, because the study was conducted at a single center, the generalizability of the findings to other healthcare settings and patient populations requires further validation. Third, the interval between symptom onset and hospital admission or blood sampling was not recorded in a standardized manner. Because IG levels and other acute-phase markers are time-dependent, the absence of this information may have introduced some measurement variability. Fourth, additional markers, such as procalcitonin and direct bilirubin, which have been associated with CAA in previous studies, were not routinely measured in all patients and therefore could not be included in the analysis. Fifth, no analysis of postoperative outcomes (intra-abdominal abscess, surgical-site infection, and readmission) was performed; future studies should evaluate the association between biomarkers and these clinical endpoints. Sixth, validated clinical scoring systems (e.g., Alvarado and AIR scores) and preoperative imaging findings (ultrasonography or computed tomography) were not incorporated into the analytical models. Consequently, the incremental value of IG% beyond standard preoperative assessment could not be quantified. Seventh, the definition of CAA encompassed a broad pathological spectrum, including phlegmonous inflammation, which some authors do not classify as complicated appendicitis. As a result, the observed CAA prevalence (52.3%) was at the upper end of the reported range and may have attenuated the discriminative performance of the evaluated biomarkers. Future studies should consider sensitivity analyses restricted to gangrenous, abscess-forming, and perforated appendicitis. Eighth, although the achieved sample size provided acceptable precision for AUC estimates, the a priori sample size calculation was based on differences in means rather than diagnostic accuracy metrics; therefore, sample-size adequacy was confirmed post hoc. Finally, because the CAA definition included a broad spectrum of pathological entities, subgroup analyses of specific complications, such as gangrene, abscess, or plastron formation, were not feasible due to limited statistical power. Although this study represents one of the larger series in the existing literature, these limitations underscore the need for larger, multicenter studies with more comprehensive data collection.

Future research should evaluate the incremental value of IG% within integrated models that incorporate symptom duration and imaging findings in larger multicenter cohorts. The study by Eickhoff et al.,[20] which demonstrated that postoperative outcomes following perforated appendicitis could be predicted with 68%-88% accuracy using a random forest-based machine-learning model, suggests that combining clinical and laboratory data with advanced statistical models may substantially improve individualized risk prediction. In this context, combining clinical scores such as the Alvarado and AIR scores, imaging findings, and laboratory parameters with machine-learning-based models may help overcome biomarker heterogeneity and facilitate early identification of patients at risk of perforation. In addition, characterization of activated IG subpopulations (e.g., CD64-positive IGs) in acute appendicitis represents a promising avenue for mechanistic investigation. The non-significant trend observed for IG% in our multivariable perforation model is consistent with, although not confirmatory of, the hypothesis that monitoring activated subpopulations rather than the total IG pool could improve diagnostic performance.

CONCLUSION

In this large adult cohort of 891 patients, IG count and IG% did not provide clinically meaningful discrimination between complicated and non-complicated acute appendicitis, in contrast to the high diagnostic performance reported in several smaller studies. The non-significant trend observed for IG% in the multivariable perforation model (p=0.053; 95% CI: 0.99–2.76,

including unity) should be regarded as hypothesis-generating and does not support clinical implementation. These findings argue against reliance on single-biomarker strategies in the preoperative assessment of acute appendicitis and indicate that IG and IG% should not be used as stand-alone diagnostic tools. Whether these markers provide incremental value when combined with validated clinical scores, imaging findings, and other laboratory parameters remains to be determined in future multicenter studies with larger sample sizes.

Ethics Committee Approval: This study was approved by the Ankara Etlik City Hospital Scientific Research Evaluation and Ethics Committee (Date: 15.04.2026, Decision No: AEŞH-BADEK1-2026-403).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Komplike akut apandisitte immatür granülositlerin acil serviste değerlendirilmesi: Retrospektif kohort çalışması

AMAÇ: Komplike akut apandisitin (KAA) ameliyat öncesinde tanınması, morbiditenin azaltılması açısından önemlidir. Bu çalışmada, acil servise başvuran erişkin hastalarda immatür granülosit (İG) sayısı ve yüzdesinin (İG%), KAA'yı ve histopatolojik perforasyonu öngörmedeki tanısal değerini değerlendirdik.

GEREÇ VE YÖNTEM: 1 Ocak 2025 ile 1 Ocak 2026 tarihleri arasında üçüncü basamak bir merkezin acil servisine başvuran ve akut apandisit tanısı histopatolojik olarak doğrulanan ardışık erişkin hastalar (≥18 yaş) retrospektif olarak incelendi. Olgular KAA veya nonkomplike akut apandisit (NKA) olarak sınıflandırıldı; perforasyon ise ayrı bir ikincil sonlanım noktası olarak analiz edildi. Tanısal performans, ROC analizi, Youden indeksi ve çok değişkenli lojistik regresyon analizi ile değerlendirildi.

BULGULAR: Toplam 891 hastanın (%58.6 erkek; ortanca yaş 35 yıl, IQR: 25–47) 466'sında (%52.3) KAA, 105'inde (%11.8) ise perforasyon saptandı. KAA ayrımında en yüksek eğri altında kalan alan (AUC) nötrofil-lenfosit oranında (NLO) gözlendi (0.547; %95 GA: 0.508–0.586); İG% için AUC değeri 0.519 (%95 GA: 0.479–0.556) idi. Perforasyon saptanan olgularda lenfosit sayısı daha düşük (p=0.032) ve NLO daha yüksekti (p=0.018). İG% değeri sayısal olarak daha yüksek olma eğilimi gösterdi ve küçük-orta düzeyde bir etki büyüklüğüne ulaştı (Cohen d=0.257), ancak istatistiksel anlamlılığa ulaşmadı (p=0.116). Çok değişkenli analizde İG%, perforasyon için bağımsız bir belirteç olarak istatistiksel anlamlılık göstermedi (düzeltilmiş OR=1.66; %95 GA: 0.99–2.76; p=0.053).

SONUÇ: İG sayısı ve İG%, KAA ile NKA arasında klinik olarak anlamlı ve kullanışlı bir ayrım sağlamamıştır. Çok değişkenli perforasyon modelinde İG% için gözlenen istatistiksel olarak anlamlı olmayan eğilim, doğrulayıcı değil, hipotez oluşturucu nitelikte değerlendirilmelidir. Bulgularımız, daha küçük örneklemli önceki çalışmalarda bildirilen yüksek tanısal performansı doğrulamamış ve erişkin akut apandisit olgularında İG veya İG%'nin tek başına ameliyat öncesi biyobelirteç olarak kullanılmasını desteklememiştir.

Anahtar sözcükler: Acil servis; akut apandisit; biyobelirteç; immatür granülositler; komplike apandisit; perforasyon.

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ORIGINAL ARTICLE

Clinical performance of the Antoine Béclère score in predicting operative requirement in adhesive small bowel obstruction

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ABSTRACT

BACKGROUND: Adhesive small bowel obstruction (ASBO) remains a common surgical emergency; however, identifying patients who are unlikely to respond to conservative management continues to be challenging. Although numerous clinical and radiologic predictors have been proposed, their accuracy is inconsistent, and simple, objective tools remain lacking.

METHODS: A retrospective cohort study was conducted including adults admitted with computed tomography (CT)-confirmed ASBO between 2020 and 2024. Demographic characteristics, comorbidities, laboratory values, prognostic nutritional index (PNI), platelet-to-lymphocyte ratio (PLR), radiologic parameters, and Antoine Béclère (AB) scores were collected. Predictors of operative intervention were evaluated using univariate and multivariable logistic regression analyses. Diagnostic performance of the AB score was assessed using receiver operating characteristic (ROC) analysis.

RESULTS: A total of 106 patients were included, of whom 51 (48.1%) required operative management. PNI and PLR did not differ significantly between operative and non-operative groups. Older age, greater comorbidity burden, and higher AB scores were associated with surgery. An AB score ≥2 predicted operative need in 82.4% of cases ($p<0.001$). In multivariable analysis adjusted for age and Charlson Comorbidity Index ≥4, an AB score ≥2 remained an independent predictor of operative intervention (odds ratio 4.20). ROC analysis demonstrated moderate discriminative ability of the AB score, with an area under the curve (AUC) of 0.71, sensitivity of 82%, and specificity of 66.

CONCLUSION: The AB score helped identify patients unlikely to respond to conservative treatment, with a score ≥2 strongly associated with operative need. Its predictive performance was not influenced by nutritional or inflammatory status. These findings support the clinical utility of simple, reproducible indicators to guide early management decisions in ASBO.

Keywords: Adhesive small bowel obstruction; Antoine Béclère; conservative; operative intervention; predictors.

INTRODUCTION

Adhesive small bowel obstruction (ASBO) remains one of the most common and clinically significant long-term complications following abdominal surgery. The annual incidence of small bowel obstruction is estimated at 3–5 per 100,000 persons, with postoperative adhesions accounting for approximately 65%–75% of cases, underscoring the substantial epidemiologic burden associated with this condition.[1] ASBO also contributes to recurrent emergency admissions and car-

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ries a considerable risk of dehydration, bowel ischemia, and sepsis, reinforcing its significant morbidity and clinical impact.[2] Despite advances in perioperative care and modern imaging modalities, ASBO continues to present important challenges in acute surgical practice.

Management of ASBO is challenging because postoperative adhesions often coexist with other factors, including internal hernias, inflammatory processes, and congenital variations, resulting in substantial clinical heterogeneity. Although conservative treatment is attempted in most patients and is successful in 60%–70% of cases, up to one-third ultimately require surgery because of persistent obstruction or early signs of bowel compromise.[3] The time-sensitive nature of ASBO further complicates management, as delayed surgery increases the risk of ischemia, whereas premature intervention carries a reported mortality rate of 5%–7%.[4] These uncertainties highlight the need for more reliable tools to identify patients unlikely to benefit from conservative management.

Identifying patients with ASBO who are at risk of deterioration remains difficult because of the condition's diverse etiologies and variable clinical presentations.[5] Although several radiologic signs have been proposed to predict severity, their accuracy varies across studies and is influenced by reader experience.[6] Reviews have also reported inconsistent performance of clinical and laboratory markers, limiting their value as standalone predictors.[7,8] Consequently, no single parameter currently provides reliable guidance for decision-making in ASBO.

Clinical guidelines provide broad recommendations for ASBO management but offer limited practical guidance in distinguishing patients suited for conservative treatment from those who may benefit from early operative intervention.[9] Proposed management algorithms demonstrate inconsistent implementation, and treatment practices vary substantially across centers. Real-world studies further indicate variability in the interpretation of clinical and radiologic findings among clinicians, contributing additional uncertainty.[10] These challenges underscore the need for objective tools to support accurate risk stratification in ASBO.

In recent years, interest has grown in the use of composite biomarkers to improve clinical assessment in surgical populations. Nutritional and inflammatory indices such as the prognostic nutritional index and platelet-to-lymphocyte ratio have demonstrated clinical relevance in malignant and inflammatory conditions by reflecting physiologic reserve and systemic immune status.[11] Parallel to these developments, efforts have been made to refine decision-making in ASBO through structured risk models that integrate clinical and radiologic findings. Among these, the Antoine Béclère (AB) score represents a notable approach for identifying patients more likely to require surgical intervention.[12] Although these strategies share the goal of improving risk stratification, their application in ASBO has not been extensively characterized, and further evaluation in well-defined cohorts is needed to clarify their role.

Given the persistent uncertainty in distinguishing patients who may benefit from continued conservative treatment from those requiring timely surgery, there is a need for tools that integrate clinical, laboratory, and radiologic information into a unified framework. Building on current evidence regarding nutritional and inflammatory indices, as well as emerging structured scoring systems, this study evaluates the performance of the AB score together with the prognostic nutritional index (PNI) and platelet-to-lymphocyte ratio (PLR) in patients presenting with ASBO. The aim was to determine whether these parameters can help identify individuals who are more likely to require operative intervention.

MATERIALS AND METHODS

Study Design and Setting

This retrospective cohort study was conducted at Aydın Adnan Menderes University, a tertiary referral center serving the Aegean region of Türkiye. The study included patients treated between January 2020 and December 2024.

Ethical Approval

The study protocol was reviewed and approved by Aydın Adnan Menderes University (Decision No. 17; Protocol No. 2025/277; Date: September 18, 2025). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Because this retrospective study used anonymized patient records, the requirement for informed consent was waived by the ethics committee.

Patient Selection

Patients aged ≥18 years admitted with adhesive small bowel obstruction and managed either conservatively or surgically were screened. ASBO was defined based on clinical presentation and radiologic evidence of small bowel obstruction in patients with a history of previous abdominal surgery.

Inclusion Criteria

Patients aged ≥18 years hospitalized between 2020 and 2024 with computed tomography (CT)-confirmed adhesive small bowel obstruction and a history of prior intra-abdominal surgery were eligible for inclusion, provided that complete radiologic and laboratory data were available. Patients were excluded if obstruction resulted from non-adhesive causes, including hernias, malignancy, volvulus, or intussusception; if primary malignancy caused the obstruction; or if bowel ischemia was present at admission. Cases with missing essential radiologic or laboratory data were also excluded. For patients with multiple admissions, only the index hospitalization was included to avoid duplication.

Data Collection

At admission, all patients underwent standardized initial management consisting of clinical assessment, laboratory evaluation, and contrast-enhanced computed tomography, followed by either conservative treatment or surgical intervention according to clinical progression.

Conservative management consisted of bowel rest, nasogastric decompression when indicated, intravenous fluid resuscitation, and close clinical monitoring.

Electronic medical records, radiology reports, and laboratory archives were reviewed. The following variables were recorded:

Demographic and Clinical Characteristics

Demographic variables included age and sex. Comorbid conditions, including diabetes mellitus, cardiovascular disease, chronic kidney disease, and malignancy, were recorded for each patient. Overall comorbidity burden was quantified using the age-adjusted Charlson Comorbidity Index.

Laboratory Parameters

Laboratory analyses included serum albumin, lymphocyte count, platelet count, C-reactive protein (CRP), lactate, and white blood cell (WBC) count. Based on these values, two composite indices were calculated. The prognostic nutritional index was calculated as:

PNI = 10 × albumin (g/L) + 5 × lymphocyte count (10^3/μL).

The platelet–lymphocyte ratio was calculated by dividing the platelet count by the lymphocyte count.

Radiologic Parameters

Computed tomography images were reviewed to determine the level of obstruction, categorized as jejunal (1) or ileal (2). The presence of distal obstruction was recorded. Measurements included maximum small bowel diameter (SBD, mm) and vertical abdominal diameter (VAD, mm), which were subsequently used to calculate the SBD/VAD ratio.

Antoine Béclère Score

To assess the predictive value of the Antoine Béclère score, three predefined components were evaluated:

- Age-adjusted Charlson Comorbidity Index ≥4
- Distal (ileal) obstruction
- SBD/VAD ratio >0.34.

The total AB score ranged from 0 to 3, with AB ≥2 defining the high-risk group.

Outcome Measure

The primary outcome was the need for surgical intervention during the index hospitalization, categorized as:

- Operative management
- Successful conservative management.

This study did not aim to develop or validate a new scoring system. Rather, it evaluated the real-world clinical performance of the Antoine Béclère score when applied to a retrospective ASBO cohort.

Statistical Analyses

Statistical analyses were performed using SPSS software version 29 (IBM Corp., Armonk, NY, USA). Continuous variables were compared using the Mann–Whitney U test, whereas categorical variables were analyzed using the chi-square test. Variables associated with operative intervention in univariate analysis ($p<0.10$) were subsequently entered into a multivariable logistic regression model to identify independent predictors. The final adjusted model included age, Charlson Comorbidity Index ≥4, and AB score ≥2.

Receiver operating characteristic (ROC) curve analysis was performed to evaluate the discriminative performance of the AB score. Area under the curve (AUC), sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated using the predefined threshold of AB ≥2. A p-value <0.05 was considered statistically significant.

Variables included in the regression model were selected based on established clinical relevance in the ASBO literature rather than for development of a predictive model. Accordingly, the regression analysis was intended to assess associations between the applied score and operative need rather than to construct a new scoring system.

Because the Antoine Béclère score an existing predefined scoring system, only its clinical performance was evaluated, and no variable selection procedures (e.g., stepwise selection, Least Absolute Shrinkage and Selection Operator [LASSO] regression, or bootstrap methods) were performed.

RESULTS

Patient Characteristics

A total of 106 patients with adhesive small bowel obstruction were included. Of these, 51 (48.1%) required operative management, whereas 55 (51.9%) were successfully treated conservatively. Baseline nutritional and inflammatory profiles were comparable between groups. Median PNI values were high in both cohorts (349 vs. 385, p=0.0046), whereas PLR values did not differ significantly (188.8 vs. 191.8, p=0.889). These findings suggest that both groups had similar systemic and nutritional profiles (Table 1).

Surgical intervention was undertaken based on the overall clinical course, including persistence of obstruction or clinical deterioration during conservative management, with radiologic findings interpreted in conjunction with clinical assessment.

Univariate Analysis

Older age (median 68 vs. 51 years, p<0.001), greater comorbidity burden (Charlson Comorbidity Index ≥4: 52.9%

Table 1. Baseline characteristics of the study population

	Operative management (n=51)	Conservative management (n=55)	p
Age, years (median)	68	51	<0.001
Female sex (%)	–	–	–
Charlson Comorbidity Index (median)	3	1	<0.001
Charlson Comorbidity Index ≥4 (%)	52.9%	10.9%	<0.001
Distal (ileal) obstruction (%)	78.4%	72.7%	0.648
SBD, mm (median)	–	–	–
VAD, mm (median)	–	–	–
SBD/VAD ratio (median)	0.382	0.366	0.440
SBD/VAD ratio >0.34 (%)	62.7%	58.2%	0.779
PNI (median)	349.0	385.1	0.0046
PLR (median)	188.8	191.8	0.889

SBD: Small bowel diameter; VAD: Vertical abdominal diameter; PNI: Prognostic nutritional index; PLR: Platelet-to-lymphocyte ratio.

Table 2. Univariate analysis of predictors of operative intervention

	Operative management	Conservative management	p
Age (median)	68	51	<0.001
Charlson Comorbidity Index (median)	3	1	<0.001
Charlson Comorbidity Index ≥4 (%)	52.9%	10.9%	<0.001
Distal obstruction (%)	78.4%	72.7%	0.648
SBD/VAD ratio (median)	0.382	0.366	0.440
SBD/VAD ratio >0.34 (%)	62.7%	58.2%	0.779
AB score (median)	2	1	<0.001
AB score ≥2 (%)	82.4%	34.5%	<0.001
PNI (median)	349.0	385.1	0.0046
PLR (median)	188.8	191.8	0.889

SBD: Small bowel diameter; VAD: Vertical abdominal diameter; PNI: Prognostic nutritional index; PLR: Platelet-to-lymphocyte ratio.

vs. 10.9%, p<0.001), and higher AB scores (median 2 vs. 1, p<0.001) were significantly associated with operative intervention requirement. Radiologic severity markers, including obstruction level and SBD/VAD ratio, did not demonstrate predictive value. An AB score ≥2 was strongly associated with operative management (82.4% vs. 34.5%, p<0.001) (Table 2).

Nutritional Indices

Neither PLR nor PNI demonstrated clinically meaningful differences between groups, suggesting broadly comparable nutritional profiles among patients. Therefore, the discriminative performance of the AB score is unlikely to be confounded by baseline nutritional or inflammatory status.

Logistic Regression Analysis

In univariate logistic regression, an AB score ≥2 was associated with a markedly increased likelihood of surgery (odds ratio [OR] 8.84, 95% confidence interval [CI] 3.56–21.96; p<0.001). When modeled as a continuous variable, each one-point increase in AB score was associated with a threefold increase in the odds of operative intervention (OR 3.08, 95% CI 1.64–5.76; p<0.001).

In the multivariable model adjusted for age and Charlson Comorbidity Index ≥4, AB score remained an independent predictor of operative management (OR 4.20, 95% CI 1.46–12.11; p=0.0079), whereas neither age nor comorbidity bur-

Table 3. Multivariable logistic regression analysis for predictors of operative intervention

	Adjusted OR	95% CI	p
Age (years)	1.03	0.99–1.06	0.112
Charlson comorbidity index ≥4	2.27	0.60–8.57	0.227
AB score ≥2	4.20	1.46–12.11	0.0079

OR: Odds ratio; CI: Confidence interval.

Table 4. Receiver operating characteristic (ROC)-based diagnostic performance of the Antoine Béclère score in adhesive small bowel obstruction (ASBO)

Metric	p
AUC (AB score)	0.71
Sensitivity (cut-off ≥2)	82%
Specificity (cut-off ≥2)	66%
Positive predictive value	69%
Negative predictive value	80%

den reached statistical significance (Table 3).

ROC Analysis

The discriminative performance of the AB score was further evaluated using ROC analysis. As shown in Figure 1, the AB score demonstrated acceptable accuracy for predicting operative management, with an AUC of 0.71. Using the predefined threshold of AB ≥2, the score achieved a sensitivity of 82% and specificity of 66%, indicating that this cutoff may help identify patients who are less likely to respond to conservative management. Performance metrics are summarized in Table 4.

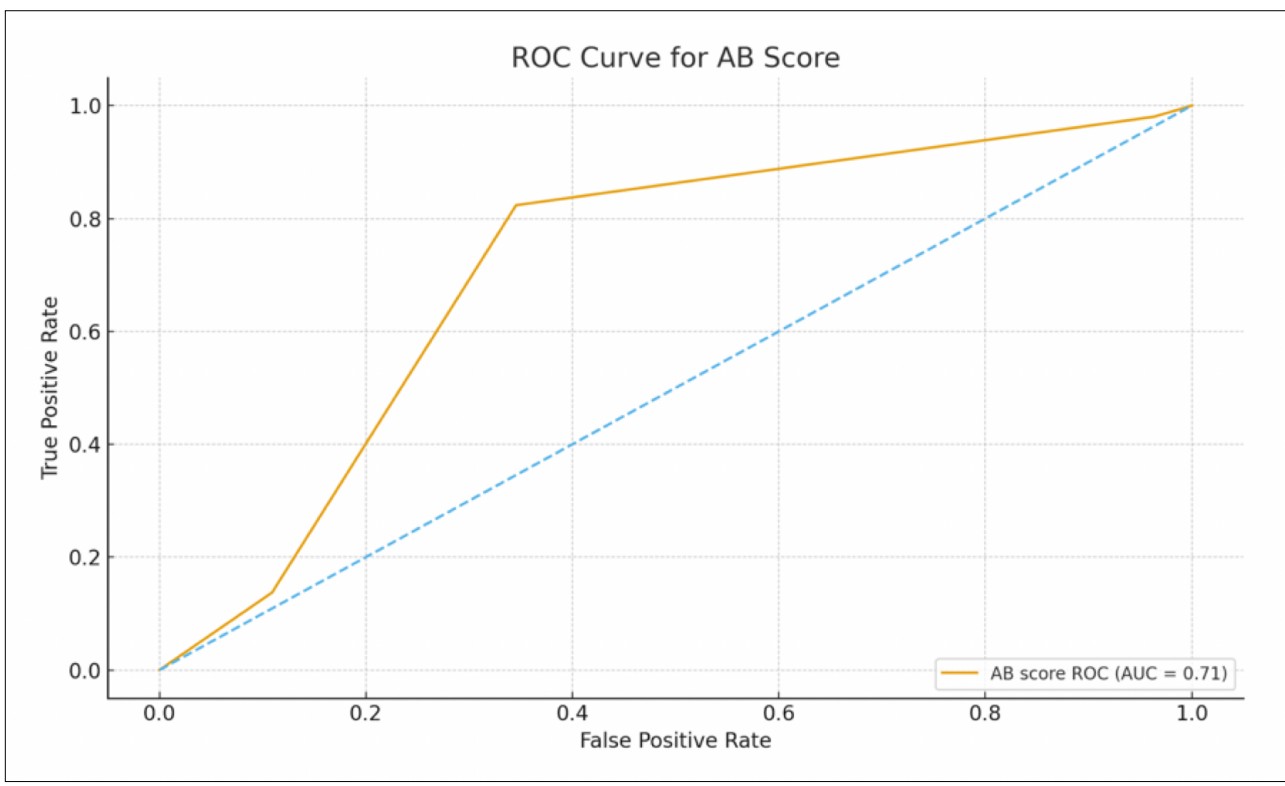

Figure 1. Receiver operating characteristic (ROC) curve of the Antoine Béclère (AB) score for predicting the need for operative intervention in adhesive small bowel obstruction. ROC curve illustrating the discriminative performance of the AB score for predicting operative intervention in patients with adhesive small bowel obstruction. The area under the curve (AUC) was 0.71, indicating acceptable discriminative ability. Using a cutoff value of AB ≥2, the score demonstrated a sensitivity of 82% and a specificity of 66% for identifying patients who ultimately required surgery.

DISCUSSION

The findings of this study suggest that the AB score, evaluated alongside selected nutritional and inflammatory indices, may help identify patients with adhesive small bowel obstruction who are more likely to require operative management. This observation is clinically relevant given the ongoing difficulty in distinguishing patients who will respond to conservative treatment from those at risk of deterioration, as highlighted in recent analyses and systematic reviews of ASBO management.[13-15] In our cohort, an AB score ≥2 was associated with operative management in 82.4% of patients, a proportion exceeding operative rates reported in several recently developed risk models evaluated in unselected ASBO populations.[16,17] These findings support the potential utility of the AB score as a pragmatic threshold for identifying patients unlikely to improve with conservative therapy.

Importantly, this study was not designed as a formal validation of the Antoine Béclère score but rather as an assessment of its clinical performance when applied to a real-world ASBO cohort.

Conservative management is successful in many patients with adhesive small bowel obstruction; however, identifying those who will ultimately fail remains challenging.[18,19] In our cohort, 48.1% of patients eventually required surgery, corresponding to the upper range of the 25%–40% operative rates reported in mixed ASBO populations. Early signs of deterioration are often subtle, and conventional predictors demonstrate limited accuracy. Practice variability further complicates outcomes, including differences in the use of nasogastric decompression.[20] System-level factors such as weekend admissions may also influence management patterns.[21] Additionally, patient characteristics, including advanced age and greater comorbidity burden, have been associated with increased operative need in recent studies.[22] Taken together, these findings reinforce the need for structured, objective frameworks to support clinical decision-making between continued observation and timely surgical intervention.

Radiologic evaluation remains central to the assessment of adhesive small bowel obstruction; however, individual CT findings often lack sufficient predictive accuracy. Recent studies suggest that point-of-care ultrasound may complement CT by identifying features of bowel compromise, although its diagnostic performance varies according to operator experience.[23] Laboratory markers such as procalcitonin have also been investigated for detecting early clinical deterioration, but results remain inconsistent across studies.[24] Several scoring systems integrating clinical, imaging, and laboratory variables have been proposed; however, most demonstrate heterogeneous performance and limited external validation.[25] In the present study, the observed AUC of 0.71 indicates moderate discriminative ability and is comparable to that reported for other radiologic and clinical predictors in the ASBO literature. Although this level of performance does not constitute formal validation, it supports the potential utility of the AB score in early clinical decision-making. These findings are consistent with prior reviews highlighting the heterogeneous performance of existing ASBO scoring systems, including the 2022 review by Coco et al.,[26] which emphasized the need for practical clinical tools rather than reconstruction or repeated redevelopment of scoring models.

The choice between open and laparoscopic surgery for adhesive small bowel obstruction varies across institutions and depends largely on patient selection. Systematic evaluations indicate that laparoscopy may be beneficial in carefully selected cases, although its broader applicability remains limited.[27,28] Reports from Türkiye similarly suggest that laparoscopic management is adopted selectively and influenced by surgeon experience and case complexity.[29] Individual national case reports further illustrate the marked heterogeneity in clinical presentation and intraoperative findings.[30] In our cohort, all operative cases were managed using an open approach, reflecting both institutional practice and the complexity of the included population.

Health system–level factors also contribute to variability in outcomes among patients with adhesive small bowel obstruction. Hospital-based analyses suggest that access to experienced surgical teams and timely operative resources may influence both treatment decisions and clinical outcomes.[31] Postoperative recovery pathways, including enhanced recovery protocols, have been proposed to improve standardization of care; however, their implementation in ASBO remains inconsistent and largely institution dependent.[32] These observations highlight the continued influence of structural factors on coordinated and timely management.

This study contributes to ongoing efforts to improve early risk stratification in adhesive small bowel obstruction through integration of clinical, laboratory, and radiologic variables. Its retrospective, single-center design limits generalizability, and external validation in larger cohorts is needed. Future studies may also incorporate advanced computational approaches, as emerging evidence suggests that data-driven models could enhance individualized prediction in this setting.[33] Despite these limitations, the present analysis provides a foundation for the development of structured, objective tools to support clinical decision-making in ASBO.

Several limitations of this study should be considered. First, the retrospective design limited control over potential confounding factors and relied on the accuracy and completeness of existing clinical records. Second, the study was conducted at a single center, which may limit generalizability, particularly with respect to institutional differences in conservative management strategies and thresholds for operative intervention. Third, radiologic assessments were based on routine clinical reporting rather than standardized re-evaluation by multiple observers, potentially introducing variability. Finally, although the sample size was sufficient for the primary analyses, sub-

group analyses, particularly those involving specific radiologic parameters, may have been underpowered. These limitations highlight the need for prospective, multicenter studies with standardized imaging and management protocols. As a retrospective study, the analysis was inherently limited by the absence of predefined decision criteria, and the findings should therefore be interpreted as hypothesis-generating rather than confirmatory.

Importantly, this study was not designed as a formal validation study of the Antoine Béclère score; consequently, larger multicenter cohorts will be required to externally validate its clinical performance.

CONCLUSION

This study demonstrates that the Antoine Béclère score, used alongside routine clinical and laboratory assessment, may help identify patients with adhesive small bowel obstruction who are unlikely to respond to conservative treatment. A AB score of ≥2 was strongly associated with operative intervention and demonstrated moderate discriminative performance, supporting its potential utility as a practical early triage threshold. Nutritional and inflammatory indices showed no clinically meaningful differences between groups, suggesting that the performance of the score was not influenced by baseline systemic status. Although external validation is required, these findings highlight the potential usefulness of simple and reproducible measures in guiding early clinical decision-making.

Ethics Committee Approval: This study was approved by the Aydın Adnan Menderes University Non-Interventional Clinical Research Ethics Committee (Date: 24.09.2025, Decision No. 17; Protocol No. 2025/277).

Peer-review: Externally peer-reviewed.

Informed Consent: The authors declare that this report does not contain any personal information that could lead to the identification of patients.

Authorship Contributions: Concept: E.B.C.; Design: A.E., O.A.; Supervision: E.B.C.; Resource: A.E., A.T.; Materials: A.E., A.T.; Data collection and/or processing: Ö.D.Y., A.V.; Analysis and/or interpretation: A.E., O.A.; Literature review: A.E., O.A.; Manuscript writing: A.E.; Critical review: A.E., E.B.C.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Yapışıklığa bağlı ince bağırsak tıkanıklığında antoine Béclère skorunun cerrahi gereksinimini öngörmedeki klinik performansı

AMAÇ: Yapışıklığa bağlı ince bağırsak tıkanıklığı (ASBO) sık görülen bir cerrahi acildir ve konservatif tedaviden yarar görmeyecek hastaları ayırt etmek halen güçtür. Çeşitli klinik ve radyolojik belirteçler önerilmiş olsa da bunların doğruluğu tutarsızdır ve basit, nesnel araçlara gereksinim devam etmektedir.

GEREÇ VE YÖNTEM: Bu retrospektif kohort çalışmasına, 2020–2024 yılları arasında BT ile doğrulanmış ASBO tanısıyla hastaneye yatırılan erişkin hastalar dahil edildi. Demografik veriler, ek hastalıklar, laboratuvar değerleri, PNI ve PLR gibi beslenme ve enflamasyon indeksleri, radyolojik parametreler ve AB skorları kaydedildi. Cerrahi gereksinimini öngören faktörler tek değişkenli ve çok değişkenli lojistik regresyon ile değerlendirildi. AB skorunun tanısal doğruluğu ROC analizi ile incelendi.

BULGULAR: Çalışmaya toplam 106 hasta alındı; bunların 51'i (%48.1) cerrahi tedavi gerektirdi. PNI ve PLR değerleri, cerrahi uygulanan ve uygulanmayan gruplar arasında anlamlı fark göstermedi. Daha ileri yaş, yüksek komorbidite yükü ve daha yüksek AB skorları cerrahi gereksinimi ile ilişkili bulundu. AB skoru ≥2 olan hastaların %82.4'ünde cerrahi gerekti ($p<0.001$). Yaş ve Charlson indeksi ≥4 için düzeltme yapılan çok değişkenli analizde AB skoru ≥2, bağımsız bir belirteç olarak kaldı (OR 4.20). ROC analizinde AB skoru için AUC 0.71 olup duyarlılık %82, özgüllük %66 olarak bulundu.

SONUÇ: AB skoru, konservatif tedaviye yanıt vermeyecek ASBO hastalarının belirlenmesine yardımcı olmuştur; skorun ≥2 olması cerrahi gereksinimi ile güçlü bir şekilde ilişkiliydi. Skorun performansı hastaların beslenme durumundan veya inflamatuvar göstergelerinden etkilenmemiştir. Bu sonuçlar, ASBO'nun erken yönetiminde basit ve tekrarlanabilir ölçütlerin klinik yararını vurgulamaktadır.

Anahtar sözcükler: Antoine Béclère, cerrahi endikasyon; konservatif tedavi; prediktörler; yapışıklığa bağlı ince bağırsak tıkanıklığı.

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ORIGINAL ARTICLE

Management of patients who ingest razor blades: a single-center experience

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ABSTRACT

BACKGROUND: This study aimed to evaluate the diagnostic approaches, treatment modalities, and clinical outcomes of patients presenting to the emergency department following razor blade ingestion.

METHODS: Hospital records of patients who presented to the emergency department with razor blade ingestion and were referred to the General Surgery Clinic between 2021 and 2024 were retrospectively reviewed. Data collected included demographics, presenting symptoms, time to presentation, number of ingested razor blades, imaging findings, treatment approaches, complications, and clinical outcomes.

RESULTS: A total of 72 patients with complete medical records were included. All patients were male and incarcerated. The mean age was 31.2 years, and the mean time to presentation was 8 hours. The mean number of ingested razor blades was 1.4. Endoscopic intervention was performed in seven patients (10%) in whom imaging localized the razor blade to the stomach; all presented within 6 hours of ingestion. Successful endoscopic removal was achieved in two patients, while no razor blade was visualized in the stomach in five patients. Surgical intervention was required in two patients (3%). A total of 63 patients (87%) recovered without intervention with outpatient conservative management and follow-up. Successful endoscopic removal was achieved in patients who presented within the first 2 hours. No morbidity or mortality was observed.

CONCLUSION: A conservative management is safe and effective in most cases of razor blade ingestion. Early endoscopy may decrease the likelihood of surgical intervention.

Keywords: Razor blade ingestion; foreign body; surgery; endoscopy; prisoner.

INTRODUCTION

Foreign body ingestion is relatively uncommon in the general adult population but represents a significant clinical concern among incarcerated individuals and patients with psychiatric disorders.[1,2] Razor blade ingestion, in particular, can lead to serious gastrointestinal complications due to its sharp, cutting nature.[3]

The majority of ingested foreign bodies (80–90%) pass spontaneously through the gastrointestinal tract without the need for intervention. Objects that reach the stomach typically pass within 3–4 days. However, objects larger than 2 cm in diameter may fail to pass through the pylorus or ileocecal valve, while those longer than 5 cm may have difficulty traversing the duodenum.

Current guidelines recommend urgent endoscopic intervention (within 24 hours) in the following situations:[4]

• Sharp-pointed objects in the stomach or duodenum (e.g., razor blades),

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• Objects larger than 5 cm located in the proximal duodenum,

• Magnets and batteries accessible to endoscopic retrieval.

Although sharp objects that reach the stomach often pass without incident, complications have been reported in up to 15–35% of cases.[5] Therefore, the literature generally recommends endoscopic removal of sharp or penetrating foreign bodies whenever feasible.[6]

In this study, we evaluated the clinical characteristics, management strategies, and outcomes of patients presenting with razor blade ingestion.

MATERIALS AND METHODS

Hospital records of patients who presented to the emergency department with razor blade ingestion and were referred to the General Surgery Clinic between 2021 and 2024 were retrospectively reviewed. Data collected included presenting symptoms, demographic characteristics, time to presentation, number of ingested razor blades, imaging findings, treatment modalities, complications, and clinical outcomes.

The following variables were analyzed: age, sex, time to presentation, number of ingested razor blades, physical examination findings, number of admissions, imaging results (abdominal X-ray and computed tomography [CT]), treatment approaches (conservative management, endoscopic intervention, or surgery), and complications. Statistical analyses were performed using IBM SPSS, version 25.0 (IBM Corp., NY, USA). Continuous variables were expressed as mean ± standard deviation, and categorical variables as percentages. Group comparisons were performed using the Mann–Whitney U test, Spearman correlation analysis, and Fisher's exact test. A p value of <0.05 was considered statistically significant.

Ethical approval for the study was obtained from the Aksaray University Health Sciences Scientific Research Ethics Committee (decision no. 2025/151).

RESULTS

A total of 72 patients with complete medical records were included in the study. All patients were male prisoners. The mean age was 31.2 years (range, 21–43 years), the mean time to presentation was 8 hours (range, 2–24 hours), the mean number of ingested razor blades was 1.4 (range, 1–4), and the mean number of admissions was 3.7 (range, 1–6) (Table 1, Fig. 1).

Physical examination findings were unremarkable in 68 patients (94%). Rectal bleeding was observed in two patients, and abdominal pain in two patients. A radiopaque image consistent with a razor blade was detected on abdominal radiography in 70 patients, whereas plain radiography was normal in the remaining two patients. CT was performed in these two patients, as well as in an additional 18 patients, to accurately localize the foreign body (Fig. 2).

Table 1. Demographic characteristics of the patients

Variable	Value
Total number of patients	72
Male patients	72 (100%)
Female patients	0
Mean age (years)	31.2±6.5
Time to presentation, mean (hours)	8 (2–24)
Number of admissions, mean	3.7 (1–6)
Patients undergoing endoscopy	7 (9.7%)
Successful endoscopic removal of razor blades	2 (2.8%)
Patients undergoing surgery	2 (2.8%)
Mortality	0
Morbidity	0

Among the 20 patients who underwent CT, a radiopaque foreign body was detected outside the stomach in 19 patients. No pathological CT findings, such as perforation, free air, or abscess, were observed. In one patient, the razor blade was located in the duodenum, with associated edema on CT.

Endoscopy was performed in seven patients (10%) in whom

Figure 1. Appearance of a razor blade (2×4 cm) on standing direct abdominal radiography.

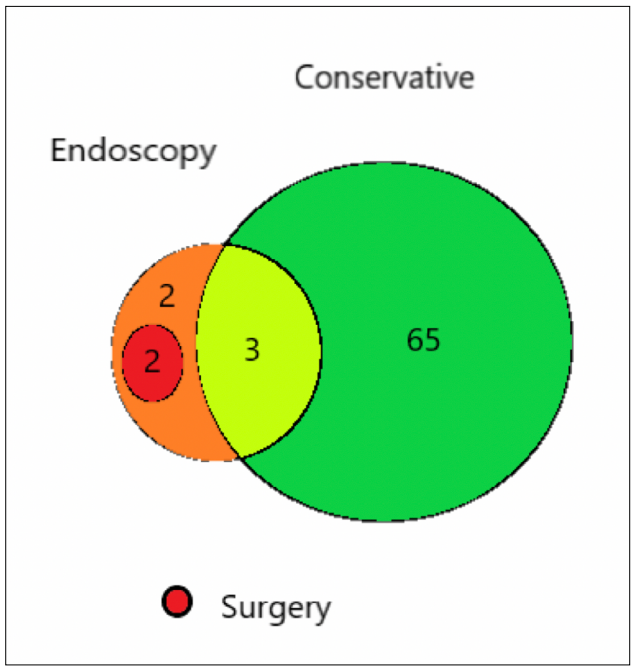

Figure 2. Distribution of patients according to management approach (endoscopic intervention, surgical treatment, and conservative management).

imaging demonstrated a razor blade at the gastric level on X-ray or CT; all had presented within 6 hours of ingestion. Successful endoscopic removal was achieved in two patients. In the remaining five patients, adequate gastric visualization was not possible due to retained food and technical limitations, and the razor blade could not be identified. Notably, successful endoscopic removal occurred only in patients who presented within the first 2 hours.

Surgical intervention was required in two patients (3%): one due to the development of an acute abdomen and the other due to failed endoscopic retrieval. In both cases, gastrotomy was performed, and the foreign body was removed from the first part of the duodenum. No perforation was observed, and no postoperative morbidity or mortality occurred.

Conservative management was applied in 68 patients. These patients were followed at three-day intervals (range, 1–4 visits) with physical examination and standing abdominal radiography. At the final follow-up, all patients had normal clinical and radiological findings.

No significant difference was found between patients undergoing endoscopic and surgical management in terms of morbidity (bleeding or perforation) or mortality (p=1.0).

As age increased, a longer time to presentation was observed (p=0.0038), indicating that younger patients tended to present earlier.

A significant association was also found between age and the number of admissions (p=0.039), with older patients having fewer admissions.

In patients who did not require hospitalization, the need for surgical intervention was statistically lower (p=0.039).

No significant association was found between the number of ingested razor blades (range, 1–4) and the need for endoscopic or surgical intervention (p=0.32) (Table 2).

DISCUSSION

In this study, we evaluated the clinical characteristics, management strategies, and outcomes of 72 patients presenting with razor blade ingestion. The fact that all patients were male prisoners is consistent with previous reports in the literature.[1,2,7] Razor blade ingestion has been shown to be more common in incarcerated populations and is often associated with secondary gain and underlying psychiatric disorders.[7] In our cohort, some patients were diagnosed with antisocial personality disorder. However, as many patients declined psychiatric evaluation and treatment, detailed psychiatric data were not available. Further studies are needed to more comprehensively assess psychiatric diagnoses in this population.

Endoscopy is widely recommended as the first-line approach for the removal of sharp foreign bodies from the gastrointestinal tract.[3,7–9] The absence of complications among patients

Table 2. Statistical analyses and corresponding p-values

Comparison	Statistical test	p-value
Age vs. time to presentation	Spearman correlation analysis	0.0038
Age vs. number of admissions	Spearman correlation analysis	0.0390
Hospitalization vs. need for surgery	Fisher's exact test	<0.001
Number of ingested razor blades vs. endoscopy	Mann–Whitney U test	0.3200
Number of ingested razor blades vs. surgery	Mann–Whitney U test	0.3200
Time to presentation vs. surgery	Mann–Whitney U test	0.0970
Time to presentation vs. endoscopy	Mann–Whitney U test	0.4100

who underwent endoscopy in our study supports its safety. However, previous studies have reported that endoscopic removal of sharp objects may carry a risk of bleeding or perforation.[11] For this reason, conservative management was preferred in the majority of our patients (68; 94%).

The success rate of endoscopy in our series was 28.5% (2/7 patients), which is lower than the 30–90% reported in the literature.[10,12,13] This discrepancy may be explained by delayed presentation in our patient population, resulting in migration of the razor blades to the small intestine rather than remaining in the stomach at the time of imaging. Prolonged time to presentation is a key factor reducing the success of endoscopic intervention. Considering both delayed presentation and the potential risk of esophageal injury during endoscopic retrieval of the razor blade, conservative treatment may be safely applied.

The reported need for surgery ranges from 5% to 15% in the literature.[8,14,15] In our series, this rate was lower (3%). Higher surgical rates reported in previous studies may be related to the inclusion of patients undergoing surgery not only for acute abdomen but also following failed endoscopic attempts in cases of sharp object ingestion. Increasing the use of conservative follow-up may reduce the need for both endoscopy and surgery.

In our study, no morbidity or mortality was observed. In contrast, morbidity rates ranging from 0% to 22% have been reported in the literature.[16,17] This finding suggests that a conservative approach can be safely applied in appropriately selected patients.[18]

No statistically significant relationship was found between the number of ingested razor blades and the need for endoscopic or surgical intervention, suggesting that the number of ingested objects alone does not determine management. In contrast, significant associations were observed between age and time to presentation, and between age and the number of admissions. Younger patients had more frequent admissions and presented earlier, which may be related to a greater tendency for secondary gain in this population.

Endoscopy was performed in seven patients who presented within the first 6 hours. In two patients who underwent endoscopy within the first 2 hours, the razor blade was successfully removed, whereas in the remaining five patients, removal was unsuccessful. At presentation, imaging studies showed that the razor blade was located beyond the esophagus and stomach in many patients. In the absence of acute abdomen findings during follow-up, 68 patients were managed conservatively. As the majority of patients in our clinic were managed conservatively, the number of patients who underwent endoscopy was insufficient to robustly evaluate endoscopic success.

No morbidity (bleeding or perforation) or mortality was observed in patients managed conservatively. Therefore, patients with normal physical examination and imaging findings may be safely followed without endoscopic intervention.

The main limitations of this study include its retrospective design, single-center setting, and the inclusion of only incarcerated patients. However, this study represents one of the largest series on this topic in Türkiye and provides contemporary data.

CONCLUSION

Contrary to common reports in the literature, most patients with razor blade ingestion can be safely managed conservatively without endoscopy. Although endoscopy is a safe and effective treatment modality, it may be reserved for selected patients. Multicenter, prospective studies with larger sample sizes are needed to better define optimal management strategies.

Ethics Committee Approval: This study was approved by The Aksaray University Health Sciences Scientific Research Ethics Committee (Decision No: 2025/151).

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Jilet yutan hastaların yönetimi: Tek merkez deneyimi

AMAÇ: Bu çalışmada, jilet yutma nedeniyle acil servise başvuran hastaların tanısı, uygulanan tedavi yöntemleri ve klinik sonuçlarının ayrıntılı olarak değerlendirilmesi amaçlanmıştır.
GEREÇ VE YÖNTEM: 2021-2024 yılları arasında jilet yutma nedeniyle acil servise başvuran ve Genel Cerrahi Kliniği'ne konsülte edilen hastaların hastane kayıt sistemindeki verileri retrospektif olarak incelendi. Şikayetler, demografik veriler, başvuru süreleri, yutulan jilet sayısı, yapılan tetkikler, görüntüleme bulguları, uygulanan tedavi yöntemleri, gelişen komplikasyonlar ve sonuçlar değerlendirildi. Çalışma tek merkezli, gözlemsel ve tanımlayıcı nitelikte planlandı.
BULGULAR: Çalışmaya kayıtlarına eksiksiz ulaşılan toplam 72 hasta dahil edildi. Tüm hastalar erkek ve mahkumdu. Ortalama yaş 31.2 yıl, ortalama başvuru süresi 8 saat ve ortalama yutulan jilet sayısı 1.4 idi. Görüntülemelerde jiletin mide seviyesinde izlendiği 7 (%10; bu hastaların tamamı ilk 6 saat içinde acile başvuran olgulardı) hastaya endoskopi yapıldı. İki hastada jilet ve/veya jiletler endoskopik olarak başarıyla çıkarıldı, beş hastada ise mide içinde jilet saptanamadı. Cerrahi girişim 2 (%3) hastada başarıyla uygulanırken, 63 (%87) hasta ayaktan konservatif gözlem ve düzenli kontrole çağrılarak herhangi bir girişim yapılmadan düzeldi. Endoskopi ile başarılı şekilde jilet çıkarılan hastalar, ilk 2 saat içinde başvuran olgulardı. Hiçbir hastada morbidite veya mortalite gelişmedi.
SONUÇ: Jilet yutma olgularında konservatif yaklaşım çoğu zaman güvenli ve etkilidir. Uygun seçilmiş hastalarda erken dönemde endoskopi denenebilir ve bu yaklaşım cerrahi gereksinimini anlamlı düzeyde azaltabilir. Elde edilen bulgular, özellikle mahkum popülasyonunda yabancı cisim yönetimine yönelik klinik algoritmaların şekillenmesine katkı sağlayabilir.

Anahtar sözcükler: Cerrahi; endoskopi; jilet yutma; mahkum; yabancı cisim.

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ORIGINAL ARTICLE

Development and prognostic performance of an admission-based mortality prediction model in Fournier's gangrene: the Kocaeli Fournier Gangrene Severity Index (KFGSI)

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ABSTRACT

BACKGROUND: Fournier's gangrene (FG) is an aggressive form of necrotizing fasciitis associated with high mortality despite advances in critical care and surgical management. Early identification of high-risk patients is essential to enable timely intervention. This study aimed to evaluate established prognostic indices and to develop a novel model for mortality prediction.

METHODS: We retrospectively reviewed the medical records of 69 patients diagnosed with FG and treated at the General Surgery Clinic of Kocaeli University Hospital between January 2017 and January 2022. Demographic, clinical, laboratory, radiological, and treatment-related data were collected. Disease severity was assessed using the Fournier's Gangrene Severity Index (FGSI), Uludağ FGSI (UFGSI), and the American Society of Anesthesiologists (ASA) score. The UFGSI was calculated by combining the FGSI physiological score with additional age and dissemination scores derived from radiological extent grading. Logistic regression and receiver operating characteristic (ROC) curve analyses were performed to identify independent predictors of mortality and to develop the Kocaeli Fournier Gangrene Severity Index (KFGSI).

RESULTS: The mean age was 58.6±13.5 years (range: 36–89), with 52 (75.4%) males and 17 (24.6%) females. The overall in-hospital mortality rate was 40.6% (n=28). On univariate analysis, admission parameters significantly associated with mortality included pulse rate, respiratory rate, body mass index (BMI), serum lactate level, radiological extent grade, body temperature, and FGSI score (all $p<0.05$). Intensive care unit (ICU) length of stay was also associated with mortality in exploratory analyses, reflecting the downstream clinical course. ROC analysis demonstrated strong prognostic performance for pulse rate (area under the curve [AUC] 0.935; 95% confidence interval [CI] 0.848–0.980) and radiological extent grade (AUC 0.898; 95% CI 0.797–0.966), as illustrated in Figure 1. The UFGSI also showed good discrimination (AUC 0.858; 95% CI 0.748–0.967), with 96.4% sensitivity and 73.2% specificity at the Youden-derived cut-off (≥10). The newly developed admission-based KFGSI, incorporating five admission parameters (pulse rate, respiratory rate, body mass index, serum lactate level, and radiological extent grade), demonstrated superior discrimination compared with FGSI in this derivation cohort (AUC 0.943; 95% CI 0.860–0.985; sensitivity 92.9%; specificity 85.4% vs. FGSI AUC 0.860; 95% CI 0.755–0.932). ICU length of stay was not included in the admission-based KFGSI model.

CONCLUSION: The KFGSI demonstrated excellent prognostic accuracy for mortality prediction in FG and outperformed FGSI in this derivation cohort. However, external validation in multicenter populations is required. Early application of the KFGSI may enhance clinical risk stratification and support timely decision-making regarding triage and management. Prospective multicenter studies are needed to confirm its validity and establish its clinical utility.

Keywords: Fournier's gangrene; mortality; prognostic score; risk stratification; ROC analysis.

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INTRODUCTION

Fournier's gangrene (FG) is an acute, rapidly progressive, and life-threatening form of necrotizing fasciitis that primarily affects the perineal, genital, and perianal regions.[1,2] It is typically polymicrobial and may spread cephalad along contiguous fascial planes to the abdominal wall, driven by infectious and inflammatory processes; urgent recognition and management are therefore essential and often require prompt resuscitation and emergency surgical debridement.[1,3] Delays in diagnosis or treatment are associated with high mortality, underscoring the importance of maintaining clinical vigilance, particularly in cases with non-specific early symptoms.[3]

Fournier's gangrene has a multifactorial etiology with several well-established risk factors, including local trauma to the perineal, perianal, or genitourinary regions, diabetes mellitus, chronic alcohol use, general debilitation, medication exposure, immunosuppression, and underlying malignancy. These factors reflect the complex pathophysiology and severe clinical course of the disease.[1,2,4,5]

The clinical presentation of FG is often heterogeneous, which can delay diagnosis. Initial findings may be limited to localized cutaneous changes; however, the disease can rapidly progress to systemic toxicity with sepsis and multiorgan failure. As the condition advances, patients may develop ecchymosis, necrosis, edema, subcutaneous crepitus, marked tenderness, and purulent collections. In debilitated or comorbid patients, early physical signs may be subtle, necessitating a high index of suspicion.[1,3-5]

Given these diagnostic challenges and the need for early risk stratification, several prognostic indices have been proposed. The Fournier's Gangrene Severity Index (FGSI) and the Uludağ FGSI (UFGSI) are commonly used to estimate mortality risk and guide management decisions. These tools provide structured, bedside-applicable frameworks for assessing disease severity, particularly when clinical evaluation is inconclusive. However, their predictive accuracy and generalizability vary across different patient populations.[6-8]

The primary aim of this study was to identify factors associated with mortality in FG and to develop a novel, admission-based prediction model. We evaluated the predictive performance of established indices (FGSI and UFGSI) in our cohort and compared them with a newly derived model tailored to our dataset. By informing early triage and treatment strategies—particularly in the setting of diagnostic uncertainty—an effective prediction model may support timely clinical decision-making and optimize patient management.

In this context, the present study introduces the Kocaeli Fournier Gangrene Severity Index (KFGSI), a composite prognostic score designed to estimate in-hospital mortality in patients with Fournier's gangrene using clinically relevant physiological, laboratory, and radiological parameters available at initial presentation. For comparison, the original descriptions of the Fournier's Gangrene Severity Index and the Uludağ FGSI were referenced at their first mention.

The primary model, hereafter referred to as the admission-based KFGSI, incorporates pulse rate, respiratory rate, body mass index (BMI), serum lactate level, and radiological extent grade. An extended exploratory model including intensive care unit (ICU)–related variables was evaluated separately to assess prognostic performance over the clinical course; however, it was not considered suitable for early bedside risk stratification.

MATERIALS AND METHODS

Study Design and Setting

This retrospective study was conducted at the General Surgery Clinic of Kocaeli University Research and Application Hospital between January 2017 and January 2022. Patients diagnosed with Fournier's gangrene were included. The primary objectives were to evaluate the prognostic performance of established indices in predicting mortality and to develop a novel scoring system, the Kocaeli Fournier Gangrene Severity Index.

Ethical approval was obtained from the Non-Interventional Clinical Research Ethics Committee of Kocaeli University (Approval No: KU GOKAEK 2022/10.11). All patient data were anonymized, and the study was conducted in accordance with the Declaration of Helsinki.

Patient Selection and Data Collection

The medical records of 69 patients diagnosed with FG were reviewed. Collected data included demographic characteristics (age, sex), clinical variables (American Society of Anesthesiologists [ASA] score, body temperature, pulse rate, respiratory rate, height, weight, and BMI), and comorbidities (diabetes mellitus, hypertension, malignancy, chronic kidney disease, steroid use, and other chronic conditions).

Disease-specific variables included infection etiology, radiological grade based on computed tomography (CT) and/or magnetic resonance imaging (MRI), and the anatomical extent of involvement. Treatment-related data comprised wound culture results, identified microorganisms, antibiotic regimens, number of debridements, and diversion procedures such as ostomy creation. Diverting stoma formation was performed at the discretion of the attending surgical team, primarily in patients with severe anorectal involvement, including sphincter compromise, rectal perforation, gross fecal contamination, or extensive perineal defects where adequate wound control was not achievable. In this cohort, severe anorectal involvement was operationally defined as imaging and/or intraoperative evidence of anal sphincter complex involvement, rectal wall defect or perforation, or gross fecal contamination of the wound field. Hospitalization parameters, including total length of stay, ICU admission, and ICU length of stay, were also recorded.

Laboratory values at admission were documented, including C-reactive protein (CRP), sodium, potassium, creatinine, white blood cell (WBC) count, bicarbonate (HCO3), and lactate levels. Categorical variables were summarized as n (%), while continuous variables were reported as mean ± standard deviation (SD) for normally distributed data and median (interquartile range) for non-normally distributed data.

Scoring Systems

The FGSI and UFGSI were calculated at admission as previously described in the literature.[6,7] Perioperative risk was also assessed using the American Society of Anesthesiologists Physical Status Classification System, in accordance with the official guidelines.[9] For UFGSI calculation, the age and dissemination components were derived from admission data and radiological extent grading. The age score was assigned as 1 for patients aged ≥60 years and 0 otherwise. The dissemination score was mapped to the radiological extent grade as follows: grade 1 (anorectal involvement) = 1 point, grade 2 (pelvic involvement) = 2 points, and grade 3 (abdominal extension beyond the pelvis) = 6 points, consistent with the original UFGSI definitions. The total UFGSI was calculated as the sum of the FGSI physiological score, dissemination score, and age score.

Statistical Analysis

Statistical analyses were performed using SPSS software (IBM Corp., Armonk, NY, USA). Continuous variables were assessed for normality using visual inspection (histograms and Q–Q plots) and the Shapiro–Wilk test. Normally distributed continuous variables are presented as mean ± standard deviation, while non-normally distributed variables are reported as median (interquartile range). Comparisons between survivors and non-survivors were performed using the independent samples t-test for normally distributed variables and the Mann–Whitney U test for non-normally distributed variables. Categorical variables were compared using Fisher's exact test or the Fisher–Freeman–Halton test, as appropriate. Correlations were assessed using Spearman's rank correlation coefficient. Logistic regression analysis was performed to identify independent predictors of in-hospital mortality. Receiver operating characteristic (ROC) curve analysis was used to determine optimal cut-off values, and diagnostic performance was reported in terms of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). Optimal cut-off values were defined using the Youden index. A two-sided p value <0.05 was considered statistically significant. The primary multivariable logistic regression model was constructed using the enter method and restricted to five clinically plausible admission-time predictors (pulse rate, respiratory rate, BMI, serum lactate level, and radiological extent grade) to preserve interpretability and minimize overfitting, given the limited number of outcome events. Multicollinearity was assessed using variance inflation factors (VIF), with values >5 considered indicative of problematic collinearity; no significant multicollinearity was observed. Patients with incomplete admission data for key predictors were excluded during cohort selection; therefore, no imputation was performed.

Development of the Kocaeli Fournier Gangrene Severity Index

Candidate predictors of in-hospital mortality were initially identified through univariate analyses based on clinical relevance and statistical significance. Variables significantly associated with mortality (p<0.05) were subsequently entered into a multivariable logistic regression model, with careful consideration of model parsimony given the limited number of outcome events.

To ensure applicability at the time of initial clinical assessment, only variables available at hospital presentation were included in the primary (admission-based) KFGSI model. Variables reflecting the downstream clinical course, such as ICU admission or ICU length of stay, were intentionally excluded from the primary model to avoid time-dependent bias.

For each independent predictor retained in the admission-based model, ROC curve analysis was performed to determine optimal cut-off values using the Youden index. Variables exceeding their respective cut-off thresholds were assigned one point, and the cumulative score constituted the Kocaeli Fournier Gangrene Severity Index. To preserve bedside usability, an unweighted point-based approach was adopted; however, weighted scoring based on regression coefficients may be explored in future validation studies. Body temperature, although significant in univariate analysis, was excluded from the final model due to borderline cut-off stability and limited incremental prognostic value in multivariable analysis.

The total KFGSI score ranged from 0 to 5 points. An overall cut-off value was determined using ROC analysis to stratify patients into low- and high-risk mortality groups. The KFGSI was developed as a derivation model for exploratory risk stratification, with the understanding that external validation is required prior to clinical implementation.

RESULTS

Between January 2017 and January 2022, a total of 81 patients diagnosed with Fournier's gangrene were identified. Twelve patients were excluded from the analysis, including five who were transferred to external intensive care units and seven with incomplete medical records. Consequently, 69 patients comprised the final study cohort.

The demographic and clinical characteristics of the patients are summarized in Table 1. Of the included patients, 52 (75.4%) were male and 17 (24.6%) were female, with a median age of 58 years (range: 36–89). The mean length of hospital stay was 24.4±21.4 days (range: 1–130). According to the American Society of Anesthesiologists Physical Status Classification, 20 patients (29.0%) were classified as ASA II, 43 (62.3%) as ASA III, and six (8.7%) as ASA IV.

Comorbid conditions were common. Diabetes mellitus was

Table 1. Baseline demographic and clinical characteristics of the study cohort (n=69)

	Value
Age, years, mean±SD (range)	58.6±13.5 (36–89)
Sex, male, n (%)	52 (75.4)
Sex, female, n (%)	17 (24.6)
ASA II, n (%)	20 (29.0)
ASA III, n (%)	43 (62.3)
ASA IV, n (%)	6 (8.7)
Length of hospital stay, days, mean±SD (range)	24.4±21.4 (1–130)
Diabetes mellitus, n (%)	38 (55.1)
Hypertension, n (%)	20 (29.0)
Malignancy, n (%)	11 (15.9)
Chronic kidney disease, n (%)	10 (14.5)
Steroid use, n (%)	17 (24.6)
Bacterial infection, n (%)	29 (42.0)
Fungal infection, n (%)	3 (4.3)
Unknown etiology, n (%)	37 (53.6)
E. coli, n (%)	11 (15.9)
A. baumannii, n (%)	9 (13.0)
Radiological grade 1, n (%)	25 (36.2)
Radiological grade 2, n (%)	30 (43.5)
Radiological grade 3, n (%)	14 (20.3)
Scrotal extension, n (%)	35 (50.7)
Stoma required, n (%)	54 (78.3)
Debridement, mean±SD (range)	3.8±3.4 (1–18)
ICU admission, n (%)	45 (65.2)
In-hospital mortality, n (%)	28 (40.6)

SD: Standard deviation; ASA: American Society of Anesthesiologists Physical Status Classification; ICU: Intensive care unit; E. coli: Escherichia coli; A. baumannii: Acinetobacter baumannii.

present in 38 patients (55.1%), hypertension in 20 (29.0%), malignancy in 11 (15.9%), chronic kidney disease in 10 (14.5%), and a history of steroid use in 17 (24.6%). Microbiological evaluation demonstrated bacterial growth in 29 patients (42.0%) and fungal growth in three (4.3%), while no causative microorganism was identified in 37 cases (53.6%). The most frequently isolated organisms were Escherichia coli (15.9%) and Acinetobacter baumannii (13.0%). Radiological assessment showed anorectal involvement (grade 1) in 25 patients (36.2%), pelvic involvement (grade 2) in 30 (43.5%), and abdominal extension (grade 3) in 14 (20.3%). Scrotal extension was observed in 35 patients (50.7%). A diverting stoma was created in 54 patients (78.3%). The number of surgical debridement procedures ranged from 1 to 18, with a mean of 3.8±3.4 procedures. Forty-five patients (65.2%) required ICU admission during hospitalization. The overall in-hospital mortality rate was 40.6% (n=28), while 41 patients (59.4%) survived.

Univariate analysis identified several clinical and laboratory parameters significantly associated with in-hospital mortality, including body temperature (p=0.021), pulse rate (p<0.001), respiratory rate (p=0.003), BMI (p=0.007), FGSI score (p<0.001), serum lactate level (p=0.015), radiological extent grade (p=0.001), and ICU length of stay (p=0.003). Comparative outcomes and variables associated with mortality are presented in Table 2.

Receiver operating characteristic curve analysis was performed to assess the discriminative ability of significant predictors. Pulse rate demonstrated the highest individual predictive performance, with an area under the curve (AUC) of 0.935 (95% confidence interval [CI]: 0.848–0.980), sensitivity of 82.1%, and specificity of 97.6%. Radiological extent grade also showed strong prognostic performance, with an AUC of 0.898 (95% CI: 0.797–0.966), sensitivity of 89.3%, and specificity of 82.9%. ROC curves for the most significant predictors are presented in Figure 1.

Other parameters, including BMI, respiratory rate, serum lactate level, and body temperature, demonstrated moderate predictive performance. ICU length of stay showed prognostic relevance in exploratory analyses, reflecting disease severity during the clinical course; however, it was not incorporated into the primary admission-based prediction model. The diagnostic performance of significant predictors is summarized in Table 3.

Based on ROC-derived cut-off values, the admission-only KFGSI was developed using five parameters available at initial hospital presentation: pulse rate, respiratory rate, BMI, serum lactate level, and radiological extent grade. Body temperature, although statistically significant in univariate analysis, was excluded from the final model due to borderline cut-off stability and limited incremental prognostic value.

ROC analysis of the admission-based KFGSI demonstrated high discrimination, with an AUC of 0.943 (95% CI: 0.860–0.985), sensitivity of 92.9%, and specificity of 85.4% (p<0.001). A KFGSI score ≥4 was associated with a very high risk of in-hospital mortality and was identified as the optimal cut-off based on overall ROC curve analysis. The comparative predictive performance of FGSI and the admission-based KFGSI is presented in Table 4. One point was assigned for each of the following admission-time thresholds: pulse rate ≥120 bpm, respiratory rate ≥24/min, body mass index ≥30 kg/m², serum lactate level ≥3.5 mmol/L, and radiological extent grade ≥2. The UFGSI was also calculated at admission for all patients. ROC analysis demonstrated good discrimination for in-hospital mortality, with an AUC of 0.858 (95% CI: 0.748–0.967). Using the Youden index, the optimal cut-off was ≥10, yielding a sensitivity of 96.4% and specificity of 73.2%. Using the predefined threshold of ≥9 proposed in the original UFGSI study, sensitivity was 100.0% and specific-

Table 2. Univariate comparison between survivors and non-survivors

Parameter	Survivors (n=41)	Non-survivors (n=28)	p-value
Body temperature (°C)	37.3 (37.0–37.8)	38.2 (37.6–39.1)	0.021
Pulse rate (bpm)	100 (92–110)	122 (114–134)	<0.001
Respiratory rate (/min)	20 (18–22)	25 (22–28)	0.003
Body mass index (kg/m²)	27.1 (25.4–29.2)	30.0 (27.8–32.6)	0.007
FGSI score	6 (5–7)	9 (8–11)	<0.001
Serum lactate (mmol/L)	2.5 (2.0–3.1)	4.0 (3.3–4.9)	0.015
Radiological extent grade	2 (1–2)	3 (2–3)	0.001
ICU length of stay (days)†	3 (2–4)	10 (8–13)	0.003

Values are presented as median (interquartile range). †Intensive care unit (ICU) length of stay reflects downstream disease severity and was not included in the primary admission-based KFGSI model. Between-group comparisons were performed using the Mann–Whitney U test.

Table 3. Diagnostic performance of significant admission variables for in-hospital mortality (ROC analysis)

Parameter	AUC	95% CI	Sensitivity (%)	Specificity (%)	p-value
Pulse rate	0.935	0.848–0.980	82.1	97.6	<0.001
Respiratory rate	0.812	0.703–0.905	75.0	78.0	0.003
Body mass index (BMI)	0.789	0.672–0.886	71.4	76.2	0.007
Serum lactate level	0.821	0.713–0.912	78.6	80.5	0.015
Radiological extent grade	0.898	0.797–0.966	89.3	82.9	0.001
Body temperature	0.742	0.621–0.852	67.9	71.4	0.021

AUC: Area under the curve; CI: Confidence interval.

ity was 56.1%. The comparative discriminative performance of FGSI, UFGSI, and admission-based KFGSI is presented in Table 4.

In multivariable logistic regression analysis restricted to admission-time variables, pulse rate, respiratory rate, BMI, serum lactate level, and radiological extent grade remained independently associated with in-hospital mortality (Table 5). These findings underscore the prognostic importance of early systemic physiological response, metabolic derangement, and disease extent at presentation. The multivariable model was fitted using the enter method with the five predictors.

DISCUSSION

Fournier's gangrene is an aggressive and rapidly progressive necrotizing fasciitis associated with substantial morbidity and mortality despite advances in critical care and surgical management.[10] Early identification of patients at high risk of death is therefore essential, as it directly influences triage decisions, timing of imaging, surgical strategy, and the level of postoperative monitoring.

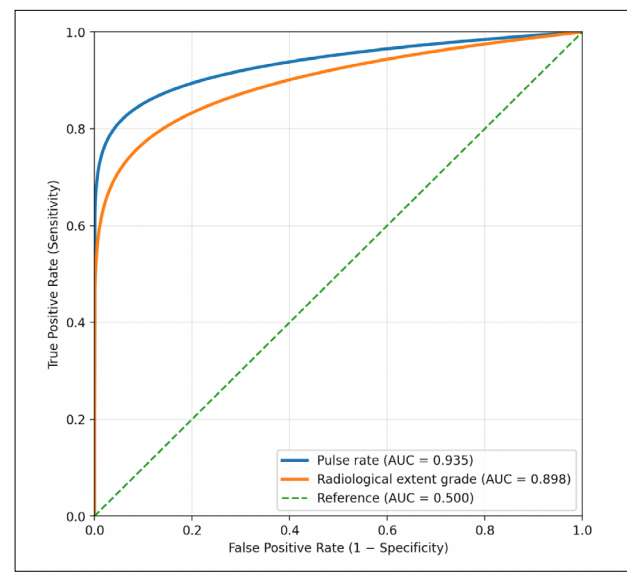

Figure 1. Receiver operating characteristic (ROC) curves illustrating the discriminative performance of pulse rate and radiological extent grade for predicting in-hospital mortality in patients with Fournier's gangrene.

Table 4. Comparative prognostic performance of FGSI, UFGSI, and admission-based KFGSI for predicting in-hospital mortality

Severity index	AUC	95% CI	Cut-off	Sensitivity (%)	Specificity (%)
FGSI	0.860	0.755–0.932	≥7	82.1	78.1
UFGSI (Youden)	0.858	0.748–0.967	≥10	96.4	73.2
UFGSI (predefined*)	0.858	0.748–0.967	≥9	100.0	56.1
Admission-based KFGSI	0.943	0.860–0.985	≥4	92.9	85.4

FGSI: Fournier's Gangrene Severity Index; UFGSI: Uludağ Fournier's Gangrene Severity Index; KFGSI: Kocaeli Fournier Gangrene Severity Index; AUC: Area under the receiver operating characteristic curve; CI: Confidence interval. *The predefined UFGSI threshold (≥9) was based on the original UFGSI description and validation studies.

Table 5. Multivariable logistic regression analysis of admission-time predictors of in-hospital mortality (n=69)

Predictor (admission variables)	Adjusted OR	95% CI	p-value
Pulse rate (per 1 bpm increase)	1.08	1.03–1.13	<0.001
Respiratory rate (per 1 /min increase)	1.29	1.10–1.53	0.002
Body mass index (per 1 kg/m² increase)	1.19	1.05–1.36	0.007
Serum lactate (per 1 mmol/L increase)	2.35	1.50–4.00	<0.001
Radiological extent grade (per 1-grade increase)	2.05	1.12–3.98	0.021

OR: Odds ratio; CI: Confidence interval; BMI: Body mass index. Note: Only admission-time variables were included in the multivariable model. Intensive care unit-related variables were excluded to avoid time-dependent bias.

Principal Findings

In this single-center cohort, several admission-time clinical and laboratory parameters—including pulse rate, respiratory rate, body mass index, serum lactate level, and radiological extent grade—were significantly associated with in-hospital mortality. Among these, pulse rate demonstrated the highest discriminative ability, followed by radiological extent grade, as reflected in the ROC curve analysis (Fig. 1). These findings underscore the prognostic importance of early systemic physiological response and disease extent at presentation.

Based on these results, we developed an admission-based composite prognostic model, the Kocaeli Fournier Gangrene Severity Index, incorporating the strongest predictors available at initial assessment. The admission-based KFGSI demonstrated higher apparent discrimination than the FGSI in this derivation cohort (AUC 0.943 vs. 0.860). Although this performance is encouraging, it should be interpreted with caution given the derivation nature of the model. Nevertheless, the findings suggest that integrating physiological derangement, metabolic stress, host-related factors, and radiological disease extent may provide more accurate early risk stratification than individual variables or traditional scoring systems alone.

Importantly, all five admission-time components of the KFGSI remained independent predictors of mortality in multivariable analysis, supporting their combined use as a practical bedside risk stratification tool.

Comparison with Existing Literature

Fournier's gangrene predominantly affects male patients; however, the impact of sex on mortality remains inconsistent across published studies. In our cohort, sex was not associated with mortality, consistent with the large review by Eke, which analyzed 1,726 cases.[10] In contrast, Czymek et al.[11] reported worse outcomes among female patients, potentially due to delayed presentation or more advanced disease at diagnosis. These discrepancies highlight the heterogeneity of FG populations and variations in healthcare settings.

Several prognostic scoring systems have been proposed to estimate mortality risk in FG. Established indices such as the FGSI and UFGSI provide structured bedside assessments; however, their predictive performance varies across different patient cohorts.[6,7,14] A recent systematic review and meta-analysis by Tufano et al.[14] confirmed the prognostic value of these tools, reporting pooled AUC values approaching 0.90–0.94, particularly for the UFGSI, while also highlighting methodological limitations and inter-study heterogeneity.

Our findings are broadly consistent with those of contemporary cohort studies. Garg et al.[15] reported substantial morbidity and persistent functional impairment among survivors, underscoring the importance of early and accurate risk strati-

fication. In contrast to smaller single-center series, Hauser et al.[16] demonstrated in a large consecutive cohort that higher FGSI scores and greater comorbidity burden independently predicted mortality, ICU admission, and hospital length of stay. Similarly, Hong et al.[17] identified key physiological and laboratory parameters as significant prognostic factors, further supporting the concept that composite risk assessment tools may outperform single-variable predictors.

In addition to established clinical indices, biomarker-based approaches have been explored to improve prognostic accuracy in necrotizing soft-tissue infections. Zil-E-Ali et al.[22] highlighted the potential utility of procalcitonin when combined with laboratory risk indicators. Although such biomarkers were not evaluated in the present study, they may represent valuable adjuncts for the future refinement of FG prognostic models.

Clinical Implications

The high apparent discriminative performance of the admission-based KFGSI suggests potential clinical utility for early risk stratification in patients with FG. Patients identified as high risk at presentation may be considered for early senior surgical review, aggressive resuscitation, prompt imaging to delineate disease extent, and closer postoperative monitoring. The strong prognostic contribution of radiological extent grade supports the role of early cross-sectional imaging in suspected FG, provided that it does not delay definitive surgical source control, in accordance with current emergency management principles.[10,12,14,17]

In the present cohort, the rate of diverting stoma creation was relatively high (78.3%). This finding should be interpreted in the context of disease severity and local surgical practice. A substantial proportion of patients presented with advanced disease, including extensive perineal involvement, anorectal spread, and pelvic or abdominal extension on imaging, which influenced intraoperative decision-making. Importantly, current evidence does not support routine fecal diversion in all patients with Fournier's gangrene, and its impact on mortality remains controversial. A systematic review and meta-analysis found no consistent association between diversion stoma and reduced mortality, suggesting that stoma formation should not be considered a universal mortality-reducing strategy.[18] Instead, diversion procedures are typically reserved for selected cases to facilitate wound care and reduce fecal contamination, particularly in patients with severe anorectal involvement, sphincter compromise, rectal perforation or gross fecal contamination, or extensive perineal defects where adequate wound control is not achievable.[19] Therefore, the high stoma rate observed in this study likely reflects a cautious institutional approach in advanced presentations rather than routine practice.

Strengths and Limitations

The strengths of this study include a well-defined cohort, comprehensive evaluation of clinical, laboratory, and radiological variables, and the development of a parsimonious, admission-based prognostic model using parameters readily available at initial hospital presentation. The use of ROC-based analyses enabled objective assessment of individual predictors and facilitated the construction of a clinically applicable composite score focused on early risk stratification.

Several limitations should be acknowledged. First, the retrospective, single-center design limits the generalizability of the findings and precludes causal inference. Second, external validation was not performed; therefore, the KFGSI should be considered a derivation model with potentially optimistic performance estimates. Third, the relatively small number of mortality events in relation to the number of candidate predictors may have increased the risk of overfitting, despite efforts to restrict the primary model to a limited set of clinically relevant variables.

The observed in-hospital mortality rate in our cohort (40.6%) was higher than that reported in large administrative and population-based database studies. For example, Sorensen et al.[20] reported substantially lower case-fatality rates in a population-based U.S. cohort. More recently, an analysis of the National Inpatient Sample (2016–2020), including 5,007 surgically debrided Fournier's gangrene hospitalizations, reported a crude in-hospital mortality rate of 5.8%, along with increased length of stay and healthcare costs compared with non-perineal necrotizing soft tissue infections.[21] This discrepancy likely reflects differences in case-mix and study setting, including referral bias to a tertiary care center, more advanced disease at presentation, delayed admission, and a higher burden of comorbidities in our cohort. Accordingly, comparisons with population-based datasets should be interpreted with caution.

Additionally, the rate of diverting stoma formation was relatively high in this cohort. This likely reflects institutional surgical practice and the advanced disease extent at presentation in a substantial proportion of patients, rather than a standardized mortality-reducing strategy. Current evidence does not consistently demonstrate a mortality benefit associated with diversion procedures in Fournier's gangrene, and decisions regarding stoma formation were made on a case-by-case basis. These factors may have influenced both treatment patterns and outcomes and should be considered when interpreting the study findings.

Calibration metrics (e.g., calibration plots or Hosmer–Lemeshow goodness-of-fit testing) were not formally assessed due to the limited sample size and number of events. In addition, internal validation techniques such as bootstrapping were not performed; therefore, the reported AUC values may reflect optimism inherent to a derivation cohort.

Future Directions

Prospective multicenter studies are required to externally validate the admission-based KFGSI, assess calibration, and benchmark its performance against established indices such

as FGSI and UFGSI. Further evaluation of additional biomarkers, including procalcitonin, as well as standardized radiological staging systems, may enhance the robustness and generalizability of FG mortality prediction models.[14,22]

CONCLUSION

This study identified several admission-time physiological, laboratory, and radiological parameters closely associated with in-hospital mortality in patients with Fournier's gangrene. Based on these findings, we developed the Kocaeli Fournier Gangrene Severity Index, an admission-based composite score designed to support early risk stratification using variables readily available at initial clinical assessment.

In our cohort, the KFGSI demonstrated higher apparent discriminative performance compared with the conventional FGSI, suggesting that integrating systemic physiological response, metabolic stress markers, and radiological disease extent may improve early prognostic assessment. Importantly, the model was constructed to exclude time-dependent variables, thereby preserving its applicability in the emergency setting.

However, these findings should be interpreted in light of the study's limitations, including its retrospective design, single-center setting, and lack of external validation. Accordingly, the KFGSI should be considered a derivation model, and its clinical utility requires confirmation in prospective, multicenter studies across diverse healthcare settings and patient populations.

Overall, this study highlights the need for refined, practical prognostic tools in Fournier's gangrene and supports further collaborative research aimed at improving early risk assessment, clinical decision-making, and patient outcomes.

Ethics Committee Approval: Ethical approval was obtained from the Non-Interventional Clinical Research Ethics Committee of Kocaeli University (Date: 09.06.2022, Decision No: KÜ GOKAEK-2022/10.11).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Kocaeli fournier gangreni şiddet indeksi (KFGSI)'nin prognostik değeri: Retrospektif karşılaştırmalı çalışma

AMAÇ: Fournier gangreni (FG), yoğun bakım ve cerrahi alandaki gelişmelere rağmen yüksek mortalite oranına sahip agresif bir nekrotizan fasiittir. Yüksek riskli hastaların erken tanımlanması, zamanında müdahaleye rehberlik etmek açısından kritik öneme sahiptir. Bu çalışma, mevcut prognostik indeksleri değerlendirmeyi ve başvuru anında uygulanabilir yeni bir mortalite tahmin modeli geliştirmeyi amaçlamıştır.
GEREÇ VE YÖNTEM: Ocak 2017–Ocak 2022 tarihleri arasında Kocaeli Üniversitesi Hastanesi Genel Cerrahi Kliniği'nde FG tanısı alarak tedavi edilen 69 hastanın tıbbi kayıtları retrospektif olarak incelendi. Demografik, klinik, laboratuvar, radyolojik ve tedaviye ilişkin veriler toplandı. Hastalık şiddeti Fournier Gangren Şiddet İndeksi (FGSI), Uludağ FGSI (UFGSI) ve Amerikan Anesteziyologlar Derneği (ASA) skorları ile değerlendirildi. UFGSI, FGSI'nin fizyolojik skoruna yaş skoru ve radyolojik yaygınlık derecesinden türetilen diseminasyon skorunun eklenmesiyle hesaplandı. Bağımsız mortalite belirteçlerini saptamak ve Kocaeli Fournier Gangren Şiddet İndeksi'ni (KFGSI) oluşturmak için lojistik regresyon ve ROC eğrisi analizleri yapıldı. Birincil model olarak yalnızca hastaneye başvuru anında elde edilebilen değişkenler kullanıldı.
BULGULAR: Hastaların medyan yaşı 58 (36–89) idi; 52'si (%75.4) erkek, 17'si (%24.6) kadındı. Hastane içi mortalite oranı %40.6 (28 hasta) olarak saptandı. Tek değişkenli analizlerde mortalite ile anlamlı ilişkili başvuru-anı parametreleri; nabız hızı, solunum sayısı, vücut kitle indeksi (VKİ), serum laktat düzeyi, radyolojik yaygınlık derecesi, vücut ısısı ve Fournier Gangren Şiddet İndeksi (FGSI) skoru idi (tümü için $p<0.05$). Yoğun bakımda kalış süresi ise klinik seyri yansıtan keşifsel analizlerde mortalite ile ilişkili bulundu. ROC analizinde, nabız hızının (AUC 0.935; %95 GA 0.848–0.980) ve radyolojik yaygınlık derecesinin (AUC 0.898; %95 GA 0.797–0.966) bireysel prognostik performansının yüksek olduğu ve bu bulguların Şekil 1'de gösterildiği saptandı. UFGSI de mortaliteyi öngörmede iyi ayırt edicilik göstermiş olup ROC analizinde AUC 0.858 (%95 GA 0.748–0.967) saptandı; Youden indeksi ile belirlenen ≥10 eşik değerinde duyarlılık %96.4 ve özgüllük %73.2 idi. Başvuru anında elde edilebilen beş parametreden (nabız, solunum sayısı, VKİ, serum laktat düzeyi ve radyolojik yaygınlık derecesi) oluşturulan başvuru-anı Kocaeli Fournier Gangren Şiddet İndeksi (KFGSI), mortaliteyi öngörmede FGSI'ye kıyasla daha yüksek ayırt edici güce sahipti (AUC 0.943; %95 GA 0.860–0.985; duyarlılık %92.9; özgüllük %85.4; FGSI için AUC 0.860; %95 GA 0.755–0.932). Yoğun bakımda kalış süresi, başvuru anında elde edilemeyen zaman bağımlı bir değişken olması nedeniyle başvuru-anı KFGSI modeline dahil edilmemiştir.
SONUÇ: Başvuru anında uygulanabilir şekilde geliştirilen KFGSI, Fournier gangreninde hastane içi mortalite riskini erken dönemde sınıflandırmada yüksek ayırt edicilik göstermiştir. Bu türetim kohortunda FGSI ve UFGSI'ye kıyasla daha yüksek görünen ayırt edicilik saptanmakla birlikte, doğrulama yapılmadığından sonuçlar temkinli yorumlanmalı ve çok merkezli ileriye dönük dış doğrulama ile desteklenmelidir.

Anahtar sözcükler: Fournier gangreni; mortalite; prognostik skor; risk sınıflandırması; ROC analizi.

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ORIGINAL ARTICLE

The role of pars plana vitrectomy in eyes with no light perception after severe open globe injury and the determination of prognostic factors

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ABSTRACT

BACKGROUND: This study aimed to identify prognostic factors in patients undergoing pars plana vitrectomy (PPV) following open globe injury (OGI) and to evaluate surgical outcomes of PPV in eyes with no light perception (NLP) at presentation after OGI.

METHODS: We retrospectively reviewed the medical records of patients who underwent primary repair for severe ocular trauma, subsequently required PPV due to posterior segment damage, and had a minimum follow-up of 6 months. Patients were divided into two groups based on initial best-corrected visual acuity (BCVA): Group 1, no light perception (NLP); and Group 2, light perception (LP) or better. Clinical characteristics, as well as final anatomical and visual outcomes, were compared between the groups. Additionally, the role of PPV was specifically evaluated in eyes that were most severely affected by trauma and presented with NLP after primary repair.

RESULTS: A total of 47 eyes from 47 patients were included. Twelve eyes had NLP after primary repair for OGI. Among these, five eyes remained NLP, two (16.7%) improved to light perception (LP), three (25.0%) to hand motion, one (8.3%) to counting fingers, and one (8.3%) achieved a visual acuity of 20/60 at final follow-up. Final anatomical success was achieved in 39 of 47 eyes (82.9%). Visual improvement was observed in 91.4% of eyes (32/35) with preoperative visual acuity of at least LP, and in 58.3% of eyes (7/12) with NLP prior to vitrectomy. No eyes required enucleation. Retinal detachment ($p<0.001$), retinectomy ($p=0.01$), silicone oil use ($p=0.001$), and the need for a second vitrectomy ($p=0.019$) were associated with poor prognosis.

CONCLUSION: In patients with loss of LP secondary to severe ocular trauma, PPV can achieve high rates of anatomical success, with a significant proportion regaining ambulatory vision when appropriate surgical techniques are employed.

Keywords: Light perception; open globe injury; pars plana vitrectomy; retinal detachment.

INTRODUCTION

Ocular trauma is one of the leading causes of non-congenital monocular vision loss and represents a significant yet preventable public health problem.[1] These injuries include penetrating and perforating injuries, ruptures, and intraocular foreign body (IOFB)-related trauma, all of which require urgent management. The development of severe and permanent vision loss following trauma has profound effects on patients' daily functioning and professional life, leading to substantial social and economic consequences.[2] Therefore, accurate diagnosis and timely surgical intervention in patients with ocular trauma are crucial for minimizing ocular morbidity.[3] In the preoperative period, identifying factors that influence visual prognosis is essential for guiding treatment decisions and counseling patients regarding expected visual outcomes.

The Ocular Trauma Score (OTS) system was developed for this purpose. It uses a scoring method based on initial best-

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corrected visual acuity (BCVA), globe rupture, perforating injury, endophthalmitis, retinal detachment, and the presence of a relative afferent pupillary defect to predict final visual outcomes.[4] Higher scores are associated with better visual prognosis, whereas lower scores indicate poorer outcomes.[5]

In open globe injury (OGI), posterior segment damage involving the retina and choroid may occur depending on the severity of the trauma, potentially leading to loss of light perception (LP). Historically, primary enucleation was considered in such cases due to the risk of sympathetic ophthalmia.[6] However, recent advances in vitreoretinal microsurgery have significantly improved the management of complex posterior segment trauma. Several patient-specific factors, including retinal tears, retinal detachment, subretinal hemorrhage, vitreous hemorrhage, proliferative vitreoretinopathy (PVR), choroidal rupture, and the presence of an IOFB, may influence surgical outcomes. The impact of surgical variables, such as the choice of intraocular tamponade, use of photocoagulation, and performance of retinectomy remains unclear. Additionally, there is ongoing debate regarding the optimal timing of vitrectomy following trauma.[7] Notably, no established scoring system specifically evaluates prognostic factors in eyes undergoing vitrectomy for posterior segment damage secondary to trauma.

In some patients with severe OGI, BCVA is reduced to no light perception (NLP) due to multiple factors. In non-traumatic conditions, the absence of LP generally indicates a poor prognosis with limited potential benefit from surgical intervention; however, the management of patients with OGI who lack LP may differ. In the present study, unlike previous reports, outcomes were specifically evaluated in eyes with NLP following primary repair. The aim of this study was to identify prognostic factors associated with outcomes of pars plana vitrectomy (PPV) after OGI and to evaluate outcomes in eyes that remained at NLP following primary repair.

MATERIALS AND METHODS

General Information

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Balıkesir University Local Research Ethics Committee (Date: 11.03.2025; Decision No: 2025/121). Informed consent was obtained from all participants.

We conducted a retrospective analysis of patients who presented with ocular trauma to the Ophthalmology Department of Balikesir University Training and Research Hospital between May 2019 and December 2024. The study included patients who underwent primary repair for severe OGI, subsequently required PPV due to posterior segment involvement, and had a minimum follow-up of 6 months. Patients with suspected OGI underwent comprehensive evaluation, including slit-lamp biomicroscopy, indirect ophthalmoscopy, and computed tomography. BCVA assessment was performed in a dark room, particularly for LP. Patients with suspected retinal pathology were further evaluated using B-mode ultrasonography in the retina department.

Medical and Surgical Treatment

All PPV procedures were performed by a single surgeon (E.K.) using a 23-gauge system. A chandelier light was used when necessary. In all cases, fluid infusion was initially established through the anterior chamber using an anterior chamber maintainer. After confirming correct placement of the infusion trocar within the vitreous cavity, infusion was continued via the trocar system. Intravenous antibiotics were administered to all patients for at least 72 hours. All eyes received topical combined corticosteroid–antibiotic therapy and cycloplegic agents.

Data Collection

Operative reports of eyes that underwent PPV following OGI and primary repair were reviewed. The presence of endophthalmitis, IOFB, retinal detachment (with or without retinal incarceration), and media opacities, including traumatic cataract, vitreous hemorrhage (with or without retinal detachment), subretinal hemorrhage, suprachoroidal hemorrhage, and PVR, was recorded. Demographic and clinical data collected included age, sex, date of injury, mechanism of ocular injury, type of traumatic material, and location and setting of the accident. Additionally, initial and final BCVA, injury zone, lens status, time to vitrectomy, and OTS parameters were recorded. Surgical variables, including the type of intraocular tamponade, use of retinectomy, and application of photocoagulation, were also documented. Anatomical success was defined as preservation of globe integrity and absence of phthisis bulbi at final follow-up. Final BCVA values were recorded and converted from Snellen to logarithm of the minimum angle of resolution (logMAR) units. Visual success was defined as an improvement of at least two Snellen lines or achieving a BCVA of counting fingers or better.

Patients were divided into two groups based on initial BCVA: Group 1 included eyes with NLP, and Group 2 included eyes with LP or better. The groups were compared in terms of baseline characteristics, intraoperative findings during PPV, and final anatomical and visual outcomes. Additionally, the anatomical and visual outcomes of PPV were specifically evaluated in eyes with NLP at presentation. All eyes with NLP at presentation remained NLP prior to PPV.

Statistical Analysis

All statistical analyses were performed using SPSS Statistics version 27.0 (IBM Corp., New York, USA). Quantitative variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Comparisons of categorical variables between the two visual acuity groups were performed using the chi-square test or Fisher's exact test, as appropriate. Comparisons between groups defined by anatomical and visual success were performed using the Mann–Whitney U test. To assess the

impact of clinical factors on visual success, univariate and multivariate logistic regression analyses were performed on the full sample. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 47 eyes from 47 patients were included. Of these, 37 patients (78.7%) were male, and 28 eyes (59.6%) were right eyes. The mean age at the time of surgery was 46.57±16.96 years (range, 12–74 years), and the mean follow-up period was 15.57±15.67 months. Ocular trauma most frequently occurred at home in 22 eyes (46.8%), followed by workplace injuries in 13 eyes (27.7%). Penetrating injuries were the most common type (37 eyes, 78.7%), followed by globe rupture (eight eyes, 17.0%) and perforating injuries (two eyes, 4.3%). The distribution of injury zones was as follows: zone I in 17 eyes (36.2%), zone 2 in 15 eyes (31.9%), and zone 3 in 15 eyes (31.9%). An IOFB was detected in nine eyes (19.1%). Initial BCVA was ≥20/40 in four eyes (8.5%), counting fingers in three eyes (6.4%), hand motion (HM) in 17 eyes (36.2%), LP in 11 eyes (23.4%), and NLP in 12 eyes (25.5%). Demographic and clinical characteristics are summarized in Table 1. There was one pediatric patient, who had a zone I injury associated with an intraocular foreign body and endophthalmitis.

Table 1. Demographic and clinical characteristics of patients undergoing pars plana vitrectomy (PPV) after open globe injury (OGI)

Age (years)	46.57±16.96
Sex	
F/M	37/10
Cause of trauma, n (%)	
Home accident	22 (46.8)
Workplace accident	13 (27.7)
Traffic accident	3 (6.4)
Assault	9 (19.91)
Mechanism of injury, n (%)	
Rupture	8 (17.0)
Penetrating injury	37 (78.7)
Perforating injury	2 (4.3)
Zone of injury (highest), n (%)	
Zone I	17 (36.2)
Zone II	15 (31.9)
Zone III	15 (31.9)
BCVA before PPV, n (%)	
≥20/40	4 (8.5)
20/40 to 20/200	0 (0)
CF	3 (6.4)
HM	17 (36.2)
LP	11 (23.4)
NLP	12 (25.5)
IOFB, n (%)	
Yes	9 (19.1)
No	38 (80.9)

BCVA: Best-corrected visual acuity; CF: Counting fingers; HM: Hand motion; LP: Light perception; NLP: No light perception; IOFB: Intraocular foreign body.

The mean time from trauma to primary surgery was 18.08±34.01 hours, and the mean interval between primary surgery and PPV was 36.76±65.83 days for the entire cohort. Among the 12 eyes with NLP, the interval to PPV was 83.3 days (range, 5-367 days). There was no association between the time from primary repair to vitrectomy and either visual or anatomical success (p=0.89 and p=0.86, respectively) (Fig. 1).

During PPV, 13 eyes (27.6%) had no lens damage, and one eye (2.1%) was pseudophakic without intraocular lens (IOL) damage. Trauma-related lens damage was observed in 28 eyes (59.5%), while five eyes (10.6%) were aphakic secondary to trauma. Overall, vitreous hemorrhage was present in 37 eyes (80.7%), and retinal detachment in 26 eyes (55.3%). Retinal incarceration to the wound site was observed in 23 (88.5%) of the 26 eyes with retinal detachment. PVR was present in eight of 26 eyes (30.7%) with retinal detachment. Among 47 eyes, subretinal hemorrhage was detected in 12 (25.5%), suprachoroidal hemorrhage in six (12.7%), and endophthalmitis in four (8.5%). Comparison between the NLP group and the

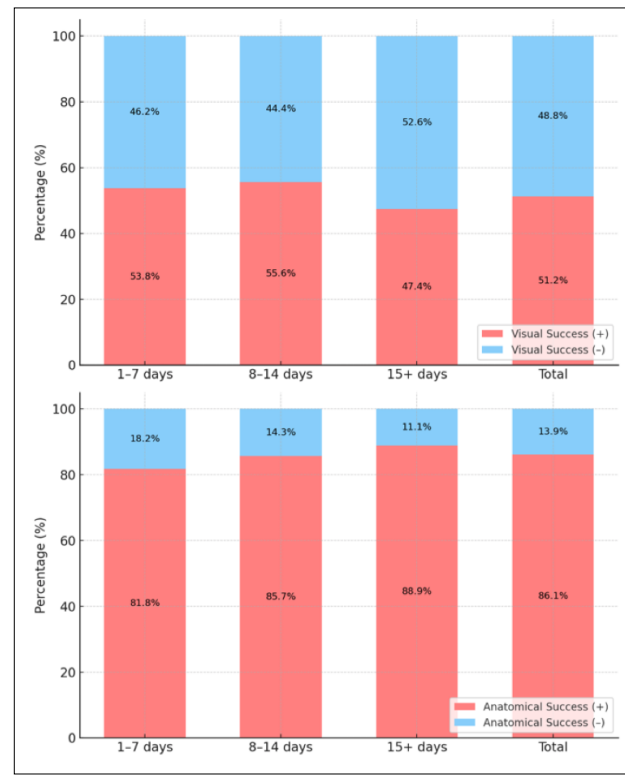

Figure 1. Relationship between pre-vitrectomy time and visual and anatomical outcomes.

Table 2. Comparison of eyes with no light perception (NLP) and better-than-NLP best-corrected visual acuity (BCVA) at initial examination

	Group 1 (n=12)	Group 2 (n=35)	p
Age	42.8±19.4	47.0±16.7	0.474
Sex			
Male/Female	10/2	27/8	0.651
Mechanism of injury			
Rupture	10	27	
Penetrating injury	1	1	0.438
Perforating injury	1	7	
Zone of injury			
Zone I	3	14	
Zone II	4	11	0.313
Zone III	5	10	
IOFB			
Yes/No	1/11	10/25	0.123
Endophthalmitis			
Yes/No	0/12	4/31	0.115
Lens status			
No lens damage	2	10	
Lens rupture	6	19	0.084
Aphakia	4	6	
Vitreous hemorrhage			
Yes/No	9/3	27/8	0.881
Retinal detachment			
Yes/No	8/4	18/17	0.365
Retinal incarceration			
Yes/No	8/4	15/20	0.159
Subretinal hemorrhage			
Yes/No	4/8	8/27	0.477
Suprachoroidal hemorrhage			
Yes/No	6/6	8/27	0.079
Final anatomical success			
Yes/No	9/3	32/3	0.215
Final BCVA (%)			
≥LP	7/5 (58.3)	32/3 (91.4)	0.09*
Final BCVA (%)			
≥20/200	1/11 (0.08)	11/24 (31.4)	0.117

BCVA: Best-corrected visual acuity; IOFB: Intraocular foreign body.

LP-or-better group showed no significant association with lens injury, endophthalmitis, IOFB, retinal pathology, or intraocular hemorrhage (Table 2).

Laser photocoagulation was applied in 37 eyes (80.5%), and retinectomy was performed in 20 (76.9%) of the 26 eyes with retinal detachment; 16 (80%) of these were 3600 retinectomies. A scleral buckle was not used in any case. Regarding intraocular tamponade, silicone oil was most commonly used (57.4%, n=27), followed by gas tamponade (23.9%, n=11), air (10.6%, n=5), and fluid (8.5%, n=4) left in situ at the end of surgery. All eyes were considered operable, and retinal attachment was achieved intraoperatively in all cases. A second vitrectomy was required for redetachment in 13 (50%) of the 26 eyes with retinal detachment at presentation.

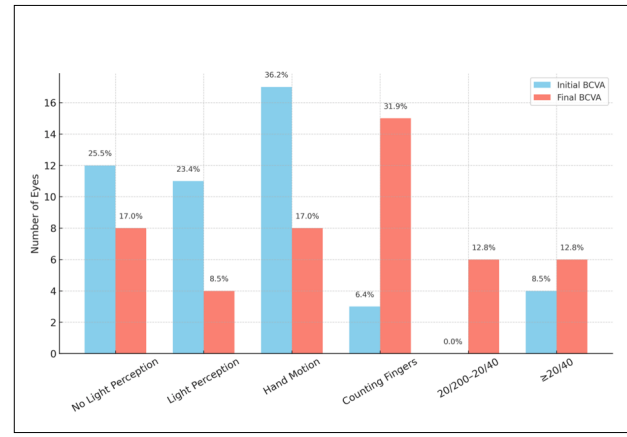

Figure 2. Distribution of initial and final best-corrected visual acuity (BCVA) among all patients.

The mean OTS for all patients was 62.54±16.2 and was higher in those who achieved anatomical and visual success. The mean OTS was 65.03±16.96 in eyes with anatomical success and 47.33±7.44 in those without (p=0.01). Similarly, the mean OTS was higher in eyes with visual success compared to those without (67.42±18.0 vs. 57.23±12.28, p=0.03).

In univariate logistic regression analysis, retinal detachment (p<0.001), retinectomy (p=0.01), silicone oil use (p=0.001), and the need for a second vitrectomy (p=0.019) were significantly associated with worse visual outcomes. However, in multivariate logistic regression analysis, none of these factors remained significantly associated with visual outcomes. Initial BCVA (p=0.07), injury zone (p=0.46), type of injury (p=0.88), lens damage (p=0.84), endophthalmitis (p=0.35), vitreous hemorrhage (p=0.33), presence of an IOFB (p=0.85), and laser photocoagulation (p=0.68) were not significantly associated with visual success.

Final anatomical success was achieved in 39 of 47 eyes (82.9%). Final BCVA was ≥20/40 in six eyes (12.8%), 20/200–20/40 in six eyes (12.8%), counting fingers in 15 eyes (31.9%), HM in eight eyes (17.0%), LP in four eyes (8.5%), and NLP in eight eyes (17.0%). The distribution of initial and final BCVA is shown in Figure 2.

In the pediatric patient, BCVA was at the HM level after primary repair but improved markedly to better than 20/40 following PPV.

At final follow-up, among the 12 eyes that initially had NLP, five (41.7%) remained NLP. Visual improvement was observed in the remaining eyes: LP in two (16.7%), HM in three (25.0%), counting fingers in one (8.3%), and 20/60 in one eye (8.3%).

DISCUSSION

In the present study, the demographic profile of patients undergoing PPV for severe mechanical ocular trauma was characterized by a predominantly middle-aged population with a male preponderance. This pattern is consistent with trends reported in previous studies on ocular trauma.[8,9] The high incidence of metallic foreign body–related penetrating injuries suggests that occupational exposure remains a significant risk factor for severe ocular trauma, particularly among young men. This finding highlights the ongoing need for preventive measures, especially in high-risk work environments where compliance with protective eyewear is suboptimal. Our results support the notion that demographic and occupational risk factors contribute substantially to both the incidence and severity of OGI, underscoring the importance of targeted public health strategies to reduce the burden of these injuries.

In severe OGI, posterior segment damage may occur, and approximately four decades ago, 94% of cases with an initial BCVA of NLP resulted in globe enucleation.[10] This approach is largely driven by concerns regarding the development of sympathetic ophthalmia following severe ocular trauma. However, subsequent studies have demonstrated that post-traumatic sympathetic ophthalmia is rare.[11-13] Moreover, there is no definitive test to determine the necessity of enucleation. LP is a subjective measure, and its reliability decreases in the presence of severe media opacity.[14] Advances in vitreoretinal surgical techniques have significantly improved both globe preservation and visual outcomes in traumatic cases. In a study based on the Eye Injury Vitrectomy Study database, nine of 33 eyes with post-traumatic NLP that underwent vitrectomy required enucleation, while four developed phthisis bulbi.[15] In the present study, most eyes undergoing PPV for severe posterior segment damage achieved anatomical success, and approximately half demonstrated significant visual improvement. Notably, enucleation was not required in any case.

Several studies have investigated clinical factors influencing final visual and anatomical outcomes following ocular trauma. The OTS system suggests that better initial BCVA is associated with a more favorable prognosis, whereas perforation, rupture, relative afferent pupillary defect, endophthalmitis, and retinal detachment are linked to poorer outcomes.[4] Although better initial BCVA increases the likelihood of achieving improved final vision, advances in surgical techniques indicate that poor initial BCVA does not necessarily preclude a favorable outcome. A study evaluating PPV outcomes in ocular trauma reported visual success in 93% of patients with an initial BCVA ≥0.5, compared to 33% in those with an initial BCVA of 0.02–LP.[16] In our study, the highest visual success rate was observed in patients with an initial BCVA >20/40 (75%). Notably, 64.3% of eyes with baseline BCVA ranging from NLP to HM achieved visual improvement to a level sufficient for ambulatory vision. These findings suggest that even in cases of severe vision loss following ocular trauma, appropriate surgical intervention may help preserve globe integrity and offer the potential for visual recovery.

In one study, closed-funnel retinal detachment, ciliary body damage, and choroidal injury were identified as risk factors for the development of NLP following ocular trauma.[17] Other studies have reported that poor initial BCVA, relative afferent pupillary defect, multiple surgeries, posterior ocular (zone III) injury, vitreous hemorrhage, and hyphema are associated with worse visual prognosis.[18-20] Meng et al.[21] further demonstrated that poor visual outcomes in OGI are strongly associated with irreversible photoreceptor loss due to trauma-related retinal detachment. In our study, eyes with retinal detachment exhibited worse visual outcomes. The high rate of retinal incarceration at the injury site in these cases suggests more severe trauma, which likely contributed to the poorer prognosis. Logistic regression analysis in present study showed that retinectomy, silicone oil tamponade, and the need for repeat vitrectomy were associated with worse final BCVA. Retinectomy is typically performed in eyes with advanced PVR to remove contracted retinal tissue and facilitate reattachment of the remaining healthy retina. Similarly, silicone oil is commonly used as an intraocular tamponade in severe cases of PVR with retinal detachment, and our findings suggest that eyes requiring these interventions tend to have poorer visual outcomes.

There is no consensus regarding the optimal timing of vitrectomy in ocular trauma, and the literature reports conflicting findings. In cases of post-traumatic endophthalmitis or a high risk of infection due to an IOFB, primary repair combined with immediate vitrectomy is often performed. However, the timing of vitrectomy in other types of posterior segment injury remains controversial.[22] Yu et al.[7] categorized patients with severe ocular trauma into three groups based on timing of vitrectomy (1–7 days, 8–14 days, and >14 days) and reported the best visual outcomes in the 8–14-day group. A systematic review found that early vitrectomy (1–4 days) was associated with increased intraoperative complications, such as vitreous hemorrhage and iatrogenic retinal tears, whereas delayed vitrectomy (>14 days) was linked to complications including PVR, ciliary body damage, and phthisis bulbi.[23] In contrast, Chauhan et al.[24] reported that same-day PPV resulted in better anatomical and visual outcomes, with each additional day of delay reducing success rates. Mansouri et al.[25] found no significant difference between early (<7 days) and late (>7 days) vitrectomy in terms of visual outcomes. Similarly, another study evaluating posterior segment trauma reported that early vitrectomy (<5 days) was not significantly associated with improved visual outcomes.[16] In our study, the interval between primary repair and PPV was not sig-

nificantly associated with final visual or anatomical outcomes. However, both excessively early and delayed intervention may carry potential risks. Therefore, even in cases with a prolonged interval after primary repair, PPV should still be considered, as it may offer the potential for anatomical preservation and visual improvement.

It is well established that BCVA may decline to NLP following severe ocular trauma due to various underlying factors. In the current era, NLP after OGI does not necessarily indicate that the eye is surgically unsalvageable. However, data on outcomes after PPV in eyes that remain NLP following primary repair are limited. In our study, no statistically significant differences were observed between eyes with NLP and those with better-than-NLP BCVA in terms of trauma type, injury zone, retinal status, or the presence of intraocular hemorrhage. However, intraocular hemorrhages were recorded only as present or absent in our study, without consideration of their extent or location; therefore, subtle differences between groups may not have been detected.

In a study evaluating outcomes of vitrectomy in eyes with NLP following OGI, visual improvement (LP or better) was achieved in 88.9% of cases (16/18), and useful vision (≥20/200) was obtained in 33.3% (6/18).[14] In another study, visual improvement was observed in 63.1% of eyes (12/19), and 10.53% (2/19) achieved a BCVA between 20/60 and 20/400.[26] In contrast, visual recovery was observed in four of 24 eyes (16%) with initial NLP following OGI in another study.[27] Wang et al.[28] demonstrated that 55% (21/38) of eyes with NLP improved to LP or better following vitrectomy. In our study, LP or better vision was achieved in seven of 12 eyes (58.3%), and BCVA ≥20/200 was achieved in one eye (8%). Anatomical success was observed in nine of 12 eyes (75.0%). The mean interval between ocular trauma and PPV was 11 days (range, 3–14 days) in the aforementioned study, compared to 83.3 days (range, 5–367 days) in the present study. This difference likely reflects variability in the timing of patient presentation and the feasibility of performing surgery even in delayed cases. The lower visual success rates may be attributable to more advanced PVR developing during the prolonged interval before vitrectomy.

The retrospective design and relatively small sample size are important limitations of this study, potentially reducing its power. Additionally, although all surgeries were performed by a single surgeon, ensuring procedural consistency—this may limit the generalizability of the findings.

CONCLUSION

This study demonstrates that significant anatomical and visual improvement can be achieved with appropriate surgical intervention in eyes with severe posterior segment damage secondary to trauma. Although poor visual acuity is generally associated with worse prognosis in trauma patients, our findings indicate that even eyes presenting with no light perception may benefit from PPV, which can prevent the development of phthisis and potentially improve visual acuity. Therefore, eyes with NLP after severe ocular trauma should not be excluded from surgical consideration, similar to eyes with LP or better vision. Additionally, our findings indicate that the interval between primary repair and PPV does not impact surgical outcomes, suggesting that efforts to salvage traumatized eyes may be justified regardless of this time frame. Even when visual recovery is limited, preservation of globe integrity is crucial for maintaining psychological well-being and social functioning.

Ethics Committee Approval: This study was approved by the Balıkesir University Local Research Ethics Committee (Date: 11.03.2025, Decision No: 2025/121).

Informed Consent: Written informed consent was obtained.

Peer-review: Externally peer-reviewed.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Şiddetli açık glob yaralanması sonrası ışık persepsiyonu olmayan gözlerde pars plana vitrektominin rolü ve prognostik faktörlerin belirlenmesi

AMAÇ: Bu çalışmanın amacı, açık glob yaralanması (AGY) sonrası pars plana vitrektomi (PPV) uygulanan hastalarda prognostik faktörleri belirlemek ve ışık persepsiyonu negatif (IPN) olan olgularda PPV sonuçlarını değerlendirmektir.
GEREÇ VE YÖNTEM: Şiddetli oküler travma sonrası primer onarım uygulanan, arka segment hasarı nedeniyle PPV gereken ve en az 6 ay takip süresi bulunan hastaların tıbbi kayıtları retrospektif olarak incelendi. Başlangıç en iyi düzeltilmiş görme keskinliği düzeyine göre hastalar iki gruba ayrıldı: Grup 1'de ışık persepsiyonu negatif (IPN) olan, Grup 2'de ise ışık persepsiyonu pozitif (IPN) olan veya daha iyi görme düzeyine sahip gözler mevcuttu. Final anatomik ve görsel sonuçlar ile klinik özellikler gruplar arasında karşılaştırıldı. Primer tamir cerrahisi sonrasında travmadan en ağır şekilde etkilenmiş olup, görme keskinliği NLP seviyesinde olan gözlerde PPV'nin rolü ayrıca irdelendi.
BULGULAR: Çalışmaya 47 hastaya ait 47 göz dahil edildi. Bunların 12'sinde görme keskinliği primer onarım sonrası IPN seviyesindeydi. Bu 12 gözün 5'i (%41.7) final vizitte de IPN düzeyinde kaldı. Diğer olguların; 2'sinde (%16.7) ışık persepsiyonu pozitif (IPP), 3'ünde (%25.0) el hareketi, 1'inde (%8.3) parmak sayma ve 1'inde (%8.3) 20/60 düzeyinde görme keskinliği elde edildi. Tüm gözlerin 39'unda (%82.9) anatomik başarı sağlandı. Preoperatif görme keskinliği en az IPP olan grupta %91.4 (32/35), IPN olan grupta ise %58.3 (7/12) oranında görsel iyileşme gözlendi. Hiçbir hastada enükleasyon gereksinimi olmadı. Retina dekolmanı ($p<0.001$), retinektomi uygulanması ($p=0.01$), silikon yağı kullanımı ($p=0.001$) ve ikinci vitrektomi ($p=0.019$) uygulanması kötü prognoz ile ilişkili bulundu.
SONUÇ: Şiddetli oküler travmaya bağlı ışık persepsiyonu kaybı gelişen olgularda, uygun cerrahi teknik ile uygulanan PPV sayesinde yüksek oranda anatomik başarı elde edilebilmekte, ayrıca hastaların önemli bir kısmında ambulatuar düzeyde görme sağlanabilmektedir.

Anahtar sözcükler: Açık glob yaralanması; ışık persepsiyonu; pars plana vitrektomi; retina dekolmanı.

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ORIGINAL ARTICLE

Spontaneous chest wall hematoma as a rare complication of anticoagulant and antiaggregant therapy

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ABSTRACT

BACKGROUND: Anticoagulant and antiaggregant drugs (commonly referred to as blood thinners) are widely used for various clinical indications. The most significant complication associated with these medications is hemorrhage. In this study, we evaluated patients receiving blood thinners who developed spontaneous chest wall hematomas.

METHODS: Between January 2016 and December 2024, a total of 13 patients with a history of blood thinner use who developed spontaneous chest wall hematoma were referred to our clinic. The analysis included radiological findings, demographic characteristics, underlying pathologies, and treatment modalities.

RESULTS: Nine of the 13 patients had no history of major chest wall trauma but presented with large or progressively enlarging hematomas, and therefore underwent surgical intervention with hematoma evacuation. Intraoperatively, no active bleeding source was identified; the hematomas were localized between the muscle fascia and were successfully evacuated. These patients were discharged with full recovery. During the course of medical treatment and follow-up, two of the four patients, who had poor overall clinical status, died.

CONCLUSION: Bleeding is the most significant adverse effect of blood thinner medications. Spontaneous chest wall hematoma is a rare clinical entity. Repetitive microtrauma, particularly in elderly or mobility-limited patients supported at the axillary or pectoral regions during positioning or mobilization, may contribute to hemorrhage and hematoma formation under the effects of anticoagulant therapy. Surgical drainage, when appropriately indicated, provides symptomatic relief and may help prevent secondary complications such as infection.

Keywords: Anticoagulants; antiaggregants; spontaneous hemorrhage; chest wall; hematoma.

INTRODUCTION

Several studies have investigated the risk of bleeding associated with the use of blood thinner medications. The incidence of major bleeding has been reported to range from 3% to 12%, with the gastrointestinal tract being the most common site. Intramuscular bleeding accounts for approximately 5% of all hemorrhagic complications. Comorbid conditions such as chronic renal failure (CRF), advanced age, hypertension, diabetes, and malignancy further increase the risk in patients receiving anticoagulant therapy.[1-7]

Bleeding may occur following trauma or spontaneously. Spontaneous muscle hematomas are most frequently observed in the rectus abdominis and iliopsoas muscles, with anticoagulant use being the most commonly reported cause.[8-9] In contrast, spontaneous hematoma formation within the chest wall musculature associated with anticoagulant use is a rare complication.

This condition is more commonly seen in elderly patients, those with limited mobility, and bedridden individuals receiving long-term anticoagulant therapy. The pathogenesis of

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hematoma formation in these patients is multifactorial, with microangiopathic processes, associated with conditions such as diabetes, renal failure, and hypertension, playing a contributory role. Although the condition is described as "spontaneous," minor trauma, such as repositioning the patient in bed, may initiate the process.

In addition to sudden, externally visible and palpable swelling, ecchymosis and pain may also be present. In some cases, respiratory difficulty may occur due to pain or pressure. The diagnosis of chest wall hematoma is established by thoracic computed tomography (CT), which also allows detection of associated conditions such as hemothorax or rib fractures.

The decision between conservative management and surgical evacuation of the hematoma should be based on symptom severity and hematoma size, with careful consideration of the patient's overall clinical condition and comorbidities. This study presents 13 patients who were referred to our clinic, were receiving anticoagulant or antiaggregant therapy for various indications, and were diagnosed with spontaneous chest wall hematoma.

MATERIALS AND METHODS

A retrospective review was conducted of 13 patients receiving anticoagulant or antiaggregant therapy who developed chest wall hematomas without a history of trauma between January 2016 and December 2024. All patients presenting with findings such as chest wall swelling, ecchymosis, and hyperemia underwent thoracic CT (Fig. 1). A comprehensive evaluation was performed, including demographic and clinical characteristics such as age, sex, type of anticoagulant medication, indication for therapy, hematoma location, need for anticoagulant reversal, treatment modality (surgical or conservative), complete blood count (hemogram), coagulation parameters, referring department, and treatment outcomes (Table 1).

Hematomas larger than 10 cm in diameter or those demonstrating progression during follow-up were managed surgically. After evacuation, a Hemovac drain was placed following local irrigation with tranexamic acid. Discontinuation of anticoagulant therapy was determined based on the severity of the underlying condition. Vitamin K and fresh frozen plasma were administered when the international normalized ratio (INR) was outside the therapeutic range, and bridging antico-

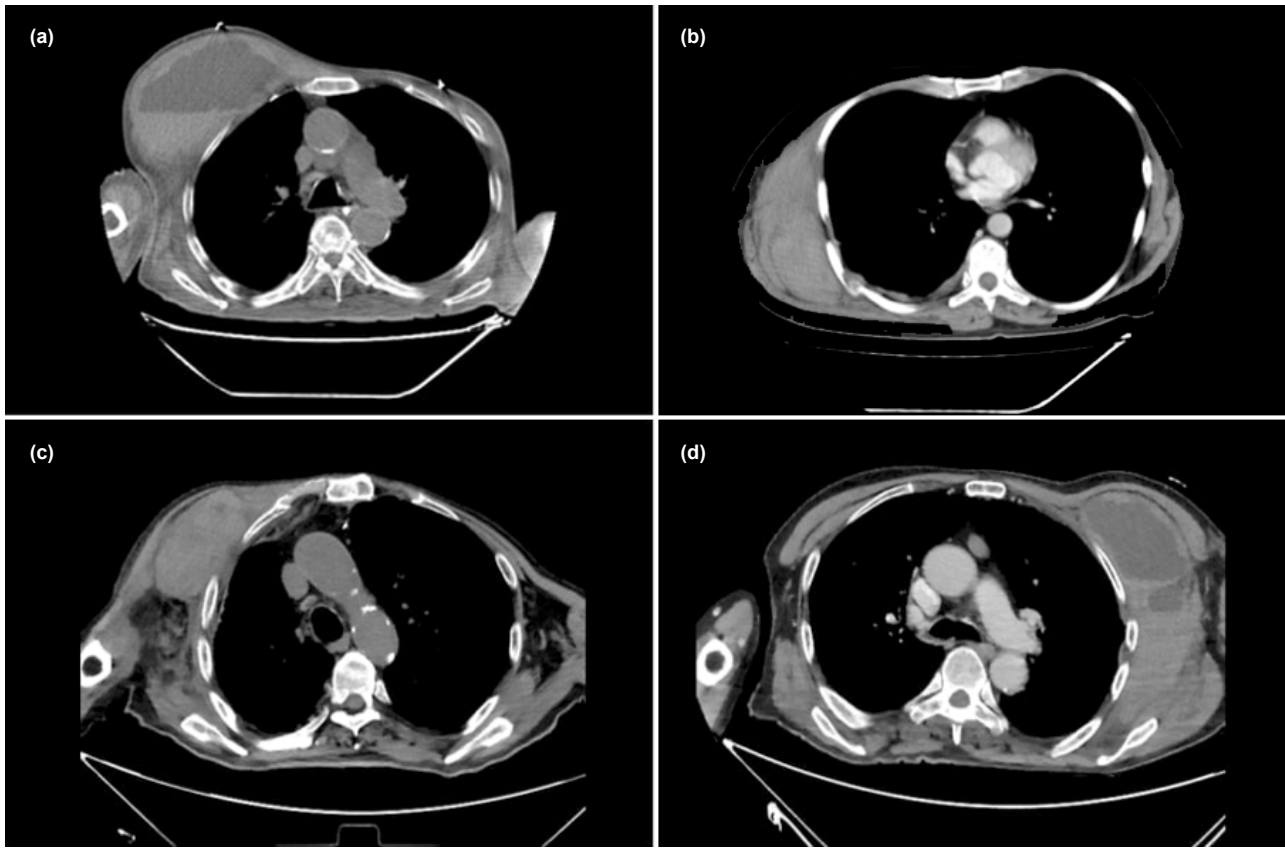

Figure 1. Computed tomography (CT) scans demonstrating chest wall hematomas. **(a)** Pectoral hematoma in a patient receiving enoxaparin for a pelvic fracture. **(b)** Lateral chest wall hematoma in a patient receiving enoxaparin. **(c)** Pectoral hematoma in a conservatively managed patient receiving warfarin for cerebrovascular disease. **(d)** Large pectoral hematoma extending to the axilla.

Table 1. Demographic characteristics, diagnoses, treatments, medications used, and hematoma localization

Age/ Sex	Anticoagulant	Indication	Clinic	Condition	Hematoma location	Laboratory findings	Treatment	Outcome	Transfusion	Recurrence	Postoperative complication
65/M	Enoxaparin	MVR+TVR	CVS-ICU	Postoperative day 10, intubated, moderate-poor	Latissimus-serratus	Hgb: 8.2 g/dL Htc: 25%	Drainage	Discharged	–	No	No
87/M	Warfarin	Atrial fibrillation	Emergency	Immobile, moderate	Pectoral	Hgb: 8.3 g/dL Htc: 25% INR: 2.6	Drainage	Discharged	–	No	No
51/M	Enoxaparin (prophylaxis)	Pelvic fracture	Emergency	Impaired mobility	Latissimus - serratus	Hgb: 11.3 g/dL Htc: 35%	Drainage	Discharged	–	No	No
68/F	Enoxaparin	MVR+TVR	CVS-ICU	Postoperative day 12, moderate-poor	Pectoral and axillary	Hgb: 7.6 g/dL Htc: 23%	Drainage	Discharged	Erythrocyte	No	No
79/M	Enoxaparin Clopidogrel	Peripheral arterial disease	CVS-ICU	Postop day 16, moderate	Latissimus - serratus	Hgb: 9.6 g/dL Htc: 31%	Drainage	Discharged	–	No	No
80/M	Enoxaparin	Pulmonary embolism	Chest Diseases	Immobile, poor	Pectoral	Hgb: 8.7 g/dL Htc: 29%	Conservative	Exitus	–	No	–
71/F	Warfarin	Cerebrovascular disease	Emergency	Immobile, moderate-poor	Pectoral	INR: 15 Hgb: 10.4 g/dL Htc: 33%	Conservative	Discharged	FFP+Vit K	No	–
73/M	Enoxaparin	CAD+MR+CRF	CVS	Impaired mobility, moderate	Latissimus-serratus	Hgb: 6.6 g/dL Htc: 19.2%	Drainage	Discharged	Erythrocyte	No	No
79/M	Warfarin	Atrial fibrillation+ heart failure	Cardiology	Impaired mobility, moderate	Latissimus-serratus	Hgb: 6.7 g/dL INR: 15 Htc: 20.6%	Conservative	Discharged	Erythrocyte, FFP+Vit K	No	–
73/M	Enoxaparin Clopidogrel	PE+PRV+CRF	Hematology	Impaired mobility, poor	Latissimus-serratus	E: 540,000 Hgb: 8.2 g/dL Htc: 27.2%	Conservative	Exitus	–	No	–
64/F	Enoxaparin	MVR+TVR	CVS-ICU	Postoperative 1st, month intubated, moderate-poor	Pectoral	Hgb: 6.8 g/dL Htc: 22.2%	Drainage	Discharged	Erythrocyte	No	No
70/M	ASA	Thrombocytosis	Emergency	Impaired mobility, moderate	Latissimus-serratus	Hgb: 9.7 g/dL Htc: 32% PLT: 899,000	Surgery	Discharged	–	No	No
82/M	Clopidogrel	Atrial fibrillation+ aplastic anemia	Neurology ICU	Immobile, moderate	Pectoral	Hgb: 7.2 g/dL Htc: 20% PLT: 7,000	Surgery	Discharged	Platelet+ erythrocyte	No	No

CVS-ICU: Cardiovascular surgery intensive care unit; FFP: Fresh frozen plasma; Vit K: Vitamin K; M: Male; F: Female; PLT: Platelet.

agulation was used in patients receiving warfarin.

In patients managed conservatively, cold compression and, when feasible, discontinuation of anticoagulation were recommended. The diameter of the hematoma, signs of infection, respiratory parameters, and pain scores were assessed during routine daily evaluations. Antibiotic therapy was not initiated unless the patient was already receiving antibiotics.

Approval for this study was obtained from the Non-Interventional Ethics Committee (Registration Number: 192.168.157.28-57284-11.06.2025). The study was conducted in accordance with the principles of the Declaration of Helsinki.

RESULTS

A total of 13 patients were evaluated, including 10 (77%) males and four (23%) females. The mean age was 72.5 years (range: 51-87). The hematoma was located in the subpectoral region in five patients (38.5%) and between the serratus anterior and latissimus dorsi muscles in eight patients (61.5%). The indications for anticoagulant therapy included atrial fibrillation in three patients (23%), mitral valve replacement plus tricuspid valve replacement (MVR+TVR) in three patients (23%), and pulmonary embolism (PE) in two patients (15%). Anticoagulant therapy was used prophylactically in one patient (7.8%) with pelvic fracture, in one patient (7.8%) with cerebrovascular disease (CVD), in one patient (7.8%) with coronary artery disease (CAD), mitral regurgitation (MR), and chronic renal failure (CRF), and in one patient (7.8%) with peripheral arterial disease. One patient (7.8%) had a history of acetylsalicylic acid (ASA) use due to thrombocytosis.

In one patient monitored for PE, polycythemia (polycythemia rubra vera, PRV) and CRF were also present, and dual anticoagulant therapy was administered. Another patient with peripheral arterial disease was on postoperative day 16. Three patients had undergone MVR+TVR surgery and were in the postoperative period; two of them were intubated. These patients were on postoperative days 30, 10, and 12, respectively. Given the absence of hematoma in the immediate postoperative period and the time elapsed since surgery, these cases were considered spontaneous. The patients were predominantly immobile or bedridden, with limited mobility due to underlying diseases and comorbid conditions.

Laboratory evaluation revealed markedly elevated INR values (INR: 15) in two patients receiving warfarin and an INR of 2.6 in one patient; coagulation parameters in the remaining patients were within normal limits. The erythrocyte count was 540,000 M/uL in the patient with polycythemia, the platelet count was 899,000 K/uL in the patient with thrombocytosis, and 7,000 K/uL in the patient followed for atrial fibrillation (AF). Hemoglobin levels were below 8 g/dL in five patients (38.5%) at the time of diagnosis (range: 6.6–7.6 g/dL). Three patients were receiving enoxaparin, one warfarin, and one clopidogrel. These patients received erythrocyte suspension transfusions. Platelet transfusion was administered in the patient with thrombocytopenia. In the remaining nine patients, hemoglobin levels ranged from 8.2 g/dL to 11.3 g/dL, and no transfusion was required. Fresh frozen plasma (FFP) and vitamin K were administered for reversal in patients with markedly elevated INR values (INR: 15), whereas no reversal was performed in the patient with an INR of 2.7.

Physical examination revealed chest wall pain and swelling, with some patients also demonstrating erythema and/or ecchymosis. Thoracic CT was performed in all patients to confirm the diagnosis. Four patients were managed conservatively: two with small hematomas (one with AF and one with CVD) and two patients with PE for whom surgery was not recommended due to poor general condition. Of the 13 patients, eight (61.5%) underwent surgical intervention, including hematoma evacuation. All surgically treated patients recovered, whereas two patients (15.4%) with PE who were managed conservatively died during follow-up.

DISCUSSION

Spontaneous chest wall hematoma associated with anticoagulant and antiaggregant therapy is a rare clinical entity. Notably, none of the 13 patients in this series had a documented history of major trauma. However, most patients were elderly, immobile or had limited mobility, and were in moderate to poor general condition. Support of patients, particularly at the axillary, pectoral, or dorsal regions, during routine care activities such as repositioning or transferring from bed to a seated position may lead to hemorrhage. This is likely due to repetitive minor trauma affecting the muscle groups in these areas.[10] Our findings indicate that bedridden patients receiving anticoagulant therapy are at increased risk for developing chest wall hematomas.

In elderly patients receiving long-term anticoagulant therapy, particularly those with renal failure, microangiopathic fragility and reduced tissue elasticity may predispose to bleeding. Additionally, decreased creatinine clearance is known to increase the risk of bleeding in patients treated with enoxaparin.[11-13] The mean age of patients in this study was 72.5 years; excluding the 51-year-old patient who received prophylactic anticoagulation for pelvic fracture, the mean age increased to 74 years (range: 64-87). One patient had CRF, further contributing to bleeding risk.

In addition to previously mentioned factors such as CRF, hypertension, and advanced age, which predispose patients to bleeding during anticoagulant therapy, elevated INR levels and increased bleeding may result from inadvertent excessive dosing, particularly due to food-drug or drug-drug interactions, as seen with warfarin. Patients may have multiple underlying conditions requiring warfarin therapy. In cases of large extrathoracic hematomas, discontinuation of warfarin and surgical intervention may be necessary; however, cessation carries a risk of thromboembolic events. Therefore,

Figure 2. Pectoral and axillary hematoma in a patient receiving enoxaparin who had undergone mitral valve replacement and tricuspid valve replacement (MVR+TVR) 12 days prior.

Figure 3. Image of a patient who underwent drainage for a pectoral hematoma one month after mitral valve replacement and tricuspid valve replacement (MVR+TVR).

close INR monitoring is essential. Furthermore, intramuscular bleeding may occur even within therapeutic INR ranges.[14-16] Of the 11 patients analyzed, three were receiving warfarin. Two had markedly elevated INR values (INR: 15), while one had an INR within the therapeutic range (INR: 2.6). No evidence of overdose or consumption of interacting foods was documented; however, concomitant use of antibiotics and analgesics was noted.

The decision to perform surgery was based on the patients' overall clinical condition and the size of the hemorrhage. Small, self-limited, and non-progressive hematomas did not require intervention, and four patients were managed conservatively with follow-up. Surgical drainage was performed to relieve discomfort, pain, and respiratory difficulty associated with the hematoma. Upper extremity edema should be carefully assessed during physical examination, particularly when determining the need for surgical intervention. In pectoral hematomas, especially those extending toward the axilla, compression may impair circulation and lead to edema. This finding was observed in three patients with pectoral hematomas (Figs. 2, 3).

The operated patients underwent hematoma evacuation and were followed postoperatively with Hemovac drains. No active bleeding focus was identified during surgical exploration. However, oozing-type hemorrhage between and within muscles was observed. The bleeding appeared to be controlled and contained by compression of the coagulum within the muscle fascia. Consequently, no cases of life-threatening blood loss or hemorrhagic shock were observed. Nevertheless, in patients with borderline anemia due to chronic disease or prior surgery, the need for blood replacement and the risk of hemorrhagic shock should be considered, even when the amount of bleeding appears limited.[17] In this cohort, five patients (38.5%) required erythrocyte suspension transfusion.

No further surgical intervention was required, and no recurrence was observed. However, one patient who underwent MVR+TVR and received postoperative enoxaparin developed a spontaneous hemothorax requiring tube thoracostomy. In patients receiving anticoagulant therapy, careful monitoring is needed for the development of hemothorax as well as other soft tissue or systemic hemorrhages.[18-20] In the presence of related clinical symptoms, additional radiological imaging should be selected according to established protocols. Thoracic CT imaging provides sufficient diagnostic information in cases of chest wall hemorrhage, mediastinal hematoma, or hemothorax, and is also useful for detecting hemorrhages in other systems.[21]

In the postoperative period, 1 g of tranexamic acid diluted in 100 mL saline was administered via the Hemovac drain in the operating room to reduce bleeding and transfusion requirements. The drain was initially clamped and then left to free drainage.[22,23] Additionally, a tight compression bandage was applied to the incision site. Given the high thrombotic risk in this patient group, postoperative anticoagulation therapy was initiated as early as possible. The Hemovac drain was removed after completion of hemorrhagic drainage.

International normalized ratio values were elevated in two of the three patients receiving warfarin therapy (INR: 15), while one patient remained within the therapeutic range (INR: 2.6). In patients with elevated INR levels, the effects of warfarin were reversed with FFP and vitamin K, with daily INR monitoring performed. In the early postoperative period, warfarin therapy was resumed after bleeding complications were controlled. Antidote therapy was not administered to patients receiving anticoagulants, except for those treated with warfarin.

The literature includes reports of giant (>10 cm) anticoagulant-associated hematomas managed conservatively.[13,24,25] However, in our series of 13 patients, we preferred drainage of hematomas of this size when the patient's general condition permitted. Given the prolonged time required for spontaneous resolution, drainage may help prevent complications such as pain, respiratory distress, and infection.[26,27] This approach is particularly important in patients presenting with hemorrhagic shock.[17,24]

Lorena López et al.[28] reported nine patients receiving anticoagulant therapy for Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) infection who developed hemorrhagic complications. All patients were successfully treated with embolization, although only two had chest wall muscle hematomas. Embolization may represent an alternative treatment option in patients with active bleeding, potentially avoiding surgical intervention. However, no active bleeding was observed in our surgically treated patients, and the lack of readily available technical resources for embolization may limit its use in emergency settings.

This study presents 13 cases of spontaneous chest hematoma associated with anticoagulant therapy over an eight-year period. Apart from isolated case reports published in English over the past decade, no study has included a larger patient series. We hope that sharing our experience will raise awareness among clinicians, particularly those managing patients on anticoagulant therapy, regarding this rare but important complication.

CONCLUSION

Spontaneous chest wall hematoma is a rare complication of anticoagulant therapy. Hematoma size, pain, dyspnea, risk of infection, and potential circulatory compromise are key factors guiding the decision for surgical intervention. Careful evaluation of the patients' overall clinical status and comorbidities is essential when determining the appropriate management strategy, including conservative follow-up or surgical drainage. Patients and their caregivers should be informed that even minor trauma during anticoagulant therapy may lead to significant bleeding. Awareness of potential drug–drug and food–drug interactions is also critical. Careful handling of bedridden patients by appropriately trained personnel is essential. Clinicians should remain vigilant for signs of bleeding in patients presenting with recent swelling, induration, hyperemia, or ecchymosis.

It should also be noted that many of these patients require ongoing antiplatelet therapy. In cases of major bleeding or large hematoma formation, discontinuation of this therapy may increase the risk of thromboembolic events. Although all surgically treated patients in our study recovered, the risks associated with surgery, including tissue trauma and bleeding, should not be overlooked. Even hematoma evacuation may cause tissue injury and increase the risk of recurrence. Furthermore, the physiological stress of surgery may adversely affect recovery in this patient population, who are often already compromised by comorbidities and underlying disease. Therefore, close monitoring is essential to ensure that bleeding-related complications do not outweigh the benefits of anticoagulant therapy.

Ethics Committee Approval: This study was approved by the Pamukkale University Ethics Committee (Date: 03.06.2025, Decision No: 192.168.157.28-57284-11.06.2025).

Informed Consent: Written informed consent was obtained.

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: A.K., U.A.; Design: A.K.; Supervision: U.A.; Data collection and/or processing: A.K., G.O.; Analysis and/or interpretation: A.K., G.O.; Literature review: A.K., G.O.; Writing: A.K.; Critical review: U.A.

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Antikoagülanlar ve antiagregantların nadir bir komplikasyonu olarak spontan göğüs duvarı hematomu

AMAÇ: Antikoagülan ve antiagregant ilaçlar (kan sulandırıcılar) günümüzde çeşitli endikasyonlarla kullanılmaktadır. Bu ilaçlarla ilişkili en önemli komplikasyon kanamadır. Bu çalışmada, kan sulandırıcı ilaçlar kullanan ve spontan göğüs duvarı hematomları gelişen hastalar değerlendirilmiştir.
GEREÇ VE YÖNTEM: Ocak 2016-Aralık2024 arasında antikoagülan veya antiagregan kullanım hikayesi olan ve spontan göğüs duvarı hematomu nedeniyle kliniğimize refere edilen 13 hasta, radyolojik bulguları; demografik özellikleri primer patolojileri ve tedavi yöntemleri açısından değerlendirilerek sunulmuştur.
BULGULAR: Majör göğüs duvarı travma öyküsü olmayan 13 hastanın, hematomu büyük olan veya progrese olan 9 tanesine cerrahi olarak müdahele edilerek, hematom tahliyesi yapıldı. Kas fasyaları arasında sınırlanmış hematom tahliye edilirken aktif kanama odağı saptanmadı; hastalar şifa ile taburcu edildi. Takip edilen 4 hastadan genel durumu bozuk olan 2 tanesi kaybedildi, diğer iki hastada komplikasyonsuz tam regresyon izlendi.
SONUÇ: Antikoagülan ilaçların en önemli yan etkisini, kanama oluşturmaktadır. Göğüs duvarını oluşturan kaslara kanama nadir görülmektedir. Özellikle yaşlı ve hareket kısıtlılığı olan hasta grubunda aksiller veya pektoral bölgeden desteklenerek mobilize edilen veya pozisyon verilen hastalarda oluşan tekrarlayan mikro travmalar antikoagülanların etkisiyle hemorajiye ve hematoma yol açmaktadır. Progrese olmayan veya boyutu küçük olan hematomlarda medikal tedavi ve takip yeterliyken; uygun hastalarda cerrahi olarak drenaj yapılması hem hasta konforu açısından hem de gelişebilecek enfeksiyöz süreçlerin önüne geçmek açısından faydalı olacaktır.

Anahtar sözcükler: Antikoagülanlar; antiaggregants; spontan hemoraji; göğüs duvarı; hematom.

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ORIGINAL ARTICLE

Prognostic value of inflammatory and metabolic markers in Fournier's gangrene: a single-center retrospective analysis

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ABSTRACT

BACKGROUND: Fournier's gangrene (FG) is a rapidly progressive, life-threatening necrotizing fasciitis of the perineal and genital region. Despite advances in surgical and medical management, morbidity remains high. Early identification of disease severity and prognosis is essential for timely intervention. This study aimed to evaluate the prognostic value of routinely available inflammatory and metabolic markers—particularly C-reactive protein (CRP) and white blood cell (WBC) count—and to establish clinically applicable admission cut-off values for predicting clinical outcomes, including prolonged hospitalization and surgical burden.

METHODS: This retrospective single-center study included 40 patients diagnosed with and treated for FG at Niğde Ömer Halisdemir University Training and Research Hospital between 2022 and 2025. Demographic, laboratory, and clinical data were reviewed. Laboratory parameters, including WBC count, CRP, glucose, and derived indices such as the neutrophil-to-lymphocyte ratio (NLR) and platelet-to-lymphocyte ratio (PLR), were recorded at three time points: admission, post-first debridement, and pre-discharge. Patients were stratified according to diabetes mellitus (DM) status, antibiotic regimen, and surgical complexity. The primary outcome was prolonged hospitalization (>14 days), and the secondary outcome was the need for multiple debridements (≥3 procedures). Statistical analyses included the Friedman test for repeated measures, Spearman correlation analysis, logistic regression, and receiver operating characteristic (ROC) analysis.

RESULTS: The mean age was 56.8±17.9 years, and 40% of patients had DM. The most common etiology was scrotal abscess (57.5%). Serial laboratory assessment demonstrated significant reductions in WBC count (median: 13.1→8.2 $\times 10^3/\mu L$, $p<0.001$) and CRP level (median: 90.4→34.6 mg/L, $p<0.001$) following serial debridements. Admission CRP and WBC levels showed positive correlations with both length of hospital stay ($\rho=+0.46$ and +0.41, respectively) and number of debridements ($\rho=+0.39$ and +0.36, respectively). In multivariate regression analysis, CRP was the only independent predictor of prolonged hospitalization (odds ratio=1.07, 95% confidence interval: 1.02–1.14; $p=0.009$). ROC analysis identified a CRP threshold of ≥128 mg/L (area under the curve=0.86) as the optimal cut-off value for predicting prolonged hospitalization. No mortality occurred during the study period.

CONCLUSION: CRP and WBC count are practical, inexpensive, and reproducible markers of disease severity and treatment response in patients with Fournier's gangrene. Serial monitoring of these parameters may facilitate early risk stratification, guide decisions regarding repeat debridement, and support optimization of antibiotic and surgical management. Incorporation of these readily available inflammatory markers into standardized treatment protocols may improve clinical decision-making and patient outcomes in FG.

Keywords: C-reactive protein; debridement; Fournier's gangrene; inflammation; prognosis; white blood cell count.

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INTRODUCTION

Fournier's gangrene (FG) is a rare but rapidly progressive form of necrotizing fasciitis that primarily affects the perineum, genitalia, and perianal region. It is characterized by extensive necrosis of the fascial planes and subcutaneous tissues, resulting in severe systemic toxicity and high mortality if left untreated.[1] Despite advances in diagnostic imaging, surgical techniques, and intensive care, reported mortality rates remain between 20% and 40% in most studies.[2,3] The disease predominantly affects older men and patients with systemic comorbidities, particularly diabetes mellitus, which impairs both microvascular circulation and immune function, contributing to delayed wound healing and a more severe clinical course.[4]

Early recognition and aggressive surgical debridement remain the cornerstones of treatment. However, FG often presents with a heterogeneous clinical spectrum, and assessment of disease severity and prognosis at admission can be challenging. To address this issue, several prognostic scoring systems, including the Fournier's Gangrene Severity Index (FGSI), Uludağ Fournier's Gangrene Severity Index (UFGSI), and Laboratory Risk Indicator for Necrotizing Fasciitis (LRINEC), have been proposed.[5-8] Although these indices provide structured assessment, they require multiple laboratory parameters, which may limit their practicality in emergency settings.

Recent research has focused on identifying simpler and more universally available laboratory markers capable of predicting disease severity and clinical outcomes with comparable accuracy.[9]

In particular, C-reactive protein (CRP) and white blood cell (WBC) count have emerged as reliable inflammatory markers reflecting both infectious burden and systemic inflammatory response. Several studies have also evaluated novel markers, including the CRP-to-albumin ratio (CAR), neutrophil-to-lymphocyte ratio (NLR), and platelet-to-lymphocyte ratio (PLR), demonstrating potential prognostic value for mortality and disease progression.[10,11] Although elevated CRP levels and serial monitoring are routinely used during follow-up, clinically useful admission cut-off values for predicting non-mortality outcomes, such as prolonged hospitalization and repeated debridement, remain poorly defined.

Furthermore, most previous studies have focused primarily on mortality outcomes and have rarely evaluated longitudinal laboratory changes alongside procedural and clinical outcomes. Few investigations have examined the relationships among inflammatory markers, length of hospital stay, number of debridements, antibiotic strategies, and adjunctive surgical procedures within the same patient cohort.[10]

Therefore, this study aimed to build on previous findings by providing a comprehensive analysis of inflammatory, metabolic, and procedural factors in a real-world cohort of patients with FG treated at a tertiary referral center. We evaluated temporal changes in WBC count, CRP level, glucose level, and derived indices (NLR and PLR) at three predefined time points: admission, after the first debridement, and before discharge. We also examined the associations between these parameters and clinical outcomes and identified clinically relevant admission cut-off values for predicting prolonged hospitalization. By focusing on simple, routinely collected markers, our study offers a practical and cost-effective alternative to more complex prognostic scoring systems.

Unlike earlier studies that primarily focused on mortality, this study emphasized functional and procedural outcomes, including length of hospital stay (LOS) and number of debridements, as more sensitive indicators of disease severity and treatment efficiency. In addition, we evaluated the impact of antibiotic selection and surgical complexity on clinical outcomes, thereby reflecting contemporary real-world management patterns of FG.

We hypothesized that elevated baseline CRP and WBC levels would be associated with a more severe disease course, prolonged hospitalization, and greater surgical burden, and that serial reductions in these markers would parallel clinical recovery. Through this approach, the study not only reinforces the prognostic value of basic inflammatory markers but also contributes to the growing evidence supporting early biochemical monitoring and individualized multidisciplinary management of FG.

MATERIALS AND METHODS

Study Design and Setting

This retrospective, single-center study included 40 patients diagnosed with and treated for FG between 2022 and 2025 at Niğde Ömer Halisdemir University Training and Research Hospital. Consecutive patients were identified through the institutional database based on a clinical diagnosis of FG and inclusion of urgent surgical debridement during the index admission. The study was conducted in accordance with the Declaration of Helsinki and reported in compliance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for observational studies. Ethical approval for this retrospective study was obtained from the Niğde Ömer Halisdemir University Ethics Committee (Decision No. 2025/151/Date. 15.12.2025).

Eligibility Criteria

The inclusion criteria were: age ≥18 years; clinical and/or radiological evidence of necrotizing fasciitis involving the perineum and/or external genitalia; and at least one operative debridement during the index admission.

The exclusion criteria were: localized perianal or genital abscess without fascial extension; incomplete laboratory or operative data at mandatory assessment time points; and prior debridement for FG performed at an outside institution during the same disease episode. A total of 40 patients met the eligibility criteria and were included in the final analysis.

Perioperative Care and Surgical Strategy

All patients received broad-spectrum intravenous antibiotics upon presentation and underwent urgent extensive debridement of devitalized tissue. Subsequent intervention, including repeat debridement, vacuum-assisted closure (VAC), orchiectomy, diverting colostomy, skin reconstruction (local flap or split-thickness skin graft), and hyperbaric oxygen therapy (HBOT), were performed according to clinical judgement based on disease extent, degree of contamination, and wound progression. Hemodynamic resuscitation and glycemic control followed standard institutional protocols.

Data Sources and Curation

Data were extracted from an institutional spreadsheet and de-identified prior to analysis. Variable names were standardized, continuous variables were converted to numeric formats, and values were screened for plausibility against embedded reference intervals. Records lacking mandatory values at all three predefined time points were excluded. For variables with <5% missingness, missing data were handled as described below.

Variables and Operational Definitions
Demographic and Clinical Variables

Age (years) and sex were recorded at admission. Data on diabetes mellitus (DM) and other predisposing conditions (paraplegia, prior pelvic surgery, malignancy, Alzheimer's disease, Parkinson's disease, dementia, cerebrovascular accident, and poor hygiene) were obtained from medical records. Length of hospital stay was calculated at the number of days from admission to discharge. Prolonged LOS was defined a priori as >14 days and served as the primary binary endpoint. The number of debridements represented the total number of operative sessions during the index admission; multiple debridements were defined as ≥3 procedures and served as the secondary binary endpoint.

Etiologic Factors

The presumed primary source of infection was categorized as a scrotal abscess, epididymo-orchitis, testicular abscess, or perianal abscess/other.

Surgical Procedures

Initial surgical management consisted of debridement in all patients. Adjunct procedures were recorded as binary variables and included VAC, orchiectomy, colostomy, skin reconstruction, and HBOT. For descriptive analyses, a surgical complexity indicator was created and defined as the presence of any adjunctive procedure.

Antibiotic Regimens

Initial inpatient antibiotic therapy was classified into three mutually exclusive groups:

• Group A (carbapenem-based): imipenem, meropenem, or ertapenem with or without additional agents;

• Group B: piperacillin–tazobactam or ampicillin–sulbactam;

• Group C (other regimens): fluoroquinolone with or without metronidazole, clindamycin, linezolid, tigecycline, or daptomycin.

If a carbapenem was included anywhere in the initial combination, the patient was assigned to Group A, reflecting severity-guided prescribing patterns.

Laboratory Time Points and Markers

Laboratory measurements were collected at three standardized time points: admission (initial), after the first debridement (post-debridement), and before discharge (final). Core laboratory variables available at all time points included white blood cell count ($\times 10^3/\mu L$), C-reactive protein (mg/L), and blood glucose (mg/dL).

Differential counts were used to calculate the neutrophil-to-lymphocyte ratio (NLR = absolute neutrophil count / absolute lymphocyte count) and platelet-to-lymphocyte ratio (PLR = platelet count / absolute lymphocyte count). Ratios were treated as missing if lymphocyte counts were unavailable or equal to zero. Albumin values were unavailable; therefore, the CRP-to-albumin ratio could not be calculated. To assess treatment response, Δ values were calculated as initial minus final values for WBC, CRP, and glucose, with positive Δ values indicating improvement.

Outcomes

The primary outcome was prolonged LOS (>14 days), and the secondary outcome was multiple debridements (≥3 procedures). Adjunctive procedure use and antibiotic group distribution were additionally summarized to characterize real-world treatment patterns.

Statistical Analysis

All analyses were performed using IBM SPSS Statistics version 29 (IBM Corp., Armonk, NY, USA) and Python version 3.12 (Python Software Foundation, Wilmington, DE, USA), using the SciPy and scikit-learn libraries. A two-sided p-value <0.05 was considered statistically significant. Data normality was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Continuous variables are presented as mean±standard deviation (SD) and median (interquartile range, IQR), whereas categorical variables are presented as n (%).

Power Analysis

Given the rarity of Fournier's gangrene and the resulting sample size limitations, a post hoc power analysis was conducted using G*Power software (version 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany).[12] For a two-tailed correlation test (H0: $\rho=0$) with $\alpha=0.05$ and n=40, the study achieved 80% power to detect a moderate correlation ($|r|\geq 0.42$). Based on the observed correlation between admission CRP and length of stay ($\rho=0.46$), the achieved statistical power was 0.88.

Descriptive and Comparative Analyses

Comparisons between DM and non-DM groups, antibiotic

groups (A/B/C), and procedure-defined subgroups were performed using Student's t-test or the Mann–Whitney U test for two-group comparisons, the Kruskal–Wallis test followed by Dunn's post hoc test for comparisons involving three or more groups, and χ^2 or Fisher's exact test for categorical variables.

Longitudinal Laboratory Trajectories

Within-patient changes in WBC, CRP, glucose, NLR, and PLR across the three laboratory time points were analyzed using the Friedman test. Significant omnibus findings were followed by pairwise Wilcoxon signed-rank tests with Bonferroni adjustment.

Correlation and Modeling

Associations between baseline inflammatory and metabolic burden and clinical outcomes were evaluated using Spearman's ρ, examining WBC, CRP, and glucose levels against LOS and number of debridements. Variables with $p<0.10$ in univariate analyses were entered into multivariate logistic regression models using forward stepwise likelihood-ratio selection for both binary outcomes (prolonged LOS and ≥3 debridements). Results are presented as odds ratios (OR) with 95% confidence intervals (CI). Model calibration and discrimination were assessed using the Hosmer–Lemeshow test and Nagelkerke R^2.

ROC Analysis

Receiver operating characteristic (ROC) curves were generated for baseline CRP, WBC, and glucose levels to predict prolonged LOS. Predictive performance was summarized using the area under the curve (AUC) with 95% CI. Optimal thresholds were determined using Youden's index.

Missing Data and Sensitivity Analyses

Continuous variables with <5% missingness were imputed using median substitution. Sensitivity analyses excluding imputed observations yielded similar results. Clinically plausible outliers were retained following source verification.

RESULTS

Patient Characteristics

A total of 40 patients were included in this study. The mean age was 56.8±17.9 years (median 59 years; IQR 44–70), and 16 patients (40%) had diabetes mellitus. The median length of hospital stay was 12.5 days (IQR 7–22), and patients underwent a median of two (IQR 1–3) surgical debridements.

As shown in Table 1, patients with diabetes were older (64.0±11.8 years) than those without diabetes (51.9±19.8 years) and tended to have longer hospital stays and undergo more debridements; however, these differences did not reach statistical significance ($p>0.05$).

At admission, the mean white blood cell count was 14.9±6.2 ×10³/μL (median 13.1 [IQR 10.7–18.9]). The mean C-reactive protein level was 133.2±98.6 mg/L (median 90.4 [IQR 67.6–201.5]), and the mean blood glucose level was 172.8±107.1 mg/dL (median 124 [IQR 103–192]). Patients with DM had significantly higher glucose levels than those without DM (255.9±129.2 mg/dL vs. 117.3±23.4 mg/dL, $p<0.001$), whereas WBC and CRP values were numerically higher but did not differ significantly (Table 1).

Table 1. Baseline demographic and laboratory characteristics according to diabetes status

Variable	Overall (n=40)	DM (n=16)	Non-DM (n=24)
Age (years)	56.8±17.9 (59 [44–70])	64.0±11.8 (60.5 [58.5–71.3])	51.9±19.8 (49.5 [34–66])
Length of hospital stay (days)	15.3±9.5 (12.5 [7–22])	16.1±8.4 (15.5 [10–19])	14.7±10.3 (8.5 [7–23])
Number of debridements	2.8±2.4 (2 [1–3])	3.3±2.6 (3 [1.8–3.5])	2.5±2.2 (2 [1–2.3])
WBC (×10³/μL)	14.9±6.2 (13.1 [10.7–18.9])	16.3±5.5 (16.3 [11.9–20.5])	14.0±6.5 (12.8 [10.2–17.5])
CRP (mg/L)	133.2±98.6 (90.4 [67.6–201.5])	162.3±95.9 (150.4 [91.8–220.6])	113.7±97.5 (85.0 [64.6–113.4])
Glucose (mg/dL)	172.8±107.1 (124 [103–192])	255.9±129.2 (263.5 [152.8–342.0])	117.3±23.4 (115.5 [100–127])

DM: Diabetes mellitus.

Etiology and Procedural Findings

The most common primary etiology was scrotal abscess (57.5%), followed by epididymo-orchitis (25%), testicular abscess (10%), and perianal abscess or other causes (7.5%). All patients underwent urgent extensive surgical debridement, which is the cornerstone of management.

Adjunctive procedures included VAC therapy in 11 patients (27.5%), orchiectomy in nine (22.5%), skin reconstruction in eight (20%), colostomy in four (10%), and HBOT in four (10%).

No in-hospital mortality occurred during the study period, which may reflect the benefits of multidisciplinary care and early intervention.

Antibiotic therapy consisted of carbapenem-based regimens in 17 patients (42.5%), piperacillin–tazobactam–based regimens in 11 (27.5%), and other broad-spectrum combinations in 12 (30%).

Patients receiving carbapenem-based therapy had higher baseline CRP levels (median 150 mg/L) than those receiving other regimens but achieved comparable outcomes in LOS and number of debridements (p>0.05) (Table 2).

Temporal Trends in Laboratory Parameters

Serial laboratory assessments demonstrated significant reductions in inflammatory and metabolic markers across the treatment course (Fig. 1). Median WBC count decreased from 13.1 to 11.5 and subsequently 8.2×10³/μL (p<0.001, Friedman test; all pairwise comparisons p<0.001). Median CRP decreased from 90.4 to 57.2 and then to 34.6 mg/L (all p<0.001). Blood glucose levels decreased modestly over time (124→122→122 mg/dL, overall p=0.032; initial vs. final measurements p=0.025). NLR declined significantly over time (5.6→3.2, p<0.001), whereas PLR did not demonstrate statistically significant change (p>0.05).

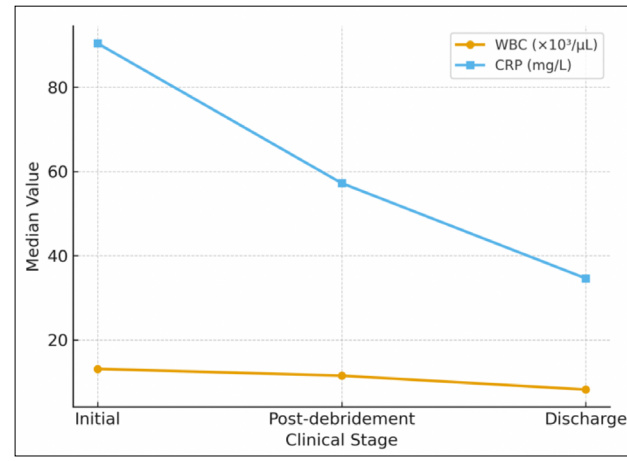

Figure 1. Sequential changes in white blood cell (WBC) count and C-reactive protein (CRP) levels across the three treatment stages (admission, post-debridement, and pre-discharge). Both inflammatory markers demonstrated a progressive decline following serial surgical debridement.

Correlation Analyses

As presented in Table 3, admission CRP and WBC values were positively correlated with both LOS and number of debridements. Higher admission CRP levels were moderately associated with prolonged hospitalization (ρ=0.46, p=0.010) and greater operative burden (ρ=0.39, p=0.025). WBC was also significantly correlated with LOS (ρ=0.41, p=0.018) and number of debridements (ρ=0.36, p=0.030). Glucose showed weaker and non-significant associations with both outcomes (ρ=0.28 and p=0.24, respectively).

Table 2. Association of antibiotic regimens and surgical procedures with clinical outcomes

Group/procedure	n (%)	Median LOS (days) [IQR]	Median number of debridements [IQR]	Significance (p)
Antibiotic regimen				
Carbapenem-based	17 (42.5%)	15 [10–23]	3 [2–4]	NS
Piperacillin–tazobactam–based	11 (27.5%)	13 [9–20]	2 [1–3]	NS
Other regimens	12 (30%)	14 [8–22]	2 [1–3]	NS
Surgical procedures				
VAC therapy	11 (27.5%)	21 [14–30]	3 [2–4]	0.019
Colostomy	4 (10%)	20 [12–26]	3 [2–5]	0.032
Orchiectomy	9 (22.5%)	19 [12–27]	3 [2–4]	0.014
Skin reconstruction	8 (20%)	18 [10–26]	2 [2–3]	NS
HBOT	4 (10%)	17 [9–24]	3 [1–4]	NS

NS: Not significant; LOS: Length of hospital stay; VAC: Vacuum-assisted closure; HBOT: Hyperbaric oxygen therapy.

Table 3. Association between baseline laboratory markers and clinical outcomes

Variable	ρ (LOS)	p (LOS)	ρ (Number of debridements)	p (Debridements)
WBC (×10³/μL)	+0.41	0.018	+0.36	0.030
CRP (mg/L)	+0.46	0.010	+0.39	0.025
Glucose (mg/dL)	+0.28	0.081	+0.24	0.115

LOS: length of hospital stay.

Table 4. Logistic regression analysis for predictors of prolonged hospital stay (>14 days) and multiple debridements (≥3)

Variable	OR (95% CI)	p	Interpretation
WBC (×10³/μL)	1.11 (1.01–1.22)	0.030	Higher admission WBC was associated with pro longed hospital stay and greater procedural burden
CRP (per 10 mg/L increase)	1.08 (1.02–1.15)	0.018	Higher inflammatory burden → more severe clinical course
Diabetes mellitus (present)	1.36 (1.10–1.70)	0.046	Significant in univariable analysis but not retained after adjustment
Carbapenem-based therapy	1.52 (1.12–2.11)	0.042	Reflects severity-based treatment selection rather than causal effect
Multivariate model (CRP only)	1.07 (1.02–1.14)	0.009	CRP is the independent predictor of prolonged hospital stay

CI: Confidence interval; CRP: C-reactive protein.

Table 5. Receiver operating characteristic (ROC) analysis for prediction of prolonged hospital stay (>14 days)

Variable	AUC (95% CI)	Cut-off	Sensitivity (%)	Specificity (%)
CRP (mg/L)	0.86 (0.74–0.97)	128 mg/L	83	75
WBC (×10³/μL)	0.81 (0.68–0.92)	14.2	80	70
Glucose (mg/dL)	0.72 (0.57–0.87)	165	71	65

Regression Analysis

Univariate logistic regression analysis identified four variables associated with the study outcomes (prolonged LOS >14 days or multiple debridements ≥3): higher admission WBC (OR 1.11, 95% CI 1.01–1.22, p=0.030), higher CRP (OR 1.08 per 10 mg/L increase, 95% CI 1.02–1.15, p=0.018), diabetes mellitus (OR 1.36, 95% CI 1.10–1.70, p=0.046), and carbapenem-based therapy (OR 1.52, 95% CI 1.12–2.11, p=0.042) (Table 4).

In the multivariate analysis, CRP remained the only independent predictor of prolonged hospitalization (adjusted OR 1.07, 95% CI 1.02–1.14, p=0.009). The model demonstrated good calibration (Hosmer–Lemeshow p=0.81) and acceptable discriminative performance (Nagelkerke R^2=0.42).

ROC Curve Analysis

ROC analysis (Table 5, Fig. 2) demonstrated excellent discriminative performance of CRP and WBC for predicting prolonged LOS. A CRP threshold ≥128 mg/L predicted LOS >14 days with an AUC of 0.86 (95% CI 0.74–0.97), sensitivity of 83%, and specificity of 75%. A WBC threshold ≥14.2 ×10³/μL yielded an AUC of 0.81 (95% CI 0.68–0.92), sensitivity of 80%, and specificity of 70%. A glucose level of ≥165 mg/dL demonstrated moderate predictive ability (AUC=0.72, 95% CI 0.57–0.87). Overall, CRP demonstrated the highest diagnostic accuracy and emerged as the strongest laboratory predictor of disease severity.

Effects of Antibiotic Regimens and Surgical Procedures

Comparative outcomes according to antibiotic and procedural subgroups are presented in Table 2. No statistically signifi-

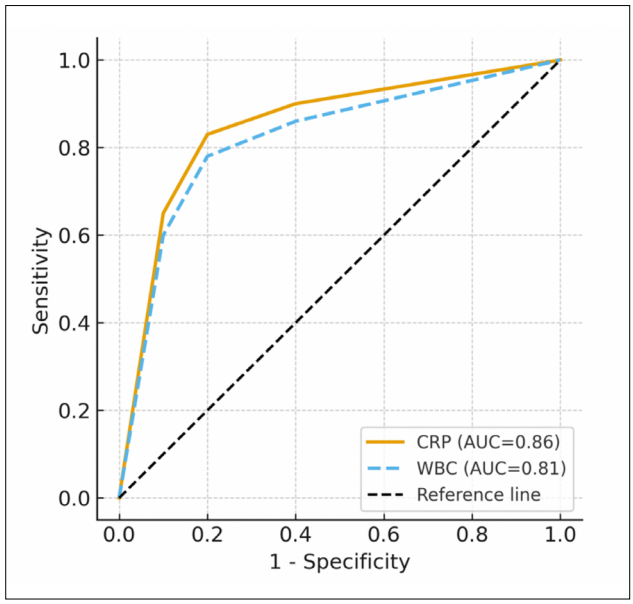

Figure 2. Receiver operating characteristic (ROC) curves comparing the prognostic performance of admission C-reactive protein (CRP) and white blood cell (WBC) levels for predicting prolonged hospital stay (>14 days). CRP demonstrated the highest discriminative performance, with an area under the curve (AUC) of 0.86.

cant differences were observed in LOS (p=0.34) or number of debridements (p=0.29) across antibiotic categories. However, patients treated with carbapenem-based regimens presented with higher baseline inflammatory marker levels, suggesting greater disease severity at admission.

Patients who underwent VAC therapy or orchiectomy experienced longer hospital stays (median, 21 vs. 10 days; p=0.019) and had higher admission CRP levels (median, 160 vs. 85 mg/L; p=0.014). No significant differences in outcomes were observed among patients undergoing colostomy, HBOT, or skin reconstruction. No mortality was observed in the cohort, which may reflect the benefits of early multidisciplinary management.

DISCUSSION

Fournier's gangrene is one of the most aggressive forms of necrotizing soft-tissue infection and is characterized by rapid fascial necrosis and systemic sepsis. Despite advances in early diagnosis, antibiotic therapy, and surgical management, morbidity and healthcare utilization remain substantial.[13] In this study, we evaluated 40 patients with FG treated at a tertiary referral center to investigate the prognostic value of routinely available inflammatory and metabolic markers (particularly CRP and WBC), and to examine their temporal changes in relation to clinical outcomes, operative burden, and hospitalization duration.

Our findings demonstrated that both CRP and WBC levels were markedly elevated at admission and declined significantly following serial debridement procedures, paralleling clinical improvement. CRP, in particular, showed strong correlations with LOS and number of debridements and remained the only independent predictor of prolonged hospitalization in the multivariate analysis. ROC analysis demonstrated superior discriminative performance of CRP (AUC=0.86) compared with WBC (AUC=0.81) and glucose (AUC=0.72) for predicting hospital stay longer than 14 days. These findings highlight the value of serially monitored, routinely available laboratory markers as reliable indicators of disease severity and treatment response. Importantly, the ROC-derived threshold (CRP≥128 mg/L) provides a simple admission-based tool to support early prognostic assessment and complements the established role of serial CRP monitoring during follow-up.

The observed associations between inflammatory markers and outcomes are consistent with previous Turkish and international studies emphasizing the prognostic significance of systemic inflammation in FG. Özgül et al.[14] reported that the CAR was an independent predictor of mortality (AUC=0.90), whereas Topuz et al.[15] demonstrated significant reductions in CRP and NLR following adequate debridement, consistent with our findings. Bolat et al.[9] highlighted the association between hyperglycemia and mortality risk and recommended aggressive glycemic control in patients with diabetes. Although patients with diabetes in our cohort presented with higher baseline glucose, CRP, and WBC values, diabetes itself was not independently associated with outcomes after adjustment for inflammatory burden, suggesting that prompt surgical management and infection control may attenuate metabolic disadvantage associated with diabetes mellitus.

Unlike earlier studies focused primarily on mortality, the present study evaluated functional and procedural outcomes, including LOS and debridement frequency, which may better reflect disease burden and healthcare resource utilization in routine practice. The positive correlations between elevated baseline CRP and WBC values and the need for multiple procedures or complex adjunctive interventions (such as VAC therapy or orchiectomy) indicate that systemic inflammatory burden parallels the extent of necrosis. These findings are consistent with previous observations indicating that greater inflammatory burden at presentation is associated with increased tissue loss and longer recovery.[16,17]

This study also provides clinically relevant insights into antibiotic management. Although no statistically significant differences were observed among antibiotic regimens, carbapenem-based combinations were more frequently prescribed in patients with higher initial CRP levels, suggesting that antibiotic selection reflected disease severity rather than differences in outcome. This observation is consistent with a severity-guided approach to antimicrobial management and aligns with pragmatic recommendations.[18,19]

A key strength of this study is the comprehensive evaluation of serial laboratory trajectories and their integration with surgical and therapeutic variables within a single cohort.

Whereas most previous studies have focused on static admission measures or composite severity indices, our findings suggest that serial monitoring of CRP and WBC provides clinically useful information while remaining practical for emergency decision-making. Inclusion of antibiotic regimens and adjunctive procedures further offers insight into contemporary multidisciplinary management of FG.

Nevertheless, certain limitations of this study should be acknowledged. The retrospective design and relatively small sample size may have limited the statistical power of the multivariable analyses and reduced the ability to detect smaller effect sizes. However, the post hoc power analysis indicated adequate power to detect moderate correlations between admission inflammatory markers and clinical outcomes. The absence of albumin measurements precluded calculation of CAR, which has demonstrated prognostic value in several previous studies. Additionally, because no mortality occurred in our cohort, the predictive value of inflammatory markers for mortality could not be assessed. Microbiological culture data were incomplete, precluding analysis of pathogen-specific outcomes. Despite these limitations, the internal consistency of the findings and the concordant trends across multiple analyses support the validity of our conclusions.

Overall, this study supports the role of CRP and WBC as simple, cost-effective, and reliable markers for early prognostic assessment and postoperative monitoring in Fournier's gangrene. Integration of these routinely available markers into clinical practice may facilitate early identification of high-risk patients, support timely re-intervention, and optimize resource utilization. Serial monitoring of these markers may provide dynamic insight into treatment response and may serve as a foundation for future prospective approaches integrating biochemical trends with clinical scoring systems.

CONCLUSION

This study highlights the importance of early, aggressive, multidisciplinary management in patients with Fournier's gangrene. Routine laboratory parameters, particularly C-reactive protein and white blood cell count, were strongly associated with disease severity, treatment response, and procedural burden.

Serial monitoring of these markers may provide dynamic insights into infection control and clinical recovery, supporting timely surgical decision-making and individualized patient management. Integration of these simple, cost-effective tests into routine clinical practice may facilitate early prognostic evaluation, optimize resource utilization, and contribute to more standardized care for this life-threatening disease.

Ultimately, the present study contributes to the growing national and international literature supporting the use of inflammatory kinetics as both prognostic and monitoring tools in Fournier's gangrene and highlights their potential role in complementing complex scoring systems with practical bedside assessment.

Ethics Committee Approval: This study was approved by the Niğde Ömer Halisdemir University Ethics Committee (Date: 15.12.2025, Decision No: 2025/151).

Informed Consent: Retrospective study

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: K.B.; Design: K.B., N.A.; Supervision: K.B.; Resource: N.A., D.N.U.; Materials: N.A., D.N.U.; Data collection and/or processing: N.A., D.N.U.; Analysis and/or interpretation: K.B., D.N.U.; Manuscript writing: K.B.; Critical review: K.B., N.A., D.N.U.

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Fournier gangreninde enflamatuvar ve metabolik belirteçlerin prognostik değeri: Tek merkezli retrospektif bir analiz

AMAÇ: Fournier gangreni (FG), perineal ve genital bölgeyi tutan, hızlı ilerleyen ve yaşamı tehdit eden nekrotizan fasiittir. Cerrahi ve medikal tedavideki gelişmelere rağmen morbidite oranı yüksek seyretmektedir. Erken dönemde hastalık şiddetinin ve prognozun belirlenmesi, zamanında müdahale için büyük önem taşır. Bu çalışmanın amacı, günlük pratikte kolayca ulaşılabilen inflamatuvar ve metabolik belirteçlerin—özellikle C-reaktif protein (CRP) ve beyaz küre (WBC) sayısının—prognoz üzerine etkisini ve cerrahi sonuçlar, hastanede kalış süresi ve tedavi yanıtı ile ilişkisini değerlendirmek ve ayrıca başvuru anındaki CRP ve WBC için klinik kullanıma uygun eşik değerleri belirlemektir.

GEREÇ VE YÖNTEM: Bu retrospektif tek merkezli çalışmaya, 2022–2025 yılları arasında Niğde Ömer Halisdemir Üniversitesi Eğitim ve Araştırma Hastanesi'nde FG tanısı alarak tedavi edilen 40 hasta dahil edilmiştir. Demografik, laboratuvar ve klinik veriler incelenmiştir. Laboratuvar parametreleri (WBC, CRP, glukoz ve türev oranlar: nötrofil/lenfosit oranı [NLR], trombosit/lenfosit oranı [PLR]) üç zaman noktasında kaydedilmiştir: başvuru, ilk debridman sonrası ve taburculuk öncesi. Hastalar diyabet (DM) varlığına, antibiyotik tedavisine ve cerrahi karmaşıklık durumuna göre gruplandırılmıştır. Birincil sonuç uzamış yatış (>14 gün), ikincil sonuç ise çoklu debridman (≥3) olarak tanımlanmıştır. İstatistiksel analizlerde Friedman, Spearman korelasyon, lojistik regresyon ve ROC analizleri kullanılmıştır.

BULGULAR: Ortalama yaş 56.8±17.9 yıl olup, hastaların %40'ında DM mevcuttu. En sık etiyoloji skrotal apseydi (%57.5). Seri laboratuvar değerlendirmesinde her debridman sonrası WBC (medyan 13.1→8.2×10³/μL, p<0.001) ve CRP (medyan 90.4→34.6 mg/L, p<0.001) düzeylerinde anlamlı düşüş izlendi. Başvuru CRP ve WBC değerleri hem hastanede kalış süresi (ρ=+0.46 ve +0.41) hem de debridman sayısı (ρ=+0.39 ve +0.36) ile pozitif korelasyon gösterdi. Çok değişkenli analizde yalnızca CRP, uzamış yatışın bağımsız öngördürücüsü olarak saptandı (OR 1.07, %95 GA 1.02–1.14, p=0.009). ROC analizinde CRP ≥128 mg/L (AUC=0.86), uzamış yatışı öngörmede en iyi eşik değer olarak bulundu. Çalışma grubunda mortalite görülmedi.

SONUÇ: CRP ve WBC, Fournier gangreninde hastalık şiddeti ve tedavi yanıtının değerlendirilmesinde pratik, ucuz ve güvenilir göstergelerdir. Bu parametrelerin seri izlenmesi, klinisyenlere erken risk sınıflandırmasında, tekrar debridman zamanlamasında ve antibiyotik/cerrahi stratejilerin planlanmasında yol gösterici olabilir. Temel inflamatuvar belirteçlerin kullanımı, Fournier gangreninde tedavi protokollerinin standartlaştırılmasına ve klinik sonuçların iyileştirilmesine katkı sağlayabilir.

Anahtar sözcükler: Beyaz küre sayısı; C-reaktif protein; debridman; Fournier gangreni; inflamasyon; prognoz.

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ORIGINAL ARTICLE

Same location, different patients: a comparison of metastatic and conventional femoral neck fractures

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ABSTRACT

BACKGROUND: Although conventional and metastatic femoral neck fractures (FNF) represent distinct patient populations in routine clinical practice, treatment management is generally similar for both groups. Systematic treatment approaches for FNF are currently used and supported by clinical guidelines; however, patients with metastatic FNF are generally managed according to treatment protocols developed for conventional FNF. The aim of this study was to determine whether the treatment strategy for conventional FNF is effective for patients with metastatic FNF.

METHODS: This retrospective study included 185 patients diagnosed with conventional FNF and 71 patients with metastatic FNF who underwent endoprosthetic reconstruction at a nationwide tertiary orthopedic oncology center. The primary outcome measures were patient- and hospital-related factors potentially affecting survival in the two groups. Secondary outcomes included complications such as thrombotic events, decubitus ulcers, and erythrocyte transfusion requirements.

RESULTS: Patients with metastatic FNF had significantly lower survival rates (p=0.021), higher rates of complications including thrombotic events (p=0.030) and decubitus ulcers (p=0.029), longer operative times (p<0.001), greater perioperative blood loss (p<0.001), and increased erythrocyte transfusion requirements (p<0.001). Compared with the conventional FNF group, metastatic FNF patients also had longer preoperative and postoperative hospital stays (p<0.001) and delayed postoperative mobilization (p=0.017).

CONCLUSION: Although treatment management for conventional femoral neck fractures has been standardized in orthopedic practice through established algorithms, these protocols do not adequately address the needs of patients with metastatic femoral neck fractures, who experience higher complication rates and lower survival.

Keywords: Femoral neck fracture; metastasis; pathologic fracture.

INTRODUCTION

Metastasis occurs most frequently in the skeletal system because of slower blood flow and a favorable microenvironment.[1,2] The femoral neck, a major stress-bearing region under axial loading, is also the most common site of metastasis in the appendicular skeleton and accounts for 50% of proximal femoral metastases.[3-7] A metastatic femoral neck fracture (FNF) indicates advanced-stage cancer with distant organ involvement and a complex disease burden.[5,7] In addition to complications caused by the primary malignancy, these patients face functional limitations resulting from loss

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of mobility. Advances in targeted anticancer therapies have improved survival outcomes for cancer patients;[8] consequently, optimizing and standardizing treatment pathways for this population has become increasingly important.

Conventional FNF is associated with high morbidity and mortality and predominantly affects the geriatric population, placing a substantial burden on orthopedic services and healthcare systems.[9] Management strategies for conventional FNF have been extensively investigated and supported by evidence-based guidelines.[10,11] However, most studies have focused on improving outcomes in conventional FNF, and few have directly compared metastatic and conventional FNF. Although patients with conventional and metastatic FNF represent fundamentally different populations before fracture occurrence, their treatment pathways become largely similar after presentation. Patients with metastatic FNF are generally managed according to treatment algorithms developed for conventional FNF. Following hospital admission, diagnosis is established through comparable imaging and physical examination protocols, followed by a period of immobilization that exposes both groups to similar risks. Endoprosthetic reconstruction is the preferred surgical treatment in both populations.[12,13] The principal treatment goals are restoration of ambulation and effective pain control, followed by postoperative physiotherapy and outpatient follow-up. Because these management pathways were primarily standardized for conventional FNF, they may not adequately address the specific needs of metastatic patients.

The aim of this study was to determine whether treatment management developed for conventional FNF is sufficiently applicable to metastatic FNF and, if not, to identify potential deficiencies. Therefore, factors affecting morbidity and mortality in patients with conventional and metastatic FNF were evaluated and compared between groups.

MATERIALS AND METHODS

Patient Selection and Study Design

This retrospective study was conducted at a tertiary-level trauma and oncology center between 2011 and 2021 and included 299 patients who underwent surgery for femoral neck fracture. Patient data were retrieved from the hospital information system, orthopedic oncology records, and physician and nursing documentation completed during inpatient care. Exclusion criteria included bilateral fractures, total hip arthroplasty, internal fixation procedures, reoperation during hospitalization, incomplete records, and revision cases referred from another institution. After exclusions, data from 185 patients in the conventional group and 93 patients in the metastatic group were analyzed. Inclusion and exclusion criteria and the final study cohort are presented in Figure 1

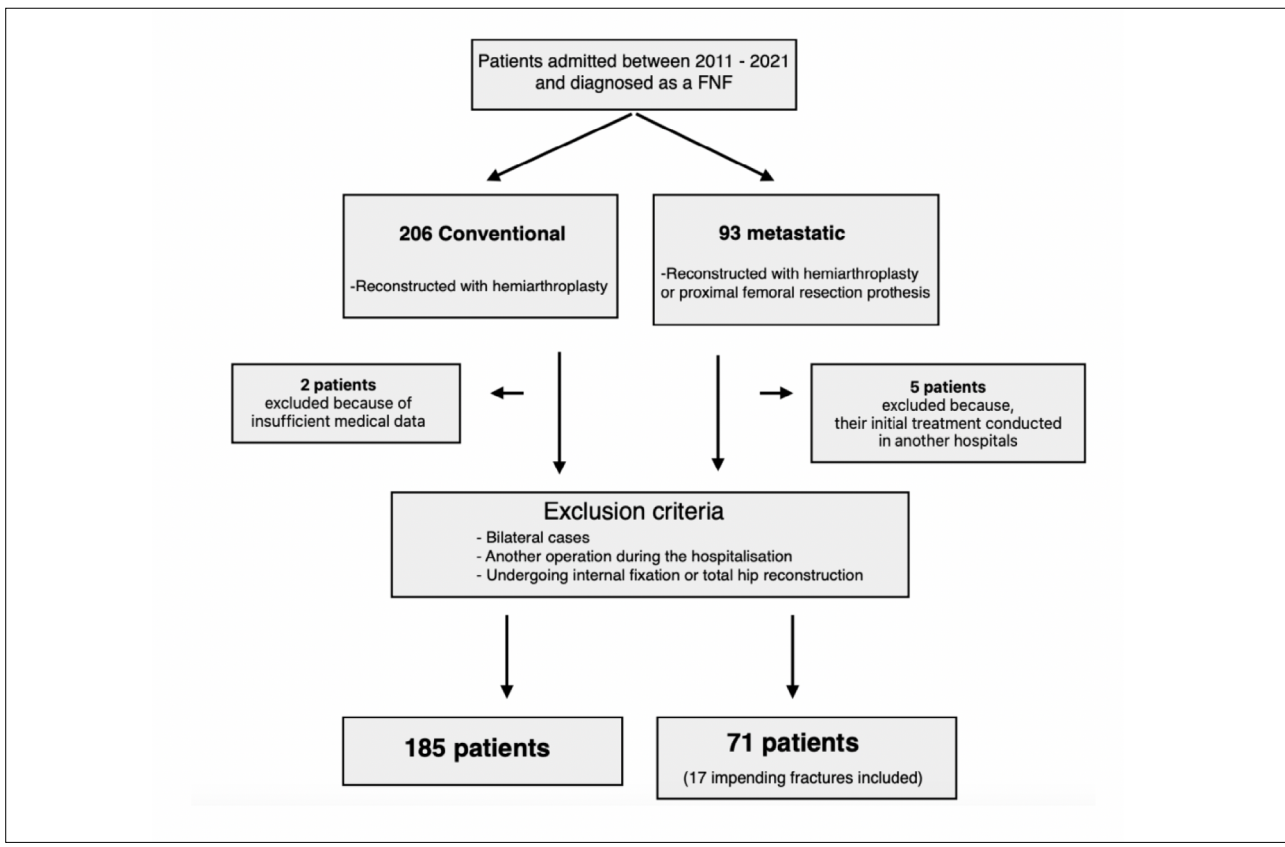

Figure 1. Flowchart of patient selection according to the inclusion and exclusion criteria. FNF: Femoral neck fracture.

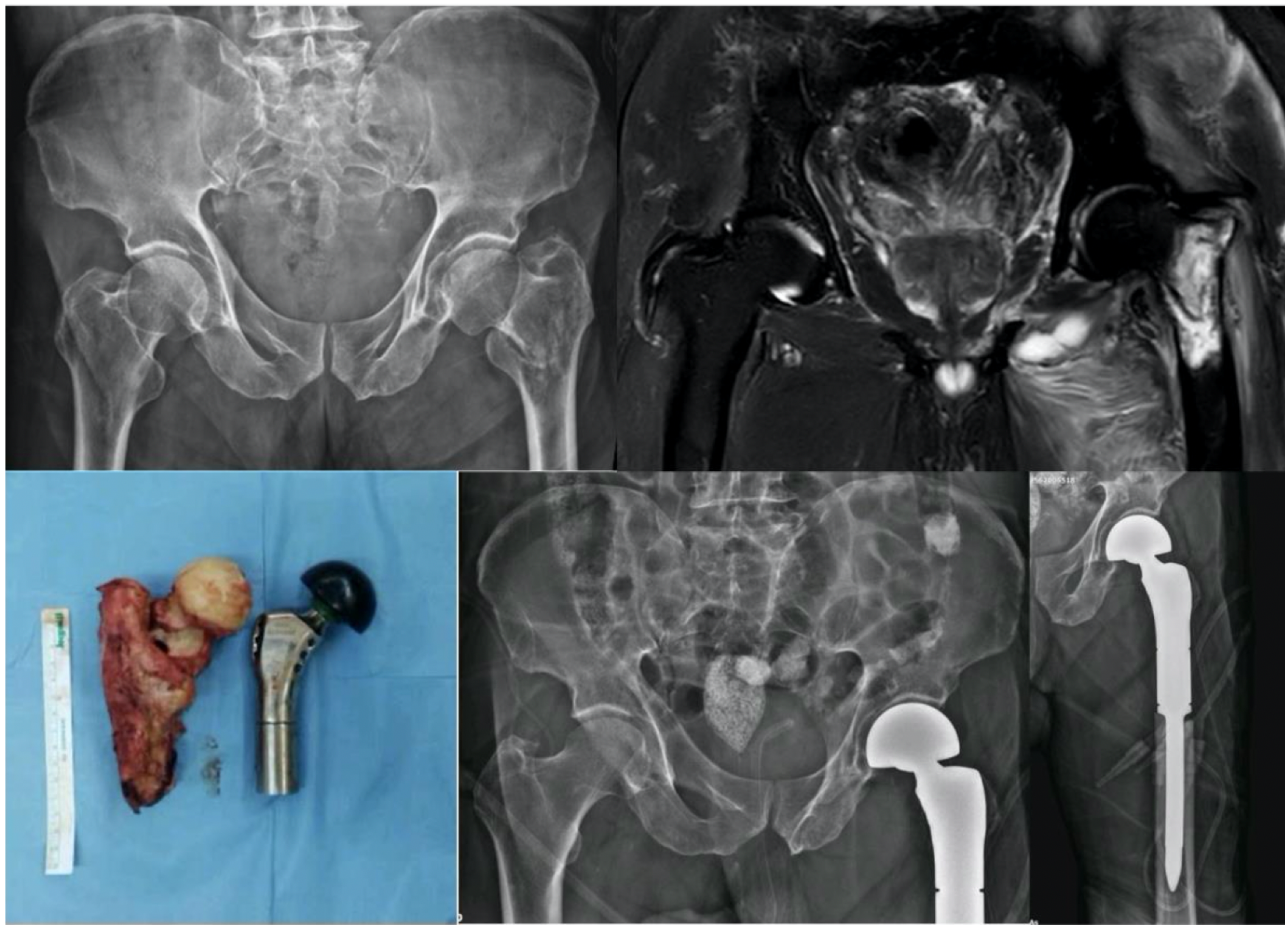

Figure 2. Representative case of a patient diagnosed with lung cancer with bone lysis extending into the trochanteric region. Reconstruction was performed using a resection prosthesis.

(flowchart), which details all exclusions and final sample sizes.

Variables evaluated included age, sex, overall survival, anesthesia technique (general or regional), reconstruction method (hemiarthroplasty vs. resection prosthesis), American Society of Anesthesiologists (ASA) score, preoperative C-reactive protein (CRP), albumin level, body mass index, preoperative waiting time, operative duration, perioperative blood loss, postoperative erythrocyte transfusion, length of postoperative hospitalization, time to mobilization, postoperative intensive care unit admission, and occurrence of deep vein thrombosis (DVT), wound complications, implant failure, decubitus ulcers, and lower urinary tract infection.

Ethics approval was obtained from the Marmara University Institutional Review Board (decision no. 09.2023.262; dated 03.02.2023). Informed consent was obtained from all patients in accordance with institutional requirements for patient and public participation. All procedures complied with the principles of the Declaration of Helsinki.

Patient Management Approach

Upon admission, all patients were provided with air mattresses and anti-embolic stockings. Low-molecular-weight heparin (LMWH) prophylaxis was administered according to current guideline recommendations for conventional FNF management.[14] Following initial evaluation, standard anteroposterior (AP) pelvic radiographs were obtained for all patients in the conventional group, and computed tomography (CT) was performed for fractures extending into the subtrochanteric region. For patients in the metastatic group, pelvic CT and magnetic resonance imaging (MRI) were routinely performed following AP pelvic radiography.[15] Thoracic and abdominal CT imaging was also performed to evaluate the primary malignancy in patients presenting with fracture and a concurrent cancer diagnosis.

Patients in the metastatic group were assessed by a multidisciplinary oncology board to determine surgical planning and adjuvant treatment strategies, including chemotherapy and radiotherapy. In patients with pathological fractures in whom the primary lesion could not be identified and primary bone malignancy was suspected, closed biopsy under fluoroscopic guidance was performed, and definitive surgery was planned after histopathological confirmation. When metastatic involvement and bone lysis extended from the femoral neck into the trochanteric region, reconstruction was performed

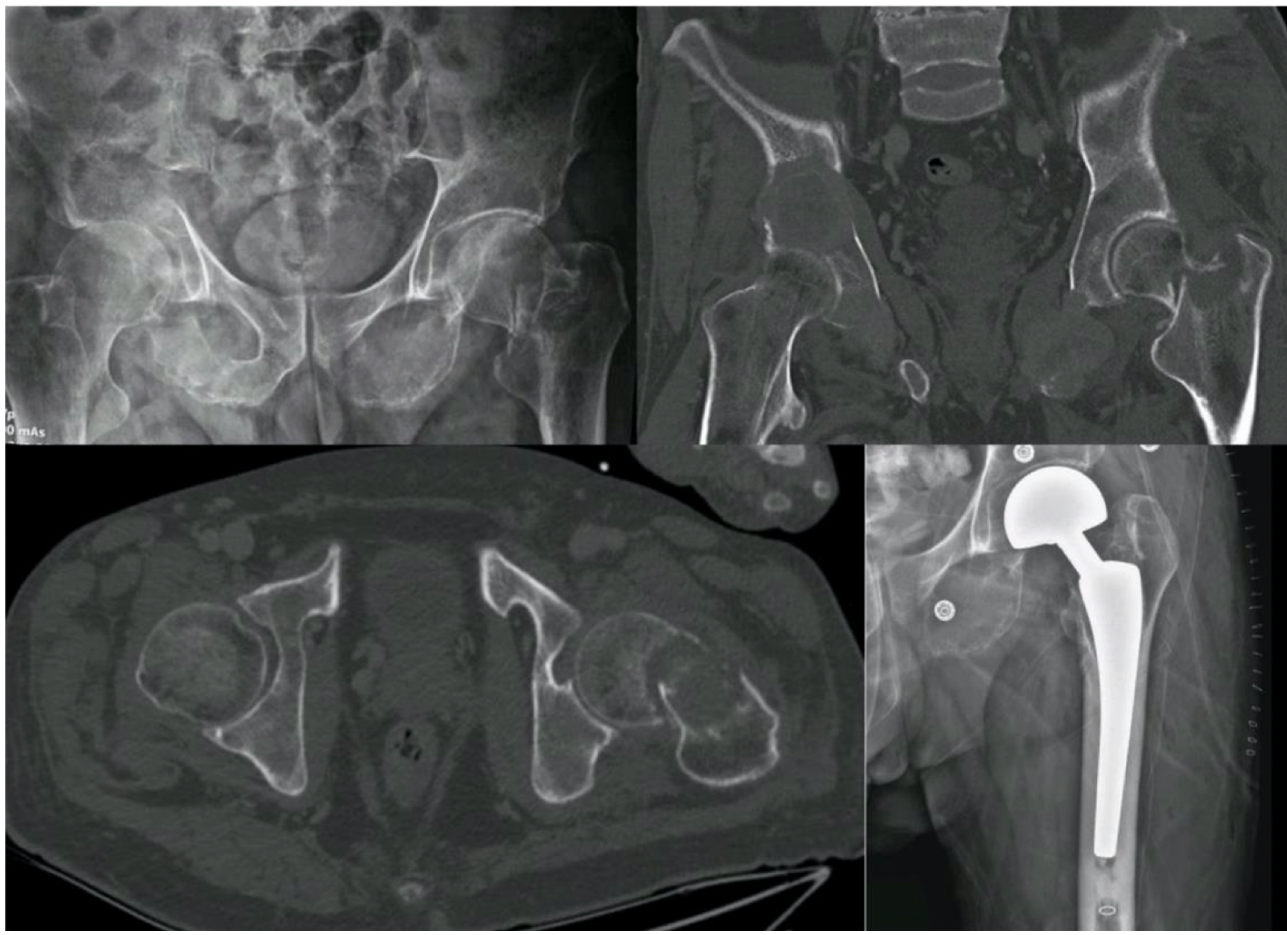

Figure 3. Representative case of a patient diagnosed with sclerosing epithelioid fibrosarcoma who underwent reconstruction with hemiarthroplasty.

using a resection prosthesis (Fig. 2). In patients without radiological evidence of metastatic extension, reconstruction was performed with hemiarthroplasty (HA), similar to the approach used for conventional FNF patients, and standard trauma surgery protocols were followed (Fig. 3).

Postoperative Evaluation

Postoperative pain control, wound monitoring, urine output assessment, and hemogram testing were routinely performed at the sixth postoperative hour. A hemoglobin level of ≤7 g/dL was considered an indication for postoperative transfusion, whereas transfusion was initiated at a hemoglobin level of <8 g/dL in patients with cardiac symptoms.[14] LMWH prophylaxis was initiated preoperatively, resumed at the 12th postoperative hour, and continued throughout hospitalization in accordance with current guidelines.[14] Hemovac drains were removed when daily drainage output was <50 cc. Postoperative antibiotic prophylaxis with cefazolin was administered for 24 hours.[16] Active and passive quadriceps exercises were initiated for all patients after the 12th postoperative hour, and mobilization with walker support under the supervision of a physiotherapist was planned beginning at 24 hours postoperatively. Patients who were unable to tolerate mobilization received daily physiotherapy-assisted exercises until mobilization was achieved.

Statistical Analysis

Data were analyzed using IBM© SPSS software, version 26 (Chicago, IL, USA). Categorical variables were compared between the conventional and metastatic groups using the Chi-square test. Normality of data distribution was assessed using the Kolmogrov–Smirnov and Shapiro–Wilk tests. The independent samples t-test and one-way analysis of variance (ANOVA) were used to compare variables that met the assumption of normality, whereas the Mann–Whitney U test was used for variables that were not normally distributed. Associations between variables were examined using Pearson and Spearman correlation analyses. Kaplan–Meier survival analysis was performed to evaluate survival according to categorical variables. To identify independent predictors of major postoperative complications (including thromboembolic events and pressure ulcers), multivariable logistic regression analysis was performed. The dependent variable was the presence of major complications (binary outcome). Indepen-

Table 1. Patient characteristics and clinical outcomes

Parameter	Conventional (n=185)	Metastatic (n=71)	p
Age77.4 (8.5)	60.5 (14.3)	<0.001***	
Sex		0.087*	
Female	108 (58.4)	33 (46.5)	
Male	77 (41.6)	38 (53.5)	
BMI		0.719*	
Underweight	7 (3.8)	2 (2.8)	
Normal weight	82 (44.3)	35 (49.3)	
Overweight	51 (27.6)	21 (29.6)	
Obesity class I	44 (23.8)	12 (16.9)	
Obesity class II	1 (0.5)	1 (1.4)	
ASA score			<0.001*
I–II	89 (48.1)	0 (0)	
III	73 (39.5)	59 (83.1)	
IV	23 (12.4)	12 (16.9)	
Anesthesia technique			0.141*
General	126 (68.1)	55 (77.5)	
Regional	59 (31.9)	16 (22.5)	
Preoperative CRP (mg/dL)	21 (6–44.5)	24 (9–64)	0.040**
Preoperative albumin (g/L)	32.7±6.9	30.6±6.8	0.036***
Preoperative waiting time (days)	3 (2–4)	4 (2–8)	<0.001**
Operative duration (min)	112±22	147±37	<0.001***
Perioperative blood loss (cc)	516±299	320±148	<0.001***
Postoperative erythrocyte transfusion	29 (15.7)	30 (42.3)	<0.001*
Postoperative hospital stay (days)	5 (4–8)	9 (7–11)	<0.001**
Time to mobilization (days)	3 (2–4)	3 (2–5)	0.017**
Postoperative ICU admission	73 (39.5)	27 (38)	0.834*
Wound complications	3 (1.6)	2 (2.8)	0.619*
Implant failure	11 (5.9)	4 (5.6)	0.924*
DVT	4 (2.2)	6 (8.5)	0.030*
Decubitus ulcers	9 (4.9)	9 (12.7)	0.029*
Lower urinary tract infection	8 (4.3)	3 (4.2)	0.972*

*Chi-square test (n (%)); **Mann–Whitney U test (median (Q1-Q3)); ***Student's t-test (mean±standard deviation). DVT: Deep vein thrombosis; ICU: Intensive care unit; ASA: American Society of Anesthesiologists; BMI: Body mass index.

dent variables entered into the model included fracture etiology (conventional vs. metastatic), age, time to mobilization (days), and operating time (minutes). Variables were selected a priori based on clinical relevance and previous hip fracture literature. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated. Bonferroni and Tamhane's T2 corrections were applied for analyses requiring post hoc testing. Statistical significance was defined as $p<0.05$ for all analyses.

RESULTS

During the study period, 256 patients who underwent surgical treatment for femoral neck fracture were evaluated. After application of the inclusion and exclusion criteria, 185 patients in the conventional group and 71 patients in the metastatic group were included in the final analysis (Fig. 1).

The conventional group (n=185) consisted predominantly of

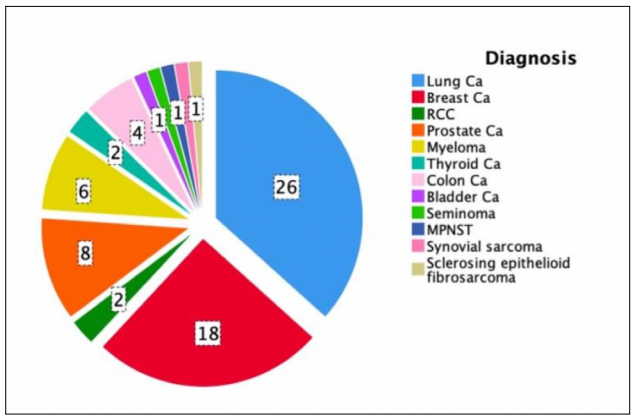

Figure 4. Pie chart showing the distribution of patients according to primary cancer diagnosis.

female patients (p>0.05) and was significantly older than the metastatic group (p<0.001). In contrast, the metastatic group (n=71) demonstrated a balanced sex distribution. Among metastatic patients, the most common primary malignancies were lung cancer (n=26) and breast cancer (n=18), followed by prostate cancer, renal cell carcinoma (RCC), myeloma, thyroid cancer, bladder cancer, seminoma, malignant peripheral nerve sheath tumor (MPNST), colon cancer, synovial sarcoma, and sclerosing epithelioid fibrosarcoma (Fig. 4).

Patients in the metastatic group had higher ASA scores (p<0.001), lower preoperative albumin levels (p=0.036), and higher CRP levels (p=0.040). Preoperative (p<0.001) and postoperative hospital stays (p<0.001) were longer, and time to postoperative mobilization was delayed (p=0.017). Operative duration was longer in the metastatic group (p<0.001), accompanied by greater perioperative blood loss (p<0.001), higher rates of thromboembolic events (p=0.030), and increased postoperative transfusion requirements (p<0.001). Patients in the metastatic group were also at greater risk of developing pressure ulcers (p=0.029), and survival was significantly shorter among patients who developed pressure ulcers (p<0.001). Additional comparative data are presented in Table 1. Multivariable logistic regression analysis, including fracture group (conventional vs. metastatic), age, time to mobilization, and operating time, demonstrated that metastatic fracture etiology was independently associated with the development of major postoperative complications (OR 4.77, 95% CI 2.07–10.98, p<0.001). Age, time to mobilization, and operating time were not independent predictors.

Within the metastatic group, 40 of 71 patients underwent reconstruction with a resection prosthesis, whereas the remaining 31 patients underwent hemiarthroplasty. The prolonged operative time and increased perioperative blood loss observed in the metastatic group were primarily attributable to patients treated with resection prosthesis. No significant difference in survival was detected between patients treated with hemiarthroplasty (HA) and those treated with tu-

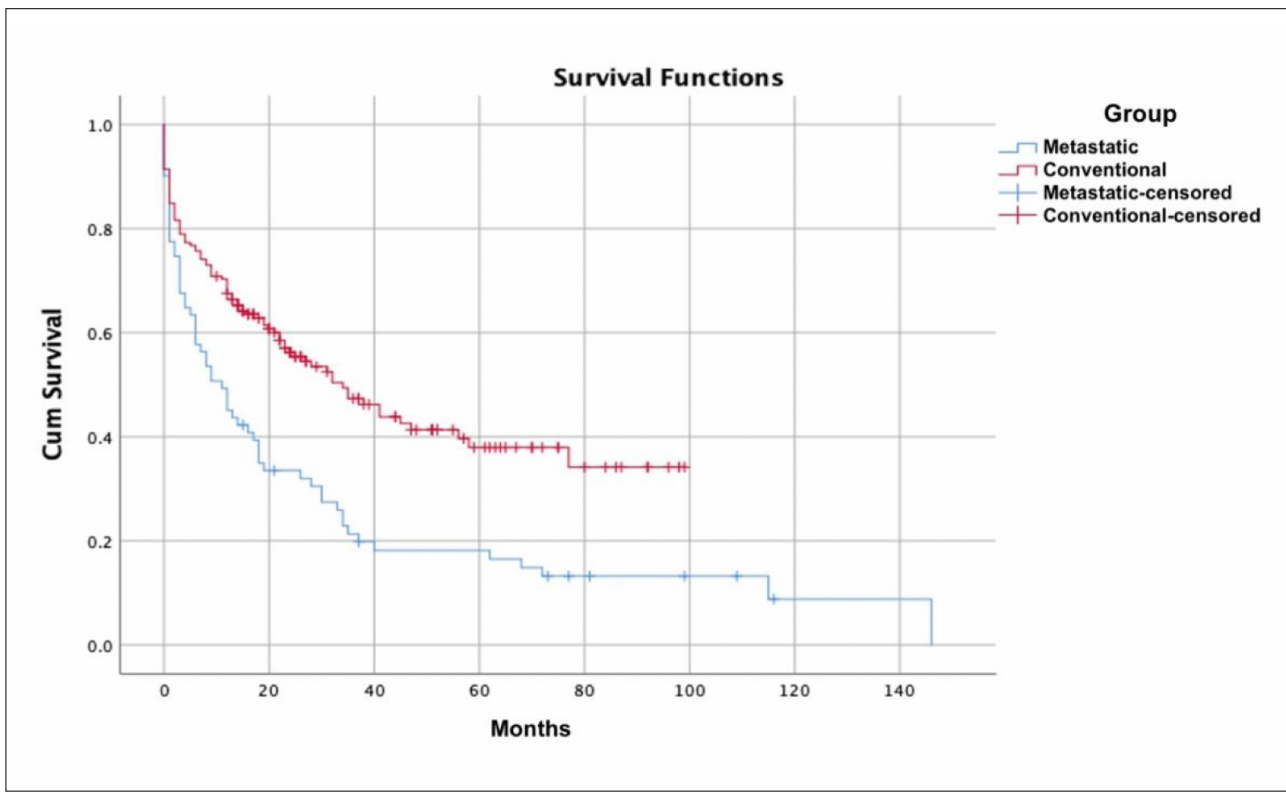

Figure 5. Kaplan–Meier analysis showing cumulative survival distributions of the groups.

mor resection prosthesis (TRP) within the metastatic group (p>0.05). Comparison of survival outcomes between the conventional and metastatic FNF groups demonstrated no significant differences at 1 month or 3 months postoperatively. However, at one year, survival was significantly lower in the metastatic group (p=0.021) (Fig. 5).

DISCUSSION

Although metastatic femoral neck fractures are known to be associated with higher complication and mortality rates than conventional FNF, they remain underrepresented in the literature. The findings of the current study demonstrated that patients with metastatic fractures experienced more postoperative complications, longer hospital stays, and lower survival rates. Based on these findings, treatment algorithms developed for conventional FNF cannot be considered fully appropriate or comprehensive for patients with metastatic FNF.

Unlike many other fracture types, patients with FNF often remain completely immobilized during the preoperative period. Early postoperative mobilization is therefore critical following the additional physiological stress imposed by surgery. In the current study, patients in the metastatic group required a longer time to achieve mobilization and experienced higher rates of DVT and pressure ulcers, both of which have been associated with prolonged immobility.[17] Previous studies have similarly reported increased rates of complications, including thromboembolic events and pressure ulcers, among patients with metastatic femoral neck fractures, emphasizing the combined effects of advanced oncological disease and prolonged immobilization on postoperative outcomes.[4,13] Furthermore, multivariable logistic regression analysis demonstrated that metastatic fracture etiology was an independent predictor of major postoperative complications, even after adjustment for age, time to mobilization, and operative duration. Patients with metastatic femoral neck fractures had significantly higher risk of complications than those with conventional fractures. In contrast, age, delayed mobilization, and longer operative time were not identified as independent predictors in the adjusted model. These findings suggest that the increased complication rate observed in metastatic patients is primarily related to the underlying oncological disease process rather than perioperative or demographic factors alone. This result supports the concept that patients with metastatic femoral neck fractures represent a distinct high-risk population and may require tailored perioperative management strategies beyond standard hip fracture protocols.

The higher frequency of thromboembolic events in metastatic patients may be explained by both modifiable and non-modifiable mechanisms. The direct adverse effects of adjuvant anticancer therapies may contribute to this increased risk.[18] In addition, direct and indirect activation of the coagulation cascade by circulating cancer cells and the mediators they release further increases thrombotic susceptibility.[19] Therefore, postoperative physiotherapy may need to be implemented more aggressively in metastatic patients, and close monitoring for pressure ulcers should be considered. Combining pharmacological and mechanical methods, including anti-embolism stockings and pneumatic compression devices, may help reduce postoperative complications. Furthermore, LMWH dosing strategies may require reassessment in future studies. Although standard thromboprophylaxis regimens are currently administered according to hip fracture guidelines, recent evidence suggests that cancer patients may remain at elevated thrombotic risk despite guideline-based prophylaxis, highlighting the need for closer surveillance and individualized thromboprophylaxis strategies in patients with metastatic femoral neck fractures.[20,21]

Kim et al.[22] reported that elevated CRP levels in patients with hip fractures were associated with increased mortality. In the current study, lower survival was observed among patients with higher CRP levels in both groups, and patients in the metastatic group had higher CRP values overall. A CRP is a non-specific marker, elevated levels may reflect the burden of the primary malignancy.[23] Consistent with these findings, survival analyses of patients with skeletal metastases have demonstrated that bone involvement is primarily an indicator of advanced-stage disease and reduced life expectancy rather than a fracture-specific prognostic factor.[20,24] Nevertheless, these patients should be monitored carefully for thromboembolic events, nosocomial infections, urinary tract infections, and related complications.

Bone metastasis is generally considered an indicator of advanced-stage cancer. Consequently, patients with end-stage malignancy are often expected to exhibit cachexia.[25] However, contrary to expectations, no significant difference in body mass index (BMI) values was observed between the conventional and metastatic groups in the current study. This finding may reflect earlier diagnosis and treatment resulting from advances in diagnostic techniques.

Despite greater perioperative blood loss and longer operative duration, no significant survival difference was observed between patients in the metastatic group treated with resection prosthesis and those treated with HA. Angelini et al.[4] reported that endoprosthetic reconstruction as a reliable treatment method for proximal femoral metastases.Based on the findings of the current study, resection prosthesis appears to be an appropriate reconstructive option for patients with femoral neck fractures and metastatic extension into the trochanteric region, as it may reduce the risk of prosthetic loosening caused by tumor progression. Moreover, this approach facilitates early weight-bearing, which is critical for functional recovery in this patient population.

In the conventional group, survival decreased significantly as preoperative waiting time increased; however, this association was not observed in the metastatic group. Similarly, Varady et al.[26] reported no correlation between prolonged preoperative waiting time and mortality.It may be recom-

mended that the preoperative waiting period be shortened as much as possible for both groups. However, in patients in the metastatic group, neoadjuvant treatments and oncological follow-up should be completed through a multidisciplinary approach during the preoperative period.

This study has certain limitations, the primary one being its retrospective design. Another limitation is the heterogeneity of primary malignancies among metastatic patients, which prevented subgroup analyses. An additional limitation was the absence of cause-specific mortality data and standardized oncologic prognostic scores, such as the Katagiri classification, precluding the use of competing-risk regression models for survival analysis. In oncologic populations, mortality related to advanced malignancy may act as a competing event and influence survival estimates. Competing-risk approaches may therefore provide additional insight into survival outcomes in metastatic femoral neck fracture patients. Future prospective studies incorporating standardized oncologic prognostic scoring systems and detailed cause-of-death data are needed to enable more robust survival modeling.

The study was conducted at a tertiary orthopedic oncology center that serves both as a regional referral center for trauma patients and a national referral center for bone and soft tissue malignancies. This referral pattern contributed to the relatively high proportion of metastatic patients within the study population. A major strength of the study is that both surgical procedures and clinical management were performed by the same orthopedic oncology team using standardized treatment approaches, thereby increasing consistency across patient care.

CONCLUSION

Patients undergoing treatment for metastatic femoral neck fractures should be monitored more closely for thromboembolic events and pressure ulcers than patients with conventional FNFs. More intensive postoperative physiotherapy protocols may improve functional recovery and potentially contribute to better survival outcomes. However, additional clinical studies are required to establish standardized treatment strategies for this patient population, particularly in the context of evolving surgical techniques and advances in oncological care accompanying the growing cancer patient population.

Ethics Committee Approval: This study was approved by the Marmara University Institutional Review Board Ethics Committee (Date: 03.02.2023, Decision No: 09.2023.262).

Informed Consent: Informed consent was obtained from all patients in accordance with institutional requirements for patient and public participation.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Aynı lokasyon farklı hastalar: Metastatik ve konvansiyonel femur boyun kırığı hastalarının karşılaştırılması

AMAÇ: Konvansiyonel ve metastatik femur boyun kırıkları (FBK), klinik uygulamada farklı hasta gruplarını oluştursa da, tedavi yönetimi sıklıkla benzer şekilde ilerlemektedir. Güncel kılavuzlar doğrultusunda sistematik yaklaşımlar uygulanmakta, ancak metastatik FBK hastaları genellikle konvansiyonel FBK için planlanmış algoritmalar doğrultusunda tedavi edilmektedir. Bu çalışmanın amacı, konvansiyonel FBK'ye yönelik standart tedavi yönetiminin metastatik FBK hastalarında etkinliğini değerlendirmektir.
GEREÇ VE YÖNTEM: Bu retrospektif çalışmaya, ulusal düzeyde üçüncü basamak bir ortopedi onkoloji kliniğinde endoprotez rekonstrüksiyonu uygulanan 185 konvansiyonel FBK ve 71 metastatik FBK tanılı hasta dahil edilmiştir. Ana değerlendirme ölçütü, hasta ve hastaneye bağlı faktörlerin sağkalım üzerindeki etkisidir. İkincil değerlendirme ölçütleri ise trombotik olaylar, dekübit ülseri gelişimi ve eritrosit replasmanı gerekliliği gibi rutin klinikte karşılaşılan komplikasyonlardır.
BULGULAR: Metastatik FBK grubunda, konvansiyonel gruba kıyasla anlamlı düzeyde daha düşük sağkalım oranı (p=0.021), daha yüksek trombotik olay (p=0.030) ve dekübit ülseri insidansı (p=0.029), daha uzun ameliyat süresi (p<0.001), artmış perioperatif kanama (p<0.001) ve daha fazla eritrosit replasmanı ihtiyacı (p<0.001) gözlendi. Ayrıca, metastatik hastalarda preoperatif ve postoperatif hastanede kalış süresi daha uzun (p<0.001) ve postoperatif mobilizasyona başlama süresi daha geç (p=0.017) olarak belirlendi.
SONUÇ: Konvansiyonel femur boyun kırıkları için ortopedi kliniklerinde oluşturulmuş standart tedavi algoritmaları, daha yüksek komplikasyon oranları ve daha düşük sağkalım ile karakterize metastatik FBK olgularını yeterli düzeyde kapsamamaktadır. Tedavi yaklaşımının bu hasta grubuna özgü olarak şekillendirilmesi gerekliliği ön plana çıkmaktadır.

Anahtar sözcükler: Femur boyun kırığı; metastaz; patolojik kırık.

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ORIGINAL ARTICLE

Is three-dimensional reconstruction really necessary for glenoid version measurement on magnetic resonance imaging in patients with glenohumeral instability?

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ABSTRACT

BACKGROUND: The importance of glenoid version in glenohumeral instability (GHI) has become increasingly recognized. However, it remains unclear whether three-dimensional (3-D) correction of magnetic resonance imaging (MRI) scans provides more accurate glenoid version measurement in patients with GHI. The primary hypothesis of this study was that a statistically significant difference would exist between glenoid version values measured on standard two-dimensional (2-D) axial slices and those measured on 3-D–corrected axial slices.

METHODS: A retrospective analysis of glenoid version measurements was performed in 54 patients (22 females, 32 males) with glenohumeral instability. Measurements were obtained using the Friedman method on standard 2-D axial MRI slices and 3-D–corrected axial MRI slices. Two observers performed each measurement twice. Measurements obtained by each observer were compared using paired t-tests. Measurement reliability was evaluated using intraclass correlation coefficients (ICC).

RESULTS: For observer 1, mean glenoid version values were −0.69°±3.95° and −1.24°±3.94° on standard and 3-D–corrected axial MRI slices, respectively (p=0.16). For observer 2, corresponding values were −2.97°±4.48° and −2.81°±4.92°, respectively (p=0.66). Interobserver reliability was good for both techniques (ICC=0.87 for 2-D and 0.83 for 3-D measurements). Intraobserver reliability was excellent for measurements performed on 2-D slices (ICC=0.95 and 0.97) and ranged from good to excellent for measurements performed on 3-D–corrected slices (ICC=0.86 and 0.98).

CONCLUSION: The findings of this study suggest that 3-D correction may not be necessary for glenoid version measurements performed on MRI in patients with glenohumeral instability. Multicenter studies with larger patient populations should be conducted to enhance the clinical relevance of these findings.

Keywords: Glenohumeral instability; magnetic resonance imaging (MRI); three-dimensional correction.

INTRODUCTION

The importance of glenoid version in patients with glenohumeral arthritis (GHA) is well established;[1-3] however, its relationship with glenohumeral instability (GHI) and labral injuries (LI) has only recently gained attention.[4-6] Several studies have reported that increased retroversion may be an important risk factor for posterior GHI.[4-8] In a study by Privitera et al.,[6] patients with posterior labral tears demonstrated 5° greater retroversion compared with controls. In

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contrast, the role of glenoid version in anterior GHI remains controversial.[6-9] Some studies have reported that decreased retroversion is associated with anterior GHI,[9-10] whereas others have found no association.[6-11] Accurate measurement of glenoid version may play an essential role in treatment selection for these conditions.[4] If excessive glenoid anteversion is accurately identified, procedures such as remplissage in combination with arthroscopic Bankart repair or the Latarjet procedure may be considered in cases of anterior glenohumeral instability with subcritical bone loss. Likewise, identifying excessive retroversion is clinically important, as it may predispose patients to recurrence following isolated soft-tissue repair and indicate the need for bony realignment procedures, such as osteotomy or bone block procedures.

Magnetic resonance imaging (MRI) is frequently used to evaluate patients with GHI and LI.[14,15] MRI also offers the advantage of avoiding ionizing radiation exposure. Owing to its widespread use and favorable safety profile, this study focused on MRI-based assessment. To date, the agreement and intraobserver/interobserver reliability of glenoid version measurements obtained from standard axial MRI slices and 3-D–corrected axial MRI slices have not been investigated. Therefore, the aims of this study were: (1) to compare glenoid version measurements obtained from standard 2-D axial slices and 3-D–corrected axial slices, and (2) to compare the intraobserver and interobserver reliability of these measurement techniques. The primary hypothesis was that a statistically significant difference would exist between glenoid version values measured on standard 2-D axial slices and 3-D–corrected axial slices. The secondary hypothesis was that intraobserver and interobserver reliability would differ significantly between the two techniques, indicating whether one method provides greater repeatability and consistency than the other.

MATERIALS AND METHODS

Patients

This study received approval from the Acıbadem University Institutional Ethics Committee (Date: 29.07.2022, Decision no: 2022-12/19) and was conducted in accordance with the ethical principles of the Declaration of Helsinki. Shoulder MRI examinations from 62 patients diagnosed with glenohumeral instability at a single institution over a two-year period were retrospectively reviewed. Written informed consent had been obtained from all patients prior to inclusion. Inclusion criteria consisted of a diagnosis of anterior or posterior GHI. GHI was defined based on patient history, clinical examination findings, and confirmatory MRI findings. Exclusion criteria included previous instability surgery, neurological conditions associated with shoulder abnormalities, significant glenohumeral arthritis, a history of glenoid or scapular fracture, presence of a glenoid bone defect, and MRI studies in which the medial border of the scapula was not adequately visualized for accurate evaluation (Table 1). A sample size analysis was performed assuming detection of a minimum difference of 1.5° between the two methods, with a standard deviation of 4° based on clinical experience. With a significance level (α) of 0.05 and statistical power ($1-\beta$) of 0.8, the required sample size was calculated as 54 patients. An additional sample size analysis for comparison of reliability using a point-biserial correlation model t-test, with α=0.05 and power=0.8, indicated a minimum requirement of 37 patients. Therefore, inclusion of 54 patients was considered sufficient for analysis. The final study cohort consisted of 22 females and 32 males with a mean age of 44.96±13.46 years (range, 16–63 years) (Table 2). Of these, 48 patients had anterior GHI and six had posterior GHI (Table 2).

All images were acquired at the same institution using the same MRI system and a standardized shoulder imaging protocol. MRI examinations were performed using a Siemens Magnetom Vida 3T system running syngo MR XA60 software (Siemens Healthcare, Erlangen, Germany). Images were obtained with a 3-mm slice thickness and no interslice gap. This slice thickness represents a standard musculoskeletal shoulder imaging parameter that provides an optimal balance between high resolution and signal-to-noise ratio.[14] This configuration is important for minimizing partial volume averaging effects, thereby improving visualization of the glenoid rim and increasing measurement accuracy. Measurements were performed on axial PD FAT-SAT (proton density fat-saturated) sequences.

Table 1. Inclusion and exclusion criteria for study participation

Inclusion criteria	Exclusion criteria
Diagnosis of anterior GHI	Previous surgery for GHI
Diagnosis of posterior GHI	Significant glenohumeral arthritis
Clinical history consistent with instability (recurrent dislocation, subluxation, or apprehension)	History of glenoid or scapular fracture
Positive physical examination findings for instability (e.g., apprehension test)	Presence of glenoid bone defect
MRI confirmation of labral, capsular, or bony injury	

GHI: Glenohumeral instability.

Table 2. Characteristics of the study population

	Data
Patients, n	54
Age, (range), years	44.96 (16–62)
Sex, n	
Female	22
Male	32
Side, n	
Left	24
Right	30
GHI, n	
Anterior	48
Posterior	6

n: Number; SD: Standard deviation.

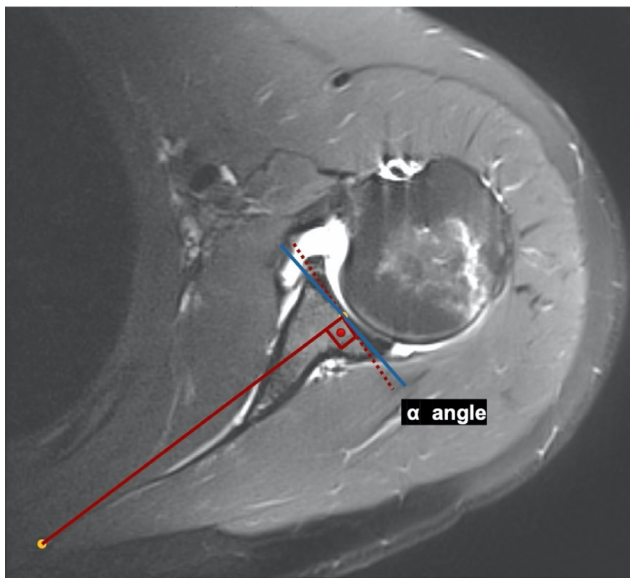

Figure 1. Measurement of glenoid version on an axial magnetic resonance imaging (MRI) slice using the Friedman method. The blue solid line represents the glenoid articular line, connecting the most prominent points of the anterior and posterior glenoid rims. The red solid line represents the scapular axis line, drawn from the midpoint of the glenoid articular line toward the medial border of the scapula. The glenoid version is measured as the angle between the glenoid articular line and a line perpendicular to the scapular axis line at the glenoid midpoint (red dotted line).

Assessment

Measurements were performed on standard 2-D and 3-D corrected axial slices by two surgeons with six and nine years of experience in shoulder surgery, respectively, using standard angle measurement tools and the Friedman method[16] in Horos v4.0.0 RC4, an open-source medical image viewer (The Horos Project; horosproject.org). The glenoid version was measured as the posterior angle between the Friedman line and a line parallel to the glenoid fossa joint surface, minus 90° (Fig. 1). Standard 2-D axial slices were selected immediately inferior to the coracoid process, as originally described by Friedman et al.[16] The 3-D corrected axial slices were generated through multiplanar reconstruction (MPR), with the measurement plane defined as perpendicular to the scapular plane and passing through both the center of the glenoid fossa surface and the medial pole of the scapular spine, based on adjustments in coronal and sagittal views (Fig. 2).[17] To clarify the generation of the 3-D corrected axial slice used for measurement (Fig. 3), a standardized MPR protocol was applied using RadiAnt DICOM Viewer (Version 2021.1; Medixant, Poznań, Poland). The procedure began in the coronal plane (Panel 3, Fig. 3), where a reference slice demonstrating both the glenoid articular surface and the acromion was selected. In this plane (Fig. 3), one axis (blue) was aligned parallel to the glenoid surface, while the second axis (yellow) was positioned perpendicular to it. Next, adjustments were performed in Panel 2 (Fig. 3). The primary axis (pink) was carefully aligned to bisect the pear-shaped glenoid surface. The yellow axis was then positioned slightly inferior to

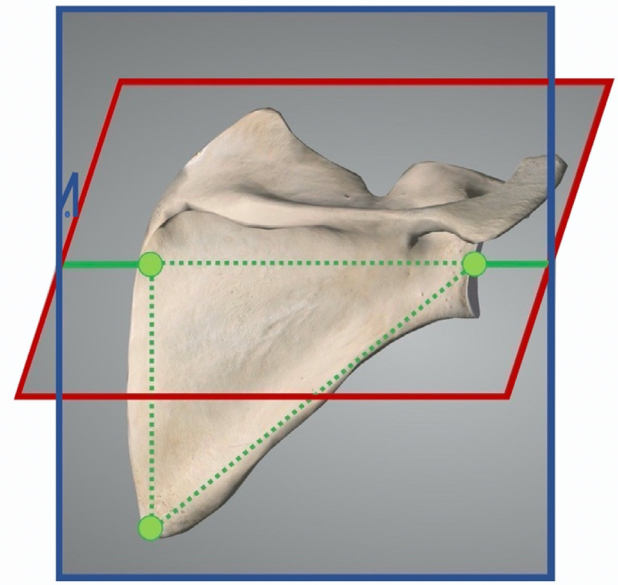

Figure 2. Principles of reconstruction of 3-D corrected slices. The scapular plane is defined using three reference points (green): the center of the glenoid, the inferomedial pole of the scapula, and the medial end of the scapular spine (forming the triangle indicated by the green dotted lines). The plane defined by these landmarks is shown within the blue frame. A second plane, including the scapular axis and perpendicular to the scapular plane, is reconstructed as the 3-D corrected slice (plane outlined by the red frame). The scapular axis is defined by lines connecting the center of the glenoid surface, the medial end of the scapular spine, and the inferior end of the scapular body (green solid lines).

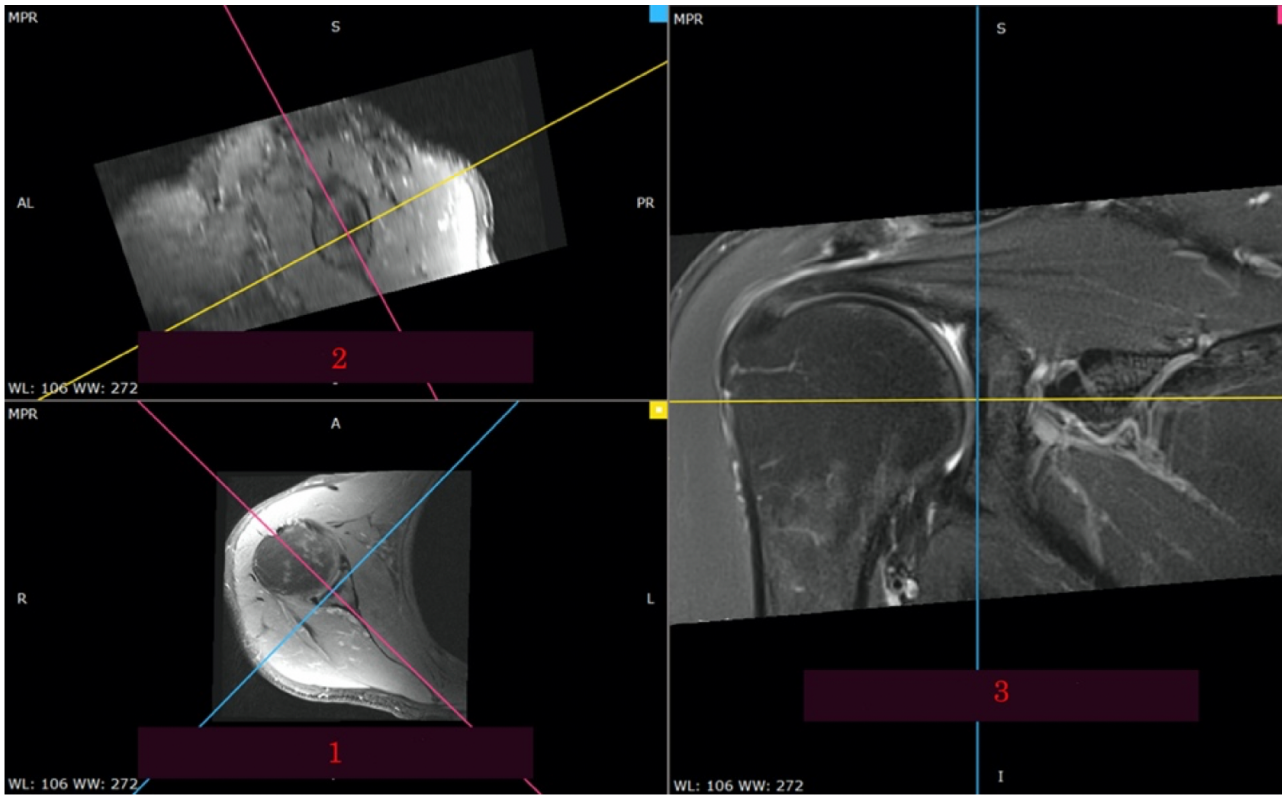

Figure 3. Generation of the standardized 3-D corrected axial slice using the multiplanar reconstruction (MPR) technique for glenoid version measurement. First, a reference section is selected in the coronal plane (Panel 3), where both the glenoid surface and acromion are clearly visualized, and the axes are aligned. Next, in the second plane (Panel 2), the axes are adjusted to align with the center of the glenoid. Through systematic fine-tuning across these planes, the final 3-D corrected axial plane (Panel 1) is generated, and all subsequent glenoid version measurements are performed on this plane.

the midpoint. This step ensured that the resulting axial slice passed through the true center of the glenoid and prevented superior or inferior tilt (Fig. 3). The combined adjustments made in Panels 2 and 3 produced the final 3-D corrected axial measurement plane (Panel 1, Fig. 3). In this reconstructed plane, the blue axis was expected to run parallel to the anterior glenoid rim, while the pink axis remained perpendicular to it. Additional iterative adjustments between Panels 2 and 3 (Fig. 3) were performed as needed to optimize alignment. All glenoid version measurements were ultimately obtained from this standardized reconstructed slice (Panel 1, Fig. 3).

To evaluate intraobserver reliability, each observer repeated all measurements after a two-month interval. Negative glenoid version values indicated retroversion, whereas positive values indicated anteversion.

Statistical Analysis

Statistical analysis was performed using SPSS (version 26.0; IBM Corp., Armonk, NY, USA). Statistical significance was defined as $p<0.05$. Paired t-tests were used to determine differences in glenoid version values measured on standard 2-D and 3-D corrected slices. For reliability analysis, intraobserver and interobserver agreement were quantified using intraclass correlation coefficients (ICC) based on a two-way random-effects model.[18] ICC values were interpreted as follows: ≥0.90 indicated excellent agreement; 0.75–0.9 indicated good agreement; 0.50–0.75 indicated moderate agreement; and <0.50 indicated poor reliability.[19] Interobserver reliability was assessed by comparing measurements between the two observers. Intraobserver reliability was assessed by comparing repeated measurements obtained by each observer at the two-month interval.

Furthermore, distinct from the reliability analyses, agreement between measurements obtained from standard 2-D MRI slices and 3-D corrected MRI slices was assessed using the Intraclass Correlation Coefficient (ICC) based on a two-way mixed-effects model with absolute agreement for single measurements. This analysis complemented the paired t-test results, which indicated no statistically significant difference between measurements. ICC was calculated separately for each observer's first set of measurements. The same reference intervals were used for interpretation.

RESULTS

For observer 1, the mean glenoid version was −0.69°±3.95°

Table 3. Glenoid versions measurements obtained from 2-D and 3-D corrected slices by each observer

	2-D slices	3-D slices
Observer 1		
First measurement		
Mean (°)†	-0.69	-1.24
Min–Max (°)	-12.8–5.5	-9.9–6.10
SD (°)	3.95	3.94
Second measurement		
Mean (°)	-0.68	-1.32
Min–Max (°)	-17.8–6.5	-17.6–8.9
SD (°)	3.73	4.43
Observer 2		
First measurement		
Mean (°)	-2.97	-2.81
Min–Max (°)	-15.99–8.69	-23.55–7.54
SD (°)	4.48	4.92
Second measurement		
Mean (°)	-2.94	-2.39
Min–Max (°)	-17.52–5	-20.58–8.27
SD (°)	4.28	5.09

2-D: Two-dimensional; 3-D: Three-dimensional; Min: Minimum; Max: Maximum; SD: Standard deviation. †Negative values indicate glenoid retroversion; positive values indicate glenoid anteversion.

Table 4. Interobserver and intraobserver reliability of glenoid version measurements (ICC)†

	2-D slices (95% CI)	3-D slices (95% CI)
Interobserver reliability	0.87 (good)	(0.78–0.92)
	0.83 (good)	(0.70–0.91)
Intraobserver reliability		
Observer 1	0.95 (excellent)	0.86 (good)
Observer 2	0.97 (excellent)	0.98 (excellent)

ICC: Intraclass correlation coefficient. †ICC values were interpreted as follows: ≥0.90=excellent agreement; 0.75–0.9=good agreement; 0.50–0.75=moderate agreement; and <0.50=poor reliability.

on standard 2-D axial MRI slices and −1.24°±3.94° on 3-D corrected axial MRI slices (Table 3). This difference was not statistically significant (p=0.16). For observer 2, the corresponding values were −2.97°±4.48° and −2.81°±4.92°, respectively (Table 4). Likewise, no statistically significant difference was observed (p=0.66).

Interobserver reliability was good for both standard 2-D measurements (ICC=0.87) and 3-D corrected measurements (ICC=0.83) (Table 4). Intraobserver reliability for standard 2-D measurements was excellent for both observers (ICC=0.95 and 0.97, respectively) (Table 4). For 3-D corrected measurements, intraobserver reliability was good for observer 1 (ICC=0.86) and excellent for observer 2 (ICC=0.98) (Table 4).

Additionally, ICC analysis using a two-way mixed-effects model with absolute agreement demonstrated moderate agreement between the 2-D and 3-D methods for observer 1 (ICC=0.734, 95% CI: 0.583–0.836) and good agreement for observer 2 (ICC=0.826, 95% CI: 0.719–0.895).

DISCUSSION

Glenoid version plays an important role in treatment selection and preoperative planning for patients with GHA, and previous studies suggest that 3-D corrected slices may improve measurement accuracy. However, generation of 3-D corrected slices is time-consuming and may require additional software and technical expertise.[2,21] To emphasize the uniqueness of the present study, it is important to compare our GHI cohort with previously studied GHA populations. Patients with GHI differ fundamentally from those with GHA in terms of mean age, glenoid morphology, and preferred imaging modalities. Previous studies advocating 3-D correction, including those by Scalise et al.[12] and Ganapathi et al.,[13] were conducted primarily in patients with GHA, in whom substantial bony deformity may compromise the reliability of 2-D measurements. In contrast, patients in our GHI cohort generally demonstrated preserved glenoid anatomy relative to GHA populations, which may explain why the additional complexity of 3-D correction did not provide meaningful benefit.

Retroversion of the glenoid due to glenoid erosion is commonly observed in patients with GHA.[22] Previous studies have reported mean glenoid version values ranging from -14.3 to -3.98 (range: -52.1 to 8.6) in patients with GHA.[2,16,20] In comparison, reported mean glenoid version values range from -1.6 to -5 (range: -19 to 7) in patients with anterior GHI.[6,9,23] and from -9.5 to -5 (range: -20 to 2) in patients with posterior GHI.[6] In patients with GHA, computed tomography (CT) imaging is commonly performed following X-ray radiographs, and glenoid version measurements are typically obtained from CT images.[24] In contrast, MRI is more frequently used for measurement in patients with GHI.[14,15] Slice thickness in CT imaging generally ranges from 1.25 to 2 mm, whereas MRI protocols for shoulder imaging typically use slice thicknesses of 3–5 mm.[1,25] This difference in slice thickness may influence measurement precision because of partial volume averaging and therefore represents an important limitation when comparing findings across imaging modalities. One possible explanation for the superiority of 3-D

correction reported in previous studies is that 2-D measurements are highly dependent on slice orientation and patient positioning. Additionally, the use of dedicated shoulder coils during MRI acquisition may help maintain a more standardized scapular position, which could partly explain why our findings differ from previous CT-based studies.

In the present study, glenoid version measurements in patients with GHI were compared between standard 2-D axial MRI slices and 3-D corrected axial MRI slices. Contrary to findings from previous CT-based studies in patients with GHA,[12,13] no statistically significant difference was observed between the two measurement methods for either observer. Our findings are consistent with those reported by Eisenhart-Rothe et al.,[23] the only previous study demonstrating that glenoid version measurements obtained using 3-D models were not significantly superior to standard 2-D measurements in patients with GHI. This agreement suggests that, unlike arthritic shoulders where substantial morphologic alteration may justify 3-D correction and result in clinically meaningful differences, the relatively preserved glenoid anatomy in GHI may allow standard 2-D measurements to provide sufficient accuracy for routine evaluation. Accordingly, our original hypothesis was rejected. Eisenhart-Rothe et al.[23] reported mean glenoid version values of 4.2°±2.4° using standard 2-D measurements and 4.4°±2.1° using 3-D models in patients with traumatic GHI. However, an important methodological difference should be noted. In the present study, measurements obtained from standard 2-D MRI slices were directly compared with measurements obtained from 3-D corrected MRI slices, whereas Eisenhart-Rothe et al.[23] compared 2-D measurements with measurements generated from virtual 3-D models. Furthermore, similar intraobserver and interobserver reliability values were observed for measurements performed on both standard 2-D and 3-D corrected slices (Table 3). Agreement analysis also demonstrated sufficient concordance to suggest that measurements obtained from 2-D axial slices and 3-D corrected axial slices may be used interchangeably.

This study has several limitations. First, its retrospective design introduces the possibility of selection bias. Because all data were obtained from a single medical center, referral bias may also be present, potentially resulting in overrepresentation of specific subsets of patients with GHI and limiting the generalizability of the findings. Second, only two observers participated in the measurements, and both were shoulder and elbow surgeons rather than musculoskeletal radiologists. Nevertheless, these measurements are frequently performed by orthopedic surgeons in routine clinical practice. One strength of this study is that it includes the largest patient cohort evaluated for this topic to date. In addition, sample size analysis was performed before study initiation to minimize issues related to insufficient statistical power. Future studies with larger populations are needed to validate these findings and further explore potential subgroup differences within patients with GHI. It should also be emphasized that the present study was conducted exclusively in patients with GHI. Significant differences between measurements obtained using 3-D correction and standard 2-D slices may be more likely in patients with GHA, in whom glenoid erosion and retroversion are typically more pronounced. Further investigation in this population is therefore required. As one of the initial MRI-based studies addressing this question, the findings should be confirmed by future studies.

CONCLUSION

This study demonstrates that glenoid version measurements obtained from standard 2-D MRI slices and 3-D corrected MRI slices yield comparable results. Neither method demonstrated superior reliability. Therefore, 3-D correction may not be necessary for obtaining accurate and reliable glenoid version measurements on MRI in patients with glenohumeral instability.

Ethics Committee Approval: This study was approved by the Acıbadem University Institutional Ethics Committee (Date: 29.07.2022, Decision No: 2022-12/19).

Peer-review: Externally peer-reviewed.

Informed Consent: Written informed consent was obtained.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Glenohumeral instabilitesi olan hastalarda manyetik rezonans görüntülemede glenoid versiyon ölçümü için 3-boyutlu rekonstrüksiyon gerçekten gerekli mi?

AMAÇ: Glenohumeral instabilitede (GHİ) glenoid versiyonun önemi giderek daha iyi anlaşılmaktadır. Ancak, manyetik rezonans görüntüleme (MRG) görüntülerinde yapılan üç boyutlu (3-B) düzeltmenin GHİ hastalarında daha doğru bir glenoid versiyon ölçümü sağlayıp sağlamadığı bilinmemektedir. Bu çalışmanın temel hipotezi, standart 2 boyutlu aksiyel kesitlerde ve 3 boyutlu düzeltilmiş aksiyel kesitlerde ölçülen glenoid versiyon değerleri arasında istatistiksel olarak anlamlı bir fark olacağıdır.

GEREÇ VE YÖNTEM: Glenohumeral instabilitesi olan 54 hastanın (22 kadın, 32 erkek) glenoid versiyon ölçümleri retrospektif olarak incelendi. Ölçümler, iki gözlemci tarafından, standart 2-B aksiyel MRG kesitleri ve 3-B düzeltilmiş aksiyel MRG kesitleri üzerinde Friedman metodu kullanılarak ikişer kez yapıldı. Her gözlemcinin ölçtüğü değerler eşleştirilmiş t-testi ile karşılaştırıldı. Ölçümlerin güvenilirliği sınıf içi korelasyon katsayısı (SKK) testi ile değerlendirildi.

BULGULAR: Birinci gözlemci için standart ve 3-B düzeltilmiş aksiyel MRG kesitlerinde ölçülen ortalama glenoid versiyon değerleri sırasıyla −0.69°±3.95° ve −1.24°±3.94° idi (p=0.16). İkinci gözlemci için bu değerler sırasıyla −2.97°±4.48° ve −2.81°±4.92° idi (p=0.66). Gözlemciler arası güvenilirlik her iki yöntem için de iyi düzeydeydi (2-B için SKK= 0.87 ve 3-B için SKK=0.83). Gözlemci içi güvenilirlik, 2-B kesitlerde yapılan ölçümler için mükemmel (SKK=0.95 ve 0.97), 3-B düzeltilmiş kesitlerde yapılan ölçümler için ise iyi-mükemmel düzeydeydi (SKK=0.86 ve 0.98).

SONUÇ: Bu çalışmada elde edilen bulgular, glenohumeral instabilitesi olan hastalarda MRG ile yapılan glenoid versiyon ölçümlerinde 3-B düzeltmenin gerekli olmayabileceğini düşündürmektedir. Daha güçlü bir klinik geçerlilik sağlamak için daha geniş hasta örneklemleri içeren çok merkezli çalışmalar planlanmalıdır.

Anahtar sözcükler: Glenohumeral instabilite; manyetik rezonans görüntüleme; üç boyutlu düzeltme.

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ORIGINAL ARTICLE

Intermediate screw placement improves initial radiographic alignment but not clinical outcomes following long-segment fixation for thoracolumbar fractures

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ABSTRACT

BACKGROUND: The role of intermediate screws in long-segment posterior fixation for thoracolumbar fractures remains controversial. This study aimed to evaluate their effectiveness in improving alignment, maintaining correction, and reducing complications.

METHODS: This retrospective comparative study included 91 patients with unstable thoracolumbar burst fractures (T11–L2) treated between 2014 and 2022. Patients were divided into two cohorts: Group A (n=61), who underwent long-segment fixation with intermediate screws inserted at the fracture level, and Group B (n=30), who received conventional fixation. Radiological outcomes, including vertebral compression angle (VCA) and anterior/posterior vertebral body height (ABH/PBH), intraoperative parameters (operative time and fluoroscopy use), clinical pain scores assessed using the Visual Analog Scale (VAS), and complications were analyzed. Statistical comparisons were performed using t-tests and chi-square tests.

RESULTS: Both groups demonstrated significant postoperative improvements in VCA and vertebral body height ($p<0.0001$). Group A achieved superior early correction of VCA compared with Group B (4.78°±3.47 vs. 6.82°±4.02, $p=0.014$), and this difference remained significant at the two-year follow-up (5.67°±3.08 vs. 8.59°±3.76, $p=0.0005$). Although correction loss was lower in Group A (1.22°±1.13 vs. 1.95°±2.12, $p=0.122$), the difference was not statistically significant. Group A required longer operative times (160.25±19.4 vs. 150.17±26.9 minutes, $p=0.044$) and greater fluoroscopy exposure (26.38±2.3 vs. 20.00±2.13, $p<0.001$). No significant differences were observed between groups in preoperative or follow-up VAS scores ($p>0.05$).

CONCLUSION: Placement of intermediate screws in long-segment constructs was associated with significantly enhanced restoration and maintenance of radiographic alignment in patients with thoracolumbar fractures, although it required longer operative time and increased fluoroscopy use. Clinical pain outcomes were comparable between groups. These findings suggest that intermediate screw placement may provide biomechanical and radiographic advantages in selected cases where optimal anatomical restoration is prioritized. This technique was associated with improved initial and long-term radiographic alignment, at the cost of longer operative time and greater radiation exposure, but did not improve pain outcomes. However, the non-random assignment of patients according to surgeon preference should be considered when interpreting these results.

Keywords: Intermediate screw; internal fracture fixation; long-segment instrumentation; pedicle screws; spinal fractures; thoracolumbar vertebrae.

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INTRODUCTION

Vertebral fractures resulting from high-energy trauma are a major cause of global morbidity and are associated with neurological deficits in 20% of cases.[1-3] The thoracolumbar junction (T11–L2) is particularly susceptible to injury, accounting for more than half of all spinal fractures because of its biomechanical transition between the spinal segments.[4-6]

Classification systems such as the Thoracolumbar Injury Classification and Severity Score (TLICS) guide treatment decisions, with surgical intervention commonly recommended for patients with a TLICS score ≥4 to prevent instability and neurological deterioration.[7-11] Among surgical options, posterior fixation has become increasingly favored over anterior or combined approaches because of its technical feasibility, shorter operative time, and lower intraoperative blood loss. Nevertheless, consensus regarding the optimal instrumentation strategy remains lacking.[2-4,6,12-15] Long-segment posterior fixation remains a standard treatment for unstable thoracolumbar fractures; however, the role of intermediate screw placement at the fracture level remains controversial. Biomechanical studies suggest that inserting screws into the fractured vertebra enhances construct stability and promotes a more favorable distribution of mechanical stress, potentially reducing excessive loading of adjacent segments.[16-19] The biomechanical function of intermediate screws differs according to construct length. In short-segment fixation, the screw acts as a central fulcrum that generates a lordotic moment and facilitates direct reduction of kyphotic deformity.[20,21] In long-segment constructs, however, the mechanical role extends beyond deformity correction. Because longer constructs are subjected to greater lever arms and mechanical forces, fracture-level screws may provide dual benefits: enhancing corrective lordotic forces through a fixed pivot point and improving long-term stability by increasing load-sharing across the fracture site. This may reduce stress concentration at terminal screws, which is considered an important mechanism of implant failure.[22] Despite these biomechanical advantages, clinical evidence supporting intermediate screw placement in long-segment constructs remains scarce, as existing studies have largely focused on short-segment fixation.

Therefore, this study aimed to evaluate the radiographic and clinical effectiveness of incorporating intermediate screws into long-segment posterior fixation for thoracolumbar fractures. We hypothesized that this technique would provide superior immediate postoperative alignment correction (primary radiographic outcome) and reduce correction loss during follow-up (secondary radiographic outcome) compared with conventional long-segment fixation without fracture-level screws. Clinical outcomes, including pain scores, were also evaluated. To our knowledge, this is the first clinical study directly comparing these specific surgical approaches and provides evidence that may inform best practices in the management of this common injury.

MATERIALS AND METHODS

Study Design and Participants

This retrospective cohort study was conducted at the Departments of Orthopedics and Traumatology of two university hospitals in Izmir. The study population consisted of consecutive eligible patients who underwent long-segment posterior instrumentation for acute traumatic fractures of the thoracolumbar junction (T11–L2) during the study period. Given the retrospective design, sample size was determined by the consecutive series of eligible patients rather than by prospective power analysis. The study protocol was approved by the institutional Ege University Medical Research Ethics Committee (Date: 09.03.2023, Decision no: 23-3T/45) and conducted in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from all participants.

Inclusion criteria were:

1. Single-level unstable burst fractures classified as AO (Arbeitsgemeinschaft für Osteosynthesefragen) type A3–A4 with a TLICS score ≥4, for which long-segment posterior fixation was the institutional treatment strategy;

2. Surgical treatment performed between March 2014 and April 2022; and

3. A minimum follow-up duration of 24 months.

Exclusion criteria included pathological fractures, previous spinal surgery, and incomplete radiographic records. A total of 91 eligible patients were included. Group A (n=61) underwent fixation with intermediate screw placement (mean age: 40.3±14.7 years), whereas Group B (n=30) underwent conventional long-segment fixation (mean age: 38.9±15.1 years). Demographic and clinical variables, including age, sex, mechanism of injury, AO classification, fracture level, and American Spinal Injury Association (ASIA) Impairment Scale scores, were recorded (Table 1).

Surgical Technique

All procedures were performed under general anesthesia by one of two senior spine surgeons, each with more than 10 years of specialized experience. A standardized posterior midline approach was used, with the incision centered over the fractured vertebra.[23,24] In both groups, pedicle screws were inserted two vertebral levels above and below the fractured segment and connected using pre-contoured titanium rods from the same implant system (Instinct®Java® Spinal Fixation System, Zimmer).

The diameter and length of the pedicle screws used in the upper and lower instrumented vertebrae were determined based on preoperative computed tomography (CT) measurements to ensure bicortical purchase, with screw lengths typically ranging from 45 to 55 mm. For intermediate screws placed at the fracture level in Group A, screw length was determined using the average screw length of the adjacent

instrumented vertebrae, supplemented by direct preoperative CT-based assessment. This strategy intentionally favored shorter screws (typically 40–50 mm) to reduce the risk of anterior cortical penetration in the compromised vertebral body. All screws were inserted using a free-hand technique, and final placement was confirmed intraoperatively using fluoroscopy.

Patients were allocated into two cohorts according to instrumentation technique. Group A (intermediate screw group) received bilateral intermediate screws inserted into the pedicles of the fractured vertebra. Group B (control group) underwent conventional long-segment fixation without fracture-level instrumentation. Group assignment was non-randomized and reflected surgeon preference and routine practice. Surgeon 1 consistently utilized the intermediate screw technique (Group A), whereas Surgeon 2 consistently performed the conventional technique (Group B), thereby maintaining clear separation between the two treatment cohorts without crossover of surgical technique.

In this study, long-segment constructs were not routinely revised or shortened; therefore, the intermediate screw was intended to enhance the stability of the definitive construct and potentially reduce long-term stress concentration at the fracture site.

Radiological and Clinical Assessment

Preoperative CT scans and postoperative radiographs were analyzed using Sectra Imaging Software (version 23.1; Sectra AB, Linköping, Sweden). Three blinded orthopedic surgeons independently performed all radiographic measurements.

The following parameters were assessed:

1. Vertebral compression angle (VCA): The angle formed between the superior and inferior endplates of the fractured vertebra (Figs. 1a–c, 2a–c). VCA was selected as the primary radiographic outcome because it directly quantifies deformity within the fractured vertebra while minimizing the influence of compensatory changes in adjacent segments. This parameter therefore provides a precise measure of fracture-level reduction and is consistent with previous studies evaluating vertebral body restoration.

2. Anterior body height (ABH): The distance between the anterosuperior and anteroinferior margins of the vertebral body.

3. Posterior body height (PBH): The distance between

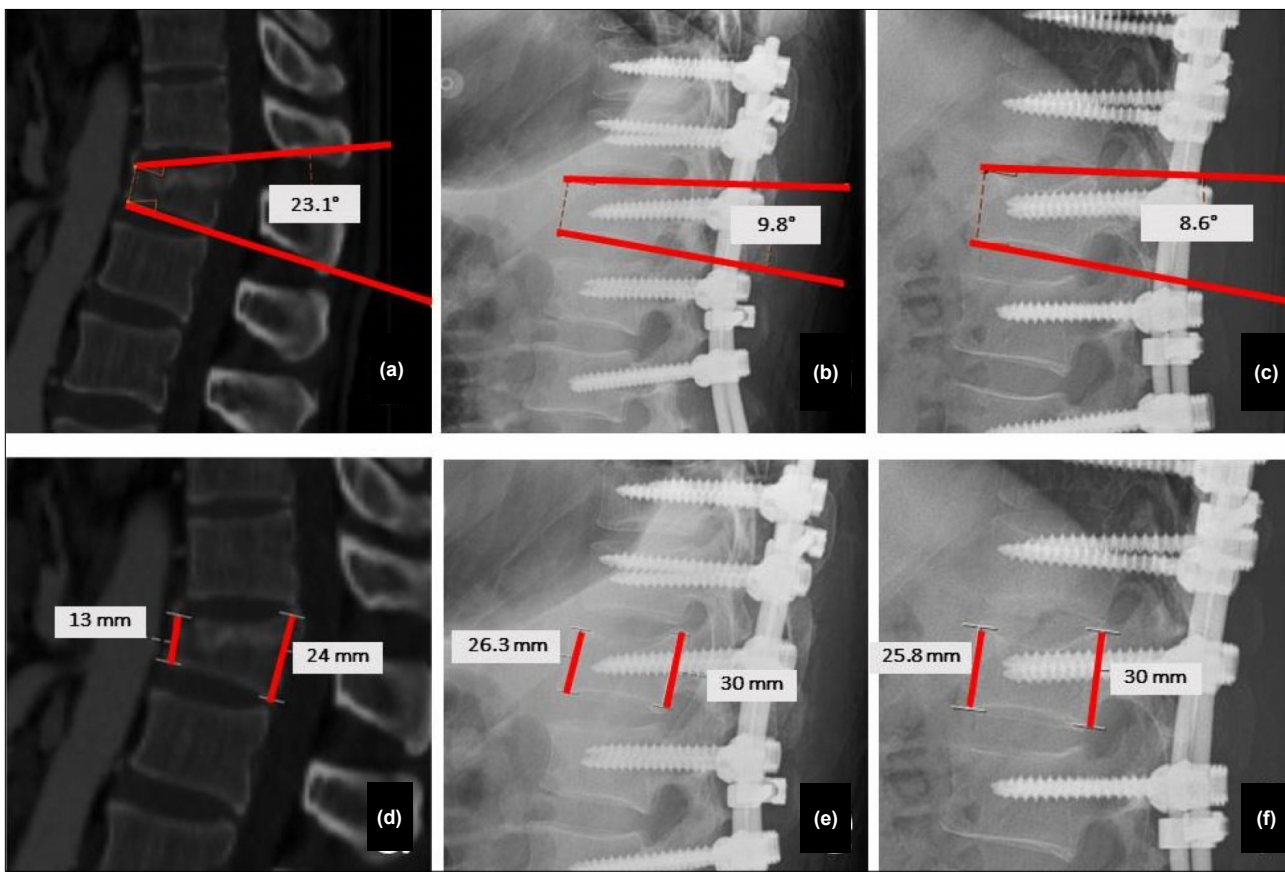

Figure 1. Radiographic measurements in Group A (intermediate screw fixation): **(a–c)** Vertebral compression angle (VCA) measured on lateral radiographs obtained preoperatively, postoperatively (postoperative day 1), and at the 2-year follow-up. **(d–f)** Anterior vertebral body height (ABH) and posterior vertebral body height (PBH) measured preoperatively, postoperatively, and at the 2-year follow-up.

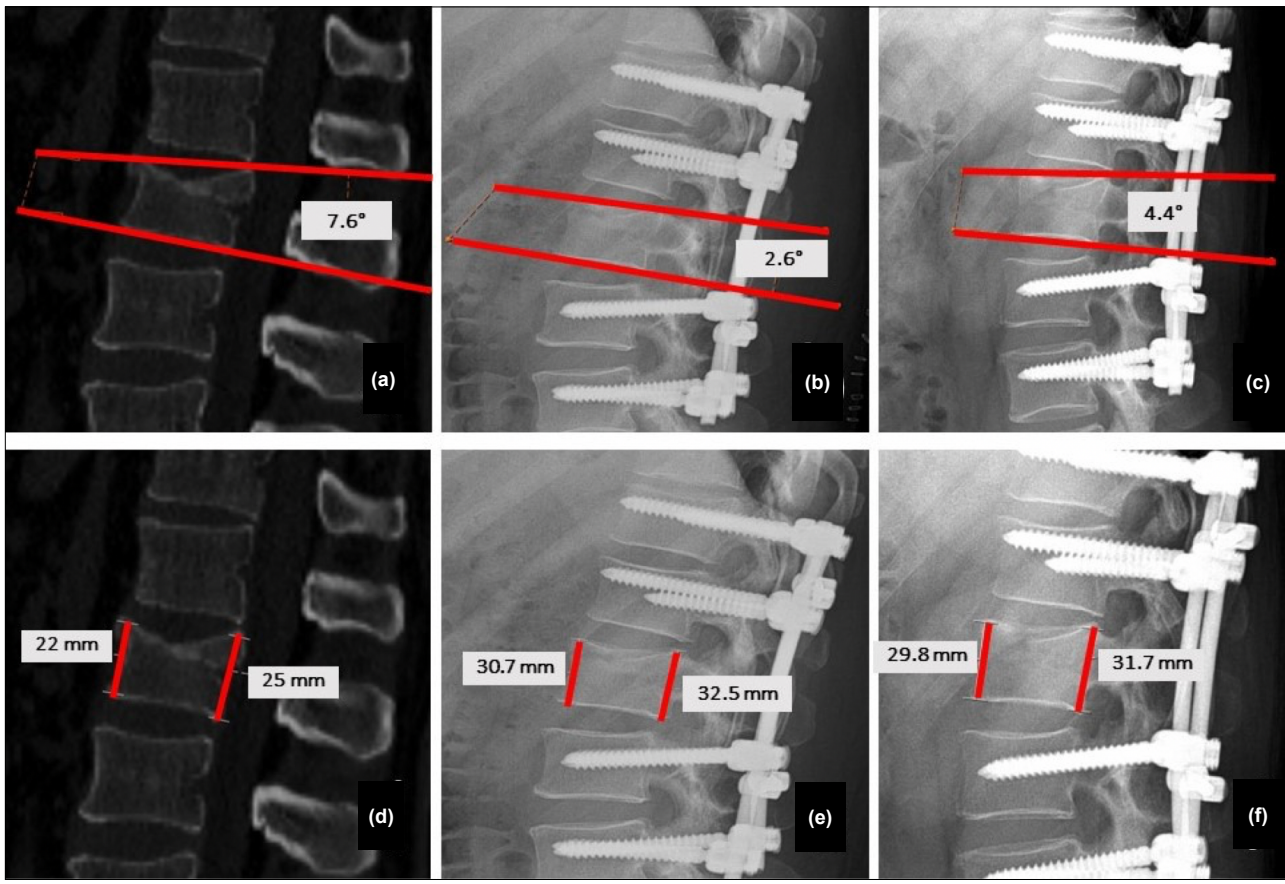

Figure 2. Radiographic measurements in Group B (conventional fixation): **(a–c)** Vertebral compression angle (VCA) measured on lateral radiographs obtained preoperatively, postoperatively (postoperative day 1), and at the 2-year follow-up. **(d–f)** Anterior vertebral body height (ABH) and posterior vertebral body height (PBH) measured preoperatively, postoperatively, and at the 2-year follow-up.

the posterosuperior and posteroinferior margins of the vertebral body (Figs. 1d–f, 2d–f).

Measurements were obtained preoperatively, on postoperative Day 1, and at final follow-up (mean follow-up duration: 44.37 months; range: 24–92 months). Intraoperative variables, including operative time and fluoroscopy exposure, were recorded. Clinical outcomes were assessed using preoperative and postoperative back pain scores measured with the Visual Analog Scale (VAS).

Multivariate linear regression models were used to evaluate continuous outcome variables while adjusting for age, sex, AO fracture classification (types A3–A4), fracture level (T11–L2), and operating surgeon (Surgeon 1 vs. Surgeon 2). For correction loss, dichotomized as ≤2° versus >2°, logistic regression analysis was performed.

Statistical Analysis

Categorical variables (e.g., sex and AO classification) are presented as frequencies and percentages and were analyzed using Pearson's chi-square test or Fisher's exact test. Continuous variables (e.g., VCA, ABH) are reported as mean±standard deviation (SD). Data normality was assessed using the Shapiro–Wilk test. Between-group comparisons were performed using independent-samples t-tests for normally distributed variables and Mann–Whitney U tests for non-normally distributed variables. Longitudinal changes in radiological measurements were analyzed using repeated-measures analysis of variance (ANOVA) with Bonferroni post hoc correction. Interobserver reliability was assessed using the intraclass correlation coefficient (ICC) based on a two-way mixed-effects model with absolute agreement. Linear regression was performed for continuous outcomes, whereas logistic regression was used to evaluate correction loss (categorized as ≤2° vs. >2°). A post hoc power analysis was conducted using G*Power software (version 3.1.9.7) to determine the statistical power to detect observed differences. Analyses were performed for the primary outcome (immediate postoperative VCA) and the principal secondary outcome (VCA correction loss) using the observed effect sizes, sample sizes (Group A: n=61; Group B: n=30), and an alpha level of 0.05. Statistical significance was defined as $p<0.05$. All analyses were performed using IBM SPSS Statistics, version 23.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Demographic and Clinical Characteristics

The study included 91 patients (Group A: n=61; Group B: n=30) with comparable baseline demographic characteristics. No statistically significant differences were observed between groups regarding age (40.3±14.7 vs. 38.9±15.1 years, p=0.679), sex distribution (female: 39.3% vs. 33.3%, p=0.582), mechanism of injury (motor vehicle accidents: 21.3% vs. 26.7%, p=0.647), fracture level (e.g., T12: 29.5% vs. 40%, p=0.206), AO classification (type A3: 62.3% vs. 53.3%, p=0.268), or ASIA Impairment Scale grades (e.g., grade E: 81.9% vs. 86.6%, p=0.808). Follow-up duration was also comparable between groups (43.5 vs. 46.2 months, p=0.266) (Table 1).

Radiological Outcomes

Interobserver reliability for radiological measurements was excellent (ICC range: 0.945–0.962). Both groups demonstrated significant postoperative improvements in VCA and vertebral body height restoration (p<0.0001). However, Group A (intermediate screws) achieved superior postoperative VCA correction compared with Group B (4.78°±3.47 vs. 6.82°±4.02, p=0.014) and maintained better alignment at the two-year follow-up (5.67°±3.08 vs. 8.59°±3.76, p=0.0005). Although VCA correction loss was lower in Group A (1.22°±1.13 vs. 1.95°±2.12, p=0.122), the difference did not reach statistical significance. Post hoc power analysis indicated that the study was underpowered (48%) to detect a statistically significant difference for this specific comparison given the observed effect size. No significant between-group differences were identified in restoration or correction loss of anterior or posterior body height (p>0.05) (Table 2).

Operative Parameters and Complications

Group A required longer operative times (160.25±19.4 vs. 150.17±26.9 minutes, p=0.044) and more greater intraoperative fluoroscopy exposure (26.38±2.3 vs. 20±2.13, p<0.001) (Table 3).

Complication rates were low and comparable between groups. Because of the small number of events, formal sta-

Table 1. Demographic and clinical characteristics of the study groups

Parameter	Group A (n=61)	Group B (n=30)	Statistic	p
Age (years)	40.3±14.7	38.9±15.1	t=0.415	0.679
Sex, n (%)			χ^2=0.520	0.582
Female	24 (39.3%)	10 (33.3%)		
Male	37 (60.7%)	20 (66.7%)		
Mechanism of injury, n (%)			χ^2=0.647	0.647
Motor vehicle accident	13 (21.3%)	8 (26.7%)		
Fall	48 (78.7%)	22 (73.3%)		
Fracture level, n (%)			χ^2=1.754	0.807
T11	6 (9.8%)	2 (6.7%)		
T12	18 (29.5%)	12 (40.0%)		
L1	23 (37.7%)	11 (36.7%)		
L2	14 (22.9%)	5 (16.6%)		
AO classification, n (%)			χ^2=1.268	0.268
Type A3	38 (62.3%)	16 (53.3%)		
Type A4	23 (37.7%)	14 (46.7%)		
ASIA Impairment Scale, n (%)			χ^2=0.754	0.808
Grade A	0 (0%)	0 (0%)		
Grade B	0 (0%)	0 (0%)		
Grade C	3 (4.9%)	1 (3.3%)		
Grade D	8 (13.1%)	3 (10%)		
Grade E	50 (81.9%)	26 (86.6%)		
Follow-up duration (months)	43.5 (24–92)	46.2 (25–90)	t=1.737	0.266

AO: Arbeitsgemeinschaft für Osteosynthesefragen; ASIA: American Spinal Cord Injury Association.

Table 2. Comparison of radiological outcomes between groups

	Group A	Group B	t	p
n	61	30		
Preoperative VCA (°)	12.29±5.7	13.82±5.65	1.2011	0.2329
Postoperative VCA (°)	4.78±3.47	6.82±4.02	2.4948*	0.0144*
VCA at 2-year follow-up (°)	5.67±3.08	8.59±3.76	3.2282*	0.0005*
Loss of VCA correction (°)	1.22±1.13	1.95±2.12	1.4403	0.1223
Preoperative ABH (mm)	15.84±3.84	17.49±4.22	1.8658	0.0654
Postoperative ABH (mm)	25.93±4.3	26.58±3.6	0.7833	0.4356
ABH at 2-year follow-up (mm)	24.22±3.5	24.89±3.8	0.2453	0.8345
Loss of ABH correction (mm)	1.32±1.41	1.76±2.53	1.1233	0.2683
Preoperative PBH (mm)	22.87±3.76	24.53±4.46	1.8560	0.0668
Postoperative PBH (mm)	30.05±3.01	31.42±4.01	1.8219	0.0718
PBH at 2-year follow-up (mm)	29.11±2.82	30.42±2.84	1.8501	0.0652
Loss of PBH correction (mm)	1.40±1.21	1.32±1.99	0.1745	0.8615
Preoperative ABH/PBH ratio	0.69±0.11	0.73±0.19	1.1474	0.2543
Postoperative ABH/PBH ratio	0.86±0.09	0.85±0.11	0.5834	0.5611
ABH/PBH ratio at 2-year follow-up	0.84±0.06	0.81±0.20	1.4790	0.1558

VCA: Vertebral compression angle; ABH: Anterior vertebral body height; PBH: Posterior vertebral body height. *p<0.05.

Table 3. Comparison of intraoperative parameters between groups

	Group A	Group B	p
n	61	30	
Operative time (minutes)	160.25±19.4	150.17±26.9	0.0443*
Fluoroscopy exposures (n)	26.38±2.3	20±2.13	0.0001*

*p<0.05.

tistical comparisons were not performed. Implant failure occurred in two patients (3.2%) in Group A and one patient (3.3%) in Group B. In Group A, one patient developed rod fracture at the fracture level (L1), identified 14 months postoperatively and managed conservatively because the patient remained asymptomatic. Another patient experienced screw breakage at L2 (caudal to the fracture) at 18 months, accompanied by mild back pain without neurological deficit; this case was also managed conservatively. In Group B, implant failure consisted of screw pull-out at the upper instrumented vertebra (T10) following a fall three months after surgery and required surgical revision with construct extension. Superficial surgical site infection occurred in two patients in Group A (3.2%) and resolved with oral antibiotic treatment. No symptomatic screw malposition, dural tears, or postoperative neurological deterioration were observed in either group (Table 4).

Table 4. Postoperative complications

Complication	Group A (n=61)	Group B (n=30)
Implant-related complications, n (%)	2 (3.2%)	1 (3.3%)
Rod fracture	1 (1.6%)	0
Screw breakage	1 (1.6%)	0
Screw pull-out	0	1 (3.3%)
Superficial SSI, n (%)	2 (3.2%)	0
Symptomatic screw malposition, n (%)	0	0
Dural tear, n (%)	0	0
Neurological deterioration, n (%)	0	0

SSI: Surgical site infection.

Table 5. Comparison of changes in Visual Analog Scale (VAS) scores between groups

	Group A	Group B	p
n	61	30	
Preoperative VAS score	7.64±0.66	7.67±0.71	0.8567
VAS score at 2-year follow-up	1.2±0.48	1.1±0.61	0.4091

*p<0.05.

Table 6. Multivariate regression analysis of radiographic and operative outcomes

Outcome	Variable	Adjusted β/OR	95% CI	p
Postoperative VCA (°)	Intermediate screw use	−2.10	−3.52 to −0.68	0.004*
	Age (per decade)	0.12	−0.25 to 0.49	0.521
	AO Type A4 (vs. A3)	1.85	0.94 to 2.76	0.001*
	Surgeon 1 (vs. Surgeon 2)	−0.45	−1.32 to 0.42	0.307
Correction loss (>2°)	Intermediate screw use	0.32	0.14 to 0.72	0.006*
	Fracture level (L1 vs. L2)	1.20	0.85 to 1.69	0.294
	Age (per decade)	1.15	0.97 to 1.36	0.104
Operative time (minutes)	Intermediate screw use	11.25	5.82 to 16.68	<0.001*

β: Regression coefficient (for continuous outcomes); OR: Odds ratio (for correction loss >2°); CI: Confidence interval. *p<0.05.

Clinical Outcomes

Preoperative VAS pain scores were comparable between groups (Group A: 7.64±0.66; Group B: 7.67±0.71, p=0.857). Both groups demonstrated significant reductions in pain at the two-year follow-up; however, differences were observed between groups (Group A: 1.2±0.48 vs. Group B: 1.1±0.61, p=0.4091) (Table 5). No significant correlation was observed between VCA correction and improvement in postoperative VAS scores (r=0.12, p=0.271).

Multivariate Regression Analysis of Radiographic and Operative Outcomes

Multivariate regression analysis adjusted for age, fracture level, AO classification, and surgeon identified intermediate screw placement as an independent predictor of improved radiographic outcomes. Intermediate screw placement was significantly associated with greater immediate postoperative VCA correction (β=-2.10, 95% confidence interval [CI]: -3.52 to -0.68; p=0.004) and lower odds of significant correction loss (>2°) at two-year follow-up (odds ratio [OR]=0.32, 95% CI: 0.14–0.72; p=0.006). Importantly, the association between intermediate screw placement and improved VCA correction remained significant after adjustment for operating surgeons, suggesting that the observed effect was more likely attributable to the instrumentation technique than to inter-surgeon variability.

Notably, multivariate analysis demonstrated that AO type A4 fractures were independently associated with reduced VCA correction (β=1.85, p=0.001), highlighting the inherent difficulty of achieving optimal reduction in severe burst fractures. As detailed in Table 6, intermediate screw placement was independently associated with a statistically significant increase in operative time (β=11.25, p<0.001). Although these findings support potential advantages of the technique, they should be interpreted cautiously because the models cannot fully account for unmeasured confounders or subtle technical differences inherent to individual surgical practice.

DISCUSSION

Principal Findings and Context Within Surgical Practice

Posterior approaches have become the preferred treatment for unstable thoracolumbar fractures because of their technical feasibility and favorable perioperative profile compared with anterior or combined approaches.[2,25-27] Nevertheless, the optimal posterior instrumentation strategy remains debated. This study specifically evaluated the role of intermediate screw placement in long-segment constructs. Although biomechanical studies suggest that fracture-level screws improve construct stability and promote more favorable stress distribution, their clinical value in long-segment fixation has remained largely unexplored compared with their established use in short-segment systems.[16-18,20]

Our findings provide clinical evidence that adding intermediate screws to long-segment posterior fixation is associated with improved restoration and maintenance of VCA. Importantly, multivariate adjustment demonstrated that this association persisted after controlling for operating surgeons, suggesting that the observed radiographic benefit is more likely attributable to the instrumentation technique than to surgeon-related variation. These findings support the biomechanical rationale for intermediate screws, whose role in long-segment constructs appears to be multifaceted. First, they may augment the corrective lordosing moment by acting as fixed pivot points that enable the longer rod to generate a greater moment arm. Second, they may enhance construct stability by anchoring the fracture site, thereby improving load-sharing and reducing stress concentration on the implant.[20-22,28]

Interpretation of Radiographic and Clinical Outcomes

Patients treated with intermediate screws demonstrated significantly better VCA correction both immediately after surgery and at final follow-up, supporting the potential value of this technique for achieving improved initial reduction and maintaining alignment.[29,30] Although the mean difference in VCA correction between groups was approximately 2°, and the isolated clinical significance of this magnitude may be questioned, it nevertheless represents a statistically significant improvement in radiographic alignment. In spinal trauma surgery, where long-term outcomes may depend on the cumulative effect of incremental gains, improved alignment may contribute to overall construct stability. This may be particularly relevant in unstable patterns such as AO type A4 fractures, which were independently associated with reduced correction in our analysis. Regarding long-term alignment maintenance, the intermediate screw group demonstrated a favorable, although not statistically significant, trend toward reduced loss of correction (1.22° vs. 1.95°, p=0.122).[17,31-33] When considered together with the significantly improved final VCA, this trend may reflect a potential biomechanical advantage; however, this finding requires confirmation in larger, adequately powered studies and should be interpreted with caution. These findings should also be interpreted in light of the study's primary methodological limitation. The non-randomized, surgeon-dependent allocation of techniques introduces the possibility of residual confounding. Although multivariate analysis demonstrated that the association between intermediate screw use and improved VCA correction was independent of the operating surgeon, this statistical adjustment cannot fully account for unmeasured technical factors and subtle differences in surgical practice.

One of the most clinically relevant findings of this study was the dissociation between radiographic outcomes and patient-reported pain. Despite improved anatomical alignment, patients treated with intermediate screws did not demonstrate superior VAS scores at follow-up.[30,34,35] This finding highlights the multifactorial nature of pain after spinal trauma, which may be influenced by neurological status, soft tissue injury, and psychosocial factors beyond radiographic correction alone.[36-38] The assessment of long-term stability, measured by the loss of VCA correction, demonstrated a numerical advantage for the intermediate screw group (1.22° vs. 1.95°), although this difference did not reach statistical significance (p=0.122). When considered together with the significantly improved final VCA, this finding may indicate a potential biomechanical advantage that warrants further evaluation in larger, adequately powered studies.

Procedural Trade-offs and Comparative Literature

The improved radiographic outcomes observed with intermediate screw placement were accompanied by increased procedural demands. Intermediate screw placement was associated with longer operative time and greater intraoperative fluoroscopy exposure. These findings are consistent with meta-analyses by Kopaen et al.[39] and Tong et al.,[35] which reported similar increases in surgical duration and resource utilization associated with fracture-level screw placement. These procedural trade-offs may be attributable to the increased technical complexity of the technique, which requires careful surgical exposure and precise pedicle cannulation within a fractured and potentially deformed vertebral body to achieve safe screw placement while avoiding spinal canal violation.

However, evidence regarding these perioperative effects is inconsistent. Li et al.[30] reported no significant difference in operative time, suggesting that surgeon experience and procedural learning curves may substantially influence efficiency. This discrepancy suggests that the procedural burden associated with the intermediate screw technique may not be fixed and could vary according to surgical experience and technical familiarity. With increasing experience and refinement of surgical technique, the additional operative time and fluoroscopy exposure associated with the procedure may potentially be reduced. Therefore, although our findings and several previous studies indicate an initial increase in resource utilization, this should be considered a potential rather than an inherent limitation of the technique.

The biomechanical and clinical rationale for intermediate screw placement is well established in short-segment posterior fixation. In these constructs, the screw's primary function is sagittal realignment; it acts as a fulcrum within a three-point bending system, generating a lordotic moment that facilitates reduction of kyphotic deformity.[20-22] Multiple studies, including randomized controlled trials and systematic reviews, have reported that this approach is associated with improved mechanical stability, lower implant failure rates, and enhanced kyphosis correction compared with conventional short-segment fixation.[16-19,28-31,35,39]

A key contribution of our study is the evaluation of this biomechanical principle within the distinct biomechanical environment of long-segment constructs. These longer instrumentations are subjected to greater lever arms and bending

moments, which may increase stress concentration at the implant–bone interfaces of the terminal vertebrae. In this setting, the role of the intermediate screw may extend beyond functioning as a reduction fulcrum to contributing to load distribution across the construct. By engaging the fractured vertebra, the screw may incorporate it into the load-bearing system and effectively shorten the working length of the instrumentation. This mechanism may improve load-sharing and reduce stress concentration at the terminal screws, a recognized contributor to long-term implant failure. Accordingly, the improved radiographic outcomes observed in this study, including both initial correction and maintenance of alignment, may reflect the combined effects of enhanced reduction and increased construct stability.

By directly comparing long-segment fixation with and without intermediate screws, our study addresses an important and relatively underexplored question in the literature. Previous studies have largely focused on comparisons between short-segment fixation with fracture-level screw augmentation and long-segment fixation without augmentation, making it difficult to distinguish the effects of construct length from those of fracture-level screw placement. Our findings suggest that the potential benefits of fracture-level augmentation may extend to long-segment constructs. These results indicate that intermediate screw placement may provide value independent of construct length and support further investigation into its role across different posterior fixation strategies.

Clinical Implications

This study suggests that intermediate screw placement may improve radiographic outcomes following long-segment posterior fixation for thoracolumbar fractures. Intermediate screw use was independently associated with superior correction and maintenance of vertebral alignment. However, the absence of a concomitant improvement in pain scores and the associated increases in operative time and radiation exposure suggest that improved radiographic alignment alone may not determine clinical success. Therefore, decisions regarding intermediate screw placement should involve careful consideration of fracture morphology, patient characteristics, and available institutional resources. The technique may be particularly relevant in selected cases where restoration and maintenance of anatomical alignment are prioritized, such as severe kyphotic deformity or complex trauma patterns. Future prospective randomized studies incorporating multidimensional functional outcome measures and longer follow-up periods are needed to better define the role of this technique and evaluate its clinical value from the patient's perspective.

Limitations

First, and most importantly, non-randomized surgeon-based allocation introduced the potential for substantial confounding. Surgeon 1 consistently performed intermediate screw fixation, whereas Surgeon 2 consistently performed conventional fixation. Consequently, observed differences may partially reflect differences in surgical execution, experience, or subtle patient selection factors rather than instrumentation strategy alone. Although multivariate analysis adjusted for surgeon variability, this approach cannot fully account for residual confounding related to surgeon-specific practice patterns. Second, clinical outcomes were assessed exclusively using VAS pain scores. Patient-reported functional outcome measures (e.g., Oswestry Disability Index, Short Form-36 [SF-36]) were not available, limiting assessment of whether the observed radiographic improvements translated into meaningful functional outcomes from the patient's perspective. Third, although the minimum follow-up duration was 24 months, the study design precludes evaluation of longer-term outcomes, including adjacent segment degeneration, delayed implant failure, and complications occurring after hardware removal. Fourth, despite adherence to standardized surgical protocols, the involvement of two surgeons may have introduced variability in technical execution and familiarity with intermediate screw placement, potentially influencing outcomes. Finally, potentially relevant variables, including bone density, rehabilitation adherence, and socioeconomic factors, were not systematically evaluated and may have influenced alignment preservation and clinical recovery. Additionally, the retrospective design of this study may have resulted in underreporting of minor or transient complications not documented in the medical records. The modest sample size and absence of an a priori power calculation may further limit generalizability and reduce statistical power for secondary outcomes, including correction loss. Future prospective studies should incorporate multidimensional outcome assessment, longer follow-up periods, and cost-effectiveness analyses to address these limitations.

CONCLUSION

In this comparative study, the incorporation of intermediate screws into long-segment posterior fixation was associated with improved radiographic outcomes in thoracolumbar fractures, including superior initial VCA correction and improved maintenance of alignment at follow-up. These radiographic benefits were accompanied by longer operative duration and greater fluoroscopy exposure. Importantly, improved radiographic alignment did not translate into superior pain outcomes or a statistically significant reduction in correction loss. The most important limitation of this study is the non-randomized, surgeon-specific assignment of the surgical technique, which introduces the possibility of residual confounding. Therefore, although our findings suggest a potential biomechanical role for intermediate screws in optimizing anatomical reduction, the present evidence does not support broad recommendations regarding their routine use. Further prospective, randomized controlled studies incorporating patient-centered functional outcome measures are needed to better define the clinical value of this technique and minimize surgeon-related bias.

Ethics Committee Approval: This study was approved by the Ege University Medical Research Ethics Committee (Date: 09.03.2023, Decision No: 23-3T/45).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Torakolomber kırıkların uzun segment fiksasyonunda ara vidalar başlangıç radyografik hizasını iyileştirmekte ancak klinik sonuçları iyileştirmemektedir

AMAÇ: Ara vidaların torakolomber kırıklarda uzun segment posterior fiksasyondaki yeri halen tartışmalıdır. Bu çalışma, söz konusu vidaların hizalanma düzeltmesini artırma ve komplikasyon oranlarını azaltmadaki etkinliğini değerlendirmektedir.
GEREÇ VE YÖNTEM: Bu retrospektif karşılaştırmalı çalışmada, 2014–2022 yılları arasında tedavi edilen, T11–L2 seviyelerinde yerleşmiş instabil torakolomber patlama kırığı bulunan 91 hasta iki kohorta ayrılmıştır: Grup A'da (n=61) kırık seviyesinde ara vidalar kullanılarak uzun segment fiksasyon uygulanırken, Grup B'de (n=30) konvansiyonel fiksasyon yapılmıştır. Radyolojik sonuçlar [vertebral kompresyon açısı (VKA), anterior/posterior korpus yüksekliği (AKY/PKY)], intraoperatif parametreler (ameliyat süresi, floroskopi kullanımı), klinik ağrı skorları (Görsel Analog Skala [VAS]) ve komplikasyonlar değerlendirilmiştir. İstatistiksel karşılaştırmalarda t-testi ve ki-kare analizleri kullanılmıştır.
BULGULAR: Her iki grupta da ameliyat sonrası dönemde VCA ve vertebra korpus yüksekliğinde anlamlı iyileşme gözlenmiştir (p<0.001). Grup A, erken dönemde daha üstün VCA düzeltmesi sağlamış (4.78°±3.47'ye karşı 6.82°±4.02; p=0.014) ve bu fark 2 yıllık takipte de anlamlılığını korumuştur (5.67°±3.08'e karşı 8.59°±3.76; p=0.0005). Düzeltme kaybı Grup A'da daha düşük olmakla birlikte (1.22°±1.13'e karşı 1.95°±2.12; p=0.122) istatistiksel olarak anlamlı bulunmamıştır. Grup A'da ameliyat süresi daha uzun (160.25±19.4 dakikaya karşı 150.17±26.9 dakika; p=0.044) ve floroskopi kullanım sayısı daha fazla (26.38±2.3'e karşı 20±2.13; p<0.001) olarak saptanmıştır. Preoperatif ve takip VAS skorlarında gruplar arasında anlamlı fark bulunmamıştır (p>0.05).
SONUÇ: Operasyon süresinin ve floroskopi kullanımının artmasına rağmen, uzun segmentli konstrüksiyonlarda ara vida yerleştirilmesi, torakolomber kırıklarda radyolojik hizalanmanın yeniden sağlanmasını ve korunmasını anlamlı iyileşme ile ilişkilendirilmiştir. Klinik ağrı sonuçları benzer olmakla birlikte, tekniğin sunduğu biyomekanik avantajlar, anatomik hassasiyetin önceliklendirildiği olgularda seçici olarak kullanılmasını desteklemektedir. Bu teknik, daha uzun ameliyat süresi ve daha fazla radyasyon maruziyeti pahasına daha iyi erken ve geç dönem radyografik hiza sağlamış, ancak ağrı skorlarında iyileşme sağlamamıştır. Bununla birlikte, sonuçlar yorumlanırken hastaların cerrah temelinde rastgele olmayan şekilde gruplandırılmış olması dikkate alınmalıdır.

Anahtar sözcükler: Ara vida; kırık internal fiksasyonu; pedikül vidaları; spinal kırıklar; torakolomber vertebra; uzun segment enstrümantasyon.

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ORIGINAL ARTICLE

Comparison of nail-plate and double-plate fixation in primary and periprosthetic distal femur fractures in older adults

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ABSTRACT

BACKGROUND: Distal femur fractures in older adults have a one-year mortality rate comparable to that of hip fractures. Similar to hip fracture management, treatment should prioritize early mobilization to reduce morbidity and mortality. Nail-plate combination (NPC) and double-plate combination (DPC) techniques have been proposed to facilitate early mobilization while maintaining low rates of mechanical complications. This study aimed to compare the clinical and radiological outcomes of NPC and DPC in elderly patients with distal femur fractures.

METHODS: Following application of the inclusion and exclusion criteria, 28 patients treated with NPC and 24 patients treated with DPC were included. Clinical records and radiographic images were reviewed using a standardized form. Operative time, intraoperative blood loss, range of motion (ROM), and Lysholm scores were obtained from medical records. Radiographic outcomes included time to union and measurements of the anterior lateral distal femoral angle (aLDFA) and anterior posterior distal femoral angle (aPDFA).

RESULTS: Mean operative time was shorter in the NPC group than in the DPC group (120±22.5 vs. 155±23.75 minutes, p<0.001). Mean intraoperative blood loss was also lower in the NPC group (422.5±115 vs. 640±237.5 mL, (p<0.001). At 3 months postoperatively, ROM was greater in the NPC group than in the DPC group (100±17.5° vs. 80±10°, p<0.001). The mean Lysholm score at 3 months was higher in the NPC group (70±12.5 vs. 68.5±10, p<0.001). Radiographic union time did not differ significantly between groups (12±2 vs. 12±3.5 weeks, p=0.290). There was no significant difference in aLDFA measurements (81±4.75 vs. 81±1.75, p=0.356), whereas aPDFA was greater in the NPC group (85.5±4 vs. 83±2, p<0.001). Immediate postoperative weight-bearing is considered important in elderly patients. Although both dual-implant systems aim to facilitate early mobilization, full weight-bearing is more frequently delayed in the DPC group. Earlier achievement of full weight-bearing in the NPC group may have contributed to the improved early ROM and clinical outcomes observed.

CONCLUSION: Compared with DPC, NPC was associated with shorter operative time, reduced blood loss, earlier full weight-bearing, improved early ROM, and superior clinical outcomes. Although complication and union rates were similar between groups, the advantages observed with NPC may be clinically meaningful.

Keywords: Distal femur; nail-plate combination; osteoporotic fracture; double-plate combination.

INTRODUCTION

Distal femur fractures in patients aged 60 years and older are typically associated with low-energy trauma in the setting of osteoporosis.[1] In the geriatric population, the one-year mortality rate is high and comparable to that observed after hip fractures.[2] Similar to hip fracture management, treatment of distal femur fractures should prioritize early mobilization to

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reduce morbidity and mortality associated with prolonged immobilization.[3,4]

In recent years, dual-implant techniques for osteoporotic distal femur fractures have gained increasing attention.[1] Both nail-plate combination (NPC) and double-plate combination (DPC) techniques have been proposed to reduce mechanical complications and facilitate earlier mobilization. Finite element analyses, biomechanical investigations, and clinical studies have supported the growing use of these approaches in both periprosthetic and native distal femur fractures.[5-9] However, the long-term clinical outcomes and cost-effectiveness of dual-implant systems remain unclear. Moreover, to our knowledge, comparative studies evaluating these two dual-implant techniques are lacking.

We hypothesized that NPC would allow earlier full weight-bearing and consequently result in better early clinical outcomes compared with DPC. Therefore, this study aimed to compare the clinical and radiographic outcomes of elderly patients with distal femur fractures treated with NPC or DPC. To our knowledge, this is the first study to compare these two techniques.

MATERIALS AND METHODS

After obtaining approval from the institutional ethics committee (January 13, 2025; Approval No. 15), all patients who underwent surgical treatment for native or periprosthetic distal femur fractures since 2013 were screened.

The inclusion criteria were age ≥65 years and surgical treatment for either an isolated native distal femur fracture or a periprosthetic distal femur fracture.

Distal femur fractures occurring after primary knee arthroplasty were included because these fractures are managed using similar treatment principles and have comparable clinical outcomes.[8,9] As the purpose of this study was to compare dual-implant systems, the study population was constructed accordingly.

The decision to use NPC or DPC was based on the indications reported by Kontakis MG et al.,[6] although final implant selection remained at the discretion of the operating surgeon. Consistent with previous literature, DPC was preferred for very distal fracture patterns and periprosthetic fractures with closed-box femoral components that precluded intramedullary nailing. Additionally, the interval since the previous knee arthroplasty incision was considered during surgical planning and evaluated according to surgeon preference.

Exclusion criteria included surgical treatment with techniques other than NPC or DPC, AO (Arbeitsgemeinschaft für Osteosynthesefragen) type B fractures, periprosthetic fractures classified as Lewis–Rorabeck (LR) type III or Vancouver type A–B, prostheses other than primary knee arthroplasty, septic conditions, septic or atrophic pseudoarthrosis in nonunion cases, age <65 years, follow-up duration of less than two years, pathological fractures, malunions, segmental fractures, malignancy, and open fractures.

A total of 182 cases meeting the inclusion criteria were initially identified by two senior orthopedic surgeons. After exclusion of 112 patients treated with techniques other than NPC or DPC, additional exclusions included one pathological fracture, one malunion, one prophylactic fixation performed for malignancy, one segmental fracture, two open fractures, six patients with insufficient follow-up, and six patients whose medical records were unavailable. The final study cohort consisted of 28 patients treated with NPC and 24 patients treated with DPC. AO type B fractures were excluded because buttress plating represents the standard treatment approach. All patients with periprosthetic fractures scheduled for NPC underwent preoperative knee computed tomography, and NPC was performed only after confirming compatibility with an open-box prosthesis design.

Surgical Technique

For the NPC technique, a lateral distal femoral incision was performed in all cases, followed by a patellar tendon–splitting approach for retrograde nail insertion. TST® (Turkish Spinal Trauma, Istanbul) LW-30 MISS Distal Femur Plate® (Ti-6Al-4V) and Tasarımmed Medical Devices Corporate® FN-3 Retrograde Femoral Nail® (Ti-6Al-4V) implants were used. The intramedullary nail was statically locked using one mediolateral distal screw and one anteroposterior proximal screw. The plate was fixed in the metaphyseal region with a minimum of three screws and secured around the nail in the shaft using either eccentric bicortical or unicortical screws to achieve at least six cortical fixation points. Although minimum fixation requirements were met in all cases, complete standardization of screw number and placement was not feasible because of technical difficulties; therefore, surgeon-dependent variability should be acknowledged.

For the DPC technique, a lateral distal femoral incision was performed, followed by a medial subvastus approach. TST® (Turkish Spinal Trauma, Istanbul) LW-30 MISS Distal Femur Plate® (27.5 cm; Ti-6Al-4V) was used. According to the surgeon's preference, either a TST® (Turkish Spinal Trauma, Istanbul) LC-DCP 4 mm plate (Ti-6Al-4V) or a TST® (Turkish Spinal Trauma, Istanbul) Distal Femur Medial Osteotomy Plate (Ti-6Al-4V) was used.[6,11] Although minimum fixation requirements for double plating were achieved in all cases, the type of medial plate and the number and positioning of screws varied according to fracture characteristics and intraoperative conditions; thus, surgeon-dependent variability should also be acknowledged.

All procedures were performed by two senior trauma surgeons. No bone grafts were used in any case.

Postoperative Care

Postoperatively, all patients received prophylactic first-generation cephalosporin therapy for three days. Thrombopro-

phylaxis was administered with low-molecular-weight heparin and continued until postoperative week 2. From postoperative weeks 2 to 8, thromboprophylaxis was continued with acetylsalicylic acid (81 mg) instead of low-molecular-weight heparin.

Postoperative Rehabilitation

Active and passive range-of-motion exercises for the knee and ankle were initiated on postoperative days 1–2. Isometric quadriceps and hamstring exercises, as well as straight-leg raise exercises, were performed regularly. In addition, full weight-bearing ambulation with a walker was initiated on postoperative day 1, and gait training was continued according to patient pain tolerance to promote safe mobilization. Between postoperative weeks 2 and 4, knee flexion and extension were progressively increased, walking distance and duration were gradually advanced, and patients were encouraged to ambulate independently. During this period, strengthening exercises were intensified, and light resistance band exercises were introduced. Between weeks 4 and 6, rehabilitation progressed to include stair climbing, sit-to-stand activities, and activities of daily living, performed independently or with minimal assistance. Strengthening and balance exercises were further intensified, and proprioceptive training was increased. Throughout rehabilitation, wound status, pain, and swelling were monitored regularly, and the exercise program was individualized according to patient tolerance.

Subsequently, clinical records and radiographic images were reviewed using a standardized data collection form. The following variables were extracted from the medical records: age, sex, affected side, duration of surgery, type of anesthesia, intraoperative blood loss, follow-up duration, interval since prosthetic surgery in periprosthetic cases, time to full weight-bearing, postoperative rehabilitation and medical treatment protocols, implants used, time to clinical union, clinical outcomes including range of motion (ROM) and Lysholm scores at 3 months, 6 months, and 2 years, and complications. Radiographic evaluation included implant configuration, fracture type and characteristics, radiographic union findings, and measurements of the anatomic lateral distal femoral angle (aLDFA) and anatomic posterior distal femoral angle (aPDFA). Clinical union was defined as the absence of pain on palpation at the fracture site and the ability to bear full weight without pain.[3] Radiographic union was defined as the presence of bridging callus visible in three planes on both anteroposterior (AP) and lateral radiographs.[3,12] Clinical and radiographic union times, as well as ROM and Lysholm scores, were obtained from outpatient follow-up records. ROM measurements were performed using a goniometer and assessed by the examining orthopedic surgeons together with Lysholm scoring. To evaluate femoral alignment, aLDFA and aPDFA measurements were obtained from the most recent radiographs and measured jointly by two senior orthopedic surgeons.[3,12] Normal values were accepted as 81° (range, 79°–83°) for aLDFA and 83° (range, 79°–87°) for aPDFA.[13] Intraoperative blood loss was calculated by measuring fluid volume in suction containers, adding the net weight of surgical swabs, and subtracting the volume of irrigation fluid used.[14]

All measurements were performed by two senior orthopedic surgeons using the hospital imaging system (PACS; Picture Archiving and Communication System, version 3.0.11.4 [BN13]®).

Statistical Analysis

Statistical analyses were performed using SPSS version 25.0 (Statistical Package for the Social Sciences – SPSS Inc., Chicago, Illinois, USA). Data distribution was assessed using the Shapiro–Wilk test. Variables between independent groups were compared using either the Student's t-test or the Mann–Whitney U test. Categorical variables were compared using the chi-square test. The threshold for statistical significance was set at p=0.05 for all analyses.

RESULTS

Patient demographic characteristics, including age, sex, affected side, time to surgery, and follow-up duration, are presented in Table 1.

Fracture types and distributions are summarized in Table 2. No cases of 33A1 or 33C1 fractures were identified in either group.

Table 1. Demographic and clinical characteristics of the NPC and DPC groups

Characteristic	NPC	DPC	p-value
Age (years)	72.7±8.3	73.8±5.2	0.890*
Sex (female/male)	24 (85.7%)/4 (14.3%)	20 (83.3%)/4 (16.7%)	0.560**
Affected side (right/left)	15 (53.6%)/13 (46.4%)	14 (58.3%)/10 (41.7%)	0.730**
Time to surgery (days)	3.4±1	3.6±1.6	0.683*
Follow-up duration (months)	53.8±15.5	52.2±18.6	0.760*

*Student's t-test; **Chi-square test; NPC: Nail-plate combination; DPC: Double-plate combination.

Table 2. Distribution of fracture types between groups

	33A2**	33A3**	33C2**	33C3**	LR1***	LR2***	Type C****	p*
NPC (100%)	6 (21.4%)	2 (7.1%)	2 (7.1%)	7 (25.0%)	2 (7.1%)	8 (28.6%)	1 (3.6%)	0.962
DPC (100%)	5 (20.8%)	2 (8.3%)	2 (8.3%)	7 (29.2%)	2 (8.3%)	6 (25.0%)	0 (0.0%)	

*Chi-square test; **AO (Arbeitsgemeinschaft für Osteosynthesefragen) classification; ***Lewis–Rorabeck classification; ****Vancouver classification; NPC: Nail-plate combination; DPC: Double-plate combination.

Table 3. Comparison of operative time, intraoperative blood loss, and Lysholm scores at 3 months, 6 months, and 2 years between groups

	NPC*** Median [IQR]	DPC Median**** [IQR]	p*
Operative time (minutes)	120 [22.50]	155 [23.75]	<0.001
Blood loss (mL)	422.5 [115]	640 [237.5]	<0.001
ROM** at 3 months	80 [10]	100 [17.5]	<0.001
ROM** at 6 months	110 [20]	100 [20]	0.096
ROM** at 2 years	140 [13.75]	140 [18.75]	0.669
Lysholm score at 3 months	70 [12.5]	68.5 [10]	<0.003
Lysholm score at 6 months	78 [9.50]	75.5 [10]	0.334
Lysholm score at 2 years	85.5 [10]	85 [10]	0.836

*Mann–Whitney U test; **Range of motion; NPC: Nail-plate combination; DPC: Double-plate combination; ROM: Range of motion.

Among all cases, 11 periprosthetic fractures were included in the NPC group and eight in the DPC group. Native distal femur fractures and periprosthetic fractures were compared across all study parameters, including operative time (138.7±26.7 vs. 135.0±27.0 min; p=0.627), intraoperative blood loss (542.1±147 vs. 541±160 mL; p=0.981), follow-up duration (51.7±18.9 vs. 55.4±17.5 months; p=0.489), clinical union time (11.0±2.0 vs. 10.5±1.8 weeks; p=0.349), ROM at 3 months (92.1±10.4° vs. 91.5±12.4°; p=0.868), ROM at 6 months (105.7±10.9° vs. 102.6±17.2°; p=0.427), ROM at 2 years (140.6±8.3° vs. 142.6±8.7°; p=0.412), Lysholm scores at 3 months (70.1±8.4 vs. 68.3±5.7; p=0.409), 6 months (78.3±7.8 vs. 74.3±4.7; p=0.053), and 2 years (85.1±4.7 vs. 84.6±5.9; p=0.730), radiological union time (12.5±2.07 vs. 12.5±2.05 weeks; p=0.975), aLDFA (80.8±2.34° vs. 81.1±2.04°; p=0.391), aPDFA (84.1±2.61° vs. 85.3±2.43°; p=0.742), and interval since prior surgery (3.4±1.5 vs. 3.5±2.0 years; p=0.878). No statistically significant differences were observed between the two groups.

In the NPC group, pseudoarthrosis cases included one 33C2 fracture, one 33A3 fracture, one LR type II fracture, and one LR type I fracture. All pseudoarthrosis cases had undergone previous lateral plating.

All periprosthetic distal femur fractures in the study involved total knee arthroplasty prostheses with an open-box femoral design.

In the DPC group, pseudoarthrosis cases included one 33C2 fracture, one 33C3 fracture, and one LR type I fracture. Initial treatment consisted of lateral plating for the 33C2 and 33C3 fractures and retrograde intramedullary nailing for the LR type I fracture. There was no significant difference in pseudoarthrosis frequency between groups (p=0.851).

Three patients in the NPC group and four patients in the DPC group underwent general anesthesia; all remaining patients received combined spinal–epidural anesthesia. No significant difference was observed between groups (p=0.531).

Comparisons of operative time, intraoperative blood loss, and Lysholm scores at 3 months, 6 months, and 2 years are presented in Table 3.

Clinical and radiographic union times and measurements of aLDFA and aPDFA are summarized in Table 4.

In the NPC group, two patients received additional antibiotic treatment for superficial wound infection, and no wound debridement was required. One patient developed deep vein thrombosis (DVT) and received treatment for DVT for 8 weeks. In the DPC group, three patients received oral antibiotics for wound infections, and one patient underwent medial

Table 4. Comparison of clinical and radiographic union times and aLDFA and aPDFA measurements between groups

	NPC Median [IQR]	DPC Median [IQR]	p*
Time to clinical union (weeks)	10 [4]	12 [3.5]	0.020
Time to radiographic union (weeks)	12 [2]	12 [3.5]	0.290
Time to full weight-bearing (weeks)	6 [1]	9 [2]	<0.001
aLDFA**	81 [4.75]	81 [1.75]	0.356
aPDFA***	85.5 [4]	83 [2]	<0.001

*Mann–Whitney U test; **Anatomic lateral distal femoral angle; ***Anatomic posterior distal femoral angle; NPC: Nail-plate combination; DPC: Double-plate combination.

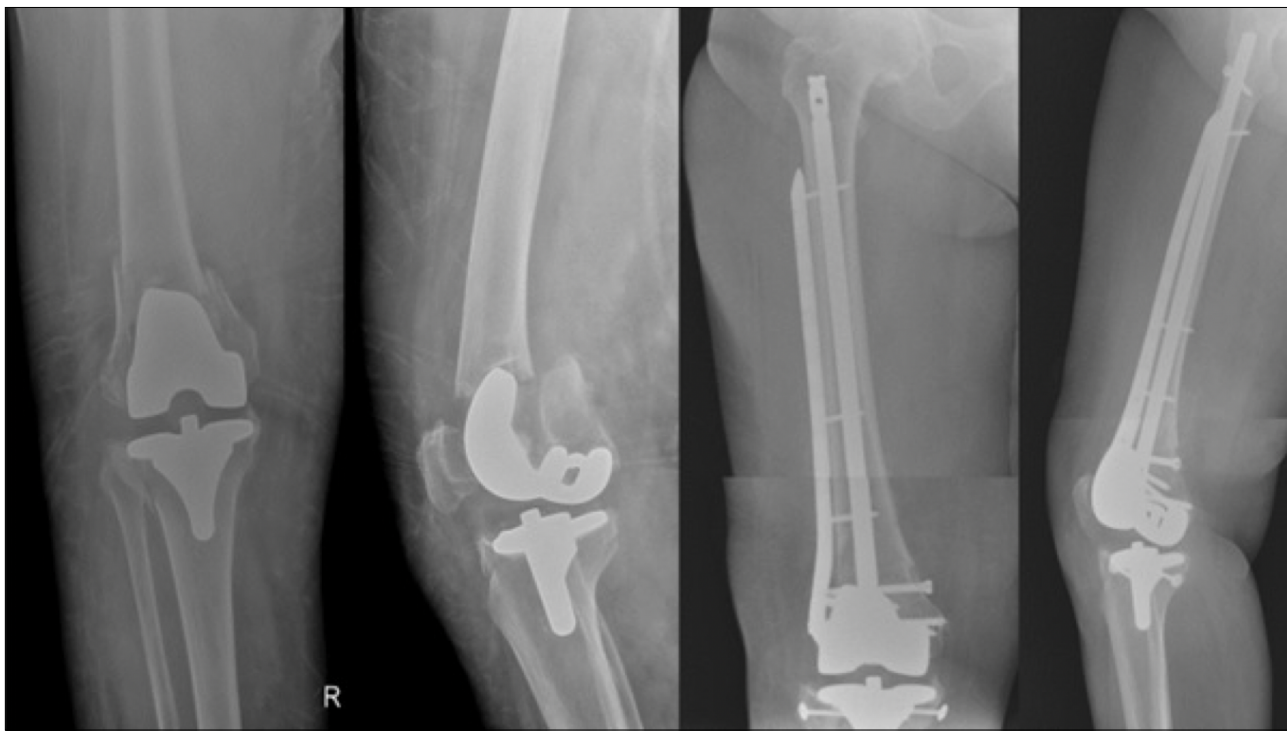

Figure 1. Preoperative and six-month postoperative radiographs of a patient treated with nail–plate combination (NPC).

plate removal at postoperative week 12 because of persistent wound drainage. No incision-related complications, including skin necrosis, were observed in either group. There was no significant difference in complication rates between groups (p=0.841).

Radiographic and clinical union were achieved in all patients.

DISCUSSION

One of the principal arguments advanced by proponents of both DPC and NPC techniques is the high union rates and low rates of mechanical complications reported for both constructs.[15,16] In our study, although the NPC group demonstrated a significantly shorter time to clinical union, no difference was observed between the groups in terms of radiographic union time. Despite similar postoperative weight-bearing and rehabilitation protocols, patients treated with NPC demonstrated superior early joint range of motion and better clinical outcomes. These findings may reflect biomechanical advantages of the nail–plate construct and reduced soft tissue disruption.

The British Orthopaedic Association Standards for Trauma (BOAST) recommend treatment strategies that facilitate early mobilization in elderly orthopedic trauma patients.[17] Although dual-implant systems for osteoporotic distal femur fractures are intended to improve construct stability and support early mobilization, many authors remain cautious re-

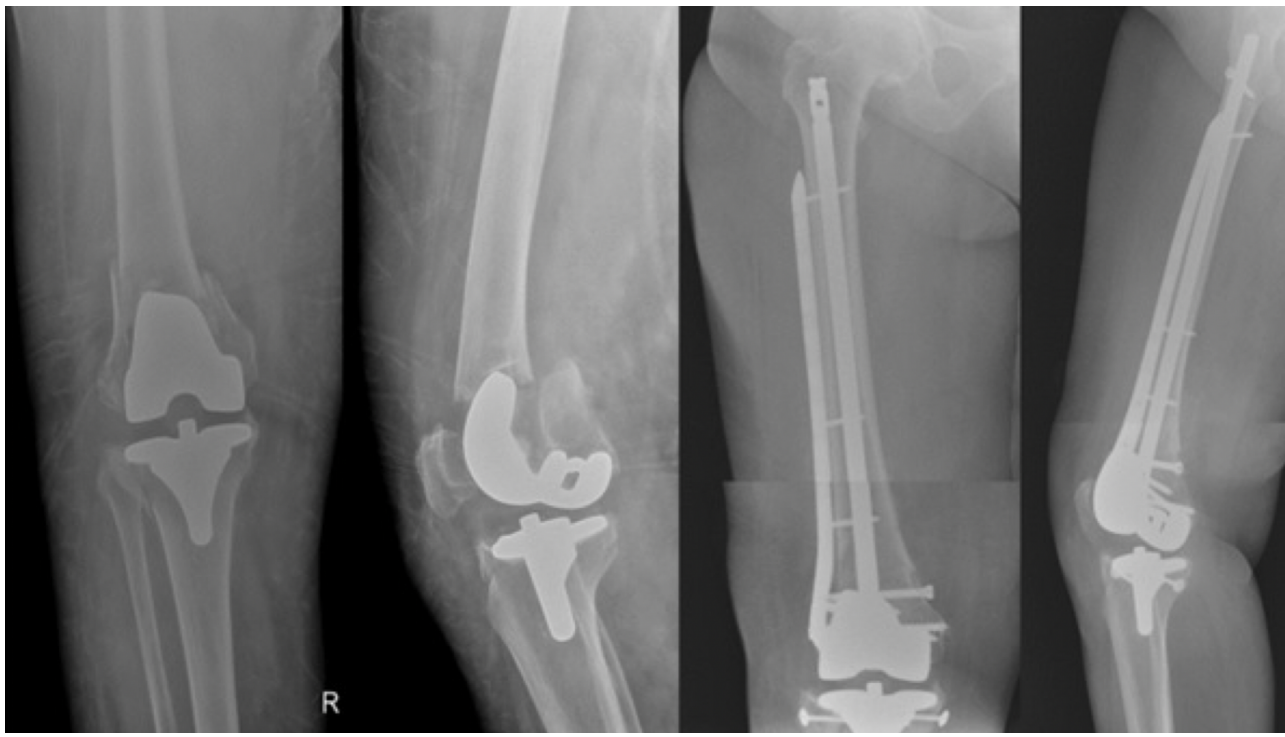

Figure 2. Preoperative and four-month postoperative radiographs of a patient treated with nail–plate combination (NPC).

garding immediate full weight-bearing, particularly following DPC fixation.[12,18] Previous studies comparing single-implant and dual-implant constructs have generally implemented similar rehabilitation protocols and reported no significant differences in knee range of motion or clinical outcomes.[7,12,19] In contrast, our findings demonstrated inferior clinical outcomes and ROM in the DPC group at three months postoperatively. The additional medial incision required for double plating may increase soft tissue trauma and postoperative discomfort, potentially limiting early rehabilitation. Whether this additional incision independently affects early functional recovery remains to be clarified in larger prospective studies.

Because NPC is frequently used in osteoporotic and periprosthetic fracture settings, retrograde nail insertion may present specific technical challenges. Increased anterior femoral bowing and the presence of a knee prosthesis may result in a relatively posterior nail entry point, potentially leading to extension deformity of the distal femur.[20] In our study, although both groups underwent lateral open reduction, the NPC group demonstrated a significantly higher aPDFA. However, consistent with the findings of Pelfort et al.,[20] who reported no functional limitations despite extension deformity following retrograde nailing in periprosthetic distal femur fractures, these alignment differences appear clinically acceptable and unlikely to compromise functional outcomes.

In the double-plate technique, one concern regarding medial plating is the potential risk of vascular injury and increased intraoperative bleeding due to disruption of the distal femoral blood supply. Computed tomography angiography studies by Steinberg et al.[21] demonstrated that this region is supplied primarily by the medial superior genicular artery and the third perforating artery entering the vastus medialis muscle. Injury to these vessels may contribute to increased intraoperative blood loss. In our study, the DPC group exhibited significantly greater intraoperative blood loss and longer operative times. The additional medial exposure, increased dissection, and closure requirements may explain these findings. Increased blood loss and surgical trauma may also adversely affect early postoperative recovery and functional outcomes. Larger randomized controlled trials are required to further investigate these associations.

In this study, native distal femur fractures and periprosthetic distal femur fractures in elderly patients were evaluated within the same cohort. No significant differences were observed between periprosthetic fractures treated with NPC and those treated with DPC across any evaluated clinical, radiographic, or functional parameter. Consistent with previous studies in the literature reporting comparable outcomes between periprosthetic and native distal femur fractures, our findings support the evaluation of these fracture types within the same elderly patient population when appropriate fixation principles are applied.[9,22,23] However, in patients treated with DPC, the presence of a previous total knee arthroplasty incision may increase the risk of skin necrosis because of the additional medial exposure.[24,25] Conversely, although NPC in periprosthetic cases may present technical challenges related

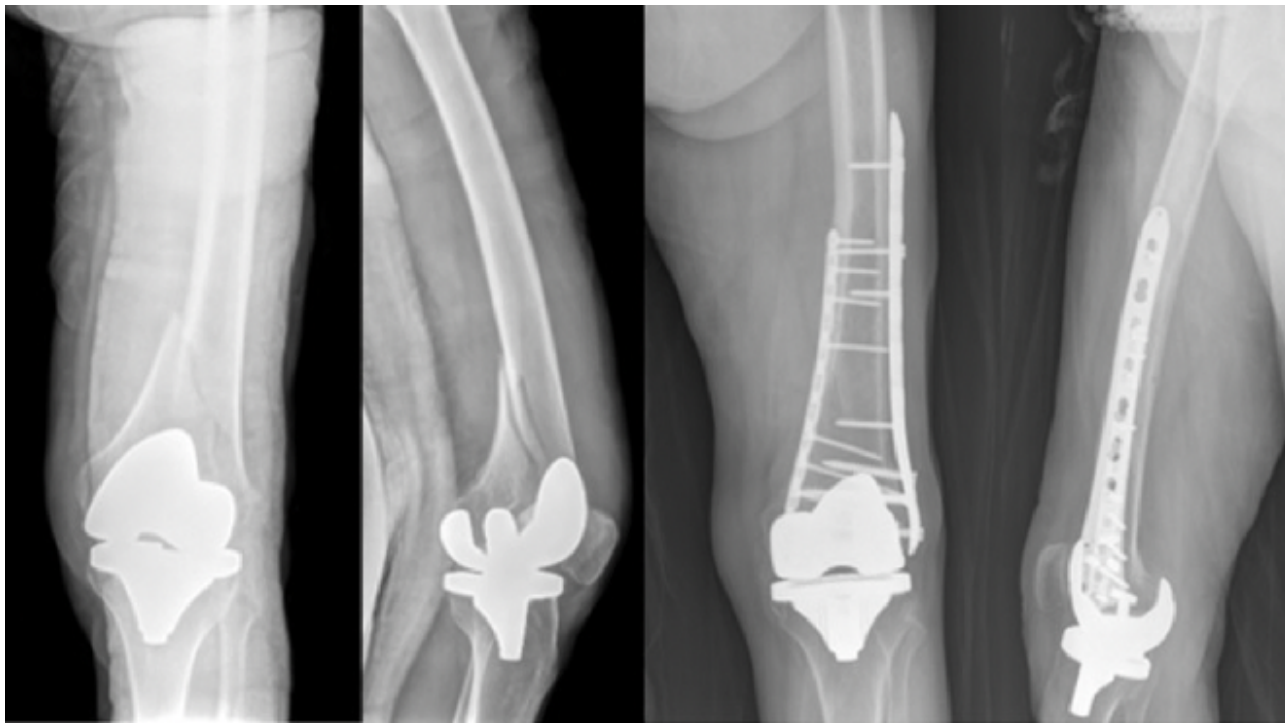

Figure 3. Preoperative and four-month postoperative radiographs of a patient treated with double-plate combination (DPC) using a limited-contact dynamic compression plate (LC-DCP).

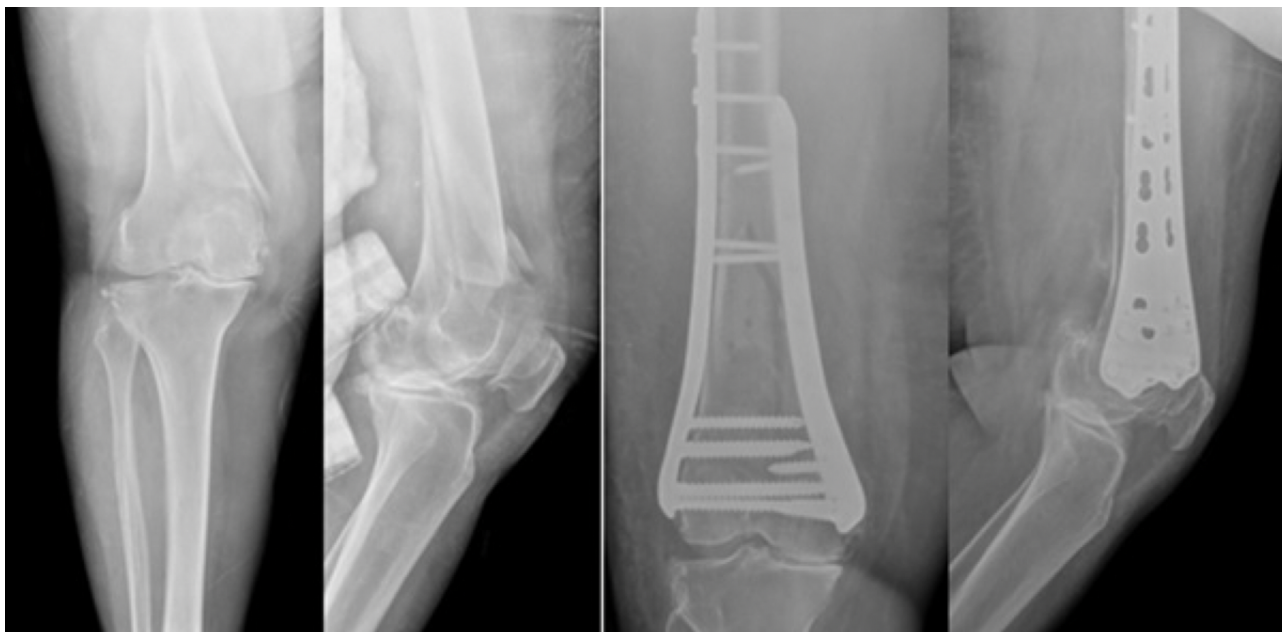

Figure 4. Preoperative and three-month postoperative radiographs of a patient treated with double-plate combination (DPC) using a medial osteotomy plate.

to very distal fracture patterns and implant compatibility, current literature suggests that the vast majority of modern knee prostheses have an open-box design.[26] Therefore, both techniques can be safely applied in appropriately selected patients and fracture patterns, and the choice of fixation should be individualized based on expected early functional outcomes, soft tissue conditions, and implant compatibility.

The main limitations of this study include its retrospective design, relatively small sample size, the assumption that peri-

prosthetic fractures following primary total knee arthroplasty are comparable to native distal femur fractures in older adults, surgeon-dependent selection of fixation technique, lack of standardization in screw number and placement within the NPC group, use of two different medial plate designs in the DPC group according to fracture characteristics, and the relatively short follow-up period.

CONCLUSION

In this study, NPC demonstrated several advantages over DPC, including reduced intraoperative blood loss, shorter operative time, earlier achievement of full weight-bearing, and improved early ROM and clinical outcomes. Complication rates and union outcomes were similar between groups. However, intramedullary fixation is not feasible in all cases. Very distal fracture patterns and femoral components without an open-box design remain important limitations to NPC application.[7] Nevertheless, given its observed advantages, NPC may be considered the preferred option when technically feasible. Because NPC cannot be applied in every clinical scenario, DPC remains a viable alternative for selected patients.

Ethics Committee Approval: This study was approved by The Ethics Committe Of Prof. Dr. Cemil Taşcıoğlu City Hospital (Date: 13.01.2025, Decision No: 15).

Peer-review: Externally peer-reviewed.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Yaşlı yetişkinlerde primer ve periprostetik distal femur kırıklarında çivi-plak ve çift plak fiksasyonunun karşılaştırılması

AMAÇ: Geriatrik yaş grubunda distal femur kırıkları, bir yıllık mortalite oranı açısından kalça kırıklarına benzerlik gösterir. Kalça kırıklarında olduğu gibi, distal femur kırıklarının tedavisi de erken mobilizasyona odaklanmalı ve hareketsizlikle ilişkili morbidite ve mortaliteyi azaltmayı hedeflemelidir. Nail-Plaka Kombinasyonu (NPC) ve Çift Plaka Kombinasyonu (DPC), distal femur kırıklarında erken mobilizasyon ve düşük mekanik komplikasyon oranları sağladığı iddia edilmektedir. Bu çalışmada, yaşlı hastalarda distal femur kırıklarında NPC ve DPC'nin klinik ve radyolojik sonuçlarını karşılaştırmayı amaçladık.

GEREÇ VE YÖNTEM: Dahil etme ve hariç tutma kriterlerinin uygulanmasının ardından, NPC ile tedavi edilen 28 hasta ve DPC ile tedavi edilen 24 hasta çalışmaya alındı. Bu hastaların klinik kayıtları ve radyolojik görüntüleri standart bir form kullanılarak değerlendirildi. Ameliyat süresi, intraoperatif kan kaybı, eklem hareket açıklığı (ROM) ve Lysholm skorları hastaların tıbbi kayıtlarından elde edildi. Radyolojik kayıtlardan radyolojik kaynama bulguları ve Anterior Lateral Distal Femur Açısı (aLDFA) ile Anterior Posterior Distal Femur Açısı (aPDFA) ölçümleri alındı.

BULGULAR: NPC grubunda ameliyat süresi 120 (±22.5) dakika, DPC grubunda ise 155 (±23.75) dakika idi (p<0.001). NPC grubunda kan kaybı 422.5 (±115) mL iken, DPC grubunda 640 (±237.5) mL idi (p<0.001). Üçüncü ayda ROM, NPC grubunda 100 (±17.5) derece, DPC grubunda 80 (±10) derece idi (p<0,001). 3. ay Lysholm skoru NPC grubunda 70 (±12.5), DPC grubunda 68.5 (±10) idi (p<0.001). Radyolojik kaynama süresi NPC grubunda 12 (±2) hafta, DPC grubunda 12 (±3.5) hafta idi (p=0.290). aLDFA ölçümleri açısından iki grup arasında anlamlı fark yoktu (81 [±4.75] vs. 81 [±1.75], p=0.356), ancak aPDFA NPC grubunda 85.5 (±4), DPC grubunda 83 (±2) idi (p<0.001). Ameliyat sonrası hemen ağırlık vermek, yaşlı ortopedik travmalı hastalarda önemlidir. Çift implant sistemlerinin birincil amacı erken mobilizasyonu kolaylaştırmak olsa da, DPC kullanıldığında erken dönemde tam ağırlık vermeye genellikle temkinli yaklaşılmaktadır. NPC grubundaki hastaların daha erken ve ağrısız şekilde tam ağırlık vermesi, erken eklem hareket açıklığının ve klinik sonuçların daha iyi olmasına katkıda bulunabilir.

SONUÇ: Çalışmamızda NPC grubu, daha az intraoperatif kan kaybı, daha kısa ameliyat süresi, hemen tam ağırlık verebilme, daha iyi erken ROM ve daha iyi klinik skorlar gibi avantajlar gösterdi. Komplikasyon ve kaynama oranları benzerdi, ancak NPC'nin sağladığı bu avantajlar klinik olarak daha anlamlı olabilir.

Anahtar sözcükler: Çift plak kombinasyonu; çivi plak kombinasyonu; distal femur; osteoporotik kırık

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ORIGINAL ARTICLE

Traumatic spinal fractures: epidemiological and clinical evaluation in a forensic medicine clinic sample

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ABSTRACT

BACKGROUND: Traumatic spinal injuries (TSI) are a major public health concern associated with substantial morbidity. As the first study to provide a regional forensic medicine perspective, this study aimed to retrospectively evaluate the clinical characteristics, etiological factors, injury patterns, and long-term sequelae of traumatic spinal fractures among patients presenting to Department of Forensic Medicine, Atatürk University between 2020 and 2022.

METHODS: Medical records of 12,029 cases evaluated at the Department of Forensic Medicine, Atatürk University between 2020 and 2022 were reviewed. A total of 277 cases with confirmed spinal fractures were included. Demographic characteristics, etiology, Injury Severity Score (ISS), fracture levels, associated injuries, and treatment methods were analyzed. Long-term sequelae were assessed in 174 patients with at least 12 months of follow-up.

RESULTS: Among the patients, 74.1% were male (male-to-female ratio: 2.85), and the mean age was 40.1±16.69 years. The most common etiology was vehicle occupant motor vehicle accidents (VO-MVA) (56.3%), followed by motor vehicle accidents involving vulnerable road users (VRUs-MVA) (15.5%) and high-energy falls (HEF) (13.4%). A statistically significant association was found between age and etiology (p=0.001); VO-MVA predominated in the 18–44-year age group, whereas VRU-related injuries increased among individuals aged ≥65 years. Injuries resulting from VRUs-MVA and HEFs were significantly associated with major trauma (ISS ≥16) (p=0.044) and multiple vertebral fractures (p=0.001). The thoracolumbar junction (T11–L2) was the most frequently affected region (31.8%). A significant association was identified between head/facial trauma and cervical fractures (odds ratio [OR]=3.59; 95% confidence interval [CI]: 1.89–6.82), and between intra-abdominal organ injuries and sacral fractures (OR=6.47; 95% CI: 2.40–17.39). Permanent sequelae were observed in 50% of patients with follow-up data; the most common were restricted spinal mobility (46.8%) and spinal cord injury (13.5%).

CONCLUSION: Although vehicle occupant traffic accidents are the most common cause of spinal fractures, accidents involving vulnerable road users and high-energy falls are associated with greater injury severity and multiple fractures. Clinicians should maintain a high index of suspicion for cervical fractures in patients presenting with head trauma and sacral fractures in those with abdominal injuries. Rapid triage and careful evaluation are essential, particularly in cases involving high-energy mechanisms and associated organ injury. These findings highlight the substantial long-term morbidity associated with traumatic spinal fractures and underscore the importance of multidisciplinary follow-up.

Keywords: Associated injury; epidemiology; forensic medicine; traumatic spinal cord injury; traumatic spinal injury.

INTRODUCTION

Traumatic spinal injury (TSI) encompasses damage to the bones, spinal cord, nerve roots, and discoligamentous structures of the spine.[1] Traumatic spinal fractures are included within this group and account for approximately 6% of all fractures annually.[2] These injuries impose substantial medical, psychological, and economic burdens on patients, their

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families, and society because of their high morbidity and mortality rates.[3] Consequently, TSI is increasingly recognized as an important public health issue.[4]

Despite its significance, information regarding the global prevalence of TSI is limited. Although spinal cord injury (SCI) is the most extensively studied topic in the literature, epidemiological evidence suggests that traumatic spinal injuries are considerably more common.[5] Furthermore, studies often focus on selected spinal regions, specific age groups, or short-term outcomes, limiting understanding of the epidemiology and long-term outcomes of TSI.[6]

Regardless of etiology, spinal injuries frequently require medico-legal evaluation. In Türkiye, individuals with TSI may undergo assessment within both compensation and criminal law frameworks through clinical forensic medicine practice. Forensic medicine specialists evaluate factors including injury mechanism, injury severity, healing process, and sequelae, and subsequently provide reports to judicial authorities.

This study retrospectively examined the clinical characteristics, etiological factors, treatment approaches, and outcomes of traumatic spinal fractures. The aim was to provide clinicians and forensic medicine specialists with evidence to support the diagnosis, treatment, and prevention of vertebral injuries.

MATERIALS AND METHODS

Ethical approval was obtained from the Atatürk University Faculty of Medicine Non-Interventional Clinical Research Ethics Committee (May 3, 2024; Session No. 3; Approval No. 4). Medical records of 12,029 patients evaluated at the Department of Forensic Medicine, Atatürk University, between January 1, 2020 and December 31, 2022, were reviewed. Cases with documented spinal fractures were included. Cases recorded as having "suspected fractures" were re-evaluated based on consultations with the Department of Radiology. Thirty-three cases without confirmed spinal fractures were excluded. When multiple reports referred to the same traumatic event in a single patient, only one report was included. Ultimately, 277 cases with confirmed spinal fractures and documented fracture levels were included in the retrospective analysis.

Variables analyzed included age, sex, injury mechanism, Injury Severity Score (ISS), spinal cord injury level, associated injuries, and treatment modality. Patients injured in motor vehicle accidents (MVAs) were categorized as either vehicle occupants (VO) or vulnerable road users (VRUs). The VRU category included pedestrians and cyclists. Because most cases referred for disability assessment in forensic medicine practice involve traffic accidents, these categories may be overrepresented; therefore, etiological analyses should be interpreted cautiously. Trauma mechanisms were classified as vehicle occupant motor vehicle accidents (VO-MVA), VRU-related accidents, high-energy falls (≥2 meters), assault, or other causes. The assault category included blunt trauma, sharp-force injuries, penetrating injuries, and firearm-related injuries. The "other" category included low-height falls onto the spine, animal-related injuries, and sports injuries. Fracture levels were categorized as cervical (C), thoracic (Th), lumbar (L), sacral (S), or coccygeal (Co). Continuous variables were categorized using clinically relevant thresholds: age (0–17, 18–44, 45–64, and ≥65 years); ISS (major trauma ≥16, minor trauma <16); and number of fractures (single, multiple [2–3], or extensive [≥4]). Associated injuries included fractures and internal organ injuries; soft tissue injuries were excluded. A total of 174 patients with final follow-up evaluations performed at least 12 months after trauma and/or surgery were identified. Sequelae were calculated according to the tables and guidelines specified in the Regulation on Disability Assessment for Adults.

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, USA). Comparisons were performed using chi-square or Fisher's exact tests as appropriate. Statistical significance was set at 0.05. Odds ratios are reported with corresponding 95% confidence intervals (CI), presented in parentheses.

This article is derived from the author's medical specialty thesis entitled "Evaluation of Columna Vertebralis Traumas in Terms of Clinical Forensic Medicine Practices" (Thesis No. 934204), submitted to Atatürk University in 2025.

RESULTS

Of the cases included in the study, 74.1% (n=205) were male and 25.9% (n=72) were female, resulting in a male-to-female ratio of 2.85. The mean age at the time of trauma was 40.1±16.69 years. A significant difference in mean age was observed between male and female patients at the time of injury ($t(275)=-1.992$, $p=0.047$); on average, male patients were approximately 4.5 years younger than female patients (Table 1).

The most common cause of fractures across all age groups was VO-MVA (56.3%), followed by motor vehicle accidents involving vulnerable road users (VRUs-MVA) (15.5%) and high-energy falls (HEF) (13.4%). Assault (9.4%) and other causes (5.4%) were less frequently observed.

A statistically significant association was found between age group and trauma etiology ($\chi^2(12)=32.518$; $p=0.001$), indicating that the distribution of etiologies differed across age groups. The highest proportion of cases was observed in the 18–44-year age group (53.1%). VO-MVA was the predominant etiology in both the 0–17 and 18–44-year age groups. HEF and assault were also relatively more common among individuals aged 18–44 years. In the 45–64 and ≥65-year age groups, VO-MVA and HEF were the predominant injury mechanisms.

Analysis of the relationship between sex and fracture etiology using Pearson's chi-square test did not demonstrate a statisti-

Table 1. Association between trauma etiology and demographic and clinical characteristics

	Etiology (n, %)						
	VO-MVA	**VRUs-MVA**	**HEF**	**Assault**	**Other**	**Total (n, %)**	**p**
Age group (years)							0.001
0–17	7 (2.5)	6 (2.2)	-	1 (0.4)	2 (0.7)	16 (5.8)	
18–44	93 (33.6)	12 (4.3)	18 (6.5)	17 (6.1)	7 (2.5)	147 (53.1)	
45–64	45 (16.2)	17 (6.1)	18 (6.5)	8 (2.9)	6 (2.2)	94 (33.9)	
≥65	11 (4)	8 (2.9)	1 (0.4)	-	-	20 (7.2)	
Sex							0.074
Male	110 (39.7)	28 (10.1)	32 (11.6)	22 (7.9)	13 (4.7)	205 (74)	
Female	46 (16.6)	15 (5.4)	5 (1.8)	4 (1.4)	2 (0.7)	72 (26)	
ISS							0.044
Major (≥16)	77 (27.8)	29 (10.5)	27 (9.7)	13 (4.7)	8 (2.9)	154 (55.6)	
Minor (<16)	79 (28.5)	14 (5.1)	10 (3.6)	13 (4.7)	7 (2.5)	123 (44.4)	
Number of fractured vertebrae							0.001
Single fracture	70 (25.3)	24 (8.7)	19 (6.9)	18 (6.5)	10 (3.6)	141 (50.9)	
Multiple fractures (2–3)	66 (23.8)	13 (4.7)	5 (1.8)	7 (2.5)	3 (1.1)	94 (33.9)	
Extensive fractures (≥4)	20 (7.2)	6 (2.2)	13 (4.7)	1 (0.4)	2 (0.7)	42 (15.2)	
Treatment							0.007
Conservative	114 (41.2)	39 (14.1)	20 (7.2)	20 (7.2)	10 (3.6)	203 (73.3)	
Surgical	42 (15.2)	4 (1.4)	17 (6.1)	6 (2.2)	5 (1.8)	74 (26.7)	
Total (n, %)	156 (56.3)	43 (15.5)	37 (13.4)	26 (9.4)	15 (5.4)	277 (100)	

*VO-MVA: Vehicle occupant motor vehicle accident; VRUs-MVA: Motor vehicle accidents involving vulnerable road users; HEF: High-energy fall.

cally significant association ($\chi^2(4)=8.523$, p=0.074). Similarly, the likelihood ratio test did not reach statistical significance (p=0.057). Among male patients (n=205), VO-MVA was the most common etiology (39.7%), followed by VRUs-MVA (10.1%) and HEF (11.6%). Among female patients, VO-MVA was also the predominant cause (16.6%), whereas other etiologies occurred less frequently.

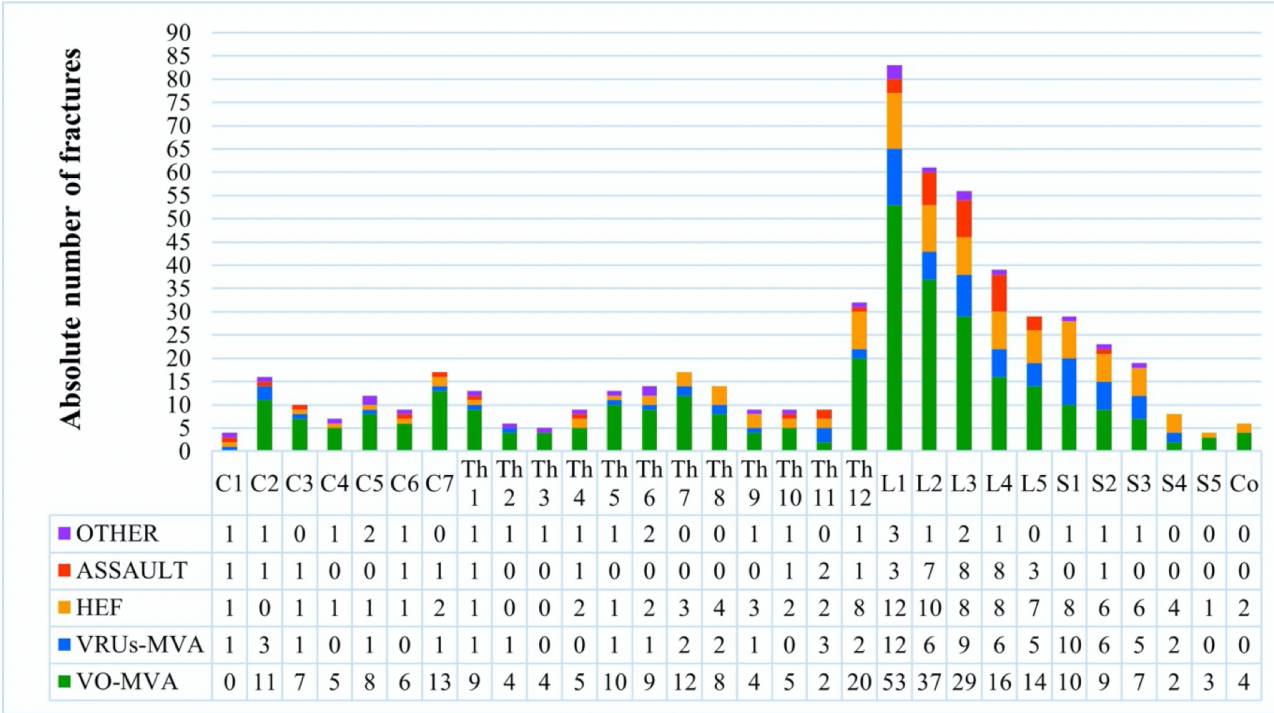
A statistically significant association was identified between Injury Severity Score category and trauma etiology ($\chi^2(4)=9.789$, p=0.044). Among patients with major trauma, the most frequent etiologies were VO-MVA (27.8%), VRUs-MVA (10.5%), and HEF (9.7%). In the minor trauma group, VO-MVA (28.5%) was the most common etiology.

Treatment modality was significantly associated with fracture etiology ($\chi^2(4)=14.163$, p=0.007). Among patients treated conservatively, VO-MVA (41.2%) and VRUs-MVA (14.1%) were the most frequent etiologies, whereas among surgically treated patients, VO-MVA (15.2%) and HEF (6.1%) predominated.

A statistically significant relationship was also observed be-

Table 2. Distribution of vertebral fractures according to vertebral level

Vertebral level	**n**	**%**	**Vertebral level**	**n**	**%**
C1	4	0.7	T9	9	1.5
C2	16	2.7	T10	9	1.5
C3	10	1.7	T11	9	1.5
C4	7	1.2	T12	32	5.5
C5	12	2.1	L1	83	14.3
C6	9	1.5	L2	61	10.5
C7	17	2.9	L3	56	9.6
T1	13	2.2	L4	39	6.7
T2	6	1	L5	29	5
T3	5	0.9	S1	29	5
T4	9	1.5	S2	23	4
T5	13	2.2	S3	19	3.3
T6	14	2.4	S4	8	1.4
T7	17	2.9	S5	4	0.7
T8	14	2.4	Co	6	1
Total				582	100



	C1	C2	C3	C4	C5	C6	C7	Th 1	Th 2	Th 3	Th 4	Th 5	Th 6	Th 7	Th 8	Th 9	Th 10	Th 11	Th 12	L1	L2	L3	L4	L5	S1	S2	S3	S4	S5	Co
OTHER	1	1	0	1	2	1	0	1	1	1	1	1	2	0	0	1	1	0	1	3	1	2	1	0	1	1	1	0	0	0
ASSAULT	1	1	1	0	0	1	1	1	0	0	1	0	0	0	0	0	1	2	1	3	7	8	8	3	0	1	0	0	0	0
HEF	1	0	1	1	1	1	2	1	0	0	2	1	2	3	4	3	2	2	8	12	10	8	8	7	8	6	6	4	1	2
VRUs-MVA	1	3	1	0	1	0	1	1	1	0	0	1	1	2	2	1	0	3	2	12	6	9	6	5	10	6	5	2	0	0
VO-MVA	0	11	7	5	8	6	13	9	4	4	5	10	9	12	8	4	5	2	20	53	37	29	16	14	10	9	7	2	3	4

Figure 1. Distribution of fracture localization according to trauma etiology. *VO-MVA: Vehicle occupant motor vehicle accident; VRUs-MVA: Motor vehicle accidents involving vulnerable road users; HEF: High-energy fall; C: Cervical; T: Thoracic; L: Lumbar; S: Sacral; Co: Coccygeal.

tween the number of fractured vertebrae and trauma etiology ($\chi^2(8)=25.515$, p=0.001). Single vertebral fractures represented the largest group (50.9%), with VO-MVA (25.3%) being the predominant etiology. Cases with two to three fractured vertebrae accounted for 33.9% of the cohort and were primarily associated with VO-MVA (23.8%) and VRUs-MVA (4.7%). Patients with four or more fractured vertebrae comprised 15.2% of cases, with HEF (4.7%) representing the most prominent etiology within this subgroup.

A total of 582 vertebral fractures were evaluated according to anatomical location and trauma mechanism. The thoracolumbar junction (T11–L2) was the most frequently affected region, accounting for 31.8% (n=185) of fractures. Within the cervical spine, C2 and C7 were the most commonly affect-

Table 3. Association between fractured spinal segment and associated injuries

	Fractured spinal segment (p-value/OR/95% CI)				
Region	**Cervical**	**Thoracic**	**Lumbar**	**Sacral**	**Coccygeal**
Head/facial	<0.001/3.594/ 1.89-6.826	0.929/0.971/ 0.513–1.839	0.114/0.621/ 0.343–1.125	0.524/0.722/ 0.265–1.970	0.843/0.804/ 0.092–7.022
Thoracic	0.311/0.715/ 0.373–1.370	<0.001/2.618/ 1.527–4.488	0.765/0.924/ 0.550–1.552	0.001/3.487/ 1.642–7.406	0.289/2.346/ 0.464–11.868
Abdominal	0.189/0.381/ 0.086–1.691	0.254/0.524/ 0.170–1.617	0.278/1.718/ 0.640–4.615	<0.001/6.472/ 2.409–17.390	0.366/2.653/ 0.295–23.870
Upper extremity	0.441/0.735/ 0.336–1.611	0.096/1.697/ 0.906–3.177	0.374/0.758/ 0.412–1.397	0.003/3.169/ 1.434–7.006	0.911/0.884/ 0.101–7.734
Lower extremity	0.225/0.545/ 0.202–1.470	0.615/0.819/ 0.376–1.783	0.480/1.298/ 0.628–2.685	0.007/3.159/ 1.326–7.528	0.134/3.485/ 0.615–19.758

*OR: Odds ratio; CI: Confidence intervals.

ed vertebrae, with VO-MVA representing the predominant mechanism of injury. In the thoracic region, Th12 was the most frequently fractured vertebra. In the lumbar region, L1 (n=83, 14.3%) and L2 (n=61, 10.5%) were the most commonly involved levels, with VO-MVA again representing the leading cause (Table 2, Fig. 1).

The relationship between associated injuries and spinal fracture location was further examined. A significant association was identified between head and facial injuries and cervical fractures ($\chi^2(1)=16.433$, $p<0.001$). Patients presenting with traumatic lesions involving the head and face had a 3.6-fold higher likelihood of sustaining cervical fractures than those

Table 4. Treatment approaches and surgical techniques applied in patients with traumatic spinal fractures

	n	%
Treatment approach		
Conservative treatment	203	73.3
Surgical treatment	74	26.7
Total	277	100
Surgical techniques performed		
Open posterior instrumentation w decompression w/o fusion	5	1.8
Open posterior instrumentation w decompression and fusion	25	9.0
Open posterior instrumentation w/o decompression w fusion	20	7.2
Open posterior instrumentation w/o decompression w/o fusion	2	0.7
Balloon kyphoplasty	2	0.7
Percutaneous posterior instrumentation	6	2.2
Anterior instrumentation	10	3.6
Vertebroplasty	4	1.4

*w: with; w/o: without.

Table 5. Frequency and systemic distribution of sequelae in patients with traumatic spinal injury (TSI)

Follow-up physical examination findings	**n**	**%**
Patients with sequelae	87	50
Patients without sequelae	87	50
Total	174	100
Distribution of sequelae according to body system	**n**	**%**
Spinal mobility restrictions	45	46.8
Musculoskeletal system*	21	21.8
Spinal cord injury	13	13.5
Digestive system	5	5.2
Peripheral nervous system	5	5.2
Mental, psychiatric, and behavioral disorders	3	3.1
Respiratory system	2	2.0
Central nervous system	2	2.0
Total**	96	100

*Excluding the spinal column. **The total number of sequelae (n=96) exceeded the number of patients with sequelae (n=87) because some patients experienced sequelae involving multiple body systems.

without such injuries (odds ratio [OR]=3.594, 95% CI: 1.892–6.826). A significant association was also observed between thoracic injuries and thoracic vertebral fractures ($\chi^2(1)=12.626$, $p<0.001$). Patients with traumatic lesions involving the thoracic region had approximately 2.6 times greater odds of sustaining thoracic spine fractures compared with patients without thoracic injuries (OR=2.618, 95% CI: 1.527–4.488). Additionally, sacral fractures showed significant associations with traumatic lesions involving the thoracic region, abdominal organs, and upper and lower extremities. Notably, patients with intra-abdominal organ injuries had a 6.4-fold greater likelihood of sustaining sacral fractures (OR=6.472, 95% CI: 2.409–17.390) (Table 3).

Analysis of treatment methods demonstrated that 73.3% (n=203) of patients were managed conservatively, whereas 26.7% (n=74) underwent surgical intervention. Among surgical procedures, the most commonly performed techniques were open posterior instrumentation with decompression and fusion (9%, n=25) and open posterior instrumentation with fusion without decompression (7.2%, n=20) (Table 4).

Following the designated recovery period (minimum 12 months after trauma or final surgical intervention), 174 patients underwent physical examination at our clinic. Permanent sequelae were identified in 50% (n=87) of these cases. Among these 87 patients, a total of 96 sequelae were documented, reflecting that some individuals experienced impairments involving multiple body systems. Analysis of affected systems showed that 46.8% (n=45) of sequelae were related to restricted spinal mobility, 21.8% involved the non-spinal musculoskeletal system, and 13.5% (n=13) resulted from spinal cord injury (Table 5).

DISCUSSION

This study is the first comprehensive regional investigation from a forensic medicine perspective to evaluate the etiology of vertebral fractures, trauma severity, treatment approaches, and long-term outcomes among patients with TSI.

The male-to-female ratio in our cohort was 2.85, which is consistent with previous reports. Kumar et al.[1] reported a global male-to-female ratio of 3.0, whereas Oliver et al.[2] reported a ratio of 3.04 in a 13-year study . This finding may reflect greater exposure among men to occupational hazards, risk-taking behaviors, and high-energy injury mechanisms. The mean age of patients was 40.1 years, and male patients were approximately 4.5 years younger than female patients, with the highest incidence observed in the 18–44-year age group. These findings are consistent with the meta-analysis by Kumar et al.,[1] which reported a mean age of 40 years for TSI globally (9), and with Leucht et al.[6] who demonstrated that traumatic spinal fractures occur more frequently in young adults. The younger age distribution among men in our cohort suggests that young males may represent a particularly vulnerable population for TSI.

Regarding etiology, VO-MVA was the leading cause of injury, followed by VRUs-MVA, HEF, assault, and other mechanisms. Previous studies from different international settings have identified motor vehicle accidents and falls as the principal causes of TSI.[2,7,8] Global epidemiological analyses similarly identify road traffic accidents and falls as the predominant mechanisms.[1] Therefore, the etiological distribution observed in our cohort is consistent with the literature. However, because a substantial proportion of cases were referred for disability assessment following traffic accidents, VO-MVA and VRUs-MVA may be overrepresented in our sample.

A significant association was identified between age group and injury etiology, indicating that mechanisms of injury vary across age groups. The predominance of traffic accidents among young adults (18–44 years) is consistent with previous reports. Kumar et al.[1] reported that motor vehicle accidents account for 36.5% of TSI cases among young adults in high-income countries. Likewise, El-Faramawy et al.[7] identified traffic accidents as the leading cause of spinal injuries among young men and recognized this population as a high-risk group.These findings support strengthening traffic safety measures targeting young adults, including speed regulation and prevention of impaired driving. Among individuals aged ≥65 years, the relatively high proportion of VRUs-MVA suggests increased vulnerability among elderly pedestrians. Oliver et al.[2] reported that older individuals experience a higher risk of pedestrian traffic accidents and may sustain more severe spinal injuries. Additionally, the increased frequency of high-energy falls among middle-aged individuals (45–64 years) may reflect greater exposure to occupational hazards and physically demanding activities. Leucht et al.[6] identified falls as the second most common cause of spinal injury in this age group, particularly among individuals employed in construction and industrial sectors. These observations emphasize the importance of strengthening workplace safety policies, including adherence to personal protective equipment and preventive health measures.

In our study, we investigated the association between TSI etiology and both trauma severity (major vs. minor trauma according to the ISS) and the number of vertebral fractures. Our findings indicate that trauma mechanisms influence both injury severity and the number of vertebral fractures. VRUs-MVA and HEF were significantly associated with major trauma. Approximately two-thirds of patients in the VRUs-MVA group and three-quarters of patients in the HEF group sustained major trauma. Previous studies have similarly demonstrated that severe trauma and multiple fractures occur more frequently among unprotected pedestrians and individuals sustaining falls from height.[1,9] These findings suggest that injury mechanisms lacking protective energy-absorbing elements may result in more severe trauma.

Similarly, a significantly greater proportion of multiple vertebral fractures (≥4 levels) was observed in HEF cases. Leucht et al.[6] reported that 77% of type B and C fractures according

to the AO (Arbeitsgemeinschaft für Osteosynthesefragen) classification system were associated with traffic accidents and falls. This finding supports the concept that high-energy falls can generate simultaneous traumatic loading across multiple spinal segments.

On the other hand, the relatively high frequency of minor trauma and single vertebral fractures among patients involved in VO-MVA is noteworthy. Previous studies suggest that passive safety measures in modern vehicles, such as seat belts and airbags, may reduce the transmission of traumatic forces to the body and thereby decrease the risk of severe injuries and multiple fractures.[2,6] In contrast, cases involving HEF and VRUs-MVA, which generally lack comparable protective mechanisms, were associated with greater trauma severity and a higher incidence of multiple vertebral fractures in our cohort. Therefore, clinicians should maintain a high index of suspicion for major trauma and multiple spinal fractures, particularly in patients presenting after VRUs-MVA or HEF.

Analysis of the anatomical distribution of 582 vertebral fractures demonstrated that the thoracolumbar junction (T11–L2) was the most frequently affected region. Within this region, L1 had the highest fracture frequency, followed by L2 and T12. These findings are consistent with previous studies identifying the thoracolumbar junction as the most common site of traumatic spinal injury.[6,10-12] Within the cervical region, C2 and C7 were more frequently affected than other cervical vertebrae, with VO-MVA representing the predominant etiology. Bakhsh et al.[13] similarly reported that C2 is the most commonly injured cervical vertebra. This pattern may be explained by the biomechanical characteristics of C2 within the atlantoaxial complex and the location of C7 at the cervicothoracic transition zone, both of which are exposed to increased mechanical stress.[6,14] These findings support the concept that traumatic vertebral fractures occur more frequently at biomechanical transition zones and highlight the importance of careful radiological evaluation of these regions.

Within the sacral region, S1 and S2 were the most frequently affected vertebrae, with VRUs-MVA, VO-MVA, and HEF representing the predominant etiologies. The increased contribution of HEF in this region is noteworthy. Sacral fractures are widely recognized as indicators of high-energy trauma and frequently occur in association with pelvic ring injuries.[15] Accordingly, careful assessment of both the sacrum and pelvic ring is required in patients presenting after HEF.

Spinal fractures are inherently complex injuries, and associated fractures or organ injuries may further complicate evaluation and management. Assessment may be particularly challenging in unconscious patients. In this context, our study aimed to assess the association between associated injuries and the likelihood of fractures in specific anatomical regions of the spine. Patients with head and facial trauma demonstrated a 3.6-fold greater likelihood of cervical fractures. Previous studies have reported similar associations between traumatic head injury, facial fractures, and cervical spine fractures.[16,17] Likewise, patients with thoracic injuries had a 2.6-fold greater likelihood of thoracic vertebral fractures. Existing evidence demonstrates that concomitant thoracic injuries frequently accompany thoracic spine fractures.[18-20] These findings emphasize the importance of careful evaluation of the thoracic spine, particularly the thoracolumbar junction, in patients presenting with thoracic trauma.

Sacral fractures were associated with the broadest pattern of concomitant injuries.[21] Significant associations were observed with injuries involving the thorax, abdomen, and upper and lower extremities. Most notably, intra-abdominal organ injuries increased the likelihood of sacral fracture by 6.4-fold. These findings suggest that sacral fractures should prompt evaluation for injuries involving adjacent anatomical structures, particularly intra-abdominal organs and the pelvic ring.

Treatment selection in traumatic vertebral fractures depends on fracture stability, neurological status, and patient-specific considerations. In our study, conservative treatment was applied in 73.3% of cases, supporting its continued role as the primary approach for stable fractures.[22] Among surgical procedures, open posterior instrumentation and fusion predominated, emphasizing the importance of stabilization in unstable injuries.[23] The relatively limited use of minimally invasive procedures suggests that these techniques remain reserved for selected indications; however, minimally invasive surgery may represent an effective alternative in patients unsuitable for conservative management, particularly those with polytrauma or significant comorbidities such as obesity or compromised pulmonary function.[23]

Half of the patients in our cohort developed sequelae following completion of recovery, highlighting the substantial long-term morbidity associated with traumatic spinal fractures. This finding is consistent with Filiberto et al.,[24] who reported mild-to-moderate functional impairment following spinal fracture. Restricted spinal mobility represented the most common sequela, underscoring the direct impact of vertebral injury on long-term physical function.

Traumatic spinal cord injury is one of the most severe complications of TSI because of its profound functional, social, and economic consequences for affected individuals, their families, and caregivers. In 2021, approximately 15.4 million individuals worldwide were estimated to be living with SCI.[25] Leucht et al.[6] reported neurological deficits in 24.7% of patients with traumatic spinal fractures. Consistent with previous findings, spinal cord injury accounted for 13.5% of sequelae in our cohort. The identification of multi-system sequelae in patients with TSI in our study highlights the broad and persistent impact of these injuries.

These findings support multidisciplinary long-term follow-up and early initiation of comprehensive rehabilitation programs. Future prospective studies incorporating forensic medicine

evaluation may further strengthen multidisciplinary assessment of these complex cases.

Limitations

Despite being the first comprehensive study examining traumatic spinal fractures from a forensic medicine perspective, several limitations should be acknowledged. First, the retrospective design may have introduced information bias and incomplete data collection. Second, selection bias is possible because many patients were referred for disability assessment following traffic accidents, potentially leading to overrepresentation of VO-MVA and VRUs-MVA and limiting the generalizability of etiological findings. Third, although statistical thresholds (p=0.05) were applied (using chi-square and Fisher's tests), clinically meaningful associations may have been overlooked; for example, the association between sex and etiology approached significance (p=0.074) but was not statistically confirmed. Finally, as a single-center study, these findings may not be fully generalizable to broader populations. Prospective multicenter studies are needed to validate these findings.

CONCLUSION

Research addressing the etiology and long-term outcomes of traumatic spinal injury is limited. In this context, our study represents the first comprehensive regional forensic medicine evaluation of traumatic spinal fractures. Our findings clinically relevant evidence to support the prevention, diagnosis, and management of these injuries and may inform public health strategies. The results emphasize the importance of strengthening traffic safety measures, implementing fall-prevention programs, and improving occupational safety standards. Furthermore, our findings reinforce the need to maintain a high index of suspicion for spinal fractures in patients presenting after high-energy trauma or with associated organ injuries and highlight the critical importance of timely triage and comprehensive clinical evaluation.

Ethics Committee Approval: This study was approved by the Atatürk University Faculty of Medicine Non-Interventional Clinical Research Ethics Committee (Date: 03.05.2024, Session No. 3; Approval No. 4).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Travmatik spinal kırıklar: Adli tıp kliniği örneğinde epidemiyolojik ve klinik değerlendirme

AMAÇ: Travmatik spinal yaralanmalar (TSY), ciddi morbiditeye neden olan önemli bir halk sağlığı sorunudur. Bölgesel bir adli tıp perspektifi sunan ilk çalışma olarak, Atatürk Üniversitesi Adli Tıp Anabilim Dalı'na (2020-2022) başvuran travmatik spinal kırıkların klinik özelliklerini, etiyolojik faktörlerini, yaralanma modellerini ve uzun dönem sekellerini retrospektif olarak incelemeyi amaçlamıştır.
GEREÇ VE YÖNTEM: Atatürk Üniversitesi Adli Tıp Anabilim Dalı'nda 2020-2022 yılları arasında değerlendirilen 12.029 olgunun tıbbi kayıtları incelendi. Spinal kırığı doğrulanan toplam 277 olgu çalışmaya dahil edildi. Demografik veriler, etiyoloji, ISS (Yaralanma Şiddet Skoru), kırık seviyeleri, eşlik eden lezyonlar ve tedavi yöntemleri analiz edildi. En az 12 ay takibi olan 174 hastada uzun dönem sekeller değerlendirildi.
BULGULAR: Hastaların %74.1'i erkek (erkek/kadın oranı: 2.85) olup, yaş ortalaması 40.1±16.69 idi. En sık görülen etiyoloji araç içi trafik kazası (AİTK) (%56.3) iken, bunu korunmasız yaya kazaları (KYK) (%15.5) ve yüksek enerjili düşme (YED) (%13.4) izledi. Yaş ile etiyoloji arasında istatistiksel olarak anlamlı bir ilişki saptandı (p=0.001); 18-44 yaş grubunda AİTK baskınken, 65 yaş üstü grupta KYK oranları arttı. KYK ve YED kaynaklı yaralanmaların majör travma (ISS ≥16) (p=0.044) ve çoklu vertebra kırıkları (p=0.001) ile anlamlı düzeyde ilişkili olduğu görüldü. En sık etkilenen bölge torakolumbar bileşke (T11-L2) (%31.8) idi. Baş/yüz travması ile servikal kırıklar (OR=3.59; %95 GA: 1.89-6,82) ve karın içi organ yaralanmaları ile sakral kırıklar (OR=6.47; %95 GA: 2.40-17.39) arasında anlamlı korelasyon saptandı. Takip edilen olguların %50'sinde kalıcı sekel gözlendi; bunlar arasında en sık spinal hareket kısıtlılığı (%46.8) ve spinal kord yaralanması (%13.5) yer aldı.
SONUÇ: Araç içi trafik kazaları spinal kırıkların en sık nedeni olsa da korunmasız yaya kazaları ve yüksek enerjili düşmeleri içeren kazalar, daha yüksek yaralanma şiddeti ve çoklu kırıklarla sonuçlanmaktadır. Klinisyenler, eşlik eden baş travması olan hastalarda servikal, batın yaralanması olanlarda ise sakral kırıklar açısından şüpheci olmalıdır. Özellikle yüksek enerjili travma ve eşlik eden organ yaralanması olan vakalarda, spinal kırık riski nedeniyle hızlı triyaj ve dikkatli değerlendirme hayati önem taşımaktadır. Bulgularımız, travmatik spinal kırıkların ciddi uzun dönem morbiditesini ortaya koymakta ve multidisipliner takibin önemini vurgulamaktadır.

Anahtar sözcükler: Adli tıp; eşlik eden yaralanma; epidemiyoloji; travmatik omurilik yaralanması; travmatik spinal yaralanma

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CASE REPORT

Progressive seatbelt-related intramammary hematoma requiring surgical evacuation in an obese female: a case report

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ABSTRACT

Seatbelt-related breast trauma is an uncommon consequence of motor vehicle collisions. Most injuries present as localized contusion or hematoma, whereas progressive breast hematomas requiring surgical intervention are exceedingly rare, particularly in patients without coagulation abnormalities. Obesity may further alter trauma biomechanics and influence hematoma progression. A 49-year-old woman with obesity (Body Mass Index: 38 kg/m^2) presented to the emergency department one hour after a motor vehicle collision with left breast swelling, firmness, and ecchymosis. Body temperature, blood pressure, and heart rate were within normal limits. Contrast-enhanced computed tomography (CT) demonstrated a 62×52 mm breast hematoma without evidence of arterial extravasation. Conservative treatment with compression therapy was continued for three days; however, pain and breast tension progressively increased, and ultrasonography demonstrated mild enlargement of the hematoma. On the fourth day, minimally invasive surgical evacuation was performed, yielding a large volume of organized hematoma. Postoperatively, symptoms improved rapidly. At two-week follow-up, breast symmetry was fully restored with no residual deformity. This case represents a rare presentation of seatbelt-related breast trauma: a progressive breast hematoma without active bleeding that ultimately required surgical evacuation. Obesity may have contributed to the failure of conservative management and earlier clinical progression. Early recognition of symptom worsening is essential to optimize cosmetic and functional outcomes.

Keywords: Breast hematoma; obesity; seatbelt injury.

INTRODUCTION

Seatbelt use has significantly reduced morbidity associated with motor vehicle collisions; however, it has also introduced a distinct pattern of thoracic soft-tissue injury referred to as seatbelt syndrome, which includes rib, clavicle, spine, and sternum fractures, rupture of hollow pelvic and abdominal viscera, mesenteric injury, and major vessel trauma. Breast injuries represent a small proportion of these cases, accounting for less than 2% of blunt chest trauma, but may present with a broad clinical spectrum ranging from contusion and ecchymosis to massive hematoma or ductal avulsion.[1] Although uncommon, emergency physicians should recognize breast trauma associated with hematoma and contusion and be familiar with available management strategies for breast injuries.[2]

The seatbelt acts as a narrow contact interface that concentrates compressive and shear forces across the breast parenchyma and Cooper's ligaments. Differential motion between the chest wall during abrupt deceleration and the more mobile breast tissue generates traction and torsional forces, predisposing to disruption of subcutaneous and intraparenchymal vessels. In patients with obesity and greater breast

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volume, increased tissue mass and inertia may augment shear stress and intramammary vessel injury, potentially contributing to progressive hematoma formation even in the absence of detectable arterial extravasation on initial imaging.

Endovascular or surgical intervention is generally recommended when active bleeding is identified radiologically; however, successful conservative management has also been reported in selected cases. Surgical treatment is typically reserved for patients with hemodynamic instability, respiratory compromise due to hematoma mass effect, hypovolemic shock secondary to multisystem trauma, open or infected wounds, or underlying coagulopathy.[3]

Although breast emergencies are relatively uncommon, they represent an important component of routine breast imaging practice. Hemorrhage and trauma-related inflammation may lead to long-term fat necrosis, which can radiologically mimic malignancy. Therefore, although detailed clinical history is the cornerstone of diagnosis, ultrasonography and computed tomography play essential roles in guiding both diagnosis and management.[4,5]

Obesity introduces an additional biomechanical variable in breast trauma. Increased soft-tissue mass may amplify shear forces during seatbelt compression and reduce the effectiveness of conservative compression therapy. However, these interactions remain poorly characterized in the current literature.

We present a rare case of progressive seatbelt-related breast hematoma in a patient with obesity that required surgical evacuation despite the absence of active bleeding.

CASE REPORT

A 49-year-old woman with obesity (Body Mass Index: 38 kg/m^2) and no other known comorbidities presented to the emergency department one hour after a motor vehicle collision. She had been the front-seat passenger and was restrained with a three-point seatbelt at the time of the accident. She denied chest pain, dyspnea, and loss of consciousness. The patient underwent an Advanced Trauma Life Support (ATLS)-based primary survey. The airway was patent with normal speech. Breathing was unlabored, with symmetric chest expansion and normal oxygen saturation. Circulation was stable, with normal blood pressure and heart rate, warm extremities, and no signs of shock. Disability assessment demonstrated normal mental status without focal neurological deficits. No chest wall deformity was identified, and respiratory and hemodynamic parameters remained within normal limits (blood pressure: 126/72 mmHg; heart rate: 92 beats/min). Physical examination revealed marked swelling and firmness of the left breast, accompanied by extensive ecchymosis corresponding to the seatbelt trajectory and significant tenderness to palpation (Fig. 1). Contrast-enhanced thoracic CT performed at presentation demonstrated a 62×52 mm intramammary fluid collection consistent with an acute hematoma, heterogeneous density, and diffuse breast edema, without associated rib fractures or intrathoracic injury (Fig. 2). Specifically, there was no evidence of pneumothorax, hemothorax, rib or sternal fractures, intra-abdominal organ injury, or pelvic injury. These findings were compatible with an isolated breast hematoma secondary to seatbelt compression.

Conservative management consisting of compression bandaging and nonsteroidal anti-inflammatory analgesia was initiated and maintained for three days. However, on the fourth day, the patient developed worsening pain, increased breast tension, and progression of ecchymosis. Ultrasonography demonstrated mild enlargement of the hematoma without a drainable fluid collection. Because of clinical progression and

Figure 1. Clinical photograph of the patient demonstrating a left breast hematoma.

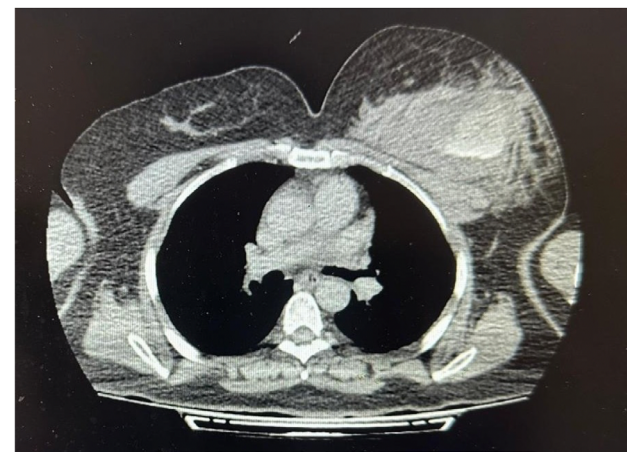

Figure 2. Axial view of computed tomography of the chest demonstrating a left breast hematoma.

increasing discomfort, conservative treatment was considered insufficient. Minimally invasive surgical evacuation was subsequently performed through a small incision. A large volume of thick, organized hematoma was evacuated, and no arterial bleeding source was identified intraoperatively. The hematoma cavity was completely decompressed, and no drain placement was required.

Postoperatively, the patient experienced rapid improvement in pain. Ecchymosis regressed promptly with adjunctive topical heparinoid therapy. At follow-up on postoperative day 1, swelling and breast tension had markedly decreased. During the two-week follow-up period, breast contour and symmetry returned completely to normal, with no residual deformity or pain.

DISCUSSION

Seatbelt-related breast trauma may present with characteristic clinical and radiological findings.[6] The literature suggests that most traumatic breast hematomas resolve with conservative management, whereas progressive enlargement is more commonly associated with arterial bleeding or hemodynamic instability and may require angiographic embolization in selected cases.[7] Representative examples include the 15 cm actively bleeding hematoma reported by Başara et al.,[8] which was managed conservatively, and the 18 cm massive hematoma causing hypovolemic shock described by Amin et al.,[9] which required surgical treatment. In contrast, our patient developed progressive hematoma enlargement despite the absence of active bleeding, suggesting a distinct pathophysiological mechanism. Surgical evacuation is generally reserved for patients with hemodynamic instability, arterial bleeding, or skin compromise. In the present case, surgical intervention was indicated because of worsening pain, increasing breast tension, concern for cosmetic sequelae, and radiological evidence of progression. These findings emphasize the importance of considering clinical progression, rather than imaging findings alone, when determining management strategy.

Progressive breast hematoma shares several features with other blunt trauma-related soft-tissue hematomas of the torso, in which bleeding may result from small-vessel disruption, venous oozing, or shearing injury to perforating branches. Similar to abdominal wall and chest wall hematomas, clinical decision-making should incorporate hemodynamic status, symptom progression, hemoglobin trends, and imaging evidence of ongoing bleeding.

In addition to the breast trauma classification proposed by Majeski et al.,[2] Song et al.[5] proposed an alternative classification system based on the interval between the traumatic event and clinical presentation. These classification schemes have been associated with different management approaches; however, due to the rarity of such injuries, no clear consensus has not been established. According to the Majeski et al.,[2] and Song et al.[5] classification models, breast trauma encompasses a broad continuum ranging from mild contusion and localized hematoma to severe crush injuries and avulsion. Notably, the Song classification generally associates acutely expanding hematomas with arterial extravasation. However, the present case demonstrated enlargement in the absence of radiologic evidence of extravasation, representing an intermediate phenotype that is not fully captured by existing classification systems.

Song et al.[5] reviewed 42 patients with breast trauma and identified four major injury patterns, with only a minority demonstrating expanding hematomas, typically associated with arterial extravasation. In this review, Song et al.[5] reported a broad therapeutic spectrum for the management of post–motor vehicle collision breast hematomas, ranging from conservative treatment to mastectomy; however, most cases were successfully managed conservatively.

Obesity may represent an additional factor influencing clinical behavior following breast trauma. Increased breast volume may amplify shear forces during deceleration injury, while greater parenchymal mobility may predispose to deeper tissue damage. Furthermore, the effectiveness of compression therapy may be reduced in larger or ptotic breasts, and increased adipose tissue may contribute to local tissue pressure. Although these mechanisms remain insufficiently studied, this case raises the possibility that obesity may act as a modifier of hematoma progression following seatbelt-related breast injury.

Breast trauma may also lead to delayed manifestations that become evident weeks to months after injury; therefore, careful follow-up is essential. However, socioeconomic and geographic factors, including residence in a rural area as in the present case, may limit adherence to recommended follow-up. Fat necrosis is a recognized late complication and may present as palpable nodularity, distortion, cyst formation, or calcifications, potentially mimicking malignancy on subsequent imaging studies. Additional long-term sequelae include persistent asymmetry, contour deformity, fibrosis, chronic pain, seroma formation, skin retraction, and, less commonly, secondary infection or abscess formation. When clinically indicated, follow-up mammography and ultrasonography approximately 3–6 months after injury may help confirm resolution and exclude occult pathology. Earlier reassessment should be considered if a persistent palpable mass develops, symptoms recur, or skin changes occur.

CONCLUSION

This case describes a rare presentation of progressive breast hematoma following seatbelt-related trauma in the absence of active arterial bleeding, ultimately requiring surgical evacuation. Obesity may have contributed to hematoma progression and reduced responsiveness to conservative management. Early recognition of symptom progression and timely surgical intervention may help prevent long-term deformity

and optimize cosmetic outcomes. As imaging technologies, including artificial intelligence–assisted approaches, continue to evolve and obesity becomes increasingly prevalent, establishing objective imaging-based classification systems for breast trauma may improve the reproducibility of evaluation and support the development of more standardized treatment algorithms.

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OLGU SUNUMU - *ÖZ*

Emniyet kemerine bağlı progresif meme hematomun obez hastada cerrahi yönetim stratejisi: Olgu sunumu

Emniyet kemerine bağlı meme travması, motorlu araç kazaları sonrasında nadir görülen bir tablodur. Olguların çoğu lokalize kontüzyon veya hematom şeklinde ortaya çıkar ve genellikle konservatif yöntemlerle izlenebilir. Bununla birlikte, progresif seyreden ve cerrahi müdahale gerektiren meme hematomları oldukça nadirdir; özellikle koagülasyon bozukluğu bulunmayan hastalarda bu durum daha da nadir bildirilmektedir. Obezite, darbe biyomekaniğini değiştirebilir; bu nedenle hematomun genişlemesi, semptomların progresyonu ve konservatif tedaviye yanıt üzerinde etkili olabilir. VKİ 38 kg/m² olan 49 yaşındaki obez kadın hasta, motorlu araç kazasından 1 saat sonra sol memede şişlik, sertlik ve morluk ile acil servise başvurdu. Vücut ısısı, kan basıncı ve kalp hızı normaldi. Kontrastlı BT'de arteriyel ekstravazasyon saptanmaksızın 62×52 mm meme hematomu izlendi. Kompresyon tedavisi 3 gün uygulandı; ancak ağrı ve meme gerginliği arttı ve ultrasonografide hematomda büyüme görüldü. Dördüncü günde minimal insizyonla cerrahi olarak hematom boşaltıldı. Postoperatif dönemde semptomlar hızla geriledi. İki haftalık takipte meme simetrisi rezidü deformite olmaksızın tamamen düzeldi. Bu olgu, aktif kanama bulgusu olmaksızın progresyon gösteren ve nihayetinde cerrahi gerektiren emniyet kemerine bağlı meme travmasının nadir bir prezentasyonudur. Obezite, konservatif tedavinin başarısızlığına ve daha erken klinik progresyona yatkınlık oluşturabilir. Bulgularda kötüleşmenin erken fark edilmesi, optimal kozmetik ve fonksiyonel sonuçların elde edilmesi için kritik öneme sahiptir.
Anahtar sözcükler: Emniyet kemeri travması; meme hematomu; obezite.

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