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EXPERIMENTAL STUDY

Fraxin as a promising molecule in the pharmacological treatment of acute mesenteric ischemia: an experimental study

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ABSTRACT

BACKGROUND: Ischemia-reperfusion (I-R) injury associated with acute mesenteric vascular occlusion can lead to severe impairment of intestinal tissue and may become a life-threatening condition if not treated in the early clinical stages. Previous studies have suggested that fraxin may exert protective effects against I-R–induced mesenteric injury due to its antioxidant and anti-inflammatory properties.

METHODS: This experimental study was conducted using healthy male Wistar albino rats. The animals were divided into four groups: a Sham group (superior mesenteric artery [SMA] isolated but not occluded), a Control group (SMA isolated and I-R induced), a 10 mg/kg Fraxin group, and a 50 mg/kg Fraxin group (fraxin administered before reperfusion). Total antioxidant status (TAS), total oxidant status (TOS), superoxide dismutase (SOD), glutathione peroxidase (GPx), and catalase (CAT) activities were evaluated. Histopathological examinations and inflammatory markers, including tumor necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), and myeloperoxidase (MPO), were also analyzed.

RESULTS: In the Sham group, SOD activity was 135.2±10.5 U/mg protein, GPx activity was 65.3±4.7 U/mg protein, and CAT activity was 85.1±5.8 U/mg protein. In the Control group, these values were 95.4±7.9, 45.7±3.6, and 60.3±4.2 U/mg protein, respectively. In 10 mg/kg Fraxin group, SOD, GPx, and CAT activities were 115.6±8.4, 55.8±4.2, and 75.6±5.5 U/mg protein, respectively; in the 50 mg/kg Fraxin group, the corresponding values were 130.8±9.7, 60.2±4.8, and 90.4±6.3 U/mg protein. Significant decreases in TNF-α, IL-6, and MPO levels were observed in the Fraxin-treated groups ($p<0.05$).

CONCLUSION: Fraxin administration preserved tissues and improved antioxidant parameters by reducing oxidative stress and inflammation in the acute mesenteric artery ischemia–reperfusion injury (AMAIRI) model. Based on these findings, fraxin may be considered a potential therapeutic option for mesenteric ischemia-reperfusion-related injuries.

Keywords: Acute mesenteric vascular occlusion; anti-inflammatory activity; antioxidant activity; fraxin; İschemia-reperfusion injury.

INTRODUCTION

Experimental models of acute mesenteric vascular occlusion with ischemia-reperfusion (I-R) injury in small intestinal tissues cause severe tissue damage and may develop into a potentially lethal surgical emergency if not diagnosed at an early clinical stage. Acute mesenteric ischemia (AMI) has been reported in 0.11% of all patients presenting to the emergency department (ED), corresponding to a frequency of nearly 1 in 1,000 patients.[1] However, despite significant advances in diagnostic techniques, perioperative management, and surgical interventions over the past decades, the mortality rate

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of AMI remains between 32% and 69%.[2] These rates may vary depending on geographical region, healthcare facilities, and population characteristics.[3] This high mortality rate underscores the severity of AMI and highlights the importance of early diagnosis and timely management.

The most common pathophysiological mechanisms of I-R injury include superior mesenteric artery (SMA) embolism, superior mesenteric artery thrombosis associated with chronic atherosclerosis, non-critical mesenteric ischemia, abdominal aortic aneurysm surgery, cardiopulmonary bypass, strangulated hernia, neonatal necrotizing enterocolitis, intestinal transplantation, and hemorrhagic-hypovolemic shock.[4] Interruption of blood circulation causes ischemic damage by rapidly disrupting tissue metabolism, whereas restoration of blood flow can further exacerbate tissue injury. Reperfusion following hypoperfusion leads to severe damage to the intestinal mucosa and cells and can trigger a range of pathological, molecular, and biochemical changes, particularly when diagnosis or treatment is delayed.[5] While ischemic tissue injury primarily results from oxygen deprivation and cell death associated with energy depletion, reperfusion further increases oxidative stress and local tissue damage and may trigger systemic inflammation or widespread inflammatory responses.

These considerations suggest that I-R injury requires further investigation, as such injuries can cause substantial impairment in both quality of life and overall health. A better understanding of I-R injury may facilitate the development of new therapeutic strategies for the management of these injuries in clinical practice.

It has been hypothesized that fraxin may prevent or attenuate mesenteric I-R injury due to its antioxidant and anti-inflammatory properties. This hypothesis is based on the ability of fraxin to act as a radical scavenger, inhibit lipid peroxidation, and suppress the production of pro-inflammatory cytokines.[6,7] Supporting this hypothesis, several studies have demonstrated that fraxin exerts protective effects against I-R injury in various organs and tissues. For example, previous studies have shown that fraxin reduces oxidative stress and exhibits anti-inflammatory activity in renal ischemia-reperfusion injury.[8] Additionally, similar protective effects of fraxin have been demonstrated in lung tissue.[9] Moreover, research findings indicate that fraxin has hepatoprotective effects against toxic injury in liver cells.[10] Therefore, this study aimed to investigate the effects of fraxin administration on intestinal I-R injury.

The aim of this study was to evaluate the potential of fraxin to regulate or attenuate I-R-induced mesenteric injury in a rat model based on biochemical and pathological findings. Furthermore, the findings of the present study may contribute to the development of novel therapeutic approaches for the treatment of mesenteric ischemia-reperfusion injury.

MATERIALS AND METHODS

This study was conducted at the Giresun University Experimental Animals Research and Application Center. Healthy young adult male Wistar albino rats with an initial body weight between 250 and 300 g were used in the study. To ensure experimental consistency, only rats weighing between 180 and 200 g were included. Inclusion and exclusion criteria were established to ensure that only healthy animals within the specified weight range were used in the experiments. To control for potential confounding variables, rats with any signs of disease, injury, or body weight outside the predefined range were excluded from the experiment. All procedures were conducted in accordance with these criteria to maintain the validity and consistency of the experimental groups, following commonly accepted research practices. The rats were assigned to four groups, each consisting of eight animals. Anesthesia was induced by intramuscular injection of ketamine HCl at a dose of 80 mg/kg (Ketalar®; Pfizer, Istanbul, Türkiye) and xylazine HCl at a dose of 3 mg/kg (Rompun®; Bayer, Istanbul, Türkiye).

Study Design

In this study, a controlled experimental design was used.

• **Group 1 (Sham group):** The superior mesenteric artery was identified but not ligated. The abdominal wall was closed in two layers using No. 2 polypropylene sutures, and the rats were euthanized after 1 hour and 45 minutes.

• **Group 2 (Control group):** The SMA was dissected, and ischemia was induced using a non-traumatic microvascular clip. The abdomen was then closed. The durations of ischemia and reperfusion were set at 45 minutes and 60 minutes, respectively, as established in previous studies. The effects of different durations were not investigated in this study; however, the selected durations are widely used in experimental models and provide reliable results.[11,12] After 45 minutes of ischemia, laparotomy was performed, the clamp was released, and reperfusion was initiated. I-R injury was induced by reperfusion, and the rats were euthanized after 60 minutes.

• **Group 3 (Fraxin 10 mg/kg group):** The procedure was identical to that used in Group 2, with the addition of intraperitoneal administration of fraxin at a dose of 10 mg/kg prior to reperfusion. The rats were euthanized after 60 minutes of reperfusion.

• **Group 4 (Fraxin 50 mg/kg group):** The procedure was identical to that used in Group 2. Fraxin was administered intraperitoneally at a dose of 50 mg/kg prior to reperfusion. The rats were euthanized after 60 minutes of reperfusion.

Dose Selection

The doses of 10 mg/kg and 50 mg/kg fraxin were selected based on previous studies in the literature. These studies determined the effective dose range and demonstrated the efficacy of these doses in I-R injuries in different organs and tissues.[8,9]

This study design was carefully planned and implemented to ensure that the experimental groups were as comparable as

possible and that the results obtained would be reliable and valid.

Interventions, Experiments, or Treatments

All animals received intramuscular injection of cefuroxime at a dose of 20 mg/kg/day following the initial surgical procedures. Throughout the experiment, the body temperature of the rats was maintained at approximately 37.5°C using a heat lamp. At the end of the experimental period, the rats were anesthetized with ketamine and xylazine. Blood samples were then collected from the heart using a syringe and transferred into microcentrifuge tubes. The samples were centrifuged at 3,000 g to obtain serum for biochemical analysis. The abdomen was subsequently reopened, and intestinal tissue samples measuring approximately 6–8 cm in length were obtained from the terminal ileum. The samples were washed with cold saline and fixed in 10% neutral formaldehyde solution. Additional blood samples were collected in ethylenediaminetetraacetic acid (EDTA)-containing tubes to prevent clotting and centrifuged to obtain plasma for biochemical analysis; the plasma samples were stored at -80°C. The intestinal tissues were embedded in paraffin blocks, and 5 µm thick sections were prepared and stained with hematoxylin and eosin (H&E). Histological sections were examined under a microscope by a pathologist who was blinded to the experimental procedures. Total antioxidant status (TAS), total oxidant status (TOS), superoxide dismutase (SOD), glutathione peroxidase (GPx), and catalase (CAT) activities in plasma and tissue samples were measured using spectrophotometric methods with commercial kits. At the end of the study, all rats were euthanized by the decapitation method.

Methods of Measurement and Calculations

Biochemical Tests

Total Antioxidant Status Measurement: TAS levels were measured using the Total Antioxidant Status kit (Rel Assay Diagnostics, Türkiye). In this method, ABTS (2,2′-azinobis (3-ethylbenzothiazoline-6-sulfonate)) is oxidized to ABTS•+ by hydrogen peroxide in an acidic buffer solution (30 mmol/L, pH 3.6). The ABTS+ forms a stable dark green-colored complex in an acetate buffer. During serial dilution, the dark green color gradually disappears upon dilution in a more concentrated, higher-pH acetate buffer solution (0.4 mol/L, pH 5). The loss of this color occurs at a rate proportional to the concentration of antioxidants present in the sample. This reaction can be monitored spectrophotometrically, and the rate of decolorization is inversely proportional to the total antioxidant capacity (TAC) of the sample. This reaction is quantified using Trolox™ (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), a water-soluble analog of vitamin E. The results obtained with this method are expressed as mmol Trolox equivalent/L.

Total Oxidant Status Measurement: TOS levels were measured using the Total Oxidant Status kit (Rel Assay Diagnostic, Türkiye). In this method, oxidant molecules in the sample convert the ferrous ion (Fe^{2+})-o-dianisidine complex to ferric ions (Fe^{3+}). The oxidation reaction is enhanced by glycerol molecules present in the reaction medium. Ferric ions then form a colored complex with xylenol orange in an acidic environment. The intensity of the color is proportional to the amount of oxidant molecules present in the sample. The assay is calibrated using hydrogen peroxide (H_2O_2). Results are expressed as micromolar hydrogen peroxide equivalents per litter (µmol H2O2 equiv./L).

SOD, GPx, and CAT Level Measurement Methods

• **SOD Activity:** SOD activity was measured using a spectrophotometric method based on the inhibition of nitroblue tetrazolium (NBT) reduction by superoxide generated by the xanthine–xanthine oxidase system. Results were expressed as units of SOD per milligram of protein (U/mg protein).

• **GPx Activity:** GPx activity was determined using a spectrophotometric method based on the oxidation of nicotinamide adenine dinucleotide phosphate (NADPH) to nicotinamide adenine dinucleotide phosphate (NADP+) in the presence of reduced glutathione, glutathione reductase, and hydrogen peroxide. The results were expressed as U/mg protein.

• **CAT Activity:** CAT activity was measured by monitoring the decomposition of hydrogen peroxide through the decrease in absorbance at 240 nm in the presence of catalase. Results were expressed as U/mg protein.

Histopathological Examination

Terminal ileum tissues were embedded in parallel wax, sectioned, and stained with hematoxylin and eosin. Histological sections were examined under light microscopy by a pathologist who was blinded to the experimental procedures. Intestinal lesions were graded according to a five-level ischemia-reperfusion injury scoring system adapted from Quaedackers et al.:

• Grade 0: Normal villi and mucosa

• Grade 1: Development of subepithelial space at the villus tip with villous edema and occlusion

• Grade 2: Development of a subepithelial space at the villus tip with bleeding and fragmentation at the villus tip

• Grade 3: Loss and fragmentation of the villus tip

• Grade 4: Complete separation of the villi from the lamina propria

• Grade 5: Necrosis of the entire wall with fragmentation of the lamina propria.

Statistical Analysis

A power analysis was performed to determine the appropriate sample size for the study. Based on the results of the power analysis, it was determined that eight rats per group were required. Experimental ischemia-reperfusion studies reported in the literature were used as references to deter-

mine the appropriate number of animals required for statistical evaluation. Based on these references, the optimal sample size was selected for this study. Statistical analyses were performed using MedCalc (MedCalc Software Ltd., Ostend, Belgium) and GraphPad Prism version 9.0.1. Variables were expressed as mean±standard deviation. The Kruskal-Wallis H test was used for comparisons among more than two groups, and Dunn's test was applied for post hoc comparisons. Statistical significance was defined as $p<0.05$ (two-tailed).

The study was conducted in compliance with ethical standards for animal experimentation. The study protocol was approved by the Local Ethics Committee of Giresun University (approval number: 08.06.2020/6859/21). All procedures involving animals were carried out in accordance with the Guide for the Care and Use of Laboratory Animals and adhered to the principles outlined in the EU Directive 2010/63/EU on the protection of animals used for scientific purposes.

RESULTS

In this study, MDA and TAS levels were compared among the four groups. In the Sham group, the MDA level was 45.5±9.0 µmol/L, whereas this value was 42.5±10.8 µmol/L in the Control group. In the Fraxin-treated groups, MDA level was 33.6±11.4 µmol/L at the 10 mg/kg dose and 56.3±16.5 µmol/L at the 50 mg/kg dose. In terms of TAS levels, the values were 1.21±0.12 mmol Trolox equiv./L in the Sham group, 1.21±0.15 mmol Trolox equiv./L in the Control group, 1.81±0.91 mmol Trolox equiv./L in the 10 mg/kg Fraxin group, and 1.27±0.28 mmol Trolox equiv./L in the 50 mg/kg Fraxin group (Table 1, Figure 1A-B).

Histopathological examinations revealed three normal, three edematous, and two fragmented villi in the Sham group. In the Control group, two normal, two edematous, two hemorrhagic, one fragmented, and one detached villus were observed. In the 10 mg/kg Fraxin group, three normal, one fragmented, one detached, and three necrotic villi were identified, whereas in the 50 mg/kg Fraxin group, five normal, one hemorrhagic, one fragmented, and one necrotic villus were observed (Table 2).

Regarding local and systemic inflammatory markers, the tumor necrosis factor alpha (TNF-α) level was 15.2±2.1 pg/mL, the interleukin-6 (IL-6) level was 12.3±1.8 pg/mL, and the myeloperoxidase (MPO) level was 10.5±1.3 U/mg protein in the Sham group. In the Control group, these values were 35.4±5.3 pg/mL, 40.6±4.9 pg/mL, and 25.8±3.6 U/mg protein, respectively. In the Fraxin-treated groups, the levels were TNF-α 20.7±3.2 pg/mL, IL-6 22.4±2.5 pg/mL, and MPO 14.2±2.0 U/mg protein at the 10 mg/kg dose, and TNF-α

Table 1. Malondialdehyde (MDA) and total antioxidant status (TAS) levels across the four study groups

Group	MDA (µmol/L)	TAS (mmol Trolox equiv./L)	p-value (MDA)	p-value (TAS)
Group 1 (Sham)	45.5±9.0	1.21±0.12	0.045	0.510
Group 2 (Control)	42.5±10.8	1.21±0.15	0.048	0.515
Group 3 (Fraxin 10 mg/kg)	33.6±11.4	1.81±0.91	0.036	0.475
Group 4 (Fraxin 50 mg/kg)	56.3±16.5	1.27±0.28	0.039	0.480

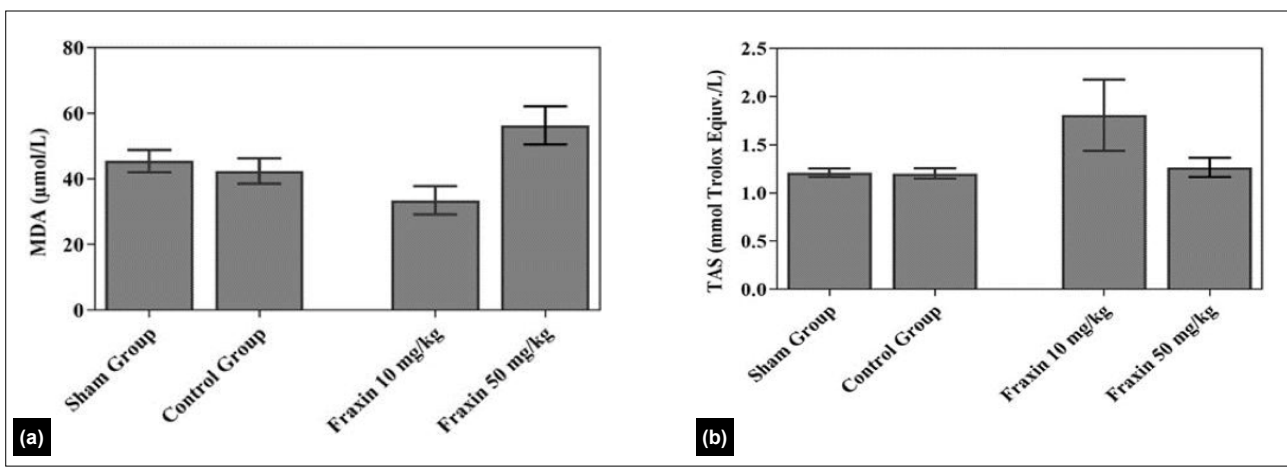

Figure 1. (a) Bar graph showing malondialdehyde (MDA) levels across the four groups (presented as mean±standard error). **(b)** Bar graph showing total antioxidant status (TAS) levels across the four groups (presented as mean±standard error).

Table 2. Histopathological grading and findings across the study groups

Group	Grade 0 (Normal)	Grade 1 (Edema)	Grade 2 (Hemorrhage)	Grade 3 (Fragmentation)	Grade 4 (Separation)	Grade 5 (Necrosis)	Total (n)
Sham	3	3	0	2	0	0	8
Control	2	2	2	1	1	0	8
Fraxin 10 mg/kg	3	0	0	1	1	3	8
Fraxin 50 mg/kg	5	0	1	1	0	1	8

Table 3. Comparison of local and systemic inflammatory markers

Group	TNF-α (Mean±SD)	IL-6 (Mean±SD)	MPO (Mean±SD)	p-value (TNF-α)	p-value (IL-6)	p-value (MPO)
Sham	15.2±2.1	12.3±1.8	10.5±1.3	0.05	0.04	0.03
Control	35.4±5.3	40.6±4.9	25.8±3.6	0.02	0.01	0.01
Fraxin 10 mg/kg	20.7±3.2	22.4±2.5	14.2±2.0	0.04	0.03	0.02
Fraxin 50 mg/kg	18.3±2.8	19.8±3.1	13.1±1.7	0.03	0.02	0.02

18.3±2.8 pg/mL, IL-6 19.8±3.1 pg/mL, and MPO 13.1±1.7 U/mg protein at the 50 mg/kg dose (Table 3).

In our study, although biochemical assessments indicated a marked improvement in antioxidant capacity, the rate of tissue necrosis was higher in the Fraxin-treated groups (particularly the low-dose group) compared to the other groups. This finding appears inconsistent with the observed biochemical improvement. We believe that studies with longer follow-up periods and larger sample sizes may provide clearer results.

In conclusion, Fraxin treatment reduced oxidative stress and inflammation while enhancing antioxidant defense mechanisms. These findings demonstrate a protective role of fraxin in acute mesenteric ischemia-reperfusion injury.

DISCUSSION

The aim of this study was to evaluate the protective effects of fraxin against ischemia-reperfusion injury of the small intestine. The results demonstrated that Fraxin exerted a protective effect against I/R-induced tissue damage by reducing oxidative stress and inflammation and by enhancing antioxidant defense mechanisms. In the present study, Fraxin-treated groups showed increased levels of total antioxidant status and decreased levels of total oxidant status. Additionally, significant increases were observed in the activities of antioxidant enzymes, including SOD, GPx, and CAT. Moreover, compared with the control group, Fraxin-treated groups exhibited markedly reduced levels of inflammatory markers such as TNF-α, IL-6, and MPO. Histopathological examination also demonstrated that Fraxin reduced intestinal damage and helped preserve the structural integrity of villi. These findings indicate that fraxin may serve as a potential therapeutic agent in mesenteric I/R injury.

The findings of this study demonstrate the protective effects of fraxin against acute mesenteric ischemia-reperfusion injury. Fraxin administration reduced oxidative stress and inflammatory responses while enhancing antioxidant defense mechanisms in tissues. Previous studies have also reported similar protective effects of fraxin in ischemia–reperfusion injury affecting other organs. For instance, Topdağı et al.[8] reported that fraxin reduces oxidative stress and inflammation during renal ischemia–reperfusion injury. Similarly, Okubo et al.[13] demonstrated its protective effects in lung ischemia-reperfusion injury. Nanayakkara et al.[14] also showed that fraxin protects against ischemic tissue damage in cardiac muscle. Together, these findings suggest that fraxin could be used as an effective agent for treating mesenteric ischemia-reperfusion injuries.

The present research findings show that fraxin has protective effects by reducing inflammatory markers such as TNF-α, IL-6, and MPO in acute mesenteric ischemia-reperfusion injury. The effects observed with fraxin are consistent with findings from other studies on I/R injuries reported in the literature. For example, İçoğlu Aksakal et al.[15] demonstrated that umbelliferone reduced TNF-α, IL-6, and MPO levels. Similarly, the present study found that fraxin produced comparable reductions in these inflammatory markers.[15] Ali et al.[16] reported that raloxifene decreased TNF-α and IL-6 levels while increasing antioxidant capacity. These findings indicate that raloxifene reduces inflammation and oxidative stress, supporting effects similar to those observed with

fraxin.[16] In another study, Karataş et al.[17] investigated tocilizumab and reported reduced TNF-α and IL-6 levels along with an enhanced antioxidant defense system. This suggests that tocilizumab suppresses the inflammatory response, further supporting the anti-inflammatory effects observed with fraxin.[17] Furthermore, Zengin et al.[18] showed that cerium oxide nanoparticles decreased TNF-α and IL-6 levels and reduced MPO activity. The The above findings demonstrate the anti-inflammatory properties of fraxin.[18] Alvani et al.[19] demonstrated that acacetin reduced TNF-α and IL-6 levels while increasing antioxidant enzyme activity. Taken together, these results demonstrate that fraxin has beneficial effects on inflammation and oxidative stress.[19] In conclusion, this study, along with other research in the literature, indicates that fraxin is an effective protective agent against mesenteric ischemia-reperfusion injuries by reducing inflammatory markers and enhancing antioxidant defenses. These findings are supported by similar outcomes, as evidenced by decreased TNF-α, IL-6, and MPO levels.

The findings of this study indicate that acute mesenteric ischemia-reperfusion injury can be mitigated by fraxin through its ability to increase the levels of antioxidant enzymes such as SOD, GPx, and CAT. Other investigations on I/R injury also support these outcomes. In research conducted by Trocha et al.,[20] liver I/R injury showed increased activities of SOD, CAT, and GPx when treated with sitagliptin. Hence, it can be inferred that these findings corroborate that fraxin has similar protective effects by enhancing the activity of these enzymes against free radicals that cause oxidative stress in cells.[20] Demirhan .'s work on resveratrol demonstrated that MDA levels decreased while SOD and CAT activities increased; this is consistent with the observed effects of fraxin in strengthening antioxidant defense mechanisms.[21] Similarly, Heidari .'s study on Withania coagulans root extract reported decreased MDA levels along with increased SOD, CAT, and GPx activity, thereby reducing oxidative stress. Fraxin demonstrated comparable effects by increasing antioxidant enzyme activities as well.[11] CoQ10, together with berberine, was reported by Apaydin and Batil (2019) to provide protection against ischemia-reperfusion injury by increasing SOD, CAT, and GPx activities, indicating that fraxin may act through similar mechanisms.[12] In light of these findings, it can be concluded from this study, as well as others reported in the literature, that mesenteric ischemia-reperfusion injuries are effectively prevented by fraxin acting as an inducer of antioxidant enzymes. Consistent with these findings, SOD, GPx, and CAT levels were shown to increase.

This study has certain limitations. First, the experimental study was conducted only in a rat model, which may limit the generalizability of these findings to humans. Additionally, the investigation assessed only short-term effects and did not examine long-term outcomes or potential adverse reactions associated with fraxin use. Moreover, specific doses were used in the experimental design without consideration of different dosage ranges; therefore, the effects of varying doses on outcome measures were not explored. Finally, only biochemical and histopathological parameters were evaluated in this research, and a detailed analysis of the molecular mechanisms of action of fraxin was not performed.

CONCLUSION

Fraxin protected tissues and strengthened the antioxidant system by reducing oxidative stress and inflammation. It increased the activity of antioxidant enzymes such as SOD, GPx, and CAT, while reducing inflammatory markers including TNF-α, IL-6, and MPO. These findings are consistent with other studies reported in the literature. The results suggest that fraxin may be a potential therapeutic agent for mesenteric ischemia-reperfusion injury. Further studies with larger sample sizes and longer follow-up periods are needed to better clarify tissue necrosis at low doses and to determine the safety of this treatment.

Ethics Committee Approval: This study was approved by the Local Ethics Committee of Giresun University Ethics Committee (Date: 08.06.2020, Decision No: 6859/21).

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Authorship Contributions: Concept: İ.A., Ö.E.; Design: İ.A., F.A.U.; Supervision: İ.A., F.A.U.; Resource: Ö.E.; Materials: İ.A., Ö.E.; Data collection and/or processing: İ.A., F.A.U.; Analysis and/or interpretation: F.A.U., D.Ş.; Literature review: D.Ş.; Writing: İ.A., F.A.U.; Critical review: İ.A., D.Ş.

Conflict of Interest: None declared.

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DENEYSEL ÇALIŞMA - *ÖZ*

Fraksin, akut mezenter iskemisinin farmakolojik tedavisinde umut veren molekül: Deneysel bir çalışma

AMAÇ: Akut mezenter iskemi (AMI), ince bağırsağa kan akışının ani kesilmesi sonucu oluşan, bağırsak nekrozu ve karın ağrısının nadir nedenlerinden biridir. Tanı ve tedavideki gecikme mortalitede ciddi artışlara neden olmaktadır. Bu çalışmada, antienflamatuvar ve antioksidan etkileri olduğu bilinen fraksin'in bağırsak iskemi-repurfüzyon hasarı üzerindeki etkilerinin araştırılması amaçlandı.

GEREÇ VE YÖNTEM: Bu çalışma, sağlıklı erkek Wistar Albino sıçanlar kullanılarak kontrollü deneysel tasarımda gerçekleştirildi. Sıçanlar dört gruba ayrıldı: Sham grubu (SMA izole edilmiş ancak kapatılmamış), Kontrol grubu (SMA izole edilmiş ve I-R ile indüklenmiş), 10 mg/kg fraksin grubu ve 50 mg/kg fraksin grubu (reperfüzyondan önce fraksin uygulandı). Toplam antioksidan kapasite (TAS), toplam oksidan durum (TOS), süperoksit dismutaz (SOD), glutatyon peroksidaz (GPx) ve katalaz (CAT) aktiviteleri değerlendirildi. Histopatolojik incelemeler ve enflamatuvar belirteçler (TNF-α, IL-6 ve MPO) da analiz edildi.

BULGULAR: Sham grubunda SOD aktivitesi 135.2±10.5 U/mg protein, GPx aktivitesi 65.3±4.7 U/mg protein ve CAT aktivitesi 85.1±5.8 U/mg protein olarak belirlendi. Kontrol grubunda ise bu değerler sırasıyla 95.4±7.9, 45.7±3.6 ve 60.3±4.2 U/mg protein olarak belirlendi. 10 mg/kg fraksin grubunda SOD 115.6±8.4, GPx 55.8±4.2 ve CAT 75.6±5.5 U/mg protein; 50 mg/kg fraksin grubunda SOD 130.8±9.7, GPx 60.2±4.8 ve CAT 90.4±6.3 U/mg protein. Fraksin uygulanan gruplarda TNF-α, IL-6 ve MPO düzeylerinde anlamlı düşüşler gözlendi ($p<0.05$).

SONUÇ: Fraksin'in mezenterik iskemi-repurfüzyon hasarında dokuları koruması, inflamasyonu ve oksidatif stresi azaltarak antioksidan göstergeleri güçlendirmesi nedeniyle bu hastalığın farmakolojik tedavisinde potansiyel bir ajan olarak kullanılabileceğinin akılda tutulması gerektiğini düşünüyoruz.

Anahtar sözcükler: Antienflamatuvar aktivite; antioksidan aktivite; fraksin; iskemi-reperfüzyon hasarı; koruyucu etki; mezenter iskemi.

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ORIGINAL ARTICLE

Comparison of posterior transversus abdominis plane block and erector spinae plane block for postoperative analgesia after caesarean section performed under spinal anesthesia: a prospective randomized trial

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ABSTRACT

BACKGROUND: This study aimed to compare the analgesic efficacy of the transversus abdominis plane block (TAPB) and the erector spinae plane block (ESPB) following cesarean delivery under spinal anesthesia. The primary endpoint was the proportion of patients requiring rescue analgesia within the first 24 hours postoperatively. Secondary outcomes included time to first rescue analgesia, Numerical Rating Scale (NRS) scores at predefined time points (30 minutes, 4, 8, 12, 16, and 24 hours), and the incidence of persistent postsurgical pain at two months.

METHODS: This single-center, prospective, randomized controlled study included patients undergoing cesarean section under spinal anesthesia. Participants were randomly allocated into two groups: TAPB and ESPB. Postoperative pain and vital signs were assessed 30 minutes after block application and at 4, 8, 12, 16, and 24 hours postoperatively. Pain intensity was measured using the NRS (0=no pain, 10=worst imaginable pain). Rescue analgesia was administered when the NRS score was ≥4. Diclofenac sodium 75 mg intramuscularly (IM) was given for NRS scores of 4–5, while intravenous (IV) morphine sulfate 0.05 mg/kg was administered for NRS scores ≥6.

RESULTS: A total of 94 patients were analyzed: 48 received ESPB and 46 received TAPB postoperatively. The TAPB group had a significantly higher proportion of patients requiring rescue nonsteroidal anti-inflammatory drug (NSAID) analgesics compared to the ESPB group (58.70% vs. 27.08%, p=0.002). NRS scores at 30 minutes, 12 hours, and 16 hours postoperatively were significantly lower in the ESPB group (p=0.03, p=0.003, and p=0.023, respectively).

CONCLUSION: For postoperative analgesia following cesarean section under spinal anesthesia, ESPB resulted in a significantly lower proportion of patients requiring rescue analgesia within the first 24 hours compared to TAPB. In addition, ESPB demonstrated a faster onset and longer duration of effective analgesia, suggesting it may be a more favorable option for postoperative pain management in this clinical setting.

Keywords: Erector spinae plane block; transversus abdominis plane block; cesarean section; regional anesthesia; postoperative pain management.

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INTRODUCTION

Pain control following cesarean delivery is challenging, as it must provide adequate pain relief for the mother while ensuring no adverse effects on the newborn. Spinal anesthesia is widely used for cesarean delivery because of its simplicity and rapid onset; however, it offers limited postoperative pain relief.[1,2] Intrathecal opioids, such as preservative-free morphine or hydromorphone, are highly effective for postoperative pain management in neuraxial anesthesia and provide prolonged analgesia, but they may be associated with side effects including pruritus, nausea, vomiting, and, rarely, respiratory depression.

The transversus abdominis plane block (TAPB) is an alternative modality for postoperative pain control following cesarean section. It involves the injection of a local anesthetic between the internal oblique and transversus abdominis muscles.[3-5] TAPB can be performed using subcostal, lateral, or posterior approaches, each targeting different dermatomes to achieve pain relief. However, TAPB has limited efficacy in controlling visceral pain.[5]

The erector spinae plane block (ESPB) involves the injection of a local anesthetic into the anatomical space between the erector spinae muscle and the transverse process of the vertebra. This technique may provide both somatic and visceral analgesia by allowing spread toward the paravertebral space.[6-8] Initially described for the management of thoracic chronic pain, ESPB has demonstrated effectiveness in pain control following cesarean delivery.[9-11] Nevertheless, some studies have questioned whether local anesthetics reliably reach the paravertebral space, suggesting that the clinical effects of ESPB may instead be related to increased blood concentrations.[12] Despite being classified as a "Plan A" block by Regional Anesthesia UK, the clinical efficacy of ESPB is considered unpredictable.[13]

This study aimed to compare the analgesic effects of TAPB and ESPB following cesarean delivery under spinal anesthesia. Although ESPB has demonstrated both somatic and visceral analgesia in abdominal surgeries, as reported in the systematic review by Mansour et al.,[14] we investigated whether ESPB offers a clinical advantage over TAPB in patients undergoing cesarean section under spinal anesthesia. The primary endpoint was the proportion of patients requiring rescue analgesia within the first 24 hours postoperatively. Secondary outcomes included the time to first rescue analgesia, Numerical Rating Scale (NRS) scores at predefined time points (30 minutes, 4, 8, 12, 16, and 24 hours), and the incidence of persistent postsurgical pain at two months.

MATERIALS AND METHODS

Patient Selection

This prospective, randomized, controlled study was conducted after obtaining approval from the Başakşehir Çam Ve Sakura City Hospital Clinical Research Ethics Committee (IRB No. 2021.10.27), in accordance with the principles of the Declaration of Helsinki. The study was registered as a clinical trial under the number NCT05625009. Written informed consent was obtained from all participants.

Patients aged 18–45 years who were scheduled to undergo elective cesarean delivery under spinal anesthesia were included in the study. A total of 138 patients met these criteria between November 15, 2022 and January 15, 2023. The exclusion criteria were: an American Society of Anesthesiologists (ASA) score >2; major intraoperative bleeding requiring surgical intervention (e.g., bilateral uterine artery ligation, B-Lynch procedure, Cho's procedure, or change in incision type); need for intubation for any reason during surgery; local infection at the block site; reoperation within the first 48 postoperative hours for any reason; and refusal to participate in the study or to undergo any of the study interventions.

Randomization and Blinding

Patients were randomly assigned in equal numbers to either the ESPB or TAPB group using computer-generated random numbers placed in separate opaque envelopes, which were opened by the study investigator immediately before block administration. All blocks were performed by the same anesthesiologist. The investigators performing the blocks and those conducting the NRS assessments were different individuals. The investigators responsible for NRS assessments were blinded to group allocation. Additionally, the care providers monitoring the patients during hospitalization were blinded to group assignment, as was the statistician analyzing the data.

Perioperative Management

Preoperative assessment was conducted according to routine institutional practice. Isotonic saline infusion was initiated after an 18-G intravenous line was secured. All patients were monitored for blood pressure, heart rate, and blood oxygen saturation and received spinal anesthesia using a standardized technique, consisting of 10–12 mg of 0.5% hyperbaric bupivacaine administered between the L3–L4 vertebrae. After confirmation of an adequate sensory block (loss of sensation at the T5 level) using a pinprick test with a Neurotip®, surgical incision was permitted. No patient required intraoperative conversion to general anesthesia. All surgeries were performed using a Pfannenstiel incision. If the mean arterial pressure decreased by more than 20% from baseline or if systolic blood pressure fell below 90 mmHg, 5 mg of ephedrine was administered. Additionally, if the heart rate decreased to 50 bpm or less, an appropriate dose of atropine was administered. After delivery, 15 U of oxytocin were administered as an intravenous (IV) infusion.

At the end of surgery, patients were transferred to the post-anesthesia care unit for follow-up.

Postoperative Management

In the recovery unit, patients randomized to the ESPB group

received bilateral ESPB at the T9 vertebral level in the sitting position. The patient beds were positioned at a 45-degree head-up angle. Because lower-extremity motor block persisted, patients were assisted into the sitting position by post-anesthesia care unit staff. After skin sterilization, the spinous process was identified using a high-frequency (12–15 Mhz) linear ultrasound (US) probe (Hitachi Arietta 65 ultrasound device). The ultrasound probe was then moved laterally to visualize the transverse process. Subsequently, 20 mL of 0.25% bupivacaine was injected bilaterally into the plane between the erector spinae muscle and the transverse process of the vertebra, resulting in a total volume of 40 mL.

Patients randomized to the TAPB group received bilateral posterior transversus abdominis plane blocks in the recovery unit. After skin sterilization, the US probe was placed posterior to the midaxillary line between the costal margin and the iliac crest. Posteriorly, the transversus abdominis muscle transitions into its aponeurosis, with the quadratus lumborum muscle visualized posteromedial to the aponeurosis. The needle was inserted using an in-plane approach, and the injection site was located between the internal oblique and transversus abdominis muscles, posterior to the midaxillary line and near the aponeurosis. US-guided TAP block was performed by bilateral injection of 20 mL of 0.25% bupivacaine solution (total volume: 40 mL).

After postoperative recovery unit follow-up for at least 30 minutes, the levels of analgesia provided by the blocks was assessed using a pinprick test. Subsequently, patients with an Aldrete score of 9 or higher were transferred to the ward. Upon admission to the ward, patients received 1 g IV paracetamol and 75 mg intramuscular (IM) diclofenac sodium as part of the standard multimodal analgesia protocol, regardless of pain score. This initial dose of diclofenac sodium was not considered rescue analgesia in the outcome analyses. During postoperative follow-up, paracetamol (1 g) was administered intravenously at 8-hour intervals.

To ensure patient safety, the total daily dose of diclofenac sodium was limited to a maximum of 150 mg. If a patient had already received two 75 mg doses of diclofenac sodium and continued to experience pain, intravenous morphine was administered instead of additional nonsteroidal anti-inflammatory drugs (NSAIDs). To prevent gastrointestinal adverse effects related to NSAID use, all patients routinely received proton pump inhibitor (PPI) therapy during the postoperative period.

Protocol

Postoperative pain status and vital signs were evaluated 30 minutes after block administration, before transfer to the ward, and subsequently at 4, 8, 12, 16, and 24 hours postoperatively. Pain intensity at rest was assessed using the NRS (range 0–10, where 0 indicates no pain and 10 indicates the worst imaginable pain). Rescue analgesia was administered to patients with an NRS score of 4 or higher at any assessment time. Diclofenac sodium (75 mg IM) was administered to patients with NRS scores of 4 and 5. If adequate pain relief was not achieved within 30 minutes following diclofenac administration, IV morphine sulfate (0.05 mg/kg) was administered to patients with an NRS score of 6 or higher.

Two months after surgery, patients were contacted by telephone and asked about the presence of low back pain or incision-site pain to determine the incidence of persistent postsurgical pain.

The primary endpoint was the proportion of patients requiring rescue analgesia within the first 24 hours postoperatively. Secondary outcomes included time to first rescue analgesia, NRS scores at specific time points (30 minutes, 4, 8, 12, 16, and 24 hours), and the incidence of persistent postsurgical pain at two months.

Statistical Analysis

The primary outcome of the study was the frequency of rescue analgesic requirement during the first 24 postoperative hours. A 50% difference in the proportion of patients requiring rescue analgesia between groups was anticipated. Based on this assumption, a sample size of 84 patients was calculated to detect this difference assuming a two-tailed α of 5% and a β of 20%. To account for potential data loss, enrollment of 100 patients was planned.

Data distribution was assessed using the Shapiro-Wilk test. Normally distributed data were expressed as mean ± standard deviation and compared using the Student's t-test. Non-normally distributed data were presented as median (25th–75th percentile) unless otherwise stated. Categorical variables were expressed as frequency (percentage) and compared using the chi-square test. NRS scores were compared between groups using the Mann–Whitney U test and within groups using the Friedman and Wilcoxon tests. All analyses were performed using NCSS 2007 Statistical Software (Utah, USA) and MedCalc Statistical Software (Ostend, Belgium).

RESULTS

This study evaluated the clinical efficacy of two regional analgesia techniques (erector spinae plane block and transversus abdominis plane block). A total of 139 patients were initially assessed for eligibility; however, 27 patients were excluded based on predefined criteria. The reasons for exclusion were an ASA score of 3 (n=15) and refusal to participate (n=12).

The flow of patient enrollment, randomization, exclusions, and final analysis for both groups is presented in Figure 1. Patient demographic characteristics are summarized in Table 1.

As shown in Table 2, the proportion of patients requiring rescue NSAIDs within the first 24 postoperative hours (primary outcome) was significantly higher in the TAPB group (58.7%) than in the ESPB group (27.1%) (p=0.002). There was no significant difference in total opioid consumption between the groups. Of the two patients in the TAPB group who required

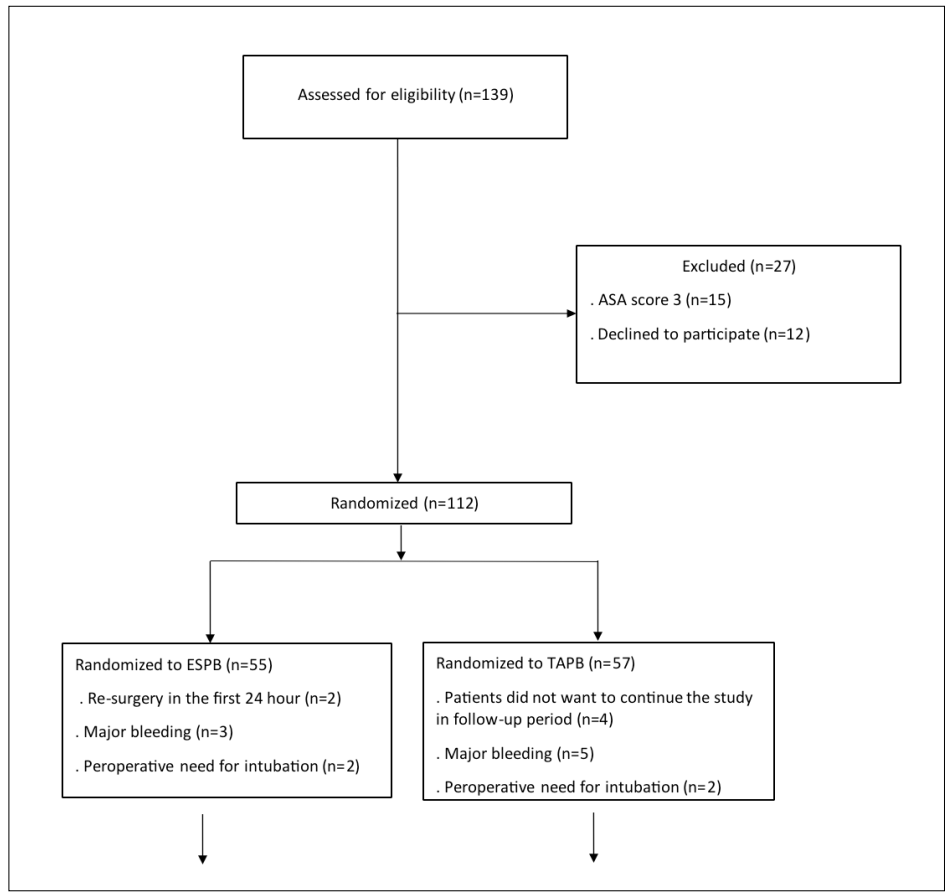

Figure 1. Flow diagram of patient enrollment and allocation.

Table 1. Demographic characteristics

	TAPB (n=46)	ESPB (n=48)	p
Age	28.97±5.53	29.85±5.83	0.457
Height (cm)	161.87±5.21	160.94±3.8	0.322
Weight (kg)	67.52±6.51	66.5±6.83	0.460
BMI (kg/m^2)	25.77±2.31	25.66±2.43	0.834

Values are expressed as mean±standard deviation (SD). TAPB: Transversus abdominis plane block; ESP: Erector spinae plane block; BMI: Body mass index.

Table 2. Rescue analgesic consumption

	TAPB (n=46)	ESPB (n=48)	p
Rescue NSAI analgesic	27 (58%)	13 (27%)	0.002
Time to first rescue analgesic (min)	720 (720-960)	960 (720-1200)	0.149
Rescue opioid analgesic	2 (4%)	0 (0%)	0.144

Values are expressed as mean±standard deviation (SD) or median (25th–75th percentile). TAPB: Transversus abdominis plane block; ESP: Erector spinae plane block; NSAI: Nonsteroidal anti-inflammatory.

Table 3. Postoperative Numeric Rating Scale scores

	TAPB (n=46)	ESPB (n=48)	p
30 minutes	2 (2-3)	2 (2-2)	0.003
4 hours	2 (2-3)	2 (2-3)	0.116
8 hours	3 (2-3)	2.5 (2-3)	0.166
12 hours	3 (3-4)	3 (2-3)	0.003
16 hours	3 (2.5-4.5)	3 (3-4)	0.023
24 hours	3 (3-4)	3 (3-4)	0.366

Values are expressed as median (25^{th}–75^{th} percentile). NRS: Numeric Rating Scale; TAPB: Transversus abdominis plane block; ESP: Erector spinae plane block.

opioid rescue analgesia, each received a single dose.

Regarding postoperative NRS scores during the first 24 hours, no statistically significant differences were observed between the groups at 4, 8, and 24 hours. However, NRS scores at 30 minutes, 12 hours, and 16 hours postoperatively were significantly lower in the ESPB group (p=0.03, p=0.003, and p=0.023, respectively) (Table 3). Trends in NRS scores over the first 24 hours are illustrated in Figure 2.

At the two-month postoperative follow-up, none of the patients reported cesarean incision pain. All reported pain complaints were related to low back pain. Pain was reported by six patients (12.5%) in the ESPB group and 10 patients (21.74%) in the TAPB group; however, this difference was not statistically significant (p=0.233). A total of four patients (4.2%), all in the TAPB group, were referred to the outpatient pain clinic for low back pain with an NRS score of 4. No other complications were observed.

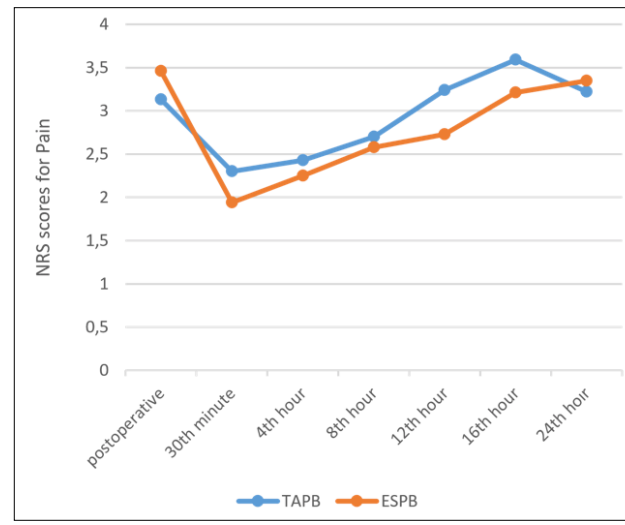

Figure 2. Trend of patients' pain scores assessed using the Numeric Rating Scale (NRS).

DISCUSSION

In this study, the primary endpoint was the requirement for rescue intravenous analgesia within the first 24 postoperative hours, which was used to assess the efficacy of the pain management strategies employed. Our findings demonstrated that although there was no significant difference in opioid consumption between the groups, a significant difference was observed in the use of rescue nonsteroidal anti-inflammatory analgesics.

These results suggest that while both blocks were similarly effective in limiting opioid consumption, the greater need for supplementary NSAID analgesia in the TAPB group may indicate less effective overall pain control compared to ESPB.

Our findings highlight the complexity of postoperative pain management and reinforce the importance of a multimodal analgesic approach. The higher consumption of rescue NSAI analgesics in the TAPB group may reflect the relatively limited analgesic efficacy of peripheral plane blocks such as TAPB compared to deeper or more extensive blocks like ESPB. Further research is warranted to investigate additional or alternative pain management strategies that may optimize analgesia and reduce reliance on rescue medications in patients receiving TAPB.

Previous studies have demonstrated that the use of TAPB for postoperative pain control following cesarean delivery under spinal anesthesia significantly reduces opioid consumption within the first 24 hours.[4] In another study evaluating ESPB for the same outcome, the authors similarly reported a reduction in postoperative opioid consumption11. In the present study, only two patients (2.08%) required opioid analgesia. Considering that all patients received a plane block, our study confirms the findings of previous studies regarding the efficacy of both TAPB and ESPB. However, the lower requirement for additional NSAID analgesics in the ESPB group suggests a more favorable analgesic profile for this technique.

In the literature, several studies have compared ESPB and TAPB in patients undergoing cesarean section under spinal anesthesia; however, only one incorporated NSAI analgesics into the postoperative analgesia protocol. In that study, ESPB was found to be significantly superior to TABP in terms of

NSAI analgesic requirements.[15] The findings of the present study are consistent with those results, demonstrating a lower need for NSAID administration in the ESPB group compared to the TAPB group within the first 24 postoperative hours. This finding is important given the potential adverse effects of NSAI analgesics, including peptic ulcer bleeding even with short-term use, as well as nephrotoxicity and other end-organ damage associated with long-term use.[16-17]

The reduced need for rescue NSAID analgesia in the ESPB group may be explained by the distinct anatomical and pharmacological characteristics of the two blocks. TAPB primarily targets the thoracolumbar nerves within the fascial plane between the internal oblique and transversus abdominis muscles and is therefore largely limited to somatic analgesia of the anterior abdominal wall. In contrast, ESPB involves deposition of local anesthetic between the erector spinae muscle and the transverse process, allowing potential spread to the paravertebral and epidural spaces. This spread may provide both somatic and visceral analgesia, which is particularly advantageous in cesarean delivery, where visceral pain contributes substantially to postoperative discomfort.[18] Furthermore, the deeper injection site and broader surface area of contact in ESPB may prolong drug absorption and extend block duration, thereby explaining the longer-lasting analgesic effect observed. Taken together, these anatomical and pharmacokinetic differences likely account for the lower NSAID consumption and the more favorable analgesic profile of ESPB compared with TAPB in obstetric patients.

In the present study, we observed a statistically significant difference in NRS scores favoring ESPB at 30 minutes postoperatively. Although this difference was no longer significant at 4 hours, the lower requirement for rescue analgesics in the ESPB group suggests a more sustained and effective analgesic profile compared to TAPB.

NRS pain scores at 12 and 16 hours postoperatively were significantly lower in the ESPB group. These findings are consistent with previous studies demonstrating a longer duration of effective analgesia with ESPB compared to TAPB. One comparative study reported the duration of analgesic efficacy to be 8 hours for TAPB and 12 hours for ESPB ($p<0.001$).[19] In another study, the difference was even more pronounced, with the mean time to first rescue analgesia reported as 43.5 hours for ESPB and 12.1 hours for TAPB ($p<0.001$).[20]

Although time to first rescue analgesic administration was longer and fewer patients required NSAID rescue analgesia in the ESPB group, only the reduction in NSAID rescue analgesic requirement reached statistical significance. These findings suggest a potential clinical advantage of ESPB over TAPB, particularly in reducing the need for additional analgesics; however, further studies with larger sample sizes are warranted to confirm these observations.

Chronic postsurgical pain is an important concern, with an incidence of 15.4% in patients undergoing cesarean section.[20] Effective postoperative pain control has been shown to play a crucial role in reducing the development of chronic pain following cesarean section.[21,22] Several studies in the literature suggest that effective analgesia provided by ESPB reduces the incidence of chronic pain after cardiothoracic procedures.[23,24] However, we were unable to identify data regarding abdominal surgeries. Although no statistically significant difference in pain at two months was observed between the ESPB and TAPB groups in this study (21.7% vs. 12.5%, $p=0.23$), the observed effect size supports the need for further studies with appropriate power analyses aimed at identifying differences in long-term pain incidence.

In our study, the ESPB was performed in the sitting position while spinal anesthesia was still active. Although no hemodynamic instability was observed, this approach may carry a theoretical risk of orthostatic hypotension, and performing the block in the lateral decubitus position may represent a safer alternative in future applications.

In obstetric postoperative analgesia, one of the key advantages of regional techniques over systemic analgesics is their ability to provide effective pain relief while minimizing systemic opioid exposure. This is particularly important in the early postpartum period, as it facilitates early mobilization.

Limitations

This study has several limitations. First, although the primary focus was on nonsteroidal anti-inflammatory drug (NSAI) analgesic consumption, adverse effects related to NSAID use were not evaluated. Second, differentiation between somatic and visceral pain, one of the potential differences in analgesic mechanisms between ESPB and TAPB, was not assessed. Additionally, pain at rest and pain during movement were not evaluated separately. Due to the nature of the interventions, neither participants nor the anesthesiologists performing the blocks could be blinded, resulting in an open-label study design.

Furthermore, pain scores at the time of block administration were not recorded, which may have affected early postoperative pain comparisons due to potential variability in spinal anesthesia regression. Additionally, because all patients routinely received paracetamol and diclofenac upon ward admission, the exact time to first analgesic request could not be accurately determined. The study also did not assess pain beyond the first 24 postoperative hours or evaluate postoperative mobilization outcomes, both of which are important in obstetric care. These factors should be addressed in future studies with longer follow-up and functional outcome measures.

CONCLUSION

In conclusion, this study demonstrated that a significantly lower proportion of patients in the ESPB group required rescue analgesia within the first 24 postoperative hours compared

to the TAPB group. Beyond this primary outcome, ESPB was also associated with a faster onset and longer duration of effective analgesia, as well as lower pain scores at selected postoperative time points. Taken together, these findings suggest that ESPB may offer a more favorable analgesic profile than TAPB for postoperative pain management following cesarean delivery.

Ethics Committee Approval: This study was approved by the Başakşehir Çam Ve Sakura City Hospital Clinical Research Ethics Committee (Date: 27.10.2021, Decision no: NCT05625009). The study was registered as a clinical trial under the number NCT05625009

Informed Consent: Written informed consent was obtained.

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Spinal anestezi altında gerçekleştirilen sezaryen operasyonlarında postoperatif analjezi yönetimi için posterior transversus abdominis plan blok ile erector spinae plan bloğunun karşılaştırılması: Prospektif randomize çalışma

AMAÇ: Bu çalışma, spinal anestezi altında gerçekleştirilen sezaryen doğumu sonrasında transversus abdominis plan bloğu (TAPB) ile erector spinae plan bloğu (ESPB) uygulamalarının analjezik etkilerini karşılaştırmayı amaçlamaktadır. Birincil sonlanım noktası, postoperatif ilk 24 saatte kurtarma analjezisi gereksinimi duyan hasta oranıdır. İkincil sonlanım noktaları arasında ilk kurtarma analjezisine kadar geçen süre, belirli zaman noktalarındaki NRS skorları (30. dakika, 4., 8., 12., 16. ve 24. saatler) ve 2. ayda persistan cerrahi sonrası ağrı insidansı yer almaktadır.

GEREÇ VE YÖNTEM: Bu tek merkezli, prospektif randomize kontrollü çalışma, spinal anestezi altında sezaryen operasyonu geçiren ve rastgele iki gruba (TAPB ve ESPB) ayrılan hastaları içermektedir. Postoperatif ağrı ve vital bulgular, blok sonrası 30. dakikada ve postoperatif 4., 8., 12., 16. ve 24. saatlerde değerlendirilmiştir. Ağrı, sayısal derecelendirme skoru (NRS; 0: ağrı yok, 10: en şiddetli ağrı) ile ölçülmüştür. NRS skoru 4 veya daha yüksek olan hastalara kurtarma analjezisi uygulanmıştır. NRS skoru 4 veya 5 olan hastalara 75 mg IM diklofenak sodyum, 6 ve üzeri olanlara ise 0.05 mg/kg IV morfin sülfat verilmiştir.

BULGULAR: Çalışmada toplam 94 hasta analiz edilmiştir: 48 hastaya postoperatif ESPB, 46 hastaya TAPB uygulanmıştır. İlk 24 saatte kurtarma NSAİ analjezik ihtiyacı TAPB grubunda anlamlı derecede daha yüksek bulunmuştur (%58.70'e karşı %27.08, p=0.002). ESPB grubunda 30. dakika, 12. saat ve 16. saatteki NRS skorları anlamlı olarak daha düşük bulunmuştur (sırasıyla, p=0.03, p=0.003 ve p=0.023).

SONUÇ: Spinal anestezi altında gerçekleştirilen sezaryen operasyonlarında postoperatif analjezi için uygulanan ESPB, TAPB'ye kıyasla ilk 24 saatte kurtarma analjezisi gereksinimi duyan hasta oranını anlamlı derecede azaltmıştır. Ayrıca ESPB, daha hızlı başlayan ve daha uzun süren etkili analjezi sağlamış ve bu yönüyle postoperatif ağrı yönetiminde daha avantajlı bir seçenek olduğunu desteklemiştir.

Anahtar sözcükler: Erector spinae plan blokajı; transversus abdominis plan blokajı; sezaryen ağrı kontrolü; sezaryen sonrası kronik ağrı; rejyonal anestezi; postoperatif ağrı yönetimi.

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ORIGINAL ARTICLE

Risk factors associated with morbidity and mortality in emergency colorectal cancer resections

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ABSTRACT

BACKGROUND: Despite efforts toward early diagnosis, approximately 25% of patients with colorectal cancer are still operated on under emergency conditions. The aim of this study was to investigate the risk factors associated with morbidity and mortality in emergency colorectal cancer resections.

METHODS: Emergency colorectal cancer resections performed at a single center were included in this retrospective study. Baseline, operative, and tumor-related data were examined. Morbidity was defined as a complication of Clavien Dindo grade ≥3. Risk factors for both morbidity and mortality were evaluated using univariate analyses and multivariable logistic regression.

RESULTS: The study included 188 patients, of whom 119 (63.3%) were men. In the multivariate analysis, factors associated with increased morbidity risk were age (odds ratio [OR]=3.02, p=0.009), American Society of Anesthesiologists (ASA) score (OR=2.04, p=0.049), duration of surgery (OR=1.01, p=0.001), and presence of perforation (OR=3.24, p=0.004). Multivariate analysis for mortality demonstrated significant effects of age (OR=3.23, p=0.017), ASA score (OR=5.92, p=0.009), duration of surgery (OR=1.01, p=0.007), and presence of perforation (OR=3.01, p=0.013).

CONCLUSION: This study highlights several key risk factors—including advanced age (≥70 years), higher ASA scores (≥3), longer operative times, and the presence of perforation—that significantly impact morbidity and mortality in emergency colorectal cancer resections. Early recognition of these factors may improve risk stratification and guide more effective perioperative care strategies for high-risk patients.

Keywords: Colorectal cancer; emergency surgery; morbidity; mortality.

INTRODUCTION

Colorectal cancer (CRC) ranks third worldwide in terms of both the number of cancer diagnoses and cancer-related deaths.[1,2] Moreover, its incidence in Eastern Europe and Asia, including Türkiye, has been reported to be increasing.[3] Despite efforts toward early diagnosis, approximately 25% of patients are still operated on under emergency conditions.[3-7] The principal reasons requiring emergency surgery for colorectal tumors include local tumor invasion, regional progression, and medical or technical problems during the treatment process. In clinical practice, these conditions most commonly present as obstruction and perforation.[3,8,9] In emergency colorectal surgery, morbidity and mortality remain significantly higher compared to elective procedures and therefore deserve particular attention.[6,7,10]

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Identifying risk factors, determining both global and local rates for morbidity and mortality, and performing appropriate risk stratification in emergency colorectal cancer surgery are essential for improving patient management. This approach may help identify patients who could benefit from additional treatments and closer postoperative follow-up.[5,6,11] In addition, operative mortality is considered an important indicator for evaluating surgical performance and quality of care.[4]

The aim of our study was to investigate the risk factors associated with morbidity and mortality in patients who underwent emergency resection for colorectal cancer in our clinic.

MATERIALS AND METHODS

Patients who underwent emergency colorectal cancer resection at a single tertiary referral center between January 2019 and December 2022 were included in this retrospective study. All patients were aged 18 years or older. Approval for the study was obtained from the Institutional Ethics Board of Istanbul Bakirkoy Dr. Sadi Konuk Training and Research Hospital (Date: 17.07.2023, Decision no: 2023-14-13). The study was registered in the Clinical Trials Protocol Registration and Results System (Trial ID: NCT06074432). The study was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement and complied with the principles of the Declaration of Helsinki.

Patients were excluded from the analysis if they met any of the following criteria: undergoing surgery without resection or undergoing surgery for indication other than primary colorectal cancer, such as diverticulitis, ischemia, inflammatory bowel diseases, or metastases from another malignancy. All data were obtained from the hospital software system, and informed consent was obtained from all patients. Surgical procedures were performed by general surgeons.

Factors such as age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) score, Charlson Comorbidity Index (CCI), smoking status, comorbidity history, presence of perioperative blood transfusion, duration of surgery, length of hospital stay, tumor location and characteristics, presence of perforation, and stoma/anastomosis preference were evaluated. During the analysis of ASA scores, patients were divided into two subgroups: ASA I–II and ASA III or higher. Tumors located distal to the midpoint of the transverse colon were classified as left-sided, whereas tumors located proximal to this point were classified as right-sided. Nutrition Risk Screening (NRS-2002) scores recorded at hospital admission were also included in the analyses. For morbidity assessment, complications with a Clavien–Dindo score of ≥3 were considered significant.

Risk factors for both morbidity and mortality were first evaluated using univariate analyses. Variables found to be significantly associated with morbidity and mortality were included in multivariate logistic regression analyses. Pearson's chi-square test, Student's t-test, and the Mann–Whitney U test were used where appropriate. Normality of distribution was assessed using the Kolmogorov–Smirnov test. Normally distributed values expressed as mean ± standard deviation (SD). Variables that did not show a normal distribution were expressed as median and 25th-75th interquartile range values (median (IQR25th-75th)). The effects of risk factors on morbidity and mortality were expressed as odds ratios (OR) with their 95% confidence intervals (CI). A p value of <0.05 was considered statistically significant. Statistical analyses were performed using SPSS for Windows, version 29.0 (SPSS, Chicago, IL, USA).

RESULTS

During the four-year study period, 222 patients who underwent surgery for an emergency colorectal mass were identified; however, 34 patients were excluded from the study according to the exclusion criteria (Fig. 1).

The study was conducted with the remaining 188 patients, of whom 69 (36.7%) were women (Table 1). Perforation was detected in 42 patients (22.3%). Among these, perforation was located at the tumoral segment in 35 patients (83.3%), whereas seven patients (16.6%) had perforation proximal to the tumor site. Patients with perforation were similar to those without perforation in terms of age (p=0.658), BMI (p=0.273), CCI score (p=0.680), diagnosis of diabetes mellitus (DM) (p=0.515), duration of surgery (p=0.245), tumor stage (p=0.508), presence of metastasis (p=0.372), and total lymph node count (p=0.365).

Among the patients, primary anastomosis was the more frequently performed procedure (61.17%, n=115). Anastomotic leakage occurred in 13 of these patients (11.3%). In the leakage subgroup, seven patients died, corresponding to 6.08% of the anastomosis group. The overall morbidity rate was 36.1% (n=68), and the 90-day mortality rate was 23.9% (n=45).

In the univariate analysis, morbidity was associated with age (>70 years), ASA score (≥3), CCI score (≥4), hypertension, duration of surgery, presence of perforation, and total lymph node count (Table 2). Four of these seven predictive variables were statistically significant in the multivariate analysis (Table 2). The presence of perforation was associated with a threefold increase in the odds of morbidity. Similarly, age over 70 years was associated with a similar increase in risk. The odds of morbidity increased by 1% for each additional minute of surgery.

On the other hand, eight factors were significantly associated with mortality (Table 3). Of these variables, only age, ASA score, duration of surgery, and presence of perforation were statistically significant in the multivariate analysis (Table 3). The results showed that both perforation and age over 70 years increased the odds of mortality approximately threefold. Similar to morbidity, each additional minute of surgery was associated with a 1% increase in the odds of mortality.

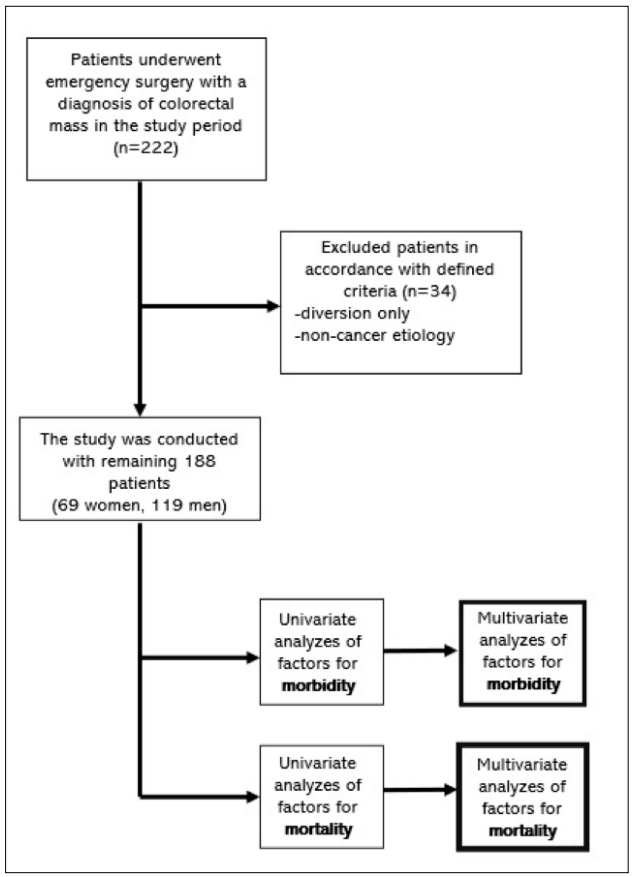

Figure 1. Flowchart diagram of the study.

DISCUSSION

In this study, emergency colorectal cancer resections were associated with mortality and morbidity rates of 23.9% and 36.1%, respectively. Perforation, age over 70 years, ASA score ≥3, and longer operative time were identified as risk factors. The morbidity rate observed in our study is consistent with findings reported in the literature.[5,12,13] However, the mortality rate appears to be slightly higher than those reported in similar studies.[5,12-14] In our study, patients with other diagnoses such as diverticulitis or colitis, as well as those who did not undergo resection, were excluded. Considering that all included patients underwent resection and were histopathologically confirmed to have colorectal cancer, it is reasonable that these rates might be higher. Previous studies have also reported that undergoing colectomy for colorectal cancer is a predictor of mortality.[13,15]

Several studies have reported that patients presenting with colonic perforations experience highly morbid and fatal surgical outcomes.[16-18] In the present study, perforation (n=42, 22.3%) was also strongly associated with worse outcomes in terms of both morbidity and mortality. According to the World Society of Emergency Surgery (WSES) Guidelines, perforation most commonly occurs at the tumor site (70%), while the remaining cases occur more proximally.[3] In our

Table 1. Baseline characteristics of the patients

Variable	n (%)
Age	
≤70	83 (44.1)
>70	105 (55.8)
Sex, n (%)	
Female	69 (36.7)
Male	119 (63.3)
BMI, n (%)	
<18.5	3 (1.6)
18.5-24.9	71 (37.8)
25-29.9	68 (36.2)
≥30	46 (24.5)
ASA score, n (%)	
I–II	55 (29.3)
III–IV	33 (70.7)
CCI score	
≤III	55 (29.3)
≥IV	133 (70.7)
Smoking history	50 (26.6)
Hypertension (HT)	72 (38.3)
Diabetes mellitus (DM)	40 (21.3)
Chronic obstructive pulmonary disease (COPD)	14 (7.4)
Chronic renal failure (CRF)	11 (5.9)
Cerebrovascular accident (CVA)	11 (5.9)
Congestive heart failure (CHF)	29 (15.4)
Presence of perforation	42 (22.3)
Type of surgery	
Resection + stoma	73 (38.8)
Resection + anastomosis	115 (61.1)
T stage	
T1-2	8 (4.3)
T3-4	180 (95.7)
Grade	
I	11 (5.9)
II	141 (75.0)
III	36 (19.1)
Stage	
I-II	78 (41.5)
III-IV	110 (58.5)
Tumor location	
Right-sided	44 (23.4)
Left-sided	144 (76.6)

Older men constituted the predominant patient group in the study. A considerable proportion of patients were obese (24.5%). Hypertension was the most common comorbidity, followed by diabetes mellitus. Perforation was detected in 22.3% of patients (n=42). Although the majority of patients were elderly and had multiple comorbidities, anastomosis was preferred over stoma formation in more than 60% of patients.

Table 2. Univariate and multivariate analyses of factors associated with morbidity

Variable	No major complication n=120 (%)	Major complication n=68 (%)	Univariate analysis	Multivariate analysis	OR	95% CI
Age						
≤70	64 (53.3)	19 (27.9)				
>70	56 (46.7)	49 (72.1)	<0.001*	0.009	3.02	1.31-6.95
Sex, n (%)						
Male	75 (62.5)	44 (64.7)	0.763*			
Female	45 (37.5)	24 (35.3)				
BMI, n (%)						
<18.5	2 (1.7)	1 (1.5)	0.530*			
18.5-24.9	43 (35.8)	28 (41.2)				
25-29.9	48 (40)	20 (29.4)				
>30	27 (22.5)	19 (27.9)				
ASA score, n (%)						
I–II	45 (37.5)	10 (14.7)	<0.001*	0.049	1.01	1.00-5.95
III–IV	75 (62.5)	58 (85.3)				
CCI score						
≤3	43 (35.8)	12 (17.6)	0.008*	0.798	0.87	0.31-2.41
≥4	77 (64.7)	56 (82.4)				
Smoking history	37 (30.8)	13 (19.1)	0.081*			
NRS-2002 score						
<3	99 (82.5)	56 (82.4)				
≥3	21 (17.5)	12 (17.6)	0.980*			
Hypertension	37 (30.8)	35 (51.5)	0.005*	0.132	1.82	0.83-4.01
Diabetes mellitus	22 (18.3)	18(26.5)	0.190*			
Chronic obstructive pulmonary disease	6 (5.0)	8 (11.8)	0.090*			
Chronic renal failure	6 (5.0)	5 (7.4)	0.509*			
Cerebrovascular accident	6 (5.0)	5 (7.4)	0.509*			
Congestive heart failure	14 (11.7)	15 (22.1)	0.058*			
Tumor location						
Right	29 (24.2)	15 (22.1)	0.743*			
Left	91 (75.8)	53 (77.9)				
Duration of operation (min)	176.75±51.46	200.44±54.47	0.003**	0.001	1.01	1.00-1.01
Perioperative blood transfusion	55 (45.8)	35 (51.5)	0.457*			
Perforation	18 (15)	24 (35.3)	0.001*	0.004	3.24	1.46-7.16
Type of surgery						
Resection + stoma	50 (35.5)	23 (48.9)	24 (51.1)	0.101*		
Resection + anastomosis		91 (64.5)				
Tumor length (cm) median	3.90 (2.65-4.50)	4 (3.00-5.00)	0.239***			
Tumor diameter (cm)	4.67±1.77	4.79±1.64	0.673**			
T stage						
T1-2	6 (5.0)	2 (2.9)	0.713*			
T3-4	114 (95.0)	66 (97.1)				
Total lymph node count, mean±SD	25.94±12.92	22.15±11.08	0.043**	0.310	0.98	0.95-1.01
Metastatic lymph nodes,	2.11±3.44	2.28±3.66	0.750**			
Grade						
I	6 (5.0)	5 (7.4)				
II	93 (77.5)	48 (70.6)				
III	21 (17.5)	15 (22.1)	0.560*			
Stage						
I-II	50 (41.7)	28 (41.2)				
III-IV	70 (58.3)	40 (58.8)	0.948*			

*Chi-square test; **Student's t-test; ***Mann–Whitney U test.

Table 3. Univariate and multivariate analyses of factors associated with mortality

	Alive n=143 (%)	Death n=45 (%)	Univariate analysis	Multivariate analysis	OR	95% CI
Age						
≤70	72 (50.3)	11 (24.4)	0.002*	0.017	3.23	1.23-8.52
>70	71 (49.7)	34 (75.6)				
Sex n (%)						
Male	92 (64.3)	27 (60.0)				
Female	51 (35.7)	18 (40.0)	0.189*			
BMI						
<18.5	3 (2.1)	0 (0)				
18.5-24.9	54 (37.8)	17 (37.8)				
25-29.9	52 (36.4)	16 (35.6)				
≥30	34 (23.8)	12 (26.7)	0.785*			
ASA score						
I–II	52 (36.4)	3 (6.7)				
III–IV	91 (63.6)	42 (93.3)	<0.001*	0.009	5.92	1.55-22.65
CCI score						
≤3	48 (33.6)	7 (15.6)				
≥4	95 (66.4)	38 (84.4)	0.021**	0.375	2.49	0.16-1.98
Duration of operation (min)	179.02±47.47	201.89±59.18	0.009***	0.007	1.01	1.00-1.01
Perioperative blood transfusion	67 (46.9)	23 (51.1)	0.618*			
Smoking history	40 (28.1)	10 (22.2)	0.446*			
NRS-2002 score						
<3	118 (82.5)	37 (82.2)				
≥3	25 (17.5)	8 (17.8)	0.964*			
Hypertension	47 (32.9)	25 (55.6)	0.006*	0.124	2.03	0.82-5.05
Diabetes mellitus	28 (19.6)	12 (26.7)	0.311*			
Chronic obstructive pulmonary disease	7 (4.9)	7 (15.6)	0.018*	0.206	2.30	0.63-8.40
Chronic renal failure	6 (4.2)	5 (11.1)	0.085*			
Cerebrovascular accident	8 (5.6)	3 (6.7)	0.789*			
Congestive heart failure	21 (14.7)	8 (17.8)	0.616*			
Perforation	25 (17.5)	17 (37.8)	0.004*			
Type of surgery						
Resection + stoma	41 (34.2)	32 (47.1)				
Resection + anastomosis	79 (65.8)	36 (52.9)	0.081*			
T stage						
T1-2	6 (4.2)	2 (4.4)				
T3-4	137 (95.8)	43 (95.6)	0.943*			
Grade						
I	7 (4.9)	4 (8.9)				
II	110 (76.9)	31 (68.9)				
III	26 (18.2)	10 (22.2)	0.468*			
Stage						
I-II	58 (40.6)	20 (44.4)				
III-IV	85 (59.4)	25 (55.6)	0.645*			
Tumor location						
Right-sided	32 (22.4)	12 (26.7)				
Left-sided	111 (77.1)	33 (73.3)	0.553*			
Metastatic lymph nodes median	1 (0-3)	1 (0-2.5)	0.916***			
Total lymph node count median	23 (16-31)	20 (14-25)	0.038***	0.376	0.98	0.95-1.01
Tumor length (cm) median	4 (2.5-4.5)	4 (3-5)	0.259***			
Tumor diameter (cm) median	4.5 (4-5)	5 (3.5-6)	0.249***	0.013	3.01	1.26-7.17

*Chi-square test; **Student's t-test; ***Mann–Whitney U test.

study, more than 80% of perforations were located at the tumor site. Age was also found to have a statistically significant relationship with both morbidity and mortality in the multivariate analyses, which is consistent with findings in the literature.[19] Elderly patients are known to be more vulnerable to intra-abdominal sepsis. The counterbalancing of septic stimuli by anti-inflammatory mechanisms may often be inadequate in this population.[14] Aging has also been associated with decreased physiological reserve and a higher burden of comorbidities, both of which may contribute to increased morbidity and mortality.[20] In the context of our study results, however, comorbidity scores did not show a significant effect on outcomes in the multivariate analyses. Therefore, the concept of physiological reserve, often described as an "elusive concept," may be particularly relevant. Physiological reserve has been defined as the ability of an organism to cope with stressors.[21] Although reserve capacity may be partially improved under certain conditions, emergency surgery generally provides limited opportunity for preoperative optimization. Nevertheless, the recommendation of the American Geriatrics Society should be emphasized: frailty assessment should be documented at hospital admission in elderly patients undergoing emergency surgery.[22] On the other hand, sex was not found to be significantly associated with outcomes in our study, which is consistent with the findings of several previous studies.[11,12]

In another study designed similarly to ours, risk factors were evaluated in three main contexts: patient-related factors, septic consequences of the disease, and the effects of the surgical procedure itself.[4] In the same study, it was noted that the third category is relatively neglected in many scoring systems. Blood transfusion is one of the factors within this category. Skala et al.[4] reported that blood loss and blood transfusion were associated with mortality; however, this association was not confirmed in multivariate analyses in the same study. In our study, blood transfusion was not found to be significantly associated with morbidity or mortality. While some studies have reported no serious adverse effects related to blood transfusion,[13,23] others have demonstrated a significant association with morbidity and mortality, even in multivariate analyses.[5,12,24] Various explanations have been proposed for this effect. Perioperative bleeding, which is an important indication for blood transfusion, may be related to patient-related factors such as malnutrition, portal hypertension, anticoagulant therapy, or liver failure.[4] Additionally, transfusion-related immunomodulation (TRIM) has been suggested as a possible mechanism contributing to adverse outcomes, particularly in this frail population with a high mean age.[24]

It may be useful to briefly address the scoring systems mentioned above. When the Physiological and Operative Severity Score for the Enumeration of Mortality and Morbidity (POSSUM) classification was first introduced, it was suggested that although several classifications existed for predicting mortality, morbidity had largely been neglected.[25] Today, however, a substantial body of evidence evaluating morbidity is available. Since then, several well-known variants of POSSUM have been developed, and multiple comparisons and evaluations have been conducted.[15,26-30] Furthermore, other classification systems have been introduced, and modified versions of these systems have also been proposed.[28,31,32] It is beyond the scope of this article to compare scoring systems or to determine which system overestimates or underestimates morbidity and mortality in emergency surgery patients. Nevertheless, all of these efforts reflect an attempt to improve predictive accuracy, better understand patient risk, and ultimately enhance the "quality of care".[25] Given the limitations of time and available resources, clinicians aim to understand the patient as accurately as possible using the fewest variables. The search for the most reliable predictive tools therefore continues.[33] Insights gained from these efforts may help guide surgical training and contribute to the evaluation of surgical quality.[11] Accurate risk assessment is also essential for providing realistic and up-to-date information to patients and their relatives.[6,26,34] Since our study also investigates potentially modifiable factors, adherence to Enhanced Recovery After Surgery (ERAS) recommendations may be beneficial.[6] Although global risk scales are important, the region and institution in which clinicians practice may have unique characteristics. Therefore, the availability of local data may also contribute to areas such as resource allocation and sustainable accountability.

ASA scores of III or IV were associated with higher mortality compared with lower ASA scores. Similarly, Skala et al.[4] reported that when the ASA score was ≥3, mortality rates approached nearly 25%, whereas the same rate was only 1–2% for patients with ASA ≤II. Another study has reported similar results.[31] Despite these findings, the possibility of interobserver variability should be considered when interpreting ASA scores, and clinical judgment should also be taken into account.[33] In terms of preexisting comorbidities, chronic obstructive pulmonary disease (COPD) was associated with mortality in the univariate analysis; however, this relationship was not supported in the multivariate analysis in our study. In another study including both elective and emergency patients, chronic lung disease was significantly associated with in-hospital mortality.[35]

Morbidity was associated with several factors in the univariate analyses. Factors such as age, ASA score, CCI score, and hypertension (HT) were patient-related and preexisting predictors of morbidity. Regarding disease-related factors, perforation, longer operative time, and total lymph node count were associated with worse outcomes. However, as wisely noted by Skala et al.,[4] correlation and causation represent different aspects of reality. Therefore, we cannot modify certain factors associated with outcomes, such as lymph node count, age, and preexisting comorbidities. On the other hand, the septic consequences of perforation may be partially modifiable. As demonstrated in the study by Krutsri et al.,[20]

rapid identification of patients requiring emergency colorectal surgery and completion of the necessary preoperative steps within specific time frames may reduce adverse outcomes. Acting promptly and appropriately may provide an opportunity to intervene before perforation occurs. Alternatively, even if perforation has already occurred before intervention, the severe septic consequences may be minimized. Additionally, factors directly related to the surgical procedure itself should not be neglected when evaluating modifiable variables.[4]

In our results, the duration of surgery was associated with adverse outcomes in both morbidity and mortality analyses. Previous studies have reported that prolonged operations are associated with higher intraoperative and postoperative complication rates.[15] However, some studies have reported conflicting findings.[4] Differences in study design may explain these discrepancies. Variables such as the type of surgery (emergency versus non-emergency) and the presence of perforation can, of course, affect the duration of surgery. The study by Skala et al.[4] is an example of a dissimilar result; however, that study included indications other than cancer, such as diverticulitis, the tumoral perforation rate was not reported, and some of the cases were non-emergency. Another example is the study by Abd-El-Aal et al.,[12] which included patients with a relatively low rate of diagnosed cancer. In that study, univariate analyses showed a significant relationship between operative duration and morbidity and mortality, whereas multivariate analyses did not. Therefore, factors related to study design may explain these differences. Naturally, more robust studies are needed. However, operative duration itself may not necessarily have a direct causal relationship with morbidity and mortality. Rather, it may represent another potential outcome and indicator of factors that contribute to morbidity and mortality. A recent study also identified prolonged surgery, blood loss, and the need for transfusion as indicators of difficult surgery.[36]

In most studies on emergency colorectal cancer surgery, nutritional evaluation was either not performed or albumin levels were primarily used as the basis for assessment.[20,23,34] However, we concluded that albumin may be misleading, considering that it is also a negative acute-phase reactant and that our patients undergo emergency surgery. This issue has also been highlighted in another study.[32] Wexner also noted that measuring albumin levels and considering them as a variable that can be rapidly modified is problematic.[11] In some studies, questionnaires were preferred to assess malnutrition instead of albumin levels.[15] In our study, we preferred the Kondrup score, also known as the NRS-2002 score, to evaluate malnutrition. To the best of our knowledge, our study is the only one investigating the relationship between the NRS-2002 score and outcomes of emergency colorectal cancer surgery. In univariate analyses, the NRS-2002 score was significantly associated with both morbidity and mortality; however, multivariate logistic regression analyses did not support this finding.

The retrospective nature of this study is the most prominent limitation. As the aim was to identify modifiable factors, the lack of data on "delay to operation" may also be considered another limitation. Furthermore, findings from a single tertiary referral center may not be easily generalizable to hospitals at different levels. However, conducting the study with a specific and relatively homogenous patient group may increase the generalizability of the results. Additionally, the use of a specific scoring system in a study focused on this particular patient population may contribute to more comparable findings in the literature. Despite these limitations, the detailed results of a considerable number of patients, analyzed through multi-stage methods and including variables that have been relatively neglected in previous studies, represent important strengths of this study.

CONCLUSION

This study highlights several significant risk factors contributing to morbidity and mortality in patients undergoing emergency colorectal cancer resections. Early identification of these well-defined risk factors may help stratify patients at higher risk and optimize management strategies. When a patient with colorectal cancer presents as an emergency case, early risk stratification is crucial, and institutional protocol-based processes with time-bound targets should be established. Once a patient is identified as high risk, close monitoring and intensive treatment are recommended to improve clinical outcomes. Emergency resections carry a high risk of complications and mortality, particularly in elderly patients, those with higher ASA scores, prolonged operative durations, and perforations. These patients may benefit from targeted perioperative strategies and closer postoperative surveillance.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Kolorektal kanserin acil rezeksiyonlarında morbidite ve mortalite ile ilişkili risk faktörleri

AMAÇ: Erken tanı için gösterilen tüm çabalara rağmen kolorektal kanser hastalarının dörtte biri hala acil şartlarda ameliyat edilmektedir. Çalışmamızın amacı acil kolorektal kanser rezeksiyonlarında morbidite ve mortalite ile ilişkili risk faktörlerini araştırmaktır.

GEREÇ VE YÖNTEM: Tek bir referans merkezde acil şartlarda yapılan kolorektal kanser rezeksiyonlarının retrospektif değerlendirmesi ile yapılan bu çalışmada, hastalara ait demografik veriler, perioperatif özellikler ve detayların yanı sıra tömür karakteristikleri incelendi. Çalışmamızda morbidite varlığı Clavien-Dindo ≥3 komplikasyon olarak tanımlandı. Hem morbidite hem de mortalite açısından önce tek değişkenli analizler ve ardından çok değişkenli lojistik regresyon testleri ile risk faktörleri araştırıldı.

BULGULAR: Çalışmamız %63'ü (119 hasta) erkek olmak üzere toplam 188 hasta ile gerçekleştirildi. Çok değişkenli analizlerde morbidite riski ile ilişkili faktörler yaş (OR=3.02, p=0.009), ASA skoru (OR=1.01, p=0.049), ameliyat süresi (OR=1.01, p=0.001) ve perforasyon varlığıydı (OR, 3.24, p=0.004). Mortalite için yapılan çok değişkenli analizde yaşın (OR, 3.23, p=0.017), ASA'nın (OR, 5.92, p=0.009), ameliyat süresinin (OR, 1.01, p=0.007) ve perforasyon varlığının (OR, 3.01, p=0.013) mortalite gelişimi ile anlamlı bir ilişkiye sahip olduğu tespit edildi.

SONUÇ: Bu çalışma, acil kolorektal kanser rezeksiyonları geçiren hastalarda morbidite ve mortaliteye katkıda bulunan birkaç önemli risk faktörünü vurgulamaktadır. Yaşın yetmiş üzerinde olması, üç ve üzerinde ASA skoru, ameliyat süresinin uzun olması ve perforasyon varlığı hem morbidite hem de mortalite sonuçlarını kötü etkileyen temel faktörler olarak belirlenmiştir. Bu risk faktörlerinin erken tanımlanması, daha yüksek risk altındaki hastaların belirlenmesi ve bu sayede hasta yönetiminin geliştirilmesine imkan tanıyacaktır. Yüksek morbidite ve mortalite oranları göz önüne alındığında, kolorektal acillerde özellikle yaşlı, daha yüksek ASA skorlarına sahip, ameliyatın uzadığı ve perforasyon tespit edilmiş hastaların yakından izlem gerektirdiği ve bu özelliklere sahip hastalarda daha dikkatli bir perioperatif bakımın faydalı olabileceği akılda tutulmalıdır.

Anahtar sözcükler: Acil cerrahi; kolorektal kanser; morbidite; mortalite.

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ORIGINAL ARTICLE

Logging-related fatalities in the Eastern Black Sea region of Türkiye: a forensic–epidemiological analysis

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ABSTRACT

BACKGROUND: Logging is widely recognized as one of the most hazardous industries. Despite the prominence of this sector in Türkiye's Eastern Black Sea region, comprehensive forensic investigations of logging-related deaths are limited.

METHODS: This retrospective study examined 102 logging-related fatalities identified among 4,878 forensic autopsies performed between 2013 and 2023 by the Recep Tayyip Erdoğan University. Demographic, occupational, environmental, seasonal, and medical response characteristics were extracted from autopsy reports and supplemented with information from police and judicial records.

RESULTS: The victims were predominantly male (93.1%) with an average age of 57.4 years. Two-thirds of them were unregistered workers, and 5.9% were foreign nationals. Tree-strike injuries were the leading cause of death (51.0%), followed by falls from trees (30.4%). Fatalities most frequently occurred in the fall (32.4%), with cranial trauma predominating in the summer and thoracic injuries in the spring. Autopsy findings revealed extensive polytrauma, including pelvic and extremity fractures (71.6%) and intracranial hemorrhage (53.9%). Most incidents were witnessed (78.4%); however, unwitnessed deaths occurred disproportionately among older informal workers on private lands. Female victims (6.9%) primarily died while performing auxiliary tasks and frequently lacked medical intervention (83%).

CONCLUSION: This study represents the first comprehensive medico-legal evaluation of logging-related fatalities in the Eastern Black Sea region. The findings highlight the pivotal role of unregulated labor, hazardous seasonal working conditions, and limited emergency response capacity in shaping mortality patterns. Targeted interventions, including stricter enforcement of occupational safety regulations, training for informal workers, and improved access to rural emergency services, are urgently needed to reduce preventable deaths in forestry and logging activities.

Keywords: Forensic autopsy; occupational injury; logging fatality; seasonal risk; Türkiye.

INTRODUCTION

Logging is recognized as one of the most hazardous industries worldwide, with some of the highest occupational fatality rates across sectors.[1] Activities such as tree felling, pruning, climbing, and transporting logs expose both professional forestry workers and amateurs to a high risk of severe traumatic injuries and deaths.[2] These incidents are often associated with environmental challenges, including rugged terrain, remote and hard-to-access work areas, and adverse weather conditions, as well as occupational exposures such as the use of heavy motorized and cutting tools and contact with allergenic flora and fauna.[3] Individual vulnerabilities, such as advanced age, pre-existing health conditions (e.g., cardiovascular disease or balance disorders), inadequate use of personal protective equipment (PPE), and noncompliance with safety protocols, further increase the risk of fatal outcomes.[4] However, beyond individual-level factors, the hazardous physical

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Figure 1. Primitive cable car system and challenging terrain conditions.

environment of forestry operations requires systemic protective measures. These measures include mechanized transport systems (e.g., cableways/teleferiks), proper terrain stabilization, controlled felling zones, and collective safeguards designed to minimize exposure to falling trees, rolling logs, and unstable slopes (Fig. 1). Therefore, effective prevention requires strict adherence to PPE standards along with comprehensive environmental and organizational interventions tailored to the high-risk nature of logging sites (Fig. 2).[5]

Several large-scale studies from the United States underscore the magnitude of this problem. An analysis of occupational deaths between 2009 and 2013 identified blunt trauma from falling trees or branches as the leading cause of death, with head injuries being most common and victims predominantly middle-aged males.[6] The authors emphasized the importance of mechanization and enhanced fall-prevention training. Similarly, a multi-state study conducted across 19 western states between 2011 and 2017 estimated an occupational fatality incidence of 3.5 per 100,000 full-time workers, with male mortality rates nearly ten times higher than those of females. Certain regions, such as Alaska and New Mexico, demonstrated disproportionately high fatality rates across different ethnic groups.[2] Long-term surveillance of tree care workers from 1987 to 2023 revealed that nearly one-quarter of fatalities occurred within the first year of employment, highlighting inexperience as a critical risk factor. The same study reported that only 39% of employers provided systematic training, and more than half lacked written safety protocols.[7] Age also plays a significant role. A study among farmers aged ≥55 years in Indiana between 1988 and 2017 reported a mean age at death of 67.4 years, with most fatalities resulting from blunt trauma caused by falling trees. Reduced physical capacity, insufficient use of protective equipment, and unsafe cutting

Figure 2. Warning and safety signs in logging areas.

techniques were identified as major contributing factors.[8] A recent U.S.-based study retrospectively evaluated injuries and fatalities among forestry and logging workers over a 16-year period (2003–2019) using data from the Bureau of Labor Statistics. The analysis found that contact with objects and equipment was the leading cause of both injuries and fatalities, followed by transportation-related incidents for fatalities and falls, slips, and trips for nonfatal injuries.[9] The authors emphasized that persistent gaps in occupational health and safety practices remain and highlighted the need for collaborative preventive strategies between researchers and the forestry industry.[10]

Findings from Türkiye mirror these international observations. Field studies report that head trauma, falls from height, and chainsaw-related injuries are more common among individuals with limited education and inadequate use of protective equipment.[11,12] However, systematic research on logging-related deaths based on forensic autopsy data remains scarce. This gap is particularly notable given the critical role of forensic medicine in elucidating causes of death, identifying environmental and individual risk factors, and providing reliable evidence for occupational safety policies. Comprehensive evaluation of autopsy findings alongside crime scene evidence, witness reports, and trauma patterns offers a unique opportunity to generate robust data for preventive strategies.

Against this background, the present study retrospectively examines logging-related fatalities in the Eastern Black Sea region of Türkiye over an eleven-year period (2013–2023), based on forensic autopsy data collected at the Recep Tayyip Erdoğan University. The study aims to characterize the mechanisms of death, distribution of traumatic lesions, autopsy findings, environmental and seasonal patterns, and occupational profiles of the victims. By including individuals engaged in unauthorized or non-professional logging activities, this research provides novel insights into the multifaceted risks associated with logging in Türkiye. The findings are expected to contribute to the forensic literature and to support the development of region-specific occupational safety interventions, including training and awareness programs in rural communities. By also incorporating cases related to unauthorized or non-professional logging activities, this study addresses a critical research gap and provides evidence-based recommendations for targeted occupational safety interventions in rural Türkiye.

MATERIALS AND METHODS

Data Source

This retrospective, autopsy-based study was conducted at the Recep Tayyip Erdoğan University, Türkiye, which is the sole authority responsible for performing forensic autopsies in the Eastern Black Sea region. The study period extended from January 1, 2013 to December 31, 2023. During this period, a total of 4,878 forensic autopsies were performed, all of which are mandatorily conducted in cases of violent, suspicious, or unnatural deaths under Turkish law.

Selection of Subjects

From the total autopsy population, 102 cases were identified in which death occurred in the context of occupational or non-occupational logging activities. Inclusion criteria required that the fatal event be clearly associated with tree felling, pruning, climbing, or wood-handling operations, as documented in the autopsy report and supported by supplementary materials (e.g., police reports, judicial records from the National Judiciary Informatics System [UYAP], and crime scene documentation). Cases with ambiguous activity contexts or deaths resulting from natural, non-traumatic causes were excluded.

Quality Control of the Autopsy Procedure

All autopsies included in this study were performed by specialists in forensic medicine at the Recep Tayyip Erdoğan University in accordance with national forensic protocols and institutional guidelines. Each case underwent a complete forensic autopsy, including external examination and internal dissection of all major body cavities. Toxicological samples were collected when indicated. As this was a retrospective study, the authors did not perform all of the autopsies themselves; instead, official autopsy reports and related documentation were systematically reviewed. During data extraction, the completeness and internal consistency of each case were verified by cross-checking relevant variables (e.g., correspondence between the cause of death, trauma patterns, and toxicological results) to ensure that all autopsies had been conducted and recorded in accordance with the institution's standardized quality procedures.

Variables Analyzed

Standardized data were extracted retrospectively for each case. The variables analyzed in this study included demographic characteristics (age, sex, and occupation), environmental factors (incident location, season of occurrence, and presence of witnesses), and injury mechanisms, such as being struck by a falling tree, falling from a tree, electrical injuries, and other trauma-related events. The cause of death was determined based on autopsy findings (e.g., multiple body trauma, head trauma, or thoracic injury) and was supported by toxicological analyses, including ethanol and other relevant substances when available.

Statistical Analysis

Statistical analyses were performed using SPSS software, version 25.0 (IBM Corp., Armonk, NY, USA). Categorical variables were analyzed using Pearson's chi-square test or Fisher's exact test when expected cell counts were <5. The normality of continuous variables was assessed using the Kolmogorov–Smirnov test. Depending on the distribution, comparisons between two groups were performed using either the Student's t-test or the Mann–Whitney U test, while analysis of

Figure 3. Unsafe and informal logging practices in rural areas.

variance (ANOVA) or the Kruskal–Wallis tests was used for comparisons involving more than two groups. Post hoc analyses with Bonferroni correction were conducted where applicable. A p value <0.05 was considered statistically significant.

RESULTS

A total of 4,878 forensic autopsies were conducted between 2013 and 2023. Among these, 102 deaths (2.1%) were confirmed to be related to forestry and logging activities and were included in the study.

Demographic and Occupational Characteristics

The victims were predominantly male (93.1%, n=95), with only seven females (6.9%). Ages ranged from 20 to 81 years (mean 57.4±15.5), with 71.6% of deaths occurring between 41 and 65 years of age. This distribution reflects the predominance of middle-aged and older men engaged in logging activities in the region. With respect to occupation, 38.2% (n=39) were officially employed forestry workers, whereas 61.8% (n=63) belonged to other occupational groups or were unregistered individuals. Many individuals in the latter group died while cutting wood on private or unauthorized land (Fig. 3). Foreign nationals accounted for six cases (5.9%), all of whom were Georgian workers. Statistical analysis revealed significant differences between forestry workers and non-workers in terms of incident location (p<0.001), presence of witnesses (p=0.002), and mechanisms of fatal injury (p=0.028). Forestry workers were more often involved in witnessed incidents occurring in forested areas (92.3%), whereas non-workers more frequently died on private lands without witnesses (Table 1).

Mechanisms and Causes of Death

The leading fatal mechanism was being struck by a falling tree (51.0%, n=52), followed by falls from trees (30.4%, n=31), falls from cliffs or slopes (6.9%, n=7), and cutting tool injuries (5.9%, n=6). Electrocution (5.9%, n=6) was observed exclusively among non-forestry workers. Autopsy findings identified blunt trauma or multiple body trauma as the most frequent cause of death (81.4%, n=83), followed by cardiovascular events (6.9%, n=7), electrocution (5.9%, n=6), and sharp force injuries (5.9%, n=6).

Medical Response and Scene Characteristics

In 64.7% of cases, death occurred at the scene (Fig. 4). Basic life support or resuscitation was attempted in 27.5% of cases, while only 7.8% of victims reached a hospital where surgical intervention was possible. Chainsaw use was recorded in 62.7% of incidents, and in 65.7% of cases the deceased was the individual directly engaged in felling the tree.

Seasonal Distribution and Anatomical Injury Patterns

Fatalities occurred most frequently in fall (32.4%), followed by summer (25.5%), winter (22.5%), and spring (19.6%). Incidents involving individuals struck by falling trees were particularly concentrated during the fall season (Fig. 5, left). Seasonal analysis revealed that cranial trauma predominated in summer, thoracic trauma in spring, and more evenly distributed trauma patterns during fall and winter. These differences appear to reflect both the seasonal intensity of forestry work and environmental conditions (Fig. 5, right).

Associations Between Age, Occupation, and Injury Type

Significant associations were identified between age and occupational status, incident location, and mechanism of injury. Forestry workers had a lower mean age (50.1±14.9 years) compared with non-workers (61.9±14.2 years; p<0.001). Victims of falls from trees were older (mean 66.9±8.3 years; p=0.011). Similarly, deaths occurring in forested areas in-

Table 1. Demographic and incident characteristics of logging-related fatalities

Variable	Forestry workers n (%)	Non-forestry/unregistered n (%)	Total n (%)
Sex			
Male	36 (92.3)	59 (93.7)	95 (93.1)
Female	3 (7.7)	4 (6.3)	7 (6.9)
Age (years)			
Range	20–79	22–81	20–81
Mean±SD	50.1±14.9	61.9±14.2	57.4±15.5
41–65 years	28 (71.8)	45 (71.4)	73 (71.6)
Nationality			
Turkish	39 (38.2%)	59 (61.8%)	98 (94.1)
Georgian	2 (5.1)	4 (6.3)	6 (5.9)
Incident characteristics			
Location: forest land	36 (92.3)	22 (34.9)	58 (56.9)
Location: private land	3 (7.7)	41 (65.1)	44 (43.1)
Witnessed events	34 (87.2)	46 (73.0)	80 (78.4)
Unwitnessed events	5 (12.8)	17 (27.0)	22 (21.6)
Mechanism of fatal injury			
Struck by falling tree	29 (74.4)	23 (36.5)	52 (51.0)
Fall from tree	7 (17.9)	24 (38.1)	31 (30.4)
Fall from cliff or slope	2 (5.1)	5 (7.9)	7 (6.9)
Cutting-tool injury	1 (2.6)	5 (7.9)	6 (5.9)
Electrocution	0 (0.0)	6 (9.5)	6 (5.9)

Figure 4. Images from the scene of the incident.

volved younger individuals (mean age 51.2 years) than those occurring on private land (mean age 64.5 years; p<0.001). These findings suggest that older individuals are more vulnerable to fall-related fatalities (Fig. 6A).

Autopsy Findings

The most frequent traumatic lesions were pelvic and extremity fractures (71.6%), followed by cranial trauma and intracranial hemorrhage (53.9%), cranial fractures (39.2%), rib and

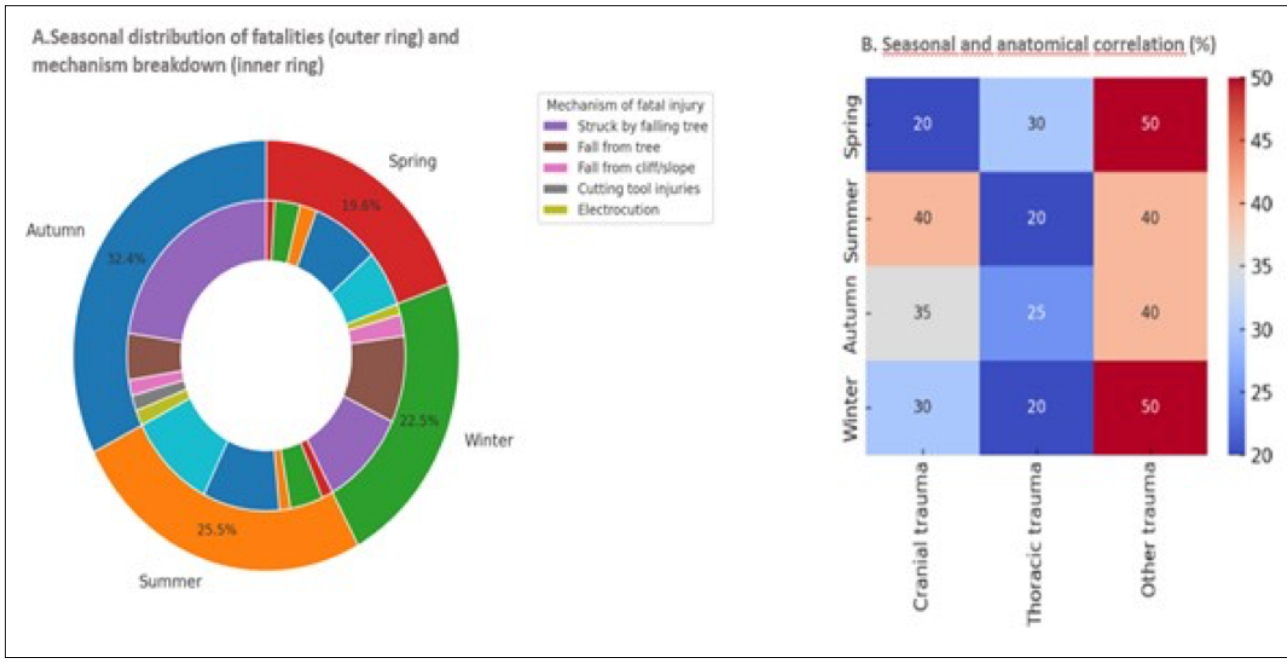

Figure 5. Seasonal distribution of logging-related fatalities by mechanism of injury and heatmap of anatomical injury correlations.

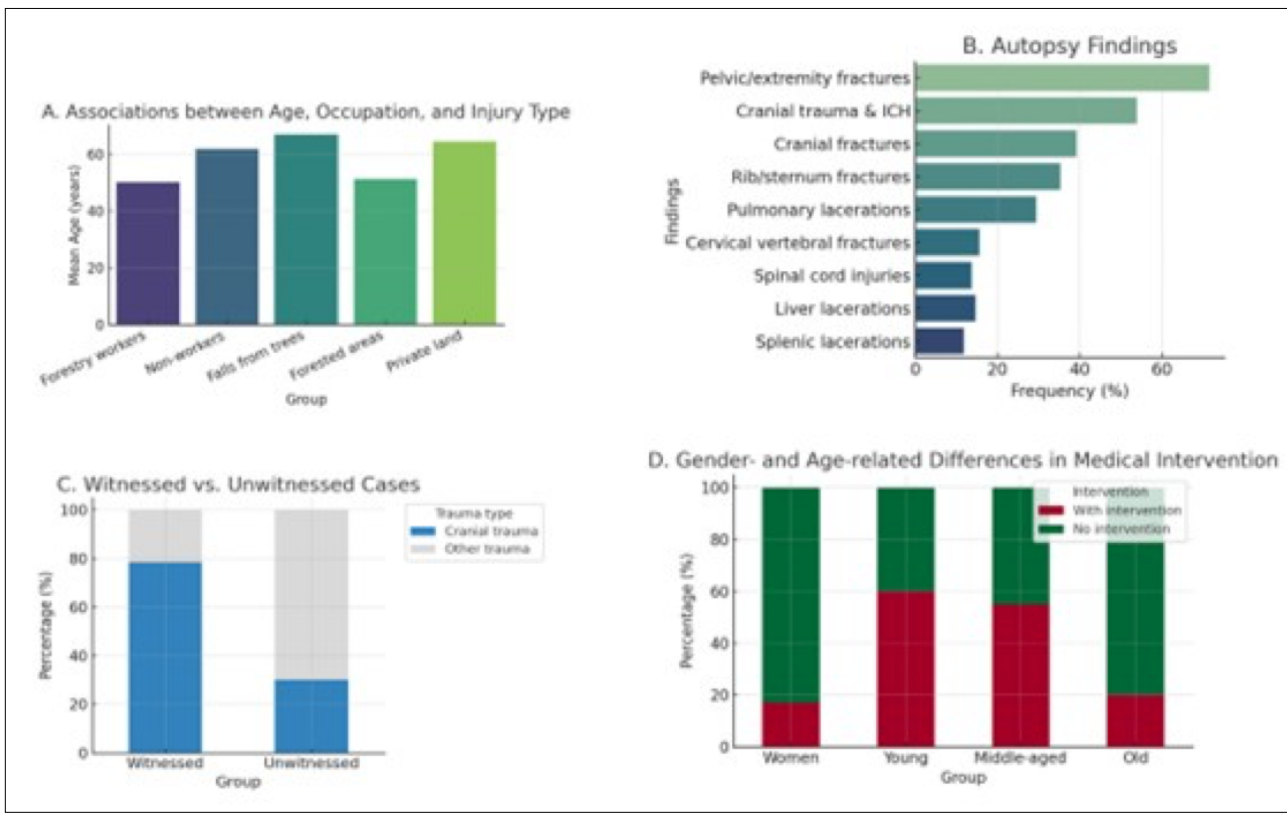

Figure 6. Multi-panel visualization of key findings in logging-related fatalities. **(a)** Mean age distribution according to occupational status, injury type, and incident location. **(b)** Prevalence of traumatic lesions identified at autopsy. **(c)** Distribution of trauma mechanisms in witnessed versus unwitnessed events. **(d)** Medical intervention rates according to age group and sex.

sternum fractures (35.3%), pulmonary lacerations (29.4%), cervical vertebral fractures (15.7%), and spinal cord injuries (13.7%). Abdominal organ injuries were also documented, including liver lacerations (14.7%) and splenic lacerations (11.8%), findings consistent with high-energy polytrauma (Fig. 6B).

Witnessed vs. Unwitnessed Cases

Most incidents were witnessed (78.4%), with cranial trauma being the predominant cause of death in this group. In unwitnessed cases, trauma mechanisms were more heterogeneous and often reflected delayed discovery of the victims (Fig. 6C).

Gender- and Age-Related Differences

Among female victims (6.9% of cases), 83% died without receiving medical intervention. Younger and middle-aged victims were more likely to receive resuscitative attempts, whereas older individuals more frequently died at the scene without intervention (Fig. 6D).

DISCUSSION

Demographic and Occupational Characteristics

Consistent with the gendered structure of forestry labor worldwide, fatalities were overwhelmingly male (>90%).[13,14] The 6.9% of female deaths were not associated with tree felling but rather with auxiliary tasks, such as wood transport. This pattern reflects the peripheral involvement of women in forestry-related activities. The mean age of 57.4 years indicates the heightened vulnerability of middle-aged and older men, contrasting with the younger professional cohorts reported in Northern Europe and North America.[15,16] Notably, two-thirds of the victims were unregistered workers, and many of the deaths occurred on private or unregulated land, highlighting systemic gaps in occupational safety oversight similar to those observed in Eastern Europe.[17] The presence of foreign nationals among the fatalities (all of whom were Georgian workers) further underscores how migrant laborers are often assigned the most hazardous tasks while lacking adequate protection. Limited access to training, language barriers, and informal employment conditions restrict their ability to benefit from occupational safety measures, thereby increasing their exposure to hazards and systemic vulnerabilities.[18]

Mechanisms and Causes of Death

In our cohort, the mortality pattern was dominated by tree-strike injuries, a finding consistent with global data on logging-related fatalities. Unlike Scandinavian forestry systems, where mechanized harvesting has progressively reduced such incidents, rural regions of Türkiye remain largely dependent on manual tree felling, perpetuating structural risk. Falls from trees and steep slopes represented the second most common cause of death and disproportionately affected older men, whose physiological decline—including impaired balance, slower reaction times, and reduced musculoskeletal resilience—increases their susceptibility to high-energy trauma. Although less frequent, chainsaw-related injuries remain a preventable subset of fatalities, reflecting gaps in training and inadequate enforcement of protective measures.[19] Electrocutions, which were largely confined to private lands near overhead power lines, highlight infrastructural hazards that could be mitigated through improved intersectoral planning.[20] Taken together, these mechanisms reveal a dual burden: the unavoidable dangers of heavy timber work and the preventable risks arising from inadequate regulation, insufficient training, and the lack of modernization in forestry practices. These findings underscore the need for urgent policy measures that combine mechanization, stricter enforcement of occupational safety standards, and community-level education to reduce both structural and modifiable hazards in forestry work.

Medical Response and Scene Characteristics

In our series, most incidents were witnessed (78.4%), enabling prompt resuscitative efforts. In contrast, unwitnessed deaths, which frequently occurred on private lands, were typically discovered hours later, eliminating any chance of survival. This contrast underscores the critical importance of immediate intervention, a finding consistent with occupational injury research indicating that the presence of bystanders significantly improves emergency response and survival outcomes.[21] The predominance of cranial trauma in witnessed cases reflects the inherently fatal nature of severe head injuries, which are often resistant to resuscitative efforts. Conversely, unwitnessed events more often involved thoracic or abdominal trauma, patterns consistent with delayed discovery and prolonged post-injury survival. Informal loggers, particularly non-forestry workers, died disproportionately in unwitnessed circumstances, highlighting the risks associated with working alone. In professional forestry operations, team-based protocols often mitigate these risks. Therefore, preventive strategies should emphasize discouraging solitary tree felling, mandating the use of communication devices in remote areas, and strengthening first-aid preparedness. In regions where informal labor predominates, community-based safety awareness programs are essential.

Seasonal Distribution and Anatomical Correlations

Our analysis revealed a clear seasonal clustering of fatalities, with fall (32.4%) representing the peak period, followed by summer, winter, and spring. Fall-related deaths were predominantly caused by tree-strike incidents, coinciding with intensive fuel preparation and woodcutting in the Eastern Black Sea region. Similar seasonal patterns of forestry injuries have been documented internationally, reflecting the influence of climatic and socio-economic cycles on labor intensity.[15,22,23] Seasonal, anatomy-specific patterns further highlighted this interaction. Cranial trauma predominated during summer, likely due to longer daylight hours and increased tree-felling activity, during which head injuries caused by falling trees and branches are well documented. In spring, thoracic trauma

was most common, possibly linked to rainfall-induced slippery slopes and crush injuries to the chest. Fall and winter showed a more balanced distribution of injury types, suggesting that harsher and more unpredictable environmental conditions may amplify diverse risks. These findings underscore that forestry hazards are not static but fluctuate with environmental conditions. From a preventive perspective, targeted, season-specific strategies—such as helmet enforcement in summer, enhanced fall-prevention measures in spring, and broader safety campaigns in fall—are critical. Incorporating seasonal risk calendars and raising forensic awareness of these correlations within occupational health policies may substantially reduce mortality.

Associations Between Age, Occupation, and Injury Type

Our analysis revealed strong associations between age, employment status, and injury mechanisms. Forestry workers were significantly younger (mean age: 50.1 years) than unregistered individuals (mean age: 61.9 years). This pattern reflects the physical demands of professional logging, which require strength, agility, and specialized training. Similar trends have been reported in occupational safety literature, where formal logging work is primarily performed by middle-aged men, whereas older individuals more frequently engage in informal woodcutting on private lands. Fatal falls from trees predominantly occurred among elderly individuals (mean age: 66.9 years), consistent with evidence indicating that reduced balance, diminished muscle strength, and slower reflexes increase the risk of falls.[24] Spatial patterns further underscored this socio-occupational divide. Younger forestry workers most often died in official forest areas, whereas older, unregistered individuals died on private lands while preparing firewood. These findings emphasize the need for prevention strategies tailored to different demographic groups. Such strategies should include technical training and protective equipment for younger workers, as well as community education, assistance programs, and fall-prevention initiatives targeting older populations. These tailored approaches may help address both occupational and broader socioeconomic vulnerabilities associated with logging-related fatalities.

Autopsy Findings

Autopsy examinations in our study revealed the multifocal and catastrophic nature of injuries sustained in logging-related fatalities. The most common injuries were pelvic and extremity fractures (71.6%) and cranial trauma with intracranial hemorrhage (53.9%), reflecting the high-energy transfer typically associated with impacts from falling trees. Similar findings have been reported in occupational accident studies, where blunt trauma to the head and torso represents the leading cause of immediate death. The substantial prevalence of cranial fractures (39.2%), rib and sternum fractures (35.3%), pulmonary lacerations (29.4%), and cervical vertebral fractures (15.7%) illustrates the extensive biomechanical forces involved. Such polytrauma configurations are often unsurvivable without immediate medical intervention, underscoring the critical importance of rapid detection.[25] Abdominal organ injuries, including hepatic (14.7%) and splenic (11.8%) lacerations, further support the frequent occurrence of combined thoracoabdominal trauma, which accelerates exsanguination and death. From a forensic perspective, the presence of both severe cranial and thoracic injuries indicates that death is rarely caused by a single lesion but rather by the combined effects of multiple traumatic injuries. This observation has important medicolegal implications. While helmets may reduce the risk of severe head trauma, they are insufficient to prevent fatal thoracoabdominal injuries. Similarly, autopsy-based research in other high-risk occupational sectors has shown that fatal trauma is seldom localized but commonly involves devastating injuries across multiple anatomical regions.[26,27] Taken together, these findings highlight the need for preventive strategies that extend beyond head protection and include thoracoabdominal safeguards, increased mechanization of felling practices, and strict adherence to safe cutting techniques.

Witnessed vs. Unwitnessed Cases

In this study, 78.4% of incidents were witnessed, and cranial trauma predominated in these cases, reflecting the inherently lethal nature of severe head injuries that often cause immediate collapse in front of coworkers or bystanders. In contrast, unwitnessed fatalities exhibited more diverse trauma patterns and were often discovered on private or unauthorized lands, suggesting delayed recognition or solitary working conditions. Thus, the presence or absence of witnesses has crucial implications for survival. While witnessed events allow for rapid recognition and attempted resuscitation, unwitnessed cases highlight systemic vulnerabilities in emergency response. Similar associations have been reported in forestry literature, where solitary tree felling and lack of supervision significantly increase the risk of fatality.[15] Comparable findings across occupational settings further confirm that immediate assistance and rapid medical intervention are critical determinants of trauma survival.[28] Therefore, preventive strategies should prioritize discouraging solitary logging, enforcing communication protocols, and extending safety education to unregistered workers to facilitate earlier intervention and reduce mortality.

Gender- and Age-Related Differences

Although women represented only 6.9% of cases, they experienced disproportionately poor outcomes, with 83% dying without receiving medical intervention. This pattern reflects the gendered distribution of forestry labor, in which women are more likely to engage in informal or unregulated woodcutting in isolated settings with limited access to care. Similar disparities have been reported in rural occupational contexts, where female victims face barriers to timely medical attention due to geographical isolation and sociocultural constraints.[29] Age-related differences were also pronounced. Younger and middle-aged individuals were more likely to receive resuscitative attempts, reflecting both their greater likelihood

of working in supervised environments and the stronger clinical motivation to intervene in patients with a potentially salvageable prognosis. In contrast, older victims often died at the scene without assistance in unwitnessed circumstances.[30] This pattern aligns with evidence indicating that aging is associated with diminished physiological reserve and reduced trauma survival. These findings underscore the need for targeted prevention strategies for vulnerable populations and highlight the importance of integrating community-based emergency response systems in rural areas.

Strengths and Limitations of the Study

This study has several notable strengths. First, the eleven-year observation period enables the identification of temporal patterns and long-term trends in logging-related fatalities in the Eastern Black Sea region. Second, the analysis is based on autopsy reports, which provide objective and detailed insights into causes of death, mechanisms of trauma, and the distribution of anatomical injuries. Reliance on forensic evidence ensures a higher degree of accuracy and reliability than studies based solely on hospital or registry data. Third, the study adopts a multidimensional framework incorporating demographic and occupational profiles, incident characteristics, seasonal variation, witness status, and detailed autopsy findings. This comprehensive approach allows for a more nuanced understanding of the multifactorial dynamics underlying these fatalities. Another important strength is the comparative evaluation of officially employed forestry workers and unregistered individuals, which highlights critical differences in occupational risk profiles. Furthermore, integrating forensic pathology with occupational health perspectives enhances the translational value of the findings for preventive strategies. Finally, the study design and reporting are aligned with international standards, facilitating comparison with global evidence and supporting its contribution to broader scientific and policy discussions. Despite these strengths, this study has several limitations that warrant consideration. First, as a retrospective analysis of institutional autopsy records, the study depended on the accuracy and completeness of existing documentation. Although standardized forensic protocols were applied, variations in the scope of ancillary investigations (e.g., toxicology and histopathology) may have influenced the level of detail available for some cases. Second, the study included only fatal incidents and therefore does not capture the broader spectrum of nonfatal logging-related injuries, which are critical for understanding the overall burden of occupational risk. Third, certain contextual variables, such as working hours, use of protective equipment, level of training, and employment arrangements beyond formal registration, could not be assessed due to incomplete documentation. Fourth, the findings are specific to the Eastern Black Sea region of Türkiye, where forestry practices, terrain characteristics, and socioeconomic conditions may differ from those in other regions of Türkiye or other countries. Thus, the results should be interpreted with caution when generalizing beyond this regional context. Finally, although autopsy data enable precise evaluation of injury mechanisms, they provide limited insight into occupational safety practices or systemic deficiencies that may have contributed to these fatalities.

CONCLUSION

This eleven-year, autopsy-based study is the first to provide a comprehensive forensic evaluation of logging-related fatalities in the Eastern Black Sea region of Türkiye. The results confirm that tree-strike trauma is the primary cause of death, reflecting the continued reliance on manual tree-felling methods. The seasonal clustering of fatalities, particularly during the fall, demonstrates how environmental conditions and labor intensity influence mortality risk. Significant associations between age, occupation, and injury type highlight the increased vulnerability of older and unregistered workers. The disproportionate impact on women and foreign nationals reveals broader structural inequities in occupational safety. Autopsy findings demonstrated catastrophic multisystem trauma, reinforcing the limited survivability of such events in the absence of immediate intervention. These findings emphasize the need for integrated prevention strategies, including mechanization of logging operations, enforcement of team-based and supervised work practices, provision of protective equipment, and community-level safety awareness initiatives. Addressing these vulnerabilities ultimately requires bridging the gap between occupational safety regulations and the realities of informal labor, ensuring that preventive measures encompass both professional forestry workers and rural populations engaged in subsistence-level logging.

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Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Türkiye'nin Doğu Karadeniz Bölgesinde odunculukla ilişkili ölümler: Adli tıbbi ve epidemiyolojik analiz

AMAÇ: Ormancılık, dünyanın en tehlikeli iş sektörlerinden biri olarak kabul edilmektedir. Türkiye'nin Doğu Karadeniz Bölgesinde bu sektörün yaygınlığına rağmen, literatürde ormancılıkla ilişkili ölümlere yönelik kapsamlı adli incelemeler sınırlıdır.
GEREÇ VE YÖNTEM: Bu retrospektif çalışmada, 2013–2023 yılları arasında Recep Tayyip Erdoğan Üniversitesi tarafından gerçekleştirilen 4.878 otopsi arasından seçilen 102 ormancılıkla ilişkili ölüm olgusu incelenmiştir. Demografik, mesleki, çevresel, mevsimsel ve tıbbi müdahale ile ilgili veriler otopsi raporlarından elde edilerek polis ve adli kayıtlarla desteklenmiştir.
BULGULAR: Olguların büyük çoğunluğu erkekti (%93.1) ve ortalama yaş 57.4 idi. Vakaların üçte ikisi kayıt dışı işçilerden oluşmakta olup, %5.9'u yabancı uyrukluydu. En sık ölüm nedeni kesilen ağacın işçiye yüksek enerjili teması (%51.0) olup bunu ağaçtan düşmeler (%30.4) izlemekteydi. Ölümler çoğunlukla sonbahar mevsiminde (%32.4) görülürken, yazın kraniyal travmalar, ilkbaharda ise torasik yaralanmalar baskın bulunmuştur. Otopsi bulguları geniş yayılımlı multitravmaları ortaya koymuştur; pelvis ve ekstremite kırıkları (%71.6) ile kafa içi kanamalar (%53.9) en sık bulgulardı. Olayların çoğu en az bir tanık huzurunda gerçekleşmiştir (%78.4); ancak tanıksız ölümler, genellikle özel arazilerde çalışan yaşlı ve kayıt dışı işçiler arasında daha sık gözlenmiştir. Kadın olgular (%6.9) çoğunlukla odunculuk ile ilişkili olan yardımcı işlerde çalışırken ölmüştür ve bu olgulara yapılan tıbbi müdahale oranı düşük bulunmuştur (%83).
SONUÇ: Bu çalışma, Doğu Karadeniz Bölgesinde ormancılıkla ilişkili ölümlerin kapsamlı adli-tıbbi değerlendirmesini sunmaktadır. Bulgular, düzensiz iş gücü, tehlikeli mevsimsel çalışma koşulları ve sınırlı acil sağlık hizmetlerinin ölüm örüntülerini belirlemedeki kritik rolünü ortaya koymaktadır. Kayıt dışı çalışanların eğitim almasının sağlanması, iş güvenliği mevzuatının daha sıkı uygulanması ve kırsal acil sağlık hizmetlerinin güçlendirilmesi, bölge insanına ilköğretim düzeyinde bazı temel eğitimlerin verilmesi gibi hedefe yönelik önlemler, ormancılık faaliyetlerine bağlı önlenebilir ölümleri azaltmak için acilen gerekli olduğu düşüncesindeyiz.

Anahtar sözcükler: Adli otopsi; iş kazası; mevsimsel risk; ormancılık ölümü; Türkiye.

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ORIGINAL ARTICLE

Is routine nasogastric decompression necessary following emergency surgery for perforated peptic ulcer?

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ABSTRACT

BACKGROUND: Nasogastric (NG) tube decompression has traditionally been used after abdominal surgery to prevent postoperative ileus and gastric distension. The aim of this study was to evaluate the necessity of NG tube decompression following emergency repair of perforated peptic ulcer (PUP).

METHODS: This retrospective study included 189 patients who underwent emergency surgery for PUP between 1999 and 2017. Patients were divided into two groups: those managed with an NG tube (Group 1, n=154) and those managed without an NG tube (Group 2, n=35). Demographic data, clinical characteristics (American Society of Anesthesiologists [ASA] scores and comorbidities), intraoperative findings, and postoperative outcomes, including length of hospital stay, time to oral intake, and complications, were analyzed.

RESULTS: The study cohort included 189 patients, of whom 84.1% were male, with a mean age of 54.1±19.9 years. Baseline demographic and clinical characteristics, including age, comorbidities, ASA scores, and operative details, were comparable between the two groups. There were no statistically significant differences in postoperative complications or 30-day mortality. However, patients in Group 2 demonstrated a significantly earlier transition to oral feeding (3.7±0.9 vs. 4.3±1.4 days; p=0.03) and a shorter duration of hospital stay (6.6±3.1 vs. 8.1±3.8 days; p=0.04) compared to Group 1.

CONCLUSION: Routine NG decompression is not necessary following surgery for PUP. Avoiding routine NG tube use does not increase morbidity or mortality and is associated with earlier oral intake and a shorter hospital stay. We recommend the use of NG decompression in selected patients when clinically indicated.

Keywords: Duodenal ulcer; gastric decompression; nasogastric tube; peptic ulcer; perforation.

INTRODUCTION

Peptic ulcer (PU) is caused by a wide range of factors that lead to erosion of the gastric and duodenal mucosa due to disruption of the mucosal barrier against gastric acid and pepsin.[1] Many factors contribute to its development, including Helicobacter pylori infection, chronic use of non-steroidal anti-inflammatory drugs, and smoking.[2,3] Peptic ulcer perforation (PUP) is a severe complication of peptic ulcer disease.[2] It involves contamination of the peritoneal cavity with gas-

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tric and duodenal contents.[3,4] Although bleeding is the most frequent complication of peptic ulcer disease, PUP remains the leading cause of mortality.[5] Operative management is recommended in patients presenting with massive pneumoperitoneum, active extraluminal contrast extravasation from the gastric lumen, and clinical signs of acute abdomen.[3] Traditionally, omentopexy is used in the treatment of perforated peptic ulcer (PPU) via open or laparoscopic surgery, and patients are managed with a nasogastric tube (NGT) during the early postoperative period.[6]

Current Enhanced Recovery After Surgery (ERAS) protocols recommend early removal of all catheters, including urinary and nasogastric (NG) tubes, following both elective and emergency surgeries. This protocol has also been safely implemented after surgery for PUP, even in elderly patients.[2] Routine nasogastric tube use after abdominal surgery largely reflects traditional practice. However, routine use of NG tubes following abdominal surgery has been associated with increased pulmonary and wound complications.[7] Furthermore, although abdominal distention may occur after abdominal surgery, only about 7% of cases require decompression with an NG tube.[7] There are no clear data in the literature regarding the necessity of NG tube use after PPU repair.[8]

The NG tube has traditionally been used in the early postoperative period after most abdominal surgical procedures, including PPU repair. The aim of this study was to examine the necessity of NG tube decompression following an important emergency procedure such as PUP repair.

MATERIALS AND METHODS

Study Population and Study Groups

Between 1999 and 2017, a total of 298 patients underwent emergency surgery for perforated peptic ulcer at our institution. For the purpose of this analysis, only patients who received primary repair via open omentopexy were considered eligible for inclusion. Consequently, patients who underwent alternative surgical procedures were excluded from the study. Specifically, nine patients who underwent gastrectomy or definitive ulcer surgery, one patient who underwent laparoscopic repair, and 46 patients whose repairs utilized the falciform ligament instead of the omentum were excluded from further analysis. One patient with a perforation diameter of 7 cm who underwent repair using an omental Graham patch was included in the study. After this initial screening, 242 patients remained eligible. An additional 53 patients were excluded due to incomplete data, resulting in a final study cohort of 189 patients. Figure 1 presents a flowchart summarizing the process of patient inclusion and exclusion based on the study criteria. The patients were divided into two groups:

- Group 1: Patients with NG tube insertion (n=154)
- Group 2: Patients without NG tube insertion (n=35).

Ethical Considerations

This study was approved by the Inonu University Scientific Research and Publication Ethics Board (Date: 27.02.2018, Decision no: 2018/5-3).As the analysis was conducted retrospectively, neither verbal nor written informed consent was required from the patients or their relatives. The study was conducted in accordance with the Declaration of Helsinki

Study Parameters

We retrospectively reviewed the institutional electronic database to collect demographic data (age and gender) and clinical characteristics, including American Society of Anesthesiologists (ASA) scores and comorbidities such as diabetes mellitus, hypertension, cardiovascular disease, chronic obstructive pulmonary disease (COPD), history of malignancy, and chronic renal disease (CRD). Preoperative laboratory values, including white blood cell count (WBC), hemoglobin, blood urea nitrogen (BUN), and creatinine levels, were recorded. Intraoperative data, such as the location and diameter of the perforation and the duration of the operation, were also documented. Postoperative outcomes assessed included length of hospital stay, time to oral intake, and specific com-

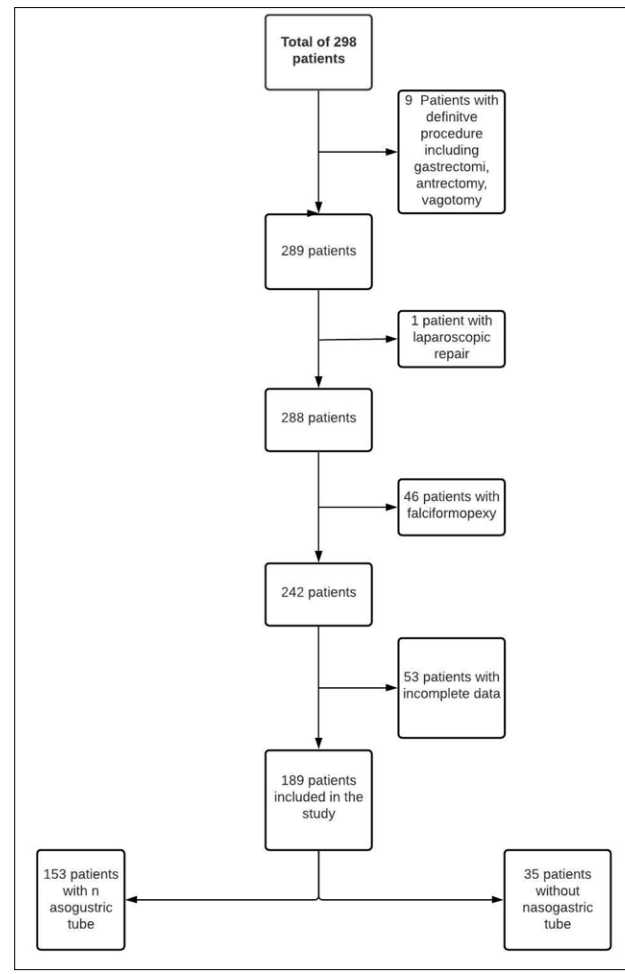

Figure 1. Flowchart illustrating patient selection at the beginning and end of the study, including the inclusion and exclusion criteria.

plications, including repair-site leakage, ileus, evisceration, atelectasis, pneumonia, surgical site infection, and the 30-day mortality rate.

Operative Technique

All patients underwent repair using the modified Graham patch technique.[9] The abdomen was entered through an upper midline incision, and the cavity was irrigated with large volumes of warm saline. After identification of the perforation, biopsies were routinely obtained from gastric ulcers; however, they were not routinely performed for duodenal perforations. The perforation was closed using 2/0 polydioxanone sutures. Following primary closure, an omental patch was prepared using energy devices and secured over the perforation site. Sump drains were placed in the subhepatic space and, when clinically indicated, in the pelvic cavity.

Statistical Analyses

The distribution of continuous variables was assessed using the Kolmogorov-Smirnov test. Normally distributed continuous variables are reported as mean±standard deviation (SD), while non-normally distributed variables are expressed as median (minimum–maximum). Categorical variables are presented as frequencies and percentages [n (%)]. For group comparisons, the Student's t-test was used for normally distributed data, and the Mann-Whitney U test was used for non-normally distributed data. Categorical variables were analyzed using the Pearson chi-square test. Statistical significance was defined as a $p<0.05$. All analyses were conducted using IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA).

Table 1. Demographic, clinical, and preoperative characteristics of the patients

	All patients (n=189)	Group 1 (n=154)	Group 2 (n=35)	p value
Age	54.1±19.9	54.2±20.4	53.5±18.7	0.84
Gender				
Male	159 (84.1)	128 (83.1)	31 (88.6)	0.30
Female	30 (15.9)	26 (16.9)	4 (11.4)	
Interval between symptoms and admission (hours)	24 (1-192)	24 (1-192)	24 (4-168)	0.67
Comorbidities				
Diabetes mellitus	9 (4.7)	9 (5.8)	0 (0)	0.10
Hypertension	24 (12.7)	21 (13.6)	3 (8.6)	0.54
Cardiovascular disease	7 (3.7)	6 (3.9)	1 (2.8)	0.37
COPD	12 (6.3)	11 (7.1)	1 (2.8)	0.13
History of malignancy	9 (4.8)	8 (5.2)	1 (2.8)	0.28
CRD	7 (3.7)	4 (2.6)	3 (8.6)	0.42
ASA score				
I	61 (32.3)	48 (31.2)	13 (37.1)	0.32
II	46 (24.3)	32 (20.8)	14 (40)	
III	19 (10.1)	17 (11.0)	2 (5.7)	
IV	4 (2.1)	4 (2.6)	0 (0)	
V	1 (0.5)	1 (0.6)	0 (0)	
Laboratory values				
WBC	13.6±6.8	14.0±6.9	11.8±6.3	0.09
Hemoglobin	14.6±2.4	14.5±2.4	15.0±2.3	0.33
Creatinine	1.2±1.1	1.2±0.8	1.4±1.8	0.44
BUN	29.4±22.8	29.7±23.0	28.8±22.6	0.84
Albumin	2.7±0.6	2.7±0.6	2.6±0.4	0.46

Chronic obstructive pulmonary disease; CRD: Chronic renal disease; ASA: American Society of Anesthesiologists; WBC: White blood cell count; BUN: Blood urea nitrogen. Age: years; WBC: 10^9/L; Hemoglobin: g/dL; Creatinine: mg/dL; BUN: mg/dL; Albumin: g/dL. *Continuous variables are expressed as mean±standard deviation (mean±SD). Categorical variables are presented as number and percentage [n (%)].

RESULTS

Demographic and Clinical Characteristics

A total of 189 patients were included in the analysis (Fig. 1). The study cohort had a mean age of 54.1±19.9 years, with a male predominance (84.1%). The median time from symptom onset to hospital admission was 24 (1-192) hours. Hypertension (12.7%) and COPD (6.3%) were the two most common comorbidities observed. The majority of patients had ASA I (32.3%) and ASA II (24.3%) scores. The median perforation diameter was 0.5 (0.2-7) cm. The most frequent site of perforation was the duodenum, accounting for 79.4% of cases. The mean duration of hospitalization was 7.8±3.7 days. The most frequent postoperative complications included evisceration in eight (4.2%) patients, atelectasis in 13 (6.9%) patients, pneumonia in 17 (9%) patients, and wound site infection in 17 (9%) patients. Mortality occurred in 13 (6.9%) patients.

Baseline Characteristics of the Study Groups

Table 1 summarizes the preoperative demographic and clinical characteristics of patients in Group 1 and Group 2. There were no statistically significant differences between the two groups regarding age, time to hospital admission, ASA risk scores, or preoperative laboratory parameters. Furthermore, the distribution of comorbidities—including diabetes mellitus, hypertension, and COPD—was comparable between the two groups.

Intraoperative Findings

Table 2 summarizes the perioperative characteristics of patients in Group 1 and Group 2. Operative data revealed no significant differences between the two groups. Specifically, the diameter of the perforation, anatomical location of the perforation, and total duration of surgery were similar in both groups.

Table 2. Perioperative characteristics of the study groups

	All patients (n=189)	Group 1 (n=154)	Group 2 (n=35)	p value
Perforation diameter (cm)	0.5 (0.2-7)	0.5 (0.2-7)	0.5 (0.3-2)	0.58
Site of perforation [n (%)]				
Duodenum	150 (79.4)	125 (81.2)	25 (71.4)	0.17
Prepyloric	8 (4.2)	8 (5.2)	0 (0)	
Pyloric	6 (3.2)	3 (1.9)	3 (8.6)	
Cardia/corpus	19 (10.1)	13 (8.4)	6 (17.1)	
Gastroenterostomy anastomosis	3 (1.6)	2 (1.3)	1 (2.6)	
Operative time (minutes)	70 (30-210)	70 (30-210)	65 (60-120)	0.75

Continuous variables are expressed as median (minimum–maximum). Categorical variables are expressed as number and percentage [n (%)].

Table 3. Postoperative outcomes and distribution of complications

	All patients (n=189)	Group 1 (n=154)	Group 2 (n=35)	p value
Length of hospital stay (days)	7.8±3.7	8.1±3.8	6.6±3.1	0.04
Time to oral intake (days)	4.2±1.3	4.3±1.4	3.7±0.9	0.03
Complications				
30-day mortality	13 (6.9)	12 (7.8)	1 (2.9)	0.33
Leakage	4 (2.1)	3 (1.9)	1 (2.9)	0.55
Ileus	4 (2.1)	4 (2.6)	0 (0)	0.45
Evisceration	8 (4.2)	7 (4.5)	1 (2.9)	0.56
Atelectasis	13 (6.9)	10 (6.5)	3 (8.9)	0.42
Pneumonia	17 (9)	14 (9.1)	3 (8.9)	0.64
Wound site infection	17 (9)	15 (9.7)	2 (5.7)	0.38

Continuous variables are expressed as mean±standard deviation (mean±SD). Categorical variables are presented as number and percentage [n (%)].

Postoperative Outcomes and Complications

Regarding postoperative morbidity and mortality, the use of an NGT did not provide a statistically significant advantage. There were no significant differences between the groups in terms of repair-site leakage, postoperative ileus, wound site infection, or pulmonary complications (atelectasis and pneumonia). Twelve patients (7.8%) in Group 1 and one patient (2.9%) in Group 2 died within 30 days after surgery. The 30-day mortality rate was comparable between the two groups. All variables related to postoperative outcomes are summarized in Table 3.

Comparison of Recovery Characteristics

Significant differences were observed in postoperative recovery times. Patients in Group 2 demonstrated a significantly earlier transition to oral feeding compared to patients in Group 1 (3.7±0.9 days vs. 4.3±1.4 days, respectively; p=0.03). Consequently, the length of hospital stay was significantly shorter in Group 2 compared to Group 1 (6.6±3.1days vs. 8.1±3.8 days, respectively; p=0.04). All variables related to postoperative recovery are summarized in Table 3.

DISCUSSION

The routine use of NG tubes was popularized following McIver's thesis, which postulated that swallowed air after abdominal surgery exacerbates abdominal distension. Consequently, many surgeons adopted NG tube decompression in the belief that draining stomach contents would accelerate the resolution of postoperative paralytic ileus. However, clinical observations frequently reveal minimal drainage from the NG tube, prompting a re-evaluation of its efficacy and benefits. Therefore, the use of NG decompression has largely remained a traditional practice.[9,10] This high-volume, single-center study analyzed the effects of NG tube decompression on gastrointestinal function and perioperative patient outcomes. We found that patients managed without NG tube decompression experienced a significantly shorter time to oral feeding and a reduced duration of hospitalization. Our results suggest that NG tube decompression should not be used routinely but rather reserved for selected cases where it is clinically indicated.

In the present study, we demonstrated that in peptic ulcer perforation repair, routine nasogastric tube decompression should be avoided, as it delays the recovery of gastrointestinal function. Patients managed without NG decompression exhibited accelerated recovery, evidenced by earlier initiation of oral feeding and significantly shorter hospital stays. In elective colorectal surgery, several studies have shown that NG tube use does not hasten the recovery of gastrointestinal function; conversely, it has been associated with a significantly increased risk of respiratory tract infections.[11] Furthermore, routine NG tube use has not demonstrated advantages regarding surgical site infection, nausea, vomiting, or ileus rates.[12] Some studies have reported that, contrary to traditional expectations, intestinal peristalsis returns earlier in patients managed without an NG tube.[12] Similarly, other studies have shown that patients without an NG tube achieve earlier oral intake and a faster transition to solid food following colorectal procedures.[13] It has been suggested that nasogastric tube decompression of the upper gastrointestinal tract may disrupt reflexes triggered by orogastric secretions, potentially contributing to postoperative ileus.[13] Several factors are known to contribute to postoperative ileus, including autonomic nervous system dysfunction, systemic inflammatory responses, anesthetic medications, and the use of opioid analgesics.[14] A Cochrane meta-analysis further supported these findings, concluding that omitting NG tubes after abdominal surgery accelerates the return of bowel function and reduces pulmonary complications without increasing repair-site leak rates.[15]

We demonstrated that NG tube decompression does not reduce leakage from the repair site. This finding is consistent with observations from other upper gastrointestinal surgeries. Following esophagectomy, no differences were observed in repair-site leakage, pulmonary complications, or mortality between early and late NG tube removal groups.[16] In an experimental rabbit model of esophageal repair, Yurtcu et al.[17] reported higher repair success rates in the group without NG tubes. Similarly, after gastrectomy for gastric cancer, omission of the NG tube did not negatively affect rates of repair-site leakage, wound infection, morbidity, or mortality. Instead, the non-NG tube group benefited from earlier oral intake and shorter hospital stays.[18] Akbaba et al.[19] also reported that avoiding NG tubes after total gastrectomy and esophagojejunostomy resulted in fewer postoperative fevers, sore throats, and pulmonary complications, without an increase in leakage rates.

Nasogastric tube insertion is not without risk; complications primarily arise from traumatic insertion or malposition. Because insertion is typically performed blindly, it may cause superficial mucosal injury or severe complications such as perforation or fistula formation. Reported complications include arytenoid trauma,[20] posterior pharyngeal wall hematoma,[21] gastric perforation,[22] esophageal perforation, and pneumothorax.[23] Predisposing factors for these injuries include malpositioning and the absence or misplacement of an endotracheal tube.[24] In severe cases, such as in patients with skull base trauma, intracranial placement of the NG tube has been documented.[25] Fortunately, no NG tube-related complications were observed in our study. Nevertheless, NG tube decompression of the gastrointestinal tract is required under certain clinical circumstances.

According to the latest guidelines of the World Society of Emergency Surgery (WSES), nasogastric tube decompression of the stomach is recommended in the non-operative management of self-contained perforations.[3] NG decompression has been used for the past three centuries for the treatment and diagnosis of various gastrointestinal diseases,

such as intestinal obstruction and gastrointestinal bleeding. The primary objective is the evacuation of gastrointestinal fluids and air from the upper gastrointestinal system.[15] The use of an NG tube is a routine surgical practice to decrease intestinal distention caused by postoperative ileus after major abdominal surgeries. Its main purpose is to decrease complications such as repair-site leakage, prevent vomiting secondary to ileus, and reduce the risk of pulmonary complications.[26] Although elective surgery for PU disease has decreased, emergency surgery for PUP or hemorrhage due to PU is still performed. As with any abdominal surgery, gastric dilatation due to swallowed air, postoperative ileus, and postoperative nausea and vomiting are common postoperative problems.[27] Traditionally, all these conditions have been managed with NG tube insertion.[28] Postoperative ileus is often observed in critically ill patients, particularly those with severe sepsis or those requiring mechanical ventilation. Therefore, routine NG tube insertion is not justified. However, NG tube decompression may be necessary in selected cases, such as elderly patients with severe abdominal sepsis or critically ill patients requiring mechanical ventilation, to prevent complications related to gastrointestinal distention.[28,29]

We attempted to reduce selection bias by including only patients who underwent open repair. A major strength of this study lies in the comparability of the cohorts; preoperative demographic characteristics, clinical and laboratory parameters, as well as perioperative variables, were similar between the two groups, thereby reducing the impact of confounding factors. However, the study has certain limitations. The retrospective design and the lack of a standardized randomization protocol introduce the potential for selection bias.

CONCLUSION

In the present study of patients undergoing repair for peptic ulcer, those managed without an NG tube experienced significantly shorter hospital stays and an earlier return to oral intake, without an increase in morbidity or mortality. Based on these findings, we do not recommend the routine use of NG tubes after PPU repair. Avoiding routine NG tube use improves patient comfort, eliminates potential tube-related complications, accelerates the resumption of oral feeding, and reduces the length of hospital stay.

Ethics Committee Approval: This study was approved by the Inonu University Scientific Research and Publication Ethics Board (Date: 27.02.2018, Decision No: 2018/5-3).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: E.Ç., C.A., C.K.; Design: E.Ç., C.A., C.K.; Supervision: C.K., T.T.Ş., C.A.; Data collection and/or processing: E.Ç., M.Ş., E.Ö.; Analysis and/or interpretation: T.T.Ş., E.Ö., E.Ç.; Literature review: E.Ç., M.Ş., E.Ö.; Writing: T.T.Ş., E.Ö., E.Ç.; Critical review: T.T.Ş., E.Ç., C.K.

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Perfore peptik ülser nedeniyle yapılan acil cerrahi sonrasında rutin nazogastrik dekompresyon gerekli midir?

AMAÇ: Nazogastrik (NG) tüp dekompresyonu, abdominal cerrahi sonrası postoperatif ileus ve gastrik distansiyonu önlemek amacıyla kullanılagelmiştir. Bu çalışmanın amacı, perfore peptik ülserin (PPÜ) acil onarımı sonrasında NG tüp dekompresyonunun gerekliliğini değerlendirmektir.
GEREÇ VE YÖNTEM: Bu çalışma, 1999 ve 2017 yılları arasında PPÜ nedeniyle acil ameliyat edilen 189 hastayı içeren retrospektif bir çalışmadır. Hastalar iki gruba ayrıldı: NG tüp ile takip edilenler (Grup 1, n=154) ve NG tüp uygulanmadan takip edilenler (Grup 2, n=35). Demografik veriler, klinik özellikler (ASA skorları, komorbiditeler), intraoperatif bulgular ve hastanede kalış süresi, oral alıma başlama zamanı ve komplikasyonları içeren postoperatif sonuçlar incelendi.
BULGULAR: Çalışma grubu, yaş ortalaması 54.1±19.9 yıl olan 189 hastadan (%84.1'i erkek) oluşmaktaydı. Yaş, komorbiditeler, ASA skorları ve ameliyat detaylarını içeren temel demografik ve klinik özellikler iki grup arasında benzerdi. Postoperatif komplikasyonlar veya 30 günlük mortalite açısından istatistiksel olarak anlamlı bir fark saptanmadı. Ancak, Grup 2'deki hastalar, Grup 1'e kıyasla istatistiksel olarak anlamlı düzeyde daha erken oral beslenmeye geçiş (3.7±0.9'a karşı 4.3±1.4 gün; p=0,03) ve daha kısa hastanede kalış süresi (6.6±3.1'e karşı 8.1±3.8 gün; p=0.04) gösterdi.
SONUÇ: PPÜ cerrahisi sonrası rutin NG dekompresyonu gerekli değildir. Bu yaklaşım morbidite veya mortaliteyi artırmamakla birlikte, anlamlı derecede daha kısa oral alıma başlama süresi ve kısalmış hastanede kalış süresi ile ilişkilidir. NG dekompresyonunun bu hasta grubunda yalnızca gerekli koşullarda ve seçilmiş vakalarda kullanılmasını önermekteyiz.

Anahtar sözcükler: Duodenal ülser; gastrik dekompresyon; nazogastrik tüp; peptik ülser; perforasyon.

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ORIGINAL ARTICLE

Factors influencing mechanical failure following intramedullary nailing of proximal femur fractures: a retrospective cohort study

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ABSTRACT

BACKGROUND: Proximal femur fractures are a common injury in elderly patients and are associated with high morbidity and mortality worldwide. Recent data indicate that the age-standardized incidence of hip fractures in adults over 55 years has increased significantly. We aimed to identify radiographic stability parameters and patient- or procedure-related factors associated with clinical fixation success following intramedullary nailing of proximal femur fractures.

METHODS: In this retrospective study, we evaluated 373 patients aged ≥35 years who underwent proximal femoral nail (PFN) implantation for intertrochanteric, pertrochanteric, subtrochanteric, or reverse-oblique femur fractures at our tertiary center between 2012 and 2024. Fractures were classified preoperatively using the Evans classification system, and the quality of reduction was graded as good, fair, or poor according to the standard radiographic Modified Baumgaertner criteria. Radiographic variables, including proximal lag screw tip-head distance (ApLAG1), distal lag screw tip-head distance (ApLAG2), ApLAG2-calcar distance, lesser trochanter-calcar distance, lateral lag screw tip-apex distance (LatTAD), and normal-side lesser trochanter-calcar distance, were measured postoperatively. Clinical outcomes were categorized into two groups: success or failure.

RESULTS: The cohort (mean age: 78.06±12.79 years; 66.5% female) included 262 (70.2%) standard PFNs, 79 (21.2%) integrated intertrochanteric antegrade nails (InterTAN) PFNs, and 32 (8.6%) single-screw PFNs. Overall, 359 patients (96.2%) had successful fixation and 14 (3.8%) experienced failure. No significant differences were found in radiographic parameters between the success and failure groups. PFN type did not influence radiographic measurements except for ApLAG2-related variables, in which InterTAN and single-screw nails differed from standard PFNs ($p<0.001$). Univariate analysis revealed that only poor reduction quality was significantly associated with failure ($\chi^2=36.298$; $p<0.001$).

CONCLUSION: Quality of fracture reduction emerged as the sole independent predictor of PFN fixation success, whereas patient demographics, Evans classification, and implant design did not significantly affect outcomes. Surgeons should prioritize achieving near-anatomic alignment and stable implant positioning to minimize mechanical failure.

Keywords: Proximal femur fractures; proximal femoral nail; radiological assessment; reduction quality.

INTRODUCTION

Proximal femur fractures are one of the most commonly encountered injuries in elderly patients and are associated with high rates of morbidity and mortality worldwide.[1] These injuries particularly affect individuals aged 55 years and older, with incidence rates ranging from 434 to 616 per 100,000 population depending on the region.[2,3] Moreover, previous

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studies have revealed that the global age standardized incidence rate of hip fractures in adults aged ≥55 years increased from 781.56 per 100,000 in 1990 to 948.81 per 100,000 in 2021, reflecting an increasing burden on healthcare systems due to population aging.[4] Most proximal femur fractures in this demographic result from low energy, ground level falls, underscoring the interplay between osteoporosis, frailty, and fall risk.[5] The global burden of hip fractures is projected to nearly double by 2050 due to population aging, exacerbating the socioeconomic strain on health systems and emphasizing the need for optimal surgical strategies.[6,7]

The AO/OTA (Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association) classification system categorizes proximal femur fractures into femoral neck (31B), intertrochanteric (31A), and subtrochanteric (32) patterns, offering a standardized framework to guide surgical planning.[8] Within intertrochanteric fractures, simple two part patterns (31A1) are considered stable, whereas comminuted or reverse oblique configurations (31A2–31A3) pose biomechanical challenges that require more robust fixation constructs.[8] Extramedullary devices such as dynamic hip screws have been widely used; however, intramedullary nails, by virtue of their load-sharing design, shorter lever arm, and minimally invasive insertion, offer superior biomechanical stability, particularly in unstable fracture patterns.[9-11] Randomized clinical trials have demonstrated comparable one year functional outcomes between intramedullary nailing and sliding hip screws, with intramedullary nails showing advantages in maintaining reduction and enabling earlier weight bearing.[12]

Postoperative radiographic parameters such as tip apex distance (TAD), restoration of the neck shaft angle, and calcar support serve as quantitative measures of implant positioning and mechanical stability.[13,14] A TAD exceeding 25 mm is reported to be strongly associated with an increased risk of lag screw cut out, emphasizing the importance of precise implant placement.[14] Cephalomedullary nailing in unstable intertrochanteric fractures yields union rates of 85–93% at three to six months postoperatively, with most patients achieving full or near full weight bearing by three months.[15,16] Despite these favorable union rates, mechanical complications such as screw cut out and peri implant fractures occur in up to 10% of cases, indicating the need for meticulous reduction techniques and appropriate implant selection.[17]

In accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for observational studies, we aimed to identify stability parameters and patient or procedure related factors associated with optimal fixation and early functional recovery by conducting a retrospective cohort analysis of patients treated with intramedullary nailing for proximal intertrochanteric, pertrochanteric, subtrochanteric, and reverse oblique femur fractures.

MATERIALS AND METHODS

Study Design and Patient Selection

This retrospective cohort study was conducted in accordance with the STROBE guidelines. Ethics approval was obtained from the Marmara University Faculty of Medicine Local Clinical Research Ethics Committee (Approval No: 09.2024.998; Date: 2024). Written informed consent was obtained from each patient or their relatives prior to surgery. All procedures performed in this study involving human participants were conducted in accordance with the ethical standards of the institutional research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

We reviewed the medical records of all patients aged ≥35 years who sustained a proximal femur fracture (intertrochanteric, pertrochanteric, subtrochanteric, or reverse-oblique patterns) and underwent proximal femoral nail (PFN) implantation at our institution between 2012 and 2024. Patients with a follow-up period of <6 months, incomplete medical records, or a previous surgical history at the operated site were excluded from the study.

Additionally, our inclusion criteria encompassed various proximal femoral fracture types (intertrochanteric, pertrochanteric, subtrochanteric, and reverse-oblique). While this broad inclusion provides a real-world representation of fracture patterns encountered in daily orthopedic practice, it may also introduce heterogeneity in biomechanical behavior and outcomes. Future studies focusing on more homogeneous fracture subtypes may better delineate type-specific mechanical risk factors.

Data Collection and Baseline Variables

Demographic and clinical data, including age, sex, and fracture side, were obtained from hospital archives. All proximal femur fractures were initially classified on preoperative radiographs according to the Evans classification system. After surgery, reduction quality was classified as good, fair, or poor according to the Modified Baumgaertner criteria.

Surgical Technique and Postoperative Management

All patients were operated on in the supine position on the fracture table under fluoroscopic guidance. After achieving preoperative reduction on the fracture table, a suitable incision was made. An appropriately sized intramedullary nail was inserted through the apex of the greater trochanter. Proximal and distal locking screws of appropriate size were then placed using a guide system.

Radiological Assessments

For standard and integrated intertrochanteric antegrade nail (InterTAN)-type PFN measurements, the distances of the proximal locking screws to the femoral head were measured in millimeters, including the anteroposterior proximal lag screw tip–head distance (ApLAG1) and the anteroposterior

distal lag screw tip–head distance (ApLAG2). The distance between the lesser trochanter and the calcar was measured on both the fractured and the normal sides. The distance between the distal proximal locking screw and the calcar was also measured (ApLAG2–calcar distance). Additionally, the distance from the lag screw to the apex of the femoral head was measured on the lateral plane, defined as the lateral tip–apex distance (LatTAD) (Figs. 1, 2).

For single-screw PFN measurements, the distance of the proximal locking screw to the femoral head was measured in millimeters (ApLAG1). The distance between the lesser trochanter and the calcar was measured on both the fractured and normal sides. The distance from the proximal locking screw to the calcar was also measured and was given the same designation to allow comparison with other PFN systems (ApLAG2–calcar distance). The distance from the lag screw to the apex of the femoral head was measured on the lateral plane (LatTAD) (Fig. 3).

Data Analysis

Continuous variables were expressed as mean±standard deviation (SD). The normality of continuous variables was assessed using the Kolmogorov–Smirnov test. Comparisons among three groups were performed using one-way analysis of variance (ANOVA), followed by Tukey's honestly significant

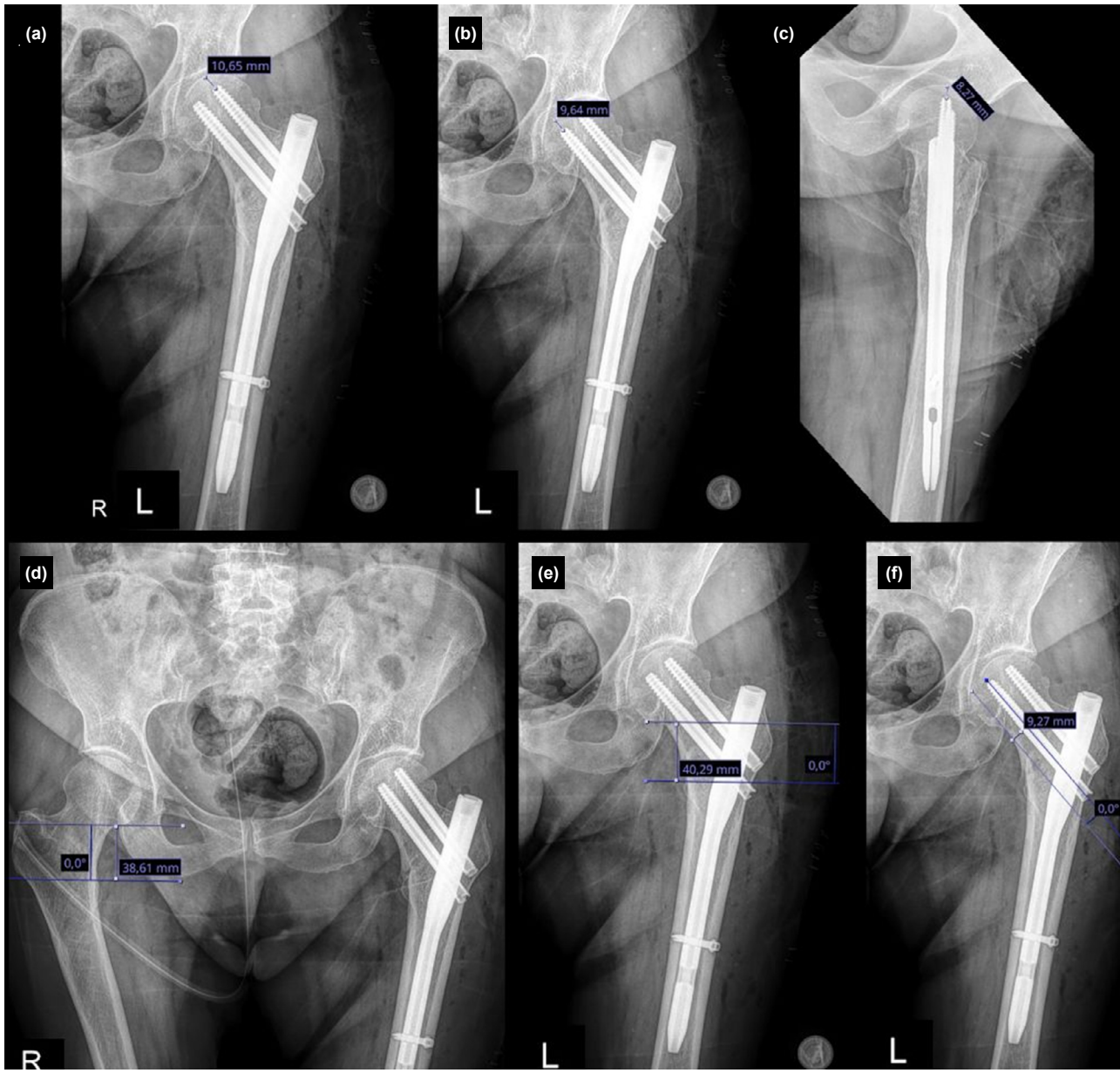

Figure 1. Radiographic measurements for the standard proximal femoral nail (PFN). **(a)** Anteroposterior proximal lag screw tip–head distance (ApLAG1); **(b)** Anteroposterior distal lag screw tip–head distance (ApLAG2); **(c)** Lateral tip–apex distance (LatTAD); **(d)** Normal-side trochanter minor-calcar distance; **(e)** Trochanter minor-calcar distance; **(f)** ApLAG2–calcar distance.

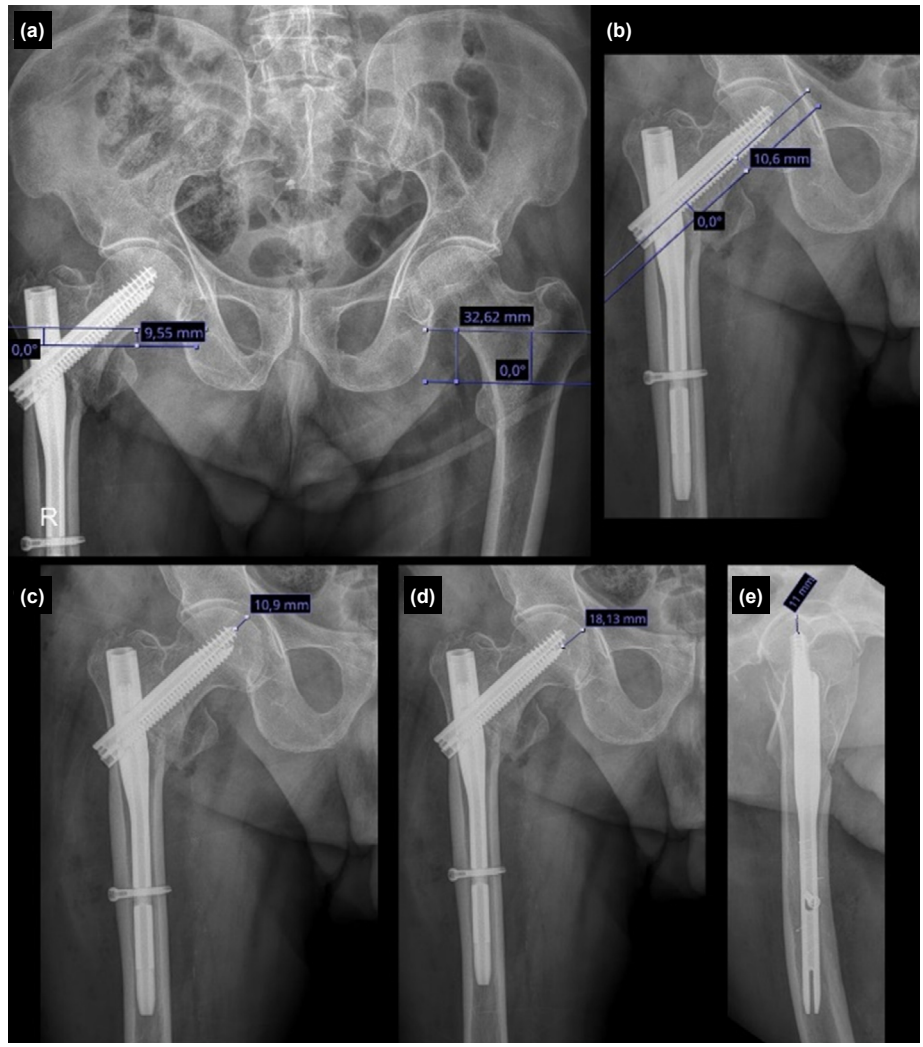

Figure 2. Radiographic measurements for the integrated intertrochanteric antegrade nail (InterTAN) type proximal femoral nail (PFN). **(a)** Trochanter minor-calcar distance and normal-side trochanter minor-calcar distance; **(b)** Anteroposterior distal lag screw–calcar distance (ApLAG2–calcar distance); **(c)** Anteroposterior proximal lag screw tip–head distance (ApLAG1); **(d)** ApLAG2; **(e)** Lateral tip–apex distance (LatTAD).

difference (HSD) test. Comparisons between two groups were conducted using Student's t-test. Categorical variables were presented as frequencies and percentages, and comparisons were performed using the chi-square test. All hypothesis tests were two-tailed, and a p-value <0.05 was considered statistically significant. Statistical analyses were performed using IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, USA).

RESULTS

A total of 373 patients with complete data were included in the analysis. The mean age of the cohort was 78.06±12.79 years. Seventy-nine patients (21.2%) received an InterTAN PFN, 32 (8.6%) received a single-screw PFN, and 262 (70.2%) received a standard PFN. Of the fractures, 187 (50.1%) occurred on the right side and 186 (49.9%) on the left. According to the Evans classification, the most common fracture types were type 5 (98, 26.3%) and type 4 (92, 24.7%), whereas type R comprised nine cases (2.4%). Reduction quality was rated as "good" in 175 patients (46.9%), "moderate" in 142 (38.1%), and "poor" in 56 (15.0%). Overall, 359 patients (96.2%) had a successful clinical outcome, while 14 (3.8%) experienced failure (Table 1).

Among the continuous radiographic parameters, no significant differences were observed between patients with successful versus failed outcomes (ApLAG1, p=0.186; ApLAG2, p=0.205; ApLAG2–calcar distance, p=0.946; trochanter minor–calcar distance, p=0.632; lateral lag screw-apex distance, p=0.061; normal-side fragment–calcar distance, p=0.750) (Table 2).

Comparisons across PFN types revealed that ApLAG1 did not differ significantly (p= 0.988), whereas ApLAG2 (p<0.001), ApLAG2–calcar distance (p<0.001), trochanter minor–calcar

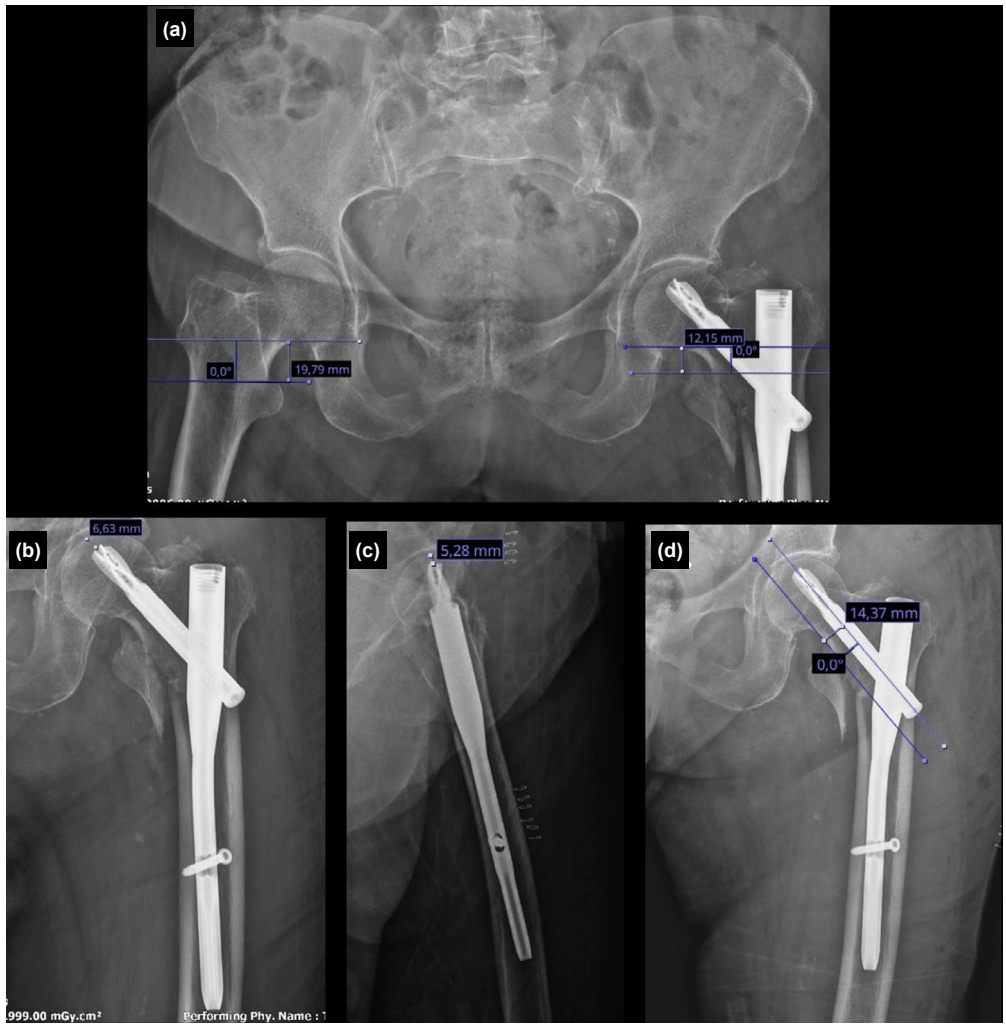

Figure 3. Radiographic measurements for the single-screw type proximal femoral nail (PFN) radiographic measurements. **(a)** Trochanter minor-calcar distance and normal-side trochanter minor-calcar distance; **(b)** Anteroposterior proximal lag screw tip–head distance (ApLAG1); **(c)** Lateral tip–apex distance (LatTAD); **(d)** Anteroposterior distal lag screw–calcar distance (ApLAG2–calcar distance).

distance (p=0.046), lateral lag screw-apex distance (p=0.023), and normal-side fragment–calcar distance (p=0.040) all varied significantly by implant type (Table 3). Post hoc analyses indicated that InterTAN PFNs had greater initial ApLAG2 angulation values and ApLAG2–calcar distances than standard PFNs, and that single-screw PFNs differed significantly from both other groups in terms of ApLAG2 measurements.

As summarized in Table 4, univariate analyses were performed to assess the association between several demographic, fracture-related, and implant-related factors and clinical outcome (success versus failure). Age was compared between groups using an independent t-test and showed no significant difference. Similarly, sex, fracture laterality (right versus left), and PFN type (standard, InterTAN, single-screw) showed no statistically significant relationship with clinical failure. Evans classification (types 1–R) was also not associated with outcome (Table 4). By contrast, reduction quality demonstrated a highly significant association with clinical outcome, indicating that cases rated as "poor" reduction were more likely to experience failure than those with "moderate" or "good" reduction. No other factor reached statistical significance. Collectively, these results indicate that, among the variables tested, only inadequate fracture reduction was predictive of postoperative failure (Table 4).

DISCUSSION

In this cohort of patients undergoing intramedullary nailing for proximal femur fractures, we found that reduction quality was the sole independent predictor of mechanical failure, whereas age, sex, fracture laterality, nail design (standard PFN, InterTAN, single-screw PFN), and Evans classification were not significant predictors. Multivariate analysis showed that inadequate reduction (malalignment or loss of cortical support) conferred a substantially higher odds of fixation failure (e.g. cut-out, implant breakage, or nonunion requiring revision), while the confidence intervals for other factors all

Table 1. Patient characteristics

Characteristic	N (%)/Mean±SD
Age (years)	78.06±12.79
Sex	
Male	125 (33.5)
Female	248 (66.5)
Fracture side	
Right	187 (50.1)
Left	186 (49.9)
Evans classification	
Type 1	24 (6.4)
Type 2	69 (18.5)
Type 3	81 (21.7)
Type 4	92 (24.7)
Type 5	98 (26.3)
Type R	9 (2.4)
Reduction quality	
Poor	56 (15.0)
Moderate	142 (38.1)
Good	175 (46.9)
PFN type	
Standard PFN	262 (70.2)
InterTAN PFN	79 (21.2)
Single-screw PFN	32 (8.6)
Clinical outcome	
Success	359 (96.2)
Failure	14 (3.8)

PFN: Proximal femoral nail.

crossed unity (p>0.05). This finding underscores that surgical technique and alignment are the dominant determinants of clinical outcomes in these cases. Cho et al.[18] reported that "poor reduction (type P)" on the lateral view was associated with a very high risk of failure (odds ratio [OR]=12.7) in geriatric trochanteric nail fixation. Similarly, recent studies emphasize that the quality of reduction is the most crucial controllable predictor of improved outcomes, as well as survival, in proximal femoral fractures.[19-21]

By contrast, patient demographics and fracture classification showed no apparent influence on failure in our cohort. We observed no significant difference in failure rates according to age or sex. This suggests that, once surgical stabilization is achieved, biological factors such as bone quality (which correlates with age and sex) may play a lesser role than the mechanical environment. Some prior studies have reported nominal associations between poor bone quality or comminution and fixation failure; however, our data did not support a clear effect of these unmodifiable factors. Similarly, we found no difference between right- and left-sided fractures. Regarding fracture type, the Evans classification did not predict failure, suggesting that the traditional Evans system may be relatively coarse. Interestingly, Donadono et al.[22] also reported that fracture pattern (AO type A1/A2/A3) did not independently affect cut-out risk when reduction quality was controlled, whereas Cho et al.[18] identified AO 31-A3 (reverse-oblique) fractures as a risk factor. However, our sample may have included too few of these cases to demonstrate significance under the Evans classification scheme. Overall, the lack of association with Evans type in our study suggests that surgeons should focus more on reduction quality than on nominal fracture classification when predicting implant success.

In our study, we did not observe any significant differences in failure rates among PFN constructs (standard PFN vs. InterTAN vs. single-screw PFN). In other words, nail design did not influence failure rates. Although our findings suggest that nail design did not significantly affect failure rates, this conclusion should be interpreted with caution. Differences in fracture morphology, surgeon experience, and implant familiarity may obscure subtle design-related effects. Furthermore, biomechanical and clinical studies have demonstrated that dual-screw systems such as the InterTAN provide superior rotational stability and resistance to varus collapse,

Table 2. Comparison of radiographic parameters according to clinical outcome

	Success (n=359)	Failure (n=14)	p value
ApLAG1 (mm)	9.65±3.48	10.97±4.89	0.186
ApLAG2 (mm)	13.04±4.77	14.83±5.79	0.205
ApLAG2–calcar distance (mm)	8.64±5.41	8.74±5.15	0.946
Trochanter minor–calcar distance (mm)	21.76±10.62	23.20±11.62	0.632
LatTAD (mm)	8.75±3.58	10.70±6.08	0.061
Normal-side trochanter minor–calcar distance (mm)	27.38±6.83	26.73±8.90	0.750

ApLAG1: Anteroposterior proximal lag screw tip-head distance; ApLAG2: Anteroposterior distal lag screw tip-head distance.

Table 3. Radiographic parameters according to proximal femoral nail (PFN) type

	Standard PFN (n=262)	InterTAN PFN (n=79)	Single PFN (n=32)	p-value
ApLAG1 (mm)	9.65±3.47	9.69±3.54	9.62±3.64	0.988
ApLAG2 (mm)	12.27±4.25	16.18±4.97	6.07±10.51	<0.001
ApLAG2–calcar distance (mm)	7.50±5.04	11.79±5.78	10.33±3.45	<0.001
Trochanter minor–calcar distance (mm)	22.70±10.82	19.56±9.77	—	0.046
LatTAD (mm)	8.48±3.68	9.65±3.75	—	0.023
Normal-side trochanter minor–calcar distance (mm)	27.95±7.10	25.99±5.90	—	0.040

ApLAG1: Anteroposterior proximal lag screw tip-head distance; ApLAG2: Anteroposterior distal lag screw tip-head distance; PFN: Proximal femoral nail.

Table 4. Association between clinical factors and clinical outcomes

Factor	Test	Statistic (df)	p-value
Sex	Chi-square	χ^2=0.953 (1)	0.329
Fracture side	Chi-square	χ^2=0.308 (1)	0.579
PFN type	Chi-square	χ^2=1.841 (2)	0.398
Reduction quality	Chi-square	χ^2=36.298 (2)	<0.001
Evans classification	Chi-square	χ^2=3.275 (5)	0.658

PFN: Proximal femoral nail; X: Chi-square.

particularly in unstable or osteoporotic fractures.[23-25] Liao et al.,[25] in a systematic review and meta-analysis, reported that InterTAN nails exhibited lower rates of cut-out, varus collapse, and shaft fracture compared with single-screw PFN systems, highlighting their enhanced mechanical stability. Similarly, Yalın et al.[23] found that InterTAN designs minimized the risk of the Z-effect and maintained reduction more effectively than other intramedullary nails. In another comparative study, Kürüm et al.[24] observed that nail protrusion occurred in 31.6% of single-screw Talon PFNs, whereas no such cases were reported with InterTAN nails, supporting the biomechanical superiority of the dual-screw construct. Including these mechanical and design factors in future analyses could further refine the understanding of implant-specific performance and guide surgical decision-making.

We suggest that, assuming proper surgical technique and adequate fracture reduction, all three implants can provide stable fixation. This finding partly diverges from some recent literature favoring the dual-screw InterTAN design. It has been reported that InterTAN nails yield superior functional scores and avoid the so-called "Z-effect" observed with some single-screw nails.[23] A systematic review, on the other hand, found that PFN antirotation (single-screw) systems had higher rates of shaft fracture, varus collapse, and cut-out than InterTAN nails, and suggested that InterTAN's advantage is attributed to its static, interlocking lag-screw system, which provides greater anti-rotational stability and prevents excessive collapse.[25] In our series, however, these design-related differences may have been mitigated by surgeon preference or the relatively small sample size. It is possible that with optimal reduction and an appropriate TAD, even a single-screw nail can avoid complications. Nonetheless, given the broader evidence, it would be prudent to acknowledge that dual-screw nails may confer greater mechanical robustness, particularly in unstable fracture patterns or osteoporotic bone.[18,23] For example, in a matched comparison of Talon PFN (single-screw) versus InterTAN, no nail protrusions occurred with InterTAN, whereas 31.6% of Talon cases demonstrated protrusion.[24] While our data do not contradict such reports, they suggest that when reduction is optimized, different implant designs can perform comparably in terms of overall failure.

Consistent with other reports, we also found that implant positioning parameters other than reduction quality, such as TAD or screw placement, were not independently associated with failure in multivariate analysis. In our cohort, nearly all nails were inserted with a TAD <25 mm and central screw positioning, reflecting contemporary surgical standards. As a result, TAD did not emerge as a risk factor, whereas studies

with greater variability in TAD often identify it as an important predictor of failure. For example, it has been reported that TAD >25 mm significantly predicts cut-out in addition to poor reduction quality.[22] Similarly, a 2025 surgical score analysis (the TSS study) demonstrated that each unit increase in an intraoperative "quality score" (encompassing TAD, screw positioning, cortical support, etc.) markedly reduced the risk of complications, highlighting modifiable factors such as lag screw placement and cortical support (factors closely related to reduction quality and surgical technique) as key drivers of outcome.[26] Our findings, combined with these reports, reinforce that even when an implant is appropriately positioned, the underlying reduction quality and cortical support (particularly medial and anterior) are paramount in preventing failure.[19,22]

As a retrospective analysis, this study is subject to several inherent limitations. First, the study design limits causal inference and may involve missing data or inconsistencies in documentation. Second, the absence of randomization means that unmeasured factors, such as the degree of fracture comminution or bone quality, could have influenced the outcomes. Moreover, the use of the Evans classification may not capture biomechanical instability as comprehensively as the AO/OTA classification system. Another limitation of our study is the relatively short follow-up period (6–12 months). Although this duration is sufficient to capture early mechanical failures such as cut-out or implant breakage, it may not fully reflect late complications such as delayed union or implant fatigue. Future prospective studies with longer follow-up periods are therefore warranted to evaluate long-term functional and radiographic outcomes. In addition, the follow-up period was limited to six to 12 months; therefore, very late failures may have been missed. Lastly, functional or patient-reported outcomes were not collected, as the focus of this study was solely on mechanical fixation success.

Given these limitations, future research should focus on several areas. Prospective, multicenter randomized trials comparing different PFN designs (including InterTAN, single-screw systems, and newer constructs) under standardized surgical protocols could help isolate implant-specific effects. Studies investigating reduction-enhancement strategies, such as 3D fluoroscopy, computer-assisted reduction, or percutaneous cerclage wires, may determine whether these techniques improve alignment and thereby reduce failure rates. Furthermore predictive scoring systems (such as the Trochanteric Surgical Score [TSS], which incorporates reduction quality, tip-apex distance, and bone quality) should be validated across diverse patient populations to guide real-time clinical decision-making. Biomechanical studies are also needed to clarify how small deviations in reduction affect failure risk for different nail designs and to establish clinically acceptable thresholds. Finally, research evaluating bone augmentation techniques—such as cement augmentation or biologic therapies—in patients with poor bone quality may help determine whether these strategies can mitigate failure when optimal reduction cannot be achieved.

CONCLUSION

In conclusion, our data indicate that the quality of fracture reduction and implant positioning exerts a more critical influence on biomechanical stability and clinical outcomes than the specific choice of intramedullary nail design. Although dual-screw constructs such as the InterTAN nail have demonstrated superior resistance to rotational forces and axial collapse in controlled laboratory studies, these theoretical advantages are realized only when anatomic alignment and cortical support are reestablished intraoperatively. Consequently, surgeons should prioritize restoration of near-anatomic alignment, ensuring medial calcar contact and an appropriate neck-shaft angle, and adhere rigorously to validated radiographic parameters (e.g., Baumgaertner or Chang criteria) at the time of fixation. A key clinical takeaway is that surgeons should devote meticulous attention to fracture reduction intraoperatively, restoring neck-shaft alignment, appropriate abduction, and medial cortical continuity, and potentially employing adjunct techniques such as traction, percutaneous clamps, or open techniques when necessary. Even the most advanced implant cannot compensate for residual malreduction. Future innovations in nail geometry or locking mechanisms should therefore be developed in parallel with surgical techniques that facilitate precise reduction, as the ultimate determinant of implant success remains the mechanical environment created by the surgeon's restoration of fracture anatomy.

Overall, by addressing variability introduced by fracture type, extending follow-up

duration, and exploring implant design differences in greater depth, future research may provide a more comprehensive understanding of factors influencing mechanical failure after intramedullary nailing.

Ethics Committee Approval: This study was approved by the Marmara University Faculty of Medicine Local Clinical Research Ethics Committee (Date: 20.09.2024, Decision No: 09.2024.998).

Peer-review: Externally peer-reviewed.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Proksimal femur kırıklarında intramedüller çivileme sonrası mekanik başarısızlığı etkileyen faktörler: Retrospektif kohort çalışması

AMAÇ: Proksimal femur kırıkları yaşlı hastalarda sık görülen yaralanmalardır ve dünya çapında yüksek morbidite ve mortalite ile ilişkilidir. Güncel veriler, 55 yaş üzeri erişkinlerde yaşa-standardize edilmiş kalça kırığı insidansının anlamlı ölçüde arttığını göstermektedir. Bu çalışmada, proksimal femur kırıklarının intramedüller çivileme sonrası klinik tespit başarısı ile ilişkili radyografik stabilite parametrelerini ve hasta/prosedür kaynaklı faktörleri belirlemeyi amaçladık.

GEREÇ VE YÖNTEM: Bu retrospektif çalışmada, 2012–2024 yılları arasında üçüncü basamak merkezimizde intertrokanterik, peritrokanterik, subtrokanterik veya ters oblik femur kırığı nedeniyle proksimal femoral çivi (PFN) uygulanan ≥35 yaşındaki 373 hasta değerlendirildi. Kırıklar ameliyat öncesinde Evans sistemi ile sınıflandırıldı ve redüksiyon kalitesi standart radyografik Modifiye Baumgaertner kriterlerine göre iyi, orta veya kötü olarak derecelendirildi. Postoperatif dönemde, proksimal lag vidası uç-baş mesafesi (ApLAG1), distal lag vidası uç-baş mesafesi (ApLAG2), ApLAG2-kalkar mesafesi, küçük trokanter-kalkar mesafesi, lateral lag vidası uç-apeks mesafesi (LatTAD) ve normal taraf küçük trokanter-kalkar mesafesi gibi radyografik değişkenler ölçüldü. Klinik sonuçlar başarı veya başarısızlık olarak iki grupta değerlendirildi.

BULGULAR: Çalışma grubunun ortalama yaşı 78.06±12.79 yıl olup, %66.5'i kadındı. Hastalara 262 (%70.2) standart PFN, 79 (%21.2) InterTAN PFN ve 32 (%8.6) tek vidalı PFN uygulandı. Genel olarak 359 hasta (%96.2) başarılı fiksasyon elde ederken, 14 hastada (%3,8) başarısızlık gözlendi. Başarı ve başarısızlık grupları arasında radyografik parametreler açısından anlamlı fark bulunmadı. PFN tipi, ApLAG2 ile ilişkili değişkenler dışında radyografik ölçümleri etkilemedi; bu parametrelerde InterTAN ve tek vidalı çiviler standart PFN'den farklı bulundu ($p<0.001$). Tek değişkenli analizde yalnızca kötü redüksiyon kalitesinin başarısızlık ile anlamlı ilişkili olduğu saptandı ($\chi^2=36.298$; $p<0.001$).

SONUÇ: Kırık redüksiyon kalitesi, PFN fiksasyon başarısının tek bağımsız belirleyicisi olarak öne çıkmıştır. Buna karşılık, hasta demografisi, Evans sınıflaması ve implant tasarımı sonuçları anlamlı olarak etkilememiştir. Cerrahların mekanik başarısızlık riskini en aza indirmek için olabildiğince anatomik hizalanma ve stabil implant pozisyonu sağlamaya öncelik vermeleri gerekmektedir.

Anahtar sözcükler: Proksimal femur kırıkları; proksimal femoral çivi; radyolojik değerlendirme; redüksiyon kalitesi.

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ORIGINAL ARTICLE

A modified subchondral raft technique using free 5.5-mm cannulated compression screws for depressed tibial plateau fractures: a prospective observational study

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ABSTRACT

BACKGROUND: In tibial plateau fractures, achieving anatomical restoration of the articular surface and preventing postoperative collapse are critical for successful outcomes. Bone grafting is still commonly used to fill subchondral voids after reduction; however, it carries risks such as donor-site morbidity and technical difficulties. To address these issues and enhance subchondral stability, subchondral raft techniques have been developed. Although various screw and plate configurations have been investigated in the literature, there is still no clear consensus regarding the most effective method. We aimed to evaluate the effectiveness of our modified technique using free 5.5-mm cannulated compression screws in preventing postoperative collapse and improving functional recovery in tibial plateau fractures.

METHODS: A total of 21 patients were included based on the following criteria: age ≥18 years, presence of >10 mm depression in the lateral tibial plateau, and no history of previous surgery on the affected knee. A subchondral raft construct was established without grafting using free 5.5-mm cannulated compression screws. Postoperative evaluation at 12 months included radiological and functional assessments using the Rasmussen Clinical Score (RCS) and Rasmussen Radiological Score (RRS).

RESULTS: The mean preoperative articular depression was 14.7 mm, improving to 1.1 mm at the one-year follow-up. Mean condylar widening decreased from 5.3 mm preoperatively to 0.7 mm postoperatively. The average postoperative hospital stay was 3.7 days, and the mean time to return to work was 3.5 months. At one year, radiological and functional outcomes were favorable, with a mean RCS of 26.6 and a mean RRS of 16.6.

CONCLUSION: The modified raft technique using 5.5-mm cannulated compression screws is a simple and effective option for managing depressed tibial plateau fractures, preventing articular collapse and facilitating faster recovery.

Keywords: Tibial plateau fracture; subchondral raft; cannulated compression screw; early rehabilitation; functional recovery; Rasmussen score.

INTRODUCTION

Tibial plateau fractures are periarticular injuries of the proximal tibia and represent some of the most challenging injuries in orthopedic practice. They account for approximately 1% of all fractures and are more common in men under 50 years of age due to high-energy trauma, while low-energy mechanisms predominate in elderly women with osteoporosis.[1,2] These injuries often result in significant morbidity, increased health-

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care costs, and prolonged recovery, particularly in younger patients during their most productive years.[3] Anatomical reduction and stable fixation are essential for restoring knee function and mobility.

Management of tibial plateau fractures often requires addressing metaphyseal bone defects resulting from elevation of depressed articular fragments. While bone grafting is commonly used to fill these voids, it is associated with several complications and technical difficulties.[4-7] To overcome these limitations and improve fixation stability, subchondral rafting techniques have increasingly been applied in clinical practice. The present study aimed to evaluate the effectiveness of a subchondral raft configuration reinforced with 5.5-mm free cannulated compression screws in the treatment of depressed tibial plateau fractures without the use of bone grafts. This technique was hypothesized to enhance articular stability, prevent early collapse, and promote faster functional recovery. To the best of our knowledge, no previous studies have reported the use of this specific screw configuration for subchondral rafting.

MATERIALS AND METHODS

The study was approved by the Clinical Research Ethics Committee of University of Health Sciences Prof. Dr. Cemil Taşcıoğlu City Hospital, University of Health Sciences (No: E-48670771-514.10; Date: May 24, 2021; Decision No: 212). All procedures were performed in accordance with the ethical principles of the Declaration of Helsinki. Informed consent was obtained from all patients.

This study was designed as a prospective observational study. Between May 2021 and May 2022, patients diagnosed with tibial plateau fractures at our hospital were evaluated. Twenty-one patients were included according to the following criteria: age ≥18 years, a lateral tibial plateau depression greater than 10 mm, and no history of prior surgery on the affected knee. Patients were excluded if they were younger than 18 years of age, had a history of previous knee surgery or fractures around the knee, had isolated split-type fractures or posterior column involvement, had less than 10 mm of depression in the lateral tibial plateau, or presented with open or pathological fractures.

Data were collected on a range of variables, including patient demographics (age, sex, and side of injury), mechanism of trauma, and fracture type according to the Schatzker classification. Perioperative data, such as operative time and duration of postoperative hospitalization, were also recorded. Radiological assessments included preoperative and postoperative measurements of articular depression and condylar widening on computed tomography (CT) images, evaluated by a blinded orthopedic surgeon who was not involved in the surgeries (Fig. 1). All radiological measurements were performed on coronal and sagittal CT images with a slice thickness of 1 mm to ensure precise evaluation of articular depression and condylar widening. Functional and radiological outcomes were assessed using the Rasmussen Clinical Score (RCS) and Rasmussen Radiological Score (RRS) at the one-year postoperative follow-up (Table 1).[8] Additionally, employment status prior to injury, return-to-work rates, and time to resume occupational activities were documented.

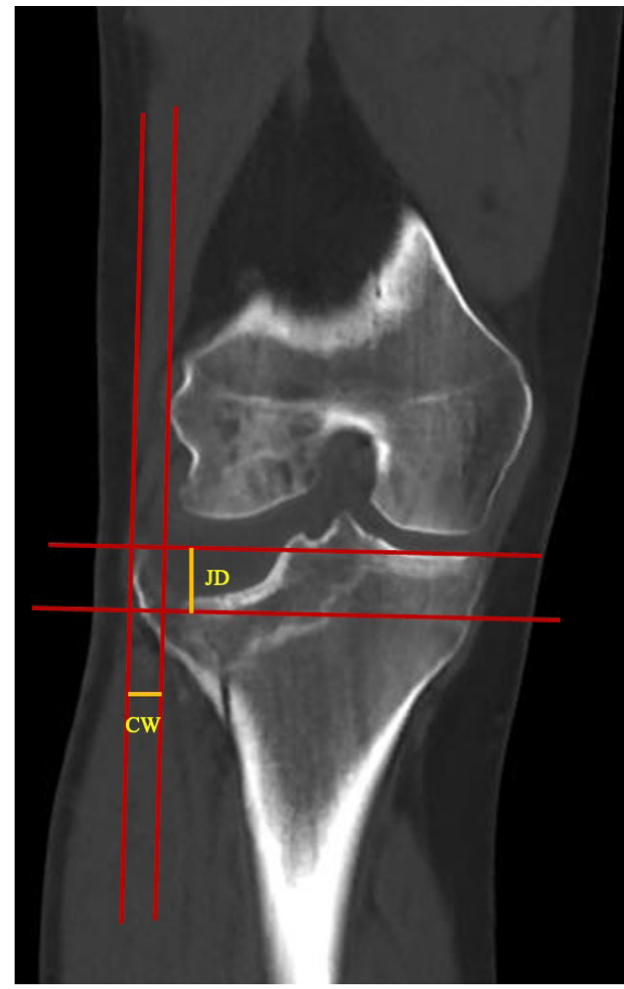

Figure 1. Method of measuring joint depression (JD) and condylar widening (CW) on computed tomography (CT) images. JD is defined as the vertical distance between the tibial joint line and the lowest point of the depressed articular surface. CW is defined as the horizontal distance between the outermost point of the femoral condyle and the outermost point of the tibial plateau.

Table 1. Evaluation criteria for Rasmussen scores

RRS	RCS	Evaluation
18 points	27–30 points	Excellent
12–17 points	20–26 points	Good
6–11 points	10–19 points	Fair
0–5 points	4–9 points	Poor

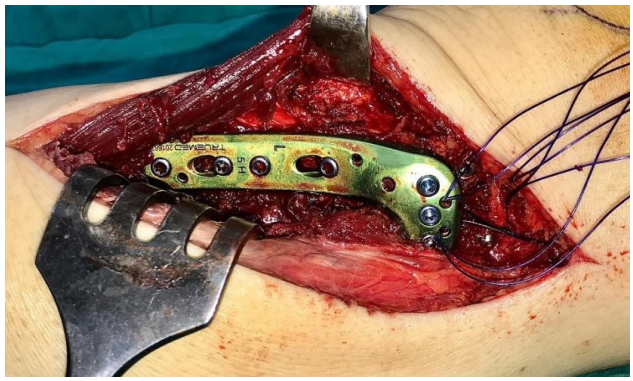

Figure 2. Intraoperative view following fixation.

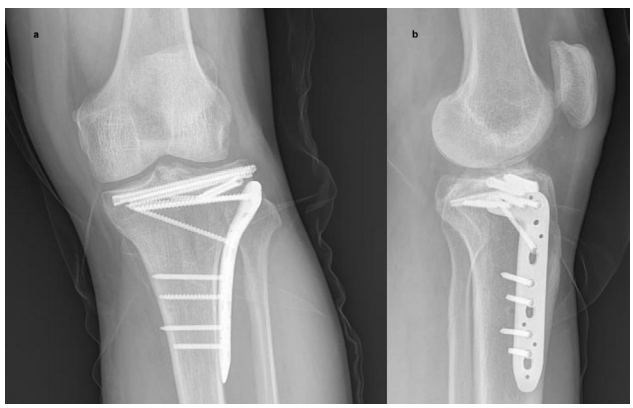

Figure 3. Postoperative one-year follow-up radiographs. **(a)** Anteroposterior view and **(b)** lateral view.

Surgical Technique

Patients with favorable soft-tissue conditions were operated on within the first 24 hours. For those with less favorable conditions, cold therapy and limb elevation were initiated, and patients were monitored for signs of compartment syndrome. Once the soft-tissue envelope was suitable for surgery, procedures were scheduled between postoperative days 3 and 5. All surgeries were performed by the same senior orthopedic surgeon.

Patients were positioned supine with a tourniquet applied, and a silicone pad was placed under the knee to maintain approximately 20–30° of flexion. Following sterile draping and skin preparation, a standard anterolateral approach was utilized. The subcutaneous tissue and fascia were incised sharply without separating the adipose layer, creating full-thickness fasciocutaneous flaps. The tibialis anterior muscle was elevated en bloc from the bone, the iliotibial band was released, and a transverse submeniscal arthrotomy was performed. Two polydioxanone (PDS) sutures were passed through the periphery of the lateral meniscus to elevate it, and the knee was placed in varus to allow visualization of the joint surface. Depressed articular fragments were elevated under direct visualization to achieve anatomical reduction. In cases involving concurrent medial plateau fractures, indirect reduction was performed using manual traction, reduction forceps, and provisional fixation with K-wires (2.0 mm). A subchondral raft construct was created using free 5.5-mm cannulated compression screws (Tasarimmed, Istanbul, Türkiye) to provide a raft effect and apply compressive force to prevent gap formation. In cases requiring additional mechanical stability based on fracture morphology and bone quality, the screws were inserted over the plate, whereas isolated screw fixation was preferred in selected cases. The screws were inserted into the subchondral region beneath the elevated fragments, with two or three screws placed—depending on the size and location of the osteochondral fragments—through the superior portion of the plate laterally and via stab incisions medially under fluoroscopic guidance. No bone grafts were used in any of the patients. The previously placed PDS sutures were secured to the plateau by passing them through the holes of the plate or around the screw heads (Fig. 2). Following hemostasis, a single drain was placed in the subfascial plane, and the surgical layers were closed anatomically.

Postoperative Care and Follow-Up

Cold therapy and limb elevation were initiated on the first postoperative day and continued until swelling subsided. Following drain removal on postoperative day 1, all patients were fitted with a hinged knee brace allowing 0–30° of flexion. Quadriceps strengthening exercises were initiated within the first postoperative week once edema had sufficiently decreased. The brace was adjusted to allow 0–60° of flexion by postoperative day 15 and 0–90° by the end of the first month, with brace removal planned at week 6. Weight-bearing was restricted until clinical examination and radiological imaging confirmed adequate fracture healing.

All patients attended their first outpatient follow-up on postoperative day 15 for incision site inspection and suture removal. Subsequent follow-ups were conducted at 1, 2, 3, and 6 months, during which routine anteroposterior and lateral knee radiographs were obtained. At the one-year follow-up, patients were additionally evaluated with CT. Clinical and radiological outcomes were assessed and scored according to the Rasmussen Clinical and Radiological Criteria (Figs. 3, 4).

Statistical Analysis

Prior to data collection, a power analysis was performed using G*Power 3.1 software to determine the minimum required sample size. Assuming an effect size of 0.8, an alpha level of 0.05, and a power (1–β) of 0.80, the analysis indicated that a minimum of 20 patients would be sufficient to detect clinically meaningful differences in postoperative outcomes based on Rasmussen scores. Accordingly, the final sample of 21 patients met the required statistical power threshold for this study design.

Statistical analyses were performed using NCSS (Number Cruncher Statistical System) 2007 Statistical Software (Utah, USA). Descriptive statistics (mean, standard deviation, minimum, and maximum) were used to summarize the data. The

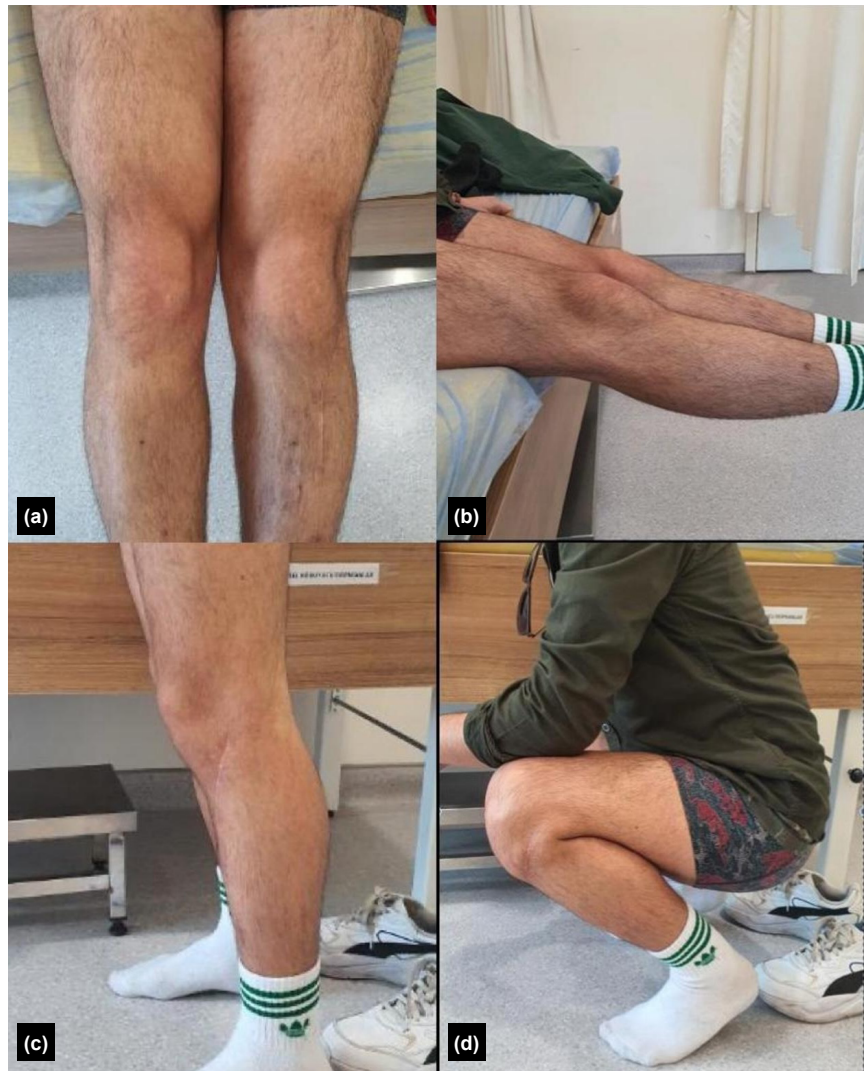

Figure 4. Clinical examination images of a patient at the one-year postoperative follow-up. **(a)** Frontal view in extension; **(b)** Lateral view in extension; **(c)** Standing lateral view; **(d)** Squatting view.

distribution of variables was assessed using the Shapiro–Wilk test. For normally distributed continuous variables, the independent samples t-test was used for comparisons between two independent groups, and Pearson correlation analysis was used to evaluate relationships between continuous variables. For non-normally distributed variables, the Mann–Whitney U test and Spearman's correlation analysis were applied. A p-value <0.05 was considered statistically significant.

RESULTS

Detailed demographic data of the patients are presented in Table 2.

In our study, the mean operative time was 91.6 minutes (range, 60–150 minutes), and the mean postoperative hospital stay was 3.7 days (range, 2–7 days).

The mean preoperative articular depression was 14.7 mm, which decreased to 1.1 mm at the one-year postoperative follow-up (p<0.001). The mean preoperative condylar widening was 5.3 mm, which improved to 0.7 mm at one year postoperatively (p<0.001) (Table 3).

At the one-year postoperative follow-up, the mean RRS was 16.6, and the mean RCS was 26.6 (Table 4).

Both RCS and RRS demonstrated a significant negative correlation with preoperative and postoperative articular depression (p<0.05). However, the correlation between RCS and condylar widening was not significant in the postoperative period (Table 5).

A positive correlation was observed between radiological and clinical scores at the one-year follow-up (p=0.043).

Table 2. Demographic characteristics of the patients

Patient No	Age	Sex	Side	BMI (kg/m2)	Mechanism	Schatzker of injury	Comorbidities type	Smoking
1	60	M	R	34.2	HE	3	DM	-
2	58	F	R	25.1	LE	3	DM	+
3	46	M	L	33	HE	6	None	+
4	45	F	L	41	LE	2	HT, DM	-
5	47	M	L	26.1	HE	3	None	+
6	27	M	R	21.6	HE	6	None	+
7	36	M	R	25.2	HE	5	None	+
8	58	M	L	28.7	HE	6	HT, DM	-
9	24	M	L	29.4	HE	5	None	+
10	56	F	R	37.7	LE	2	HT, DM	+
11	50	F	L	25.7	HE	2	HT	-
12	18	M	R	24.6	HE	3	None	+
13	42	M	L	35.5	HE	2	None	-
14	61	M	R	23.5	HE	2	None	+
15	30	M	L	24.1	LE	6	None	+
16	36	F	R	25.4	LE	2	None	+
17	36	M	L	23.9	LE	2	None	+
18	29	M	L	25.9	LE	2	None	-
19	20	F	L	19.9	HE	2	None	+
20	41	M	R	27	LE	2	None	-
21	53	M	R	38.3	HE	2	DM	-

DM: Diabetes mellitus; HT: Hypertension; R: Right; L: Left; HE: High-energy trauma; LE: Low-energy trauma; M: Male; F: Female.

Table 3. Preoperative and postoperative articular depression and condylar widening measurements

Parameter	N	Min	Max	Mean±SD
Preoperative depression (mm)	21	10.5	36.8	14.74±5.62
Postoperative depression (mm)	21	0	4.2	1.14±1.48
Preoperative condylar widening (mm)	21	2.8	16.4	5.26±3.01
Postoperative condylar widening (mm)	21	0	2.8	0.69±1.01

Table 4. Mean Rasmussen Clinical Score (RCS) and Rasmussen Radiological Score (RRS) at the one-year postoperative follow-up

	N	Min	Max	Mean±SD
RCS	21	20	29	26.67±2.35
RRS	21	14	18	16.57±1.43

Of the 18 patients who were employed prior to injury, 16 returned to their previous jobs, while two transitioned to less physically demanding occupations. Among those who resumed their original employment, the mean time to return to work was 3.5 months (range, 2–9 months).

DISCUSSION

The most significant finding of our study is that the modified

Table 5. Comparison of the Rasmussen Clinical Score (RCS) and Rasmussen Radiological Score (RRS) with preoperative and postoperative articular depression and condylar widening measurements

	RCS	RRS
Preoperative depression (mm)		
r	-0.697	-0.487*
p	<0.001	0.025*
Postoperative depression (mm)		
r	-0.476	-0.777*
p	0.029	<0.001*
Preoperative condylar widening (mm)		
r	-0.573	-0.325*
p	0.007	0.150*
Postoperative condylar widening (mm)		
r	-0.365	-0.751*
p	0.104	<0.001*

RCS: Rasmussen Clinical Score; RRS: Rasmussen Radiological Score. *Statistically significant correlation (p<0.05; p<0.001=highly significant).

raft technique effectively prevented postoperative articular surface collapse. This technique is based on the raft construct concept, which has gained recognition as a reliable method for maintaining reduction, preventing collapse, and reducing additional morbidity in tibial plateau fractures. Various plate and screw configurations have been described in the literature to achieve adequate subchondral support.[9-13] However, monoaxial locking plates do not always allow optimal screw orientation.[14,15] In our study, the anatomical position of the lateral plate limited proximal screw placement into the subchondral area; therefore, we used freely placed 5.5-mm cannulated compression screws to overcome this limitation and achieve a proper raft effect. These screws were selected to avoid the fragmentation risk associated with 6.5-mm screws while providing greater support than 3.5-mm screws. As a result, the technique proved effective in preventing postoperative collapse, and all patients achieved good or excellent outcomes at the one-year follow-up.

In our study, a standardized anterolateral approach with the shortest feasible incision was applied in all patients, regardless of fracture type, and full-thickness fasciocutaneous flaps were created. Several studies have reported higher rates of infection and soft-tissue complications associated with dual-incision techniques.[16-19] In our study, we observed more rapid resolution of postoperative edema, faster soft-tissue healing, and shorter hospital stays. No cases of superficial infection, deep infection, or skin necrosis were observed. Based on our findings, the single anterolateral approach combined with a raft construct reinforced by 5.5-mm screws appears to be an effective method for achieving adequate stability in bicondylar tibial plateau fractures without medial plateau comminution while reducing the risk of soft-tissue complications. When determining the fixation strategy, it is important to consider not only biomechanical principles but also factors such as operative duration, soft-tissue condition, and patient-specific needs.

Tibial plateau fractures are significant intra-articular injuries that frequently affect young and active individuals during their most productive years, potentially leading to substantial disruptions in social life, daily functioning, and professional activities.[20] Kraus et al.,[21] in their study on this topic, reported a mean return-to-work time of 120 days, with approximately 23% of patients switching to less physically demanding jobs and 17% reducing their weekly working hours. In our study, patients returned to their previous jobs after an average of 3.5 months, with only two reporting a transition to less physically demanding work. We also observed that the mean hospital stay was relatively short, averaging 3.7 days. While return-to-work outcomes are influenced by numerous factors—including sociocultural background, economic considerations, and concomitant injuries—the surgical technique we employed enabled early mobilization, minimized postoperative complications, and facilitated earlier reintegration into both work and social life. In addition, the shorter length of hospital stay associated with this approach suggests that it may represent a cost-effective treatment option.

Recent literature increasingly supports graftless subchondral raft fixation as a reliable alternative to conventional bone graft–assisted constructs. Hassan et al.[22] demonstrated that split-depression tibial plateau fractures treated with subchondral rafting screws and locking plates without bone grafting achieved excellent radiological alignment and functional recovery, with negligible collapse and minimal complications. Similarly, Liu et al.[23] compared grafted and graft-free constructs and found no significant difference in radiologic restoration or Rasmussen scores, concluding that graft-free fixation provided comparable mechanical support while avoiding donor-site morbidity and reducing operative time. In another recent biomechanical and clinical analysis, Jiang et al.[24] reported that raft or "jail" screw configurations beneath the articular surface provided equivalent load distribution and resistance to subsidence compared to augmented graft techniques. Collectively, these findings reinforce the biomechanical rationale of the modified raft technique used in our study, highlighting that adequately oriented subchondral screws can provide sufficient metaphyseal support without the need for grafts. Moreover, graft-free fixation eliminates the risks associated with graft harvesting or substitution and facilitates earlier mobilization and functional rehabilitation.

No postoperative complications were observed in our series. None of the patients developed superficial or deep infection, hematoma, wound dehiscence, skin necrosis, neurovascular injury, or implant-related complications. During the follow-

up period, no reoperations, implant removals, or additional surgical interventions were required. All patients achieved uneventful wound healing and early mobilization, supporting the safety and reproducibility of the modified subchondral raft technique.

This study was conducted at a single center, and all surgeries were performed by the same senior surgeon, which may represent a limitation in terms of selection bias. However, all eligible patients who met the inclusion criteria were consecutively enrolled during the study period to minimize this effect. To reduce measurement bias, all preoperative and postoperative radiological assessments were performed by an independent orthopedic surgeon who was not involved in the surgical procedures. All clinical and radiological assessments were performed using objective criteria, and the risk of information bias is therefore considered low. Nevertheless, several additional limitations should be acknowledged. First, the relatively small sample size may limit the generalizability of the findings to broader populations. Second, the absence of a control group—such as patients treated with bone grafts, alternative implant systems, or different reduction techniques—restricts the ability to draw direct comparative conclusions and limits the external validity of the findings. Although the present results demonstrate the effectiveness of the modified subchondral raft technique, its relative advantages or disadvantages compared to other fixation strategies remain to be clarified. Future prospective comparative studies are therefore warranted to validate these outcomes and further strengthen the level of evidence. Third, longer-term follow-up would be necessary to more comprehensively evaluate potential late-onset complications and the durability of the surgical outcomes.

CONCLUSION

In conclusion, the raft technique using free 5.5-mm cannulated compression screws effectively prevented articular surface collapse and enabled early rehabilitation, facilitating an early return to work and daily activities. Additionally, by reducing hospital stay, this approach demonstrated cost-effectiveness while offering a simple and reproducible treatment option for tibial plateau fractures.

Ethics Committee Approval: This study was approved by the Clinical Research Ethics Committee of University of Health Sciences Prof. Dr. Cemil Taşcıoğlu City Hospital, University of Health Sciences (Date: 24.05.2021, Decision No: E-48670771-514.10).

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Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Deprese tibia plato kırıklarında serbest 5.5 mm kanüllü kompresyon vidaları ile modifiye subkondral raft tekniği: Prospektif gözlemsel çalışma

AMAÇ: Bu çalışmanın temel amacı, tibia plato kırıklarının tedavisinde 5.5 mm'lik serbest kanüllü kompresyon vidaları ile oluşturulan subkondral raft konfigürasyonunun, postoperatif çökmeyi önlemede etkinliğini değerlendirmektir. Hipotezimiz, bu tekniğin eklem yüzeyi çökmesini önleyerek fonksiyonel iyileşmeyi hızlandıracağı yönündedir.

GEREÇ VE YÖNTEM: Çalışmaya; 18 yaş ve üzeri, lateral tibia platosunda 10 mm'den fazla çökme saptanan ve etkilenen dizinden daha önce geçirilmiş cerrahi öyküsü bulunmayan toplam 21 hasta dahil edildi. Tüm hastalarda tek anterolateral yaklaşımla açık redüksiyon yapılarak serbest 5.5 mm'lik kanüllü kompresyon vidaları ile subkondral raft konstrüksiyonu oluşturuldu. Hiçbir hastada greft uygulaması yapılmadı. Ameliyat sonrası 12. ayda hastalar, Rasmussen Klinik Skoru (RKS) ve Rasmussen Radyolojik Skoru (RRS) ile radyolojik ve fonksiyonel açıdan değerlendirildi.

BULGULAR: Ortalama preoperatif eklem yüzeyi depresyonu 14.7 mm iken, bir yıllık takipte 1.1 mm'ye; ortalama kondiler genişleme ise 5.3 mm'den 0.7 mm'ye geriledi. Ameliyat sonrası ortalama hastanede yatış süresi 3.7 gün, işe dönüş süresi ise 3.5 ay olarak saptandı. Postoperatif 1. yıl fonksiyonel ve radyolojik sonuçlar iyi düzeyde olup ortalama RKS 26.6 ve RRS ise 16.6 bulundu.

SONUÇ: Uygulamış olduğumuz 5.5 mm'lik kanüllü kompresyon vidaları ile oluşturulan subkondral raft tekniği, tibia plato kırıklarının tedavisinde postoperatif eklem yüzeyi çökmesini önleyen, iyileşmeyi hızlandıran, basit ve etkili bir yöntemdir.

Anahtar sözcükler: Erken rehabilitasyon; fonksiyonel iyileşme; kanüllü kompresyon vidası; Rasmussen skoru; subkondral raft; tibia plato kırığı.

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ORIGINAL ARTICLE

Arthroscopic biceps tenodesis: Inlay or onlay technique?

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ABSTRACT

BACKGROUND: The long-term outcomes of arthroscopic tenodesis using the onlay (groove) and inlay (groove) techniques remain debated with respect to tendon healing and graft stability. The aim of our study was to identify the optimal tenodesis strategy by comparing the effects of arthroscopic inlay and onlay techniques on postoperative complication rates, patient satisfaction, and functional recovery.

METHODS: Between 2015 and 2021, the treatment outcomes of 54 patients who underwent arthroscopic biceps tenodesis using either the inlay or onlay technique for the management of superior labrum anterior-to-posterior (SLAP) lesions or biceps tendon degeneration were retrospectively evaluated. Patient demographics and clinical variables, including age, sex, side of involvement, follow-up duration, visual analog scale (VAS) score, Constant score, postoperative cramping, and complications, were recorded. Group 1 consisted of 28 patients who underwent inlay tenodesis, while Group 2 included 26 patients who underwent onlay tenodesis.

RESULTS: Postoperatively, VAS scores improved substantially in both groups, with no significant difference between Group 1 (0.21±0.45) and Group 2 (0.18±0.37) (p=0.789). Similarly, postoperative Constant scores were high in both groups, with Group 1 at 92.73±8.23 and Group 2 at 95.47±5.12; this difference was not statistically significant (p=0.145). The mean recovery time was significantly shorter in Group 2 compared to Group 1. Specifically, the mean recovery time was 12.3±4.8 weeks in Group 1 and 8.3±3.72 weeks in Group 2 (p=0.01). Cramping was reported in 21.42% of patients in Group 1 and 7.69% in Group 2; however, this difference was not statistically significant (p=0.253). In Group 1, Popeye deformity developed in two patients (7.1%), whereas in Group 2 it developed in one patient (3.8%).

CONCLUSION: The present study demonstrates that both inlay and onlay arthroscopic biceps tenodesis techniques are effective surgical options for managing biceps tendon degeneration and superior labrum anterior-to-posterior lesions. However, the findings suggest a potential advantage of the onlay technique, as it is associated with faster recovery and a lower risk of complications.

Keywords: Arthroscopic biceps tenodesis; inlay technique; onlay technique; interference screw; knotless suture anchor.

INTRODUCTION

Pathologies of the long head of the biceps tendon are a common source of anterior shoulder pain. In these cases, tendon inflammation or instability may result in chronic pain that is refractory to conservative treatment. When such symptoms persist, arthroscopic or open biceps tenodesis or tenotomy represents an effective surgical option for symptom control.

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[1,2] Particularly in young, active patients, the ability of tenodesis to preserve the anatomical position of the tendon makes it an advantageous technique. However, patient characteristics, expectations, and the risk of complications must be carefully considered when selecting the appropriate surgical approach.[3,4]

The purpose of tenodesis is to secure the tendon in a manner that preserves the anatomical length-tension relationship and maintains the normal contour of the biceps muscle.[5,6] Recent studies have focused on the surgical approaches and fixation methods used in tenodesis techniques. The biomechanical advantages of suprapectoral, subpectoral, intra-articular, and extra-articular groove-based techniques have been compared using various fixation methods, including interference screws, suture anchors, and cortical button systems.[1,7,8]

Arthroscopic biceps tenodesis (ABT) at the proximal bicipital groove has traditionally been performed using the inlay technique, in which the tendon is anchored within a bone socket and fixation is provided by an interference screw.[9,10] The use of the onlay technique with a button has also gained popularity in open subpectoral biceps tenodesis.[11,12] Subsequently, additional arthroscopic techniques, such as arthroscopic onlay tenodesis, have been introduced.[13,14]

The long-term outcomes of arthroscopic tenodesis using the onlay (groove) and inlay (groove) techniques remain debated with regard to tendon healing and graft stability. Although it has been suggested that inlay techniques carry a lower risk of graft migration, this has not been definitively established in randomized studies.[7,8] This technical diversity underscores the need for further evidence to determine the optimal surgical protocol.

The aim of this study was to identify the optimal tenodesis strategy by comparing the effects of arthroscopic inlay and onlay techniques on postoperative complication rates, patient satisfaction, functional outcomes, and recovery time.

MATERIALS AND METHODS

The study was approved by the Acıbadem University Medical Research Ethics Committee (2025-06/268) and was conducted in accordance with the principles of the Declaration of Helsinki. Between 2015 and 2021, the outcomes of arthroscopic biceps tenodesis using either the inlay or onlay technique were retrospectively evaluated. These procedures were performed in conjunction with rotator cuff repair in patients with cuff tears (partial tears or <1 cm full-thickness tears) for the management of superior labrum anterior-to-posterior (SLAP) lesions or biceps tendon degeneration. Patients with a follow-up period of less than 12 months, revision or previous shoulder surgery, complete biceps tendon rupture, isolated SLAP lesions, or symptomatic acromioclavicular arthritis were excluded. After applying these criteria, 54 patients met the inclusion criteria and were included in the study. Patient demographics and clinical variables, including age, sex, side of involvement, follow-up duration, visual analog scale (VAS) score, Constant score, postoperative cramping, and complications, were recorded. Recovery criteria were defined as achieving 160° of forward flexion, 45° of external rotation, and internal rotation to the L3 vertebral level in terms of joint range of motion, a VAS score ≤1, and a Constant score ≥71 (good or very good) at the final follow-up. Measurements were performed by a physiotherapist who was blinded to the surgical technique and who recorded the joint range of motion in the archiving system during patient follow-up. The recovery period was determined by one of the authors, who reviewed the recorded data in the archiving system.

Group 1 consisted of 28 patients (six females, 22 males; 13 left shoulders, 15 right shoulders; 18 with biceps degeneration, 10 with SLAP lesions) who underwent inlay tenodesis. Group 2 included 26 patients (three females, 23 males; seven left shoulders, 19 right shoulders; 18 with biceps degeneration, eight with SLAP lesions) who underwent onlay tenodesis. In Group 1, eight patients had an accompanying partial tear of subscapularis, 10 patients had a small (<1 cm) full-thickness tear of the supraspinatus, and 10 patients had SLAP type II lesions. Group 2 included six patients with an accompanying partial-thickness tear of the subscapularis, 12 with a small (<1 cm) full-thickness tear of the supraspinatus, and eight with a SLAP type II lesion. All partial- and full-thickness tears were repaired. In contrast, patients with SLAP lesions underwent only one of the inlay or onlay tenodesis procedures. Baseline characteristics of the patients are summarized in Table 1.

Surgical Procedure

All surgical procedures were performed arthroscopically by a senior surgeon (A.C.A.) with the patient in the beach-chair position under general anesthesia. A diagnostic glenohumeral

Table 1. Baseline patient characteristics

	Inlay (n=28)	Onlay (n=26)	p value
Age, years	48.8 (35-67)	48.52 (14-81)	p>0.05
Sex			
Male	22	23	
Female	6	3	
Side			
Left	13	7	
Right	15	19	
Pathology			
Biceps tendinopathy	18	18	
SLAP	10	8	
Follow-up, months	58.2	60.1	p>0.05

exploration was performed through a standard posterior portal before subacromial exploration and rotator cuff repair. In patients with biceps degeneration or superior labrum anterior-to-posterior lesions, preparation for tenodesis was carried out. For later identification, a No. 2 polypropylene marking suture was placed in the long head of the biceps tendon (LHBT) through the anterosuperolateral portal using a suture passer. The biceps tendon was then released from its origin using arthroscopic scissors and retrieved through the portal. After completion of the glenohumeral joint procedure, the arthroscope was advanced into the subacromial space through the same posterior portal. With the arm in external rotation, the marked biceps tendon was identified and mobilized within the bicipital groove. The superior portion of the transverse humeral ligament was released using radiofrequency. The bony surface of the bicipital groove was prepared, and biceps tenodesis was performed using either the onlay or inlay technique. After removal of the marking suture, the biceps tendon was whipstitched for approximately 30 mm using a No. 2 suture (FiberWire; Arthrex, Inc.) with the Krackow technique. Depending on the tendon size, a 7- or 8-mm interference screw (BioComposite Tenodesis Screw; Arthrex, Inc.) was selected. A socket was then prepared at the anchor site using a reamer 0.5 mm larger than the chosen screw to a depth of 25 mm. The tendon was subsequently docked into the socket and secured with the interference screw (Fig. 1).

In the onlay technique, once the tendon was exteriorized, the proximal 25 mm along with the marking suture was resected. The remaining tendon was then whipstitched for approximately 30 mm using a No. 2 suture (FiberWire; Arthrex, Inc.) with the Krackow technique. The passed sutures were loaded into a 4.5-mm anchor (PushLock; Arthrex, Inc.), which was inserted into the prepared anchor site, ensuring that no gap remained between the tendon and the anchor bed (Fig. 2).

After completion of the tenodesis, the inflamed bursa was debrided, and acromioplasty was performed when indicated. Subsequently, the rotator cuff tears were repaired according to their specific characteristics. Once all anchors had been placed, a final inspection of both the subacromial space and the glenohumeral joint was performed to ensure proper repair. In the evaluation of treatment outcomes, the inability to visualize the tendon within the intertubercular groove on magnetic resonance imaging (MRI) was defined as failure.

Rehabilitation

A standard postoperative rehabilitation protocol for arthroscopic rotator cuff repair was applied. Immobilization with an abduction brace was maintained for four weeks in non-massive tears (<3 cm) and for six weeks in massive tears (>3 cm). Active hand, wrist, and elbow movements were initiated immediately after surgery. Following brace removal, active-assisted shoulder range-of-motion exercises were started. Once active-assisted exercises were well tolerated, patients progressed to active range-of-motion (AROM) ex-

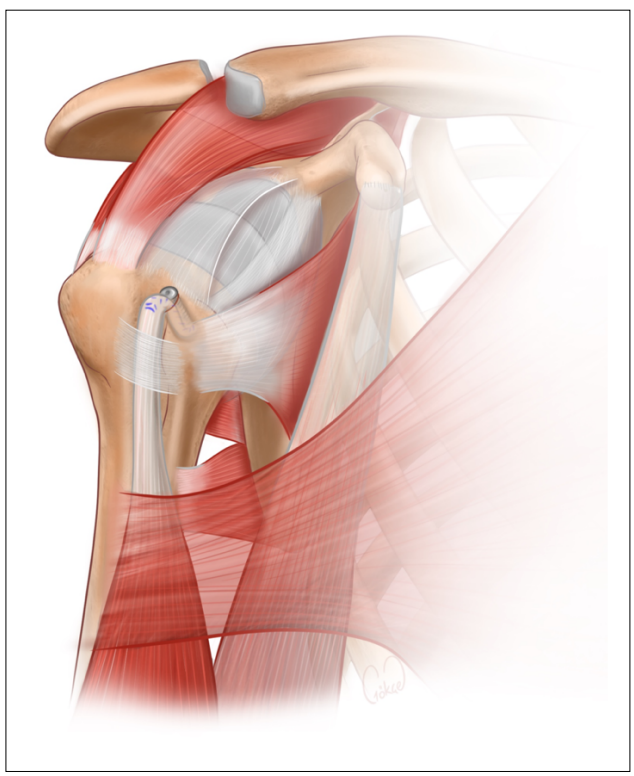

Figure 1. Illustration of the inlay technique.

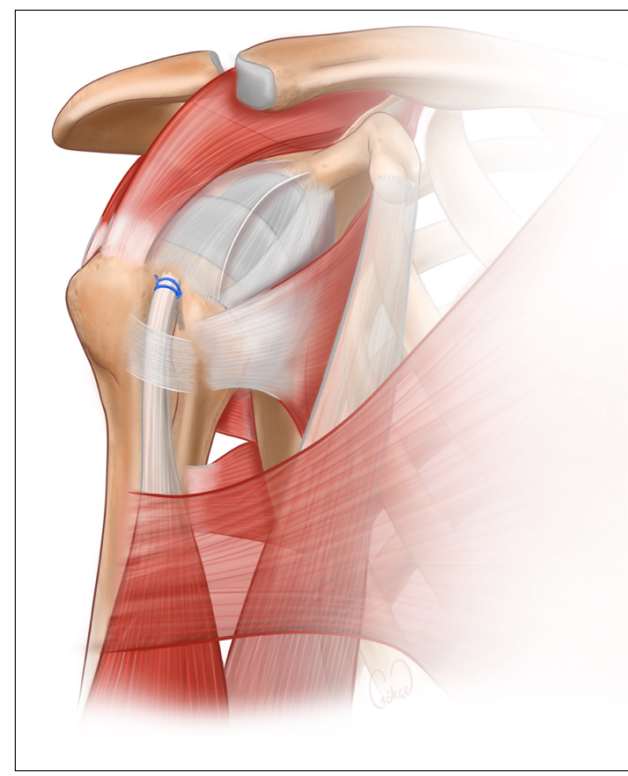

Figure 2. Illustration of the onlay technique.

ercises. Recovery time was defined as the time required to achieve full, pain-free active range of motion of the shoulder and elbow. Strengthening exercises were initiated at 16–18 weeks postoperatively, and return to sport-specific training was determined on an individual basis after six months.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for macOS, version 26.0.0.0 (IBM Corp., Armonk, NY, USA). Independent samples t-tests were used to compare preoperative and postoperative VAS and Constant scores between the groups, as well as differences in mean recovery time. Fisher's exact test was used to analyze categorical variables, including the incidence of postoperative cramping and the presence of Popeye deformity. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 54 patients with a follow-up duration exceeding 12 months were included in the study. Among them, 28 (52%) underwent tenodesis using the inlay technique (Group 1), while 26 (48%) underwent tenodesis using the onlay technique (Group 2).

There were no statistically significant differences between the groups in terms of mean patient age or mean follow-up duration. The mean age was 48.8 years (range: 35–67) in Group 1 and 48.5 years (range: 14–81) in Group 2 (p>0.05). Similarly, the mean follow-up duration was 58.2 months (range: 12–82) in Group 1 and 60.1 months (range: 12–73) in Group 2 (p>0.05).

Preoperative VAS scores were similar between Group 1 (6.09±1.92) and Group 2 (5.60±1.14), with no statistically significant difference (p=0.256). However, the preoperative Constant score was significantly lower in Group 1 (59.56±18.19) compared to Group 2 (69.75±6.75) (p=0.009). Postoperatively, VAS scores improved substantially in both groups and showed no significant difference between Group 1 (0.21±0.45) and Group 2 (0.18±0.37) (p=0.789). Similarly, postoperative Constant scores were high in both groups, with Group 1 at 92.73±8.23 and Group 2 at 95.47±5.12; this difference was not statistically significant (p=0.145).

The mean recovery time was significantly shorter in Group 2 compared to Group 1. Specifically, the mean recovery time was 12.3±4.8 weeks in Group 1 and 8.3±3.72 weeks in Group 2 (p=0.01).

Cramping was reported in 21.42% of patients in Group 1 and 7.69% in Group 2; however, this difference was not statistically significant (p=0.253). In Group 1, Popeye deformity developed in two patients (7.1%), whereas in Group 2 it developed in one patient (3.8%). All patients were managed conservatively, and no statistically significant difference was observed between the groups (p=1.000). Postoperative outcomes and complications are summarized in Table 2.

Table 2. Postoperative outcomes and complications

	Inlay (n=28)	Onlay (n=26)	p value
VAS score			
Preoperative	6.09±1.92	5.6±1.14	0.256
Postoperative	0.21±0.45	0.18±0.37	0.789
Constant score			
Preoperative	59.56±18.19	69.75±6.75	0.009
Postoperative	92.73±8.23	95.47±5.12	0.145
Postoperative complications			
Cramping (%)	21.4	7.7	0.253
Popeye deformity (%)	7.1	3.8	1.000
Mean recovery time (weeks)	12.3±4.8	8.3±3.7	0.001

In Group 1, one patient required surgical intervention due to screw pullout, and another patient from the same group underwent four aspirations because of recurrent hematoma.

DISCUSSION

Several techniques exist for the long head of the biceps tendon tenodesis. Key factors in selecting a tenodesis technique include the fixation site (subpectoral or suprapectoral, either in the subacromial space within the bicipital groove or in the intra-articular region) and the fixation method (onlay or inlay). The choice of fixation site also determines the surgical approach, which may be arthroscopic, open, or a hybrid procedure. Although no single method has been shown to be universally superior with regard to fixation technique or site, the optimal approach for each patient should be determined based on factors such as activity level, surgeon experience, and the presence of concomitant shoulder pathologies.[15,16] Each tenodesis technique presents specific advantages and limitations. For instance, the subpectoral approach allows removal of more diseased tissue and may reduce the risk of persistent pain, but it carries a slightly increased risk of humeral fracture.[17-19] Arthroscopic approaches are less invasive and allow comprehensive evaluation of the joint, although fixation is generally biomechanically weaker.[20] Regardless of the chosen method, proper tensioning and secure fixation are essential for long-term success.

The arthroscopic suprapectoral (intra-groove) tenodesis technique used in our study is increasingly favored because it allows simultaneous treatment of intra-articular pathologies and typically provides effective pain relief with low complication rates, demonstrating outcomes comparable to those of open subpectoral tenodesis.[16,21] Early functional recovery and patient-reported outcomes may also be superior with the arthroscopic approach.[21]

Another topic of debate in the literature is the optimal fixa-

tion method. There is no consensus regarding the superiority of inlay or onlay tenodesis.[22] The inlay tenodesis technique provides strong biomechanical fixation by positioning the tendon within the bone during the early postoperative period.[23] In fact, it has been reported that load-to-failure values comparable to those obtained with the inlay technique can be achieved by the end of the third week in onlay tenodesis procedures.[24] However, the widespread clinical use of onlay tenodesis techniques and the reporting of successful outcomes represent a relatively recent development.[22,25] On the other hand, inlay tenodesis is associated with increased surgical complexity, longer operative times, a higher risk of humeral fracture, and potential complications such as Popeye deformity if fixation or tensioning is inadequate or excessive.[23] In contrast, the onlay technique was developed to address some of these limitations, particularly in arthroscopic procedures. By securing the tendon onto the bone surface using knotless anchor systems or all-suture anchor systems, this method is less invasive, technically simpler, and may enable faster rehabilitation.[26] Although the biomechanical strength of onlay fixation may be slightly lower than that of inlay techniques, advances in suture methods have minimized the risk of tendon slippage, making it a reliable alternative with favorable patient outcomes.[26]

The aim of this study was to determine the most suitable tenodesis fixation technique by comparing the effects of arthroscopic suprapectoral biceps tenodesis using the inlay and onlay techniques on postoperative complications, patient satisfaction, and functional recovery.

Both inlay and onlay arthroscopic biceps tenodesis techniques have been shown in the literature to yield significant clinical improvements.[6,25,27,28] As mentioned above, complications are rare and may include persistent pain, fixation failure, Popeye deformity, or ongoing muscle tenderness. Consistent with these findings, our study also demonstrated postoperative improvement in outcome scores in both groups. However, although the incidence of cramping and Popeye deformity was proportionally higher in the inlay group, the difference did not reach statistical significance (p=0.253 and p=1.000, respectively). Although the difference observed in our study was not statistically significant with respect to Popeye deformity, Jackson et al.[22] reported that onlay tenodesis resulted in significantly less Popeye deformity than inlay tenodesis [7.80% in the onlay group versus 11.28% in the inlay group (p=0.07)]. Similarly, another study reported a rate of Popeye deformity of 9.4% in the onlay group and 27% in the inlay group.[6] We believe that Popeye deformity may be related to the mechanical interaction between the interference screw and the tendon during fixation. Specifically, as the screw is advanced into the bone socket, its threads may shear or compromise tendon integrity, potentially increasing the risk of tendon slippage or failure over time.[6,18]

When evaluated in terms of revision rates, the onlay technique has been reported to result in a lower rate of revision compared to the inlay technique.[29] In line with the findings of Cook et al.,[29] revision surgery was not required in the onlay group in our study. However, in the inlay group, revision surgery was required in one patient due to screw pullout.

In the literature, comparisons between onlay and inlay techniques have not been performed using a clearly defined recovery time. In our study, recovery time was defined as the point at which the patient achieved full, pain-free active range of motion of the shoulder and elbow. Using this definition, the onlay technique was associated with significantly faster recovery compared to the inlay technique (p=0.001). This finding is supported by Park et al.,[28] who reported that the inlay technique was associated with a slower recovery profile. As previously mentioned, existing literature has generally emphasized secondary outcomes, such as complication rates and functional scores, rather than directly comparing recovery timelines.[6,30-32] Although several studies have highlighted certain technical advantages of the onlay approach, a clear consensus regarding its superiority in terms of recovery speed remains limited. To the best of our knowledge, this study is the first to indicate that while both inlay and onlay tenodesis techniques yield favorable outcomes, onlay tenodesis enables faster recovery.

The main limitation of our study is its retrospective design, which may introduce selection bias and limit the ability to control for confounding variables. Additionally, the patients included in this study did not have isolated biceps pathology but had concomitant rotator cuff tears. Nevertheless, complications such as anterior shoulder cramping and Popeye deformity may be considered specific complications of biceps tenodesis. The heterogeneity of the groups in terms of accompanying pathologies may also be considered a limitation of the study. However, both groups consisted of patients with a similar number of associated pathologies, and since this study is the first to evaluate recovery time as an outcome measure, it may provide useful insights for clinical practice. Finally, the study included cases of both degenerative biceps pathology and SLAP lesions. As these two conditions may differ in terms of healing potential and postoperative outcomes, this factor could have influenced the study results. However, the similar number of patients with SLAP lesions in both groups mitigates this limitation. Further prospective, randomized controlled trials are warranted to validate these findings and more accurately assess the comparative efficacy of inlay and onlay biceps tenodesis techniques.

CONCLUSION

This study demonstrates that both inlay and onlay arthroscopic biceps tenodesis are effective surgical approaches for the treatment of biceps tendon degeneration and superior labrum anterior-to-posterior lesions. However, the findings indicate a potential advantage of the onlay technique, as it is associated with faster recovery and a lower risk of complications.

Ethics Committee Approval: This study was approved by the Acıbadem University Medical Research Ethics Committee Ethics Committee (Date: 17.04.2025, Decision No: 2025-06/268).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Artroskopik biseps tenodezi: Inlay mi, onlay mı?

AMAÇ: Artroskopik onlay ve inlay teknikleri kullanılarak yapılan tenodezin uzun dönem sonuçları, tendon iyileşmesi ve greft stabilitesi açısından tartışmalıdır. Çalışmamızın amacı, artroskopik inlay ve onlay tekniklerinin postoperatif komplikasyon oranları, hasta memnuniyeti ve fonksiyonel iyileşme üzerindeki etkilerini karşılaştırarak optimal tenodez stratejisini belirlemektir.

GEREÇ VE YÖNTEM: 2015–2021 yılları arasında, superior labrum anterior-posterior (SLAP) lezyonları veya biseps tendon dejenerasyonu tedavisinde inlay veya onlay tekniği ile artroskopik biseps tenodezi uygulanan 54 hastanın tedavi sonuçları retrospektif olarak değerlendirildi. Hastaların demografik ve klinik verileri; yaş, cinsiyet, etkilenen taraf, takip süresi, görsel analog skala (VAS) ve Constant skorları, postoperatif kramplar ve komplikasyonlar kaydedildi. Grup 1, inlay tenodezi yapılan 28 hastadan; Grup 2 ise onlay tenodezi yapılan 26 hastadan oluştu.

BULGULAR: Postoperatif dönemde, her iki grupta VAS skorları belirgin şekilde iyileşti ve Grup 1 (0.21±0.45) ile Grup 2 (0.18±0.37) arasında anlamlı fark bulunmadı (p=0.789). Benzer şekilde, postoperatif Constant skorları her iki grupta yüksek bulundu; Grup 1'de 92.73±8.23, Grup 2'de 95.47±5.12 idi ve bu fark istatistiksel olarak anlamlı değildi (p=0.145). Ortalama iyileşme süresi, Grup 2'de Grup 1'e göre anlamlı şekilde daha kısaydı; Grup 1'de 12.3±4.8 hafta, Grup 2'de 8.3±3.72 hafta (p=0.01). Kramplar, Grup 1'de hastaların %21.42'sinde, Grup 2'de %7.69'unda rapor edildi; ancak bu fark istatistiksel olarak anlamlı değildi (p=0.253). Grup 1'de 2 hastada (%7.1) popeye deformitesi gelişirken, Grup 2'de 1 hastada (%3.8) ortaya çıktı.

SONUÇ: Bu çalışma, hem inlay hem de onlay artroskopik biseps tenodezi tekniklerinin biseps tendon dejenerasyonu ve SLAP lezyonlarının yönetiminde etkili cerrahi seçenekler olduğunu göstermektedir. Ancak karşılaştırmalı analizimiz, onlay tekniğinin daha kısa iyileşme süreleri ve daha düşük komplikasyon oranı ile klinik bir avantaj sağlayabileceğini önermektedir.

Anahtar sözcükler: Artroskopik biseps tenodezi; düğümsüz sütür akor; inlay tekniği; interferans vidası; onlay tekniği.

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ORIGINAL ARTICLE

Radiological effectiveness and cost analysis of the spica casting method without anesthesia in emergency room conditions for femoral shaft fractures in children under five years old

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ABSTRACT

BACKGROUND: This study aimed to compare the clinical, radiological, and cost-related outcomes of early spica casting performed without anesthesia in the emergency department and spica casting performed under general anesthesia in the operating room for the treatment of femoral shaft fractures in children under five years of age.

METHODS: One hundred eleven patients who underwent closed reduction and spica casting for femoral shaft fractures between 2020 and 2024 were retrospectively reviewed. Patients were divided into two groups according to where the spica cast was applied: Emergency Department Group (ED group, n=71) and Operating Room Group (OR group, n=40). The groups were compared in terms of age, sex, fracture type, radiological alignment, and treatment costs.

RESULTS: No statistically significant differences were found between the two groups regarding age, sex, fracture pattern, or final radiological alignment. However, treatment costs were significantly lower in the emergency department group. Complication rates were also similar between the groups.

CONCLUSION: Early spica casting performed in the emergency department without general anesthesia provides radiological outcomes comparable to those achieved in the operating room while offering a significant cost advantage. With appropriate patient selection, this method represents a safe and effective treatment option.

Keywords: Cost analysis; emergency department; femoral shaft fracture; non-anesthetic treatment; spica cast; pediatric trauma; radiological outcomes.

INTRODUCTION

Femur diaphysis fractures are among the significant orthopedic injuries encountered during childhood. The incidence of femur diaphysis fractures among pediatric long bone fractures is reported to be approximately 1.6%, and it has been noted that these fractures occur more frequently in male children.[1,2]

Femur fractures in this age group usually occur as a result of falls, traffic accidents, or high-energy trauma. Femur fractures in children who are not yet walking should be carefully evaluated in terms of the possibility of child abuse. On the other hand, femur fractures resulting from low-energy trauma may indicate underlying pathological conditions such as osteogenesis imperfecta, neuromuscular diseases, or bone

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lesions. Therefore, a comprehensive physical examination and radiological assessment are essential in the initial evaluation of such a case.

In particular, a careful neurovascular examination should be performed in these patients who present with marked thigh swelling, deformity, and pain; other life-threatening injuries such as intra-abdominal organ injuries, thoracic trauma, and head trauma (known as the Waddell triad) should also be investigated simultaneously.[3]

To reduce the risk of compartment syndrome, the affected extremity should be appropriately immobilized with a temporary splint after the initial assessment, and diagnostic imaging should be performed from the hip to the knee joint in a way that fully reveals the fracture line. In the radiological evaluation, not only the localization and type of the femur fracture should be considered, but also the presence of other concurrent extremity fractures or bone lesions should be excluded.[4] The treatment plan for femur fractures in childhood is determined by considering the child's age, body weight, type of fracture, and other accompanying injuries.[5]

In stable femoral fractures occurring from the newborn period up to 6 months of age, simple and movement-permitting methods such as the Pavlik harness are generally sufficient, thanks to the advantage provided by the thick periosteum. However, in children between the ages of 6 months and 6 years, closed reduction followed by pelvipedal casting (spica cast) is the most commonly preferred treatment method.[4,6]

In this age group, successful outcomes can often be achieved without the need for surgical interventions. Table 1 summarizes the preferred treatment methods for different age groups.

If conservative treatment with a pelvipedal cast is to be applied, the acceptable reduction criteria become stricter as the child gets older. Table 2 presents the acceptable angulation and shortening limits for conservative treatment by age.[7]

Previous studies have shown that early spica casting is a safe and effective method in young children. In fact, there are even studies in the literature comparing pelvipedal cast treatment with surgical approaches such as elastic intramedullary nailing.[8,9] However, early spica casting applied in emergency settings without the use of general anesthesia and fluoroscopy has not been sufficiently evaluated in the literature.

In this study, the aim was to investigate the safety and cost-effectiveness of early pelvipedal casting performed without anesthesia and fluoroscopy in emergency room settings for the treatment of femoral shaft fractures in children aged five years and under.

MATERIALS AND METHODS

Study Design and Patient Selection

In this retrospective cohort study, children aged five years and under who were treated in our clinic with a diagnosis of isolated femoral shaft fracture between January 2021 and December 2024 were analyzed (Non-Interventional Clinical Research Ethics Committee of University of Health Sciences, Konya City Hospital, approval no: 2025/74, date: 24.04.2025). The study was conducted in accordance with the principles of the Declaration of Helsinki.

The exclusion criteria were defined as the presence of an open fracture, concomitant fractures of other long bones or polytrauma, and a follow-up period of less than 12 months. A total of 111 patients who met these criteria were included in the study. The patients were divided into two groups according to the treatment method: those who received pelvipedal casting in the emergency department or outpatient clinic settings without sedation, general anesthesia, or live radiography (fluoroscopy) were defined as the study group (n=71). Those who underwent pelvipedal casting under general anesthesia, in the operating room, and with fluoroscopic guidance constituted the control group (n=40). After the possible risks and benefits of both methods were thoroughly explained to the families, the treatment method was chosen based on the family's consent and preference. No distinction was made between the groups regarding factors such as fracture type or comminution; every type of femoral shaft fracture was treated with the method deemed appropriate. Patient files and radiographs were retrospectively reviewed, and demographic data (age, sex, body weight), fracture side, initial treatment method, time to union, lower limb length discrepancy at the final follow-up, and follow-up duration were recorded. Lower limb length discrepancy (LLD) was defined as the difference in length between the injured side and the uninjured side at the final follow-up. LLD measurement and determination of

Table 1. Treatment options for femoral shaft fractures by age

Age Range	Preferred Treatment Methods
<6 months	Pavlik harness, pelvipedal casting, traction and casting
6 months-6 years	Closed reduction + pelvipedal casting (spica); surgical treatment is generally not required
6-11 years	Flexible intramedullary nail, submuscular plate osteosynthesis, external fixation (case-based)
>11 years	Adult-type surgical methods (rigid intramedullary nail, plate-screw applications)

Table 2. Acceptance criteria by age in conservative treatment (maximum allowable deformity)

Age Range	Varus/Valgus (°)	Flexion/Extension (°)	Shortening (mm)
<2 years	30	30	20
2–5 years	15	20	20
5–10 years	10	15	15
>11 years	5	10	10

union time were performed by two independent researchers, and interobserver reliability was assessed using Cohen's kappa (κ) statistic. The success of reduction was evaluated in both groups using anteroposterior and lateral femur radiographs taken after treatment, according to the acceptance criteria (Table 2). In the study group, reduction success was assessed solely via radiographs, while in the control group, it was evaluated immediately using fluoroscopic imaging under anesthesia and later confirmed with radiographs. In both groups, if proper alignment was deemed not achieved after casting, the cast was removed within the first 24 hours, and closed reduction with recasting using the same method was performed.

Treatment cost calculation was based directly on hospital care costs, converted from Turkish Lira to U.S. Dollars (using the average exchange rate for 2024). Since patients in the control group were treated under general anesthesia in operating room conditions, anesthesia drug and equipment costs, operating room usage fees, and hospitalization costs were included in the total cost. In the study group, since patients were treated without anesthesia and without hospitalization, only outpatient/emergency intervention fees and material costs were considered.

Pelvipedal Casting Technique (Without Anesthesia)

Patients were placed in a supine position on a flat surface. The fractured limb was carefully manipulated to approximately restore its anatomical axis, and a spica cast was applied in accordance with standard techniques. First, with the knee maintained at 90° flexion, a circular cast wrap was applied from below the foot to the entire lower limb using presoaked plaster bandages, ensuring the fracture site was fully encompassed. Once the cast began to harden, the contralateral hip and pelvis were included to complete the bilateral pelvipedal cast.

During this process, the hip was positioned in approximately 60°–90° flexion and ~60° abduction, and molding was applied to the distal fragment (in valgus and/or extension direction) to counteract any tendency toward apex anterior or varus angulation. The knee joint was set at roughly 30°–40° flexion to prevent excessive pressure points, and the distal femur was placed in slight external rotation.

After the cast application was complete, areas that could cause pressure on the abdomen and perineum were checked; a small window was created at the umbilical level to reduce abdominal pressure, and adequate space was left for perineal hygiene. All patients were discharged on the same day after stabilization of vital signs following cast application (Figures 1 and 2).

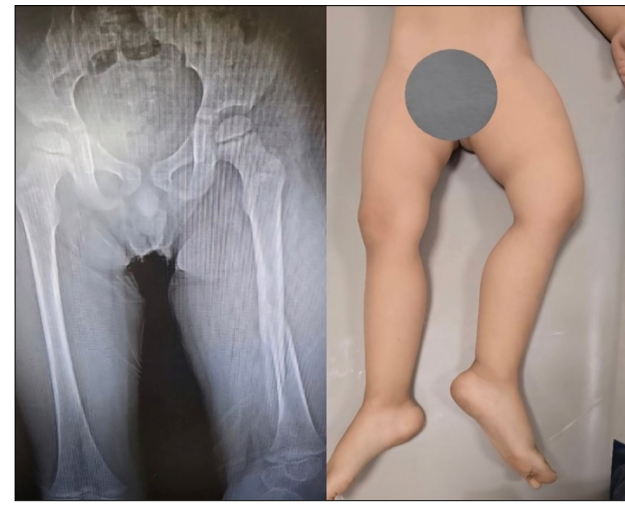

Figure 1. Clinical appearance of early pelvipedal casting applied in the emergency department without the use of general anesthesia and fluoroscopy.

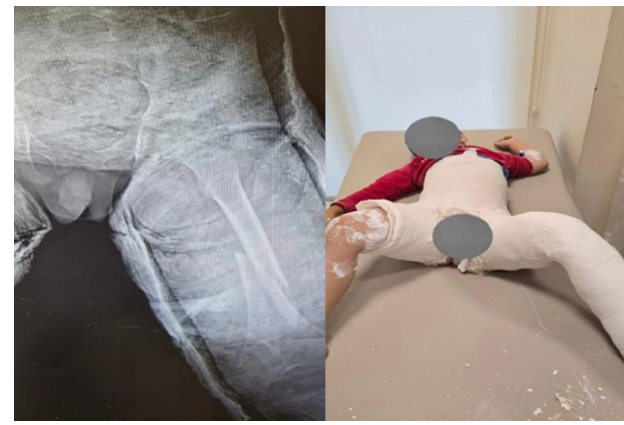

Figure 2. Radiographic view of the femoral fracture after casting in a case treated with early pelvipedal cast.

Table 3. Demographic data of the patient groups

Variable	Study Group (n=71)	Control Group (n=40)	p-value	Total (n=111)
Age (months, mean±SD, [min–max])	32.61±13.57 [7-60]	25.48±12.51 [10-52]	0.007	30.04±13.58
Sex (M/F)	41 / 30	26/14	0.546	67/44
Weight (kg, mean±SD)	15.04±3.84	15.43±3.92	0.618	15.18±3.86

Table 4. Lower limb length discrepancy by treatment group (at final follow-up measurement)

Limb Length Discrepancy (mm)	Study Group (n=71)	Control Group (n=40)	p-value	All Patients (n=111)
Mean±SD	6.13±7.66	8.43±6.94	0.029	6.96±7.46
Patients with lengthening	59 (%83)	32 (%80)	–	91 (%82)
Patients with shortening	7 (%10)	4 (%10)	–	11 (%10)
No discrepancy	5 (%7)	4 (%10)	–	9 (%8)

Statistical Analysis

For the statistical analysis of the obtained data, the chi-square test was used for categorical variables, and Student's t-test was used for continuous variables. The relationship between LLD and age, sex, and body weight was assessed using Pearson correlation analysis. A p-value of <0.05 was considered statistically significant.

Study Findings

During the specified period, a total of 135 patients who underwent pelvipedal cast treatment for femoral shaft fractures were identified. Of these, 24 patients who met the exclusion criteria (open fracture: 1, polytrauma: 4, follow-up <12 months: 19) were excluded. The remaining 111 patients comprised 71 in the study group (spica cast without anesthesia) and 40 in the control group (spica cast under general anesthesia). Demographic data are presented in Table 3. The mean age of patients in the study group was slightly higher compared to the control group (32.6±13.6 months vs. 25.5±12.5 months; p=0.007). There was no difference between the two groups in terms of sex distribution (study group: 58% male, control group: 65% male; p=0.546). Similarly, the mean initial body weights were comparable between groups (study: 15.04±3.84 kg; control: 15.43±3.92 kg; p=0.618). The mean follow-up duration for all patients was 14.7±2.2 months in the study group and 14.4±2.1 months in the control group, with no significant difference between groups (p=0.520).

In the study group, control radiographs taken after the initial cast application showed that reduction was in an acceptable position in 94% of cases (67 patients). In 4 patients (6%), where the reduction was deemed inadequate, the cast was removed within the first 24 hours, and closed reduction with pelvipedal casting was repeated using the same method. After this repeated procedure, proper alignment was achieved, and these patients were also included in the final evaluation.

In the control group, since reduction was achieved under fluoroscopic guidance, no patients required early cast replacement. During follow-up, no cases of refracture or significant malalignment occurred in either group.

At the final follow-up examinations, significant lengthening of the injured limb was detected in 66 patients (93%) in the study group (59 patients with lengthening, 7 with shortening). In the control group, lengthening occurred in 36 patients (90%) on the injured side (32 with lengthening, 4 with shortening). The mean ipsilateral (injured side) lower limb length difference compared to the contralateral healthy side was 6.13±7.66 mm in the study group and 8.43 ± 6.94 mm in the control group (p=0.029). In the remaining 9 patients (8%; 5 from the study group, 4 from the control group), no measurable length difference between the two sides was observed. A comparison of the limb length discrepancy results between the two groups is presented in Table 4.

In both groups, femoral fractures healed without complications in all patients. There was no significant difference between the groups in terms of healing time (study group: 8.3±1.4 weeks; control group: 7.9±1.4 weeks; p=0.117). However, there was a marked difference between the two groups regarding treatment cost (p<0.001). In the study group, which did not require anesthesia or operating room use, the mean treatment cost was calculated as 74.73±5.14 USD, whereas in the control group, this value was 219.8±12.22 USD. The mean cost values are presented in Table 5.

The relationship between lower limb length discrepancy (LLD) and patients' age, sex, and body weight was evaluated using correlation analysis (Table 6). In the study group, very weak negative correlations were found between LLD and age

Table 5. Comparison of treatment costs between the two groups

Average Cost (USD)	Study Group (n=71)	Control Group (n=40)	p-value	Total (N=111)
Mean±SD	74.73±5.14	219.8±12.22	<0.001	127.0±7.69

Table 6. Correlation of lower limb length discrepancy with demographic variables

Variable	Study Group (r)	Control Group (r)	Overall
Age (months)	-0.152	-0.367	-0.248
Sex (M/F)	0.072	-0.122	-0.003
Weight (kg)	-0.034	-0.451	-0.166

and weight (r=–0.152 and r=–0.034), while in the control group, weak negative correlations were observed (r=–0.367 and r=–0.451). In both groups, no significant relationship was found between sex and the resulting length discrepancy ($p>0.05$).

The consistency of the measurements performed by the two researchers was found to be very high. For lower limb length discrepancy measurements, interobserver agreement was $\kappa=0.896$ (almost perfect agreement), and for time-to-union assessment, $\kappa=0.834$.

DISCUSSION

In this study, early pelvipedal casting applied in the emergency department (without general anesthesia and fluoroscopy) was compared with the conventional pelvipedal casting performed under general anesthesia in an operating room for the conservative treatment of femoral fractures in children under five years of age. Our findings indicate that the early spica casting technique performed without anesthesia achieved comparable success to the standard method in terms of radiological outcomes and complication rates.[10-12]

In the study group, an average lengthening of 6.1 mm was observed on the fractured side, while in the control group, the mean lengthening was 8.4 mm; this difference was found to be statistically significant ($p=0.029$). Although this minimal difference does not create a clinically significant limb length discrepancy, its slightly greater presence in the control group is noteworthy. The mean time to union was approximately eight weeks in both groups and was statistically similar ($p>0.1$). No patient experienced delayed union or refracture.

The cost analysis revealed that the early casting method, which does not require anesthesia or operating room use, was significantly more cost-effective compared to the standard method (average ~$75 vs. $220; $p<0.001$). This finding demonstrates that the early spica casting technique offers a substantial advantage, particularly in healthcare settings with limited resources.

Literature includes several studies on early casting applications in the emergency department. Williams et al. treated 82 cases of femoral fractures in children aged 6 months to 5 years with spica casting either in the emergency department or in the operating room, comparing pain management between the two groups. This study reported that children in the operating room group required more opioid analgesics in the postoperative period.[13] On the other hand, in the group that received immediate casting in the emergency department, the rate of cast replacement due to inadequate reduction was found to be higher.[10-14] Similarly, in our series, cast replacement was performed in 4 patients (5.6%) in the study group after the initial casting, as the reduction position was deemed unacceptable (particularly in cases with >2 cm shortening). In the control group, no additional intervention was required since adequate reduction was achieved under fluoroscopic guidance in all patients. Nonetheless, even in the few cases where optimal cast positioning could not be achieved on the first attempt under emergency conditions, satisfactory outcomes were obtained after repeat closed intervention.

In another study, Trottier et al. reviewed a series of 246 children under the age of six with femoral fractures and reported that only 3.7% of the patients treated with early spica casting required reintervention (cast adjustment or surgery), while 20.7% of cases developed an average limb length discrepancy of 9.4 mm.[15] In our study, an average limb length discrepancy of approximately 7 mm was observed in patients from both groups, and in no case did this discrepancy reach a level (≥20 mm) requiring clinical intervention. Moreover, the slightly greater tendency for lengthening observed in the control group compared to the study group (8.4 mm vs. 6.1 mm) is consistent with similar findings reported in the literature.

Previous research on the treatment costs of femoral fractures has shown that conservative methods can deliver sim-

ilar outcomes at a much lower cost compared to surgical interventions.[16,17] In another study examining 58 pediatric femoral fracture cases, it was reported that the total cost was significantly lower in patients treated conservatively.[18] Similarly, Coyte et al. found substantially higher treatment costs in children who underwent surgical intervention.[19] Yandow and colleagues, in their study comparing spica casting with traction, reported that despite similar clinical outcomes, the treatment cost was lower in the spica cast group.[20] Hedin et al., in their cost analysis of various treatment methods for pediatric femoral fractures, emphasized that the most important factor determining total cost was the length of hospital stay.[21]

In our study, all patients were treated with spica casting, with the only difference being whether the procedure was performed under general anesthesia in an operating room. In the study group, where general anesthesia and operating room use were not required, all patients were discharged the same day, resulting in no hospitalization costs. In the control group, however, due to an average one-day hospital stay and the need for anesthesia, the total cost was nearly three times higher. These findings support the economic advantage of conservative treatment, consistent with previous literature.

The functional and radiological success of early spica casting has also been widely reported in the literature.[22,23] Illgen et al., in a study involving 114 pediatric femoral fractures in children under six years of age, stated that they achieved successful outcomes in 86% of cases without the need for cast changes or wedge removal.[24] Ferguson and Nicol, in their prospective series of 101 cases under the age of ten evaluating early pelvipedal casting, reported that only four patients required cast revision due to loss of position.[23]

In our current study, particularly in the study group treated without anesthesia, cast replacement was required in 5.6% of cases (4 patients) during the early period — a rate comparable to that reported by Ferguson et al. At the same time, regardless of whether anesthesia and fluoroscopy were used, good fracture union with low complication rates was achieved in all isolated femoral shaft fractures under five years of age, and no unacceptable limb length discrepancy exceeding 2 cm was reported. Four patients in the study group who initially presented with a length discrepancy of more than 2 cm were acutely corrected and included in the study.

Czertak et al. also reported high levels of functional and radiological success in patients treated with pelvipedal casting.[25]

Although functional assessment was not performed in any of the patients in our study, radiographically satisfactory union was achieved in all cases. No patient developed a permanent limb length discrepancy exceeding acceptable limits (>2 cm). The successful outcomes we obtained suggest that, particularly in situations where resources are limited or the risk of general anesthesia is high, spica casting without anesthesia can serve as a safe and effective alternative for the treatment of femoral fractures in young children. With appropriate patient selection and proper technique, we believe this method can achieve success rates comparable to those of treatments performed under standard operating room conditions.

Study Limitations

This study has several limitations. First, because of its retrospective design and the fact that data were obtained from a single center, the generalizability of the findings may be limited. Second, the assessment of reduction quality and fracture union was based on radiological criteria; clinical parameters such as functional outcomes or patient satisfaction were not evaluated. Furthermore, since the choice of treatment method in group comparisons was based on family preference, a fully randomized allocation could not be achieved. Although evaluations were conducted with large patient numbers in both groups to minimize this potential bias, prospective and randomized controlled studies are still needed.

CONCLUSION

In femoral shaft fractures of children under five years of age, the early pelvipedal casting method applied in the emergency department without the use of general anesthesia or live radiology demonstrated comparable reduction success, healing time, and complication rates to the standard operating room approach. Moreover, by eliminating anesthesia-related risks, reducing radiation exposure, and avoiding hospital admission, it was found to be significantly more cost-effective. This method also stands out as a safe treatment alternative for cases in which general anesthesia carries high risk or surgery is not feasible for various reasons.

In conclusion, when applied with appropriate patient selection, the early spica casting method without anesthesia offers an effective, reliable, and economical approach for the treatment of femoral fractures in preschool children.

Ethics Committee Approval: This study was approved by the Non-Interventional Clinical Research Ethics Committee of University of Health Sciences, Konya City Hospital (Date: 24.04.2025, Decision No: 2025/74).

Peer-review: Externally peer-reviewed.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Beş yaş altı çocuklarda femur cisim kırıkları için acil servis koşullarında anestezi olmadan yapılan spika alçı yönteminin radyolojik etkinliği ve maliyet analizi

AMAÇ: Bu çalışmanın amacı, 5 yaş altındaki çocuklarda femur diafiz kırıkları için acil serviste anestezisiz uygulanan erken dönem spika alçısı ile ameliyathane koşullarında genel anestezi altında uygulanan spika alçısı yöntemlerini klinik, radyolojik ve maliyet açısından karşılaştırmaktır. Bu sayede her iki yöntemin etkinliği ve maliyet verimliliği analiz edilmiştir.
GEREÇ VE YÖNTEM: 2020-2024 yılları arasında femur cisim kırığı tanısı alıp, kapalı redüksiyon ve spika alçısı işlemi uygulanan 71 çocuk retrospektif olarak incelendi. Hastalar, spika alçısının uygulandığı yere göre iki gruba ayrıldı: Acil Servis Grubu (AS Grubu, n=41) ve Ameliyathane Grubu (AY Grubu, n=30). Her iki grup, yaş, cinsiyet, kırık tipi, radyolojik hizalanma ve tedavi maliyetleri gibi kriterlere göre karşılaştırıldı.
BULGULAR: Gruplar arasında yaş, cinsiyet, kırık tipi ve son radyolojik hizalanma açısından anlamlı bir fark bulunmadı. Ancak, acil servis grubunda ortaya çıkan tedavi maliyetleri, ameliyathane grubuna kıyasla anlamlı derecede daha düşüktü. Ayrıca, her iki gruptaki komplikasyon oranları da benzer seviyelerde gözlendi.
SONUÇ: Acil serviste, genel anestezi kullanılmadan yapılan erken dönem spika alçısı uygulamaları, ameliyathane şartlarında yapılanlarla benzer radyolojik sonuçlar elde edilmesini sağlamakta ve önemli bir maliyet avantajı sunmaktadır. Bu yöntem, doğru hasta seçimi ile güvenli ve etkili bir tedavi alternatifi olarak önerilebilir.

Anahtar sözcükler: Acil servis; anestezisiz tedavi; femur şaft kırığı; maliyet analizi; pediatrik travma; radyolojik sonuçlar; spika alçı.

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ORIGINAL ARTICLE

Expanding minimally invasive horizons for pubic symphysis diastasis: The laparoscopic total extraperitoneal approach in orthopedic surgery (O-TEP)

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ABSTRACT

BACKGROUND: This study aims to present the preliminary clinical and functional outcomes of pubic symphysis diastasis (PSD) cases treated with plate-screw fixation using the laparoscopic total extraperitoneal approach in orthopedic surgery (O-TEP).

METHODS: This retrospective study included 13 patients who underwent O-TEP symphysis pubis plating for PSD between March 2022 and May 2025, all with a minimum follow-up period of 12 months. Data collected encompassed demographic characteristics, injury mechanisms, additional pathologies, and injury classifications (Young-Burgess and AO/OTA). Surgical details, including duration, blood loss, hospital stay, and postoperative follow-up, were recorded. Clinical and functional outcomes were assessed using postoperative VAS scores, as well as Iowa Pelvic and Majeed Pelvic scores at the final follow-up. The study also evaluated implant failure, the need for revision surgery, and surgery-related complications.

RESULTS: The mean age of the patients was 40±14.8 years (21–61). The gender distribution was 77% male and 23% female. The mean operating time was 113±36 minutes (65–175). The average blood loss was 127±67.3 ml (70–300), and the mean postoperative hospitalization period was 2.7±0.8 days (2–4). No postoperative complications, such as infection, implant failure, loss of reduction, or need for revision, were observed. Postoperative VAS scores on days 1 and 2 were 3.7±1.5 (1–6) and 2.2±1.03 (1–4), respectively. The mean follow-up period was 21.5±6.9 months (12–32), with a mean Iowa Pelvic Score of 87.1±4.7 (80–95) and a mean Majeed score of 84.9±4.01 (78–91).

CONCLUSION: Laparoscopic total extraperitoneal approach in orthopedic surgery (O-TEP) is an innovative minimally invasive technique that expands the available options for surgeons in the treatment of selected anterior pelvic ring injuries, providing clinically and radiologically satisfactory outcomes.

Keywords: Endoscopy; laparoscopy; orthopedic total extraperitoneal approach (O-TEP); pelvic ring injury; pubic symphysis diastasis.

INTRODUCTION

Pelvic ring disruptions are often associated with high-energy traumas and can be catastrophic and life-threatening.[1,2] Pubic symphysis diastasis (PSD) is the anterior component in various types of pelvic ring disruptions.[3] According to the Young-Burgess classification system, PSD can result from any mechanism, but anteroposterior compression is the most commonly observed mechanism.[4]

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Various surgical treatment options for PSD requiring surgery have been reported, including external fixator,[5] internal fixator,[6] plate osteosynthesis,[7] percutaneous screw fixation,[8] and the endobutton technique.[9] Open reduction and internal fixation of the pubic symphysis using plates and screws have been widely accepted as the standard treatment.[8,10] In plate osteosynthesis of the symphysis pubis, the Pfannenstiel approach or the medial window of the modified Stoppa approach is frequently used.[11] Although these approaches clearly expose the anterior pelvic ring and the symphysis pubis, they also bring potential risks associated with open surgical procedures, such as rectus abdominis muscle stripping, iatrogenic vascular and nerve injuries, increased bleeding, and higher infection rates.[12]

Endoscopy of the Retzius space, which also allows intervention in the symphysis pubis and anterior pelvic ring, is widely used by general surgeons in total extraperitoneal (TEP) inguinal hernia repair.[13] Recently, both cadaver studies and case reports have demonstrated the feasibility of a fully endoscopic approach to the anterior pelvic ring and full endoscopic symphysis pubis plating.[11,12,14–16]

The aim of this study is to present clinical experiences with the full endoscopic approach for the surgical treatment of PSD, including initial short-term clinical outcomes. Furthermore, this study seeks to offer preliminary insights into the technique, including its potential advantages, disadvantages, and complications.

MATERIALS AND METHODS

This retrospective study was conducted at a Level 1 trauma center. This study was approved by the Bakırköy Dr. Sadi Konuk Training and Research Hospital Clinical Ethics Committee (Date: 07.08.2023, Decision no: 2023-15-11). Additionally, the study was registered with ClinicalTrials.gov (Registration Number: NCT06634082).

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Study Design and Population

A total of 19 patients with pubic symphysis diastasis were scheduled for total extraperitoneal (O-TEP) endoscopic symphysis pubis plating between March 2022 and May 2025 at a single Level 1 trauma center. Of these, four patients with a follow-up period of less than 12 months and two patients who required conversion to open surgery due to pneumoperitoneum that developed during the procedure were excluded. Ultimately, 13 patients who successfully underwent plating via O-TEP and had a minimum follow-up period of 12 months were included in the study.

Patient Characteristics and Data Collection

All patients underwent immediate pelvic AP radiographs and CT scans following the injury. The following data were recorded for each patient: demographic information, injury mechanisms, additional pathologies, pelvic ring injury classifications (according to Young-Burgess and AO-OTA classifications), body mass index (BMI), surgical duration, blood loss, complications, reasons for conversion to open surgery, hospital stay duration, and postoperative follow-up duration.

Surgical Technique (Fig. 1, Technical video)

All procedures were performed by a senior orthopedic surgeon with at least five years of experience in pelvic and ac-

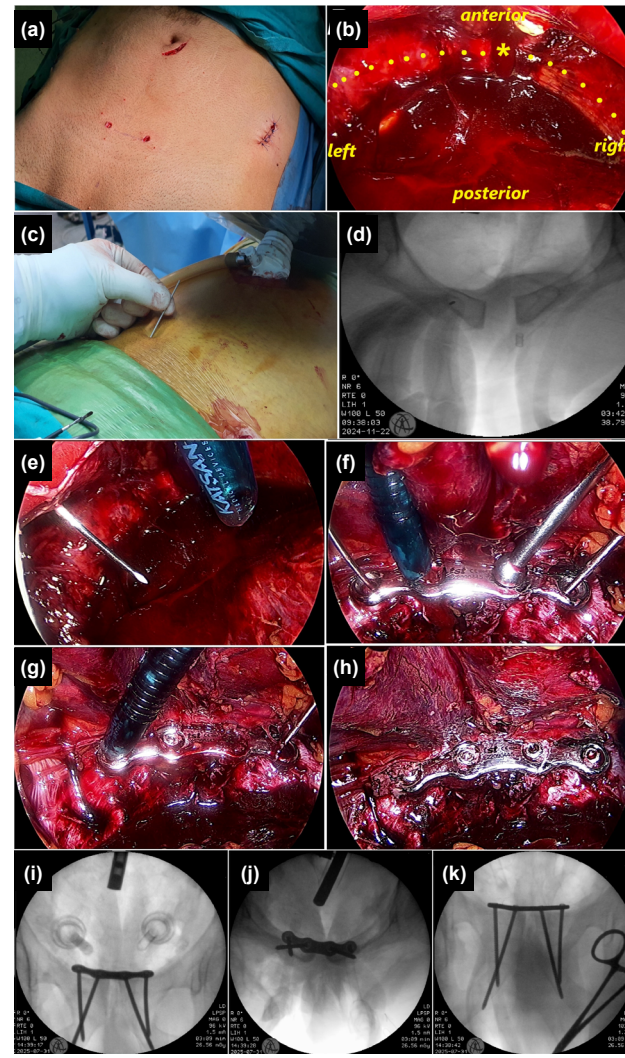

Figure 1. Surgical technique: **(a)** Imaging and instrumentation portals; **(b)** Endoscopic evaluation of the anterior pelvic ring; dotted marks indicate the right and left superior pubic rami, while * marks the symphysis pubis; **(c-d)** Determination of optimal instrumentation portal sites under fluoroscopic guidance; **(e)** Creation of instrumentation portals under direct endoscopic visualization; **(f)** Placement of the plate after reduction and temporary fixation of the plate with K-wires; **(g)** Drilling under endoscopic guidance and fixation of the plate with screws; **(h)** Endoscopic view of anterior arch plate fixation; **(i-k)** Fluoroscopic checks after the surgical procedure.

etabular fracture surgery, who had received structured training in the laparoscopic total extraperitoneal (TEP) technique through participation in laparoscopic inguinal hernia procedures performed by general surgeons. During the initial five cases, general surgeons were actively involved in the procedures. In subsequent cases, general surgeons were present in the operating room and available if needed, while the procedures were independently performed by the orthopedic surgeon.

After positioning the patient supine, the imaging portal, identical to that used by general surgeons during laparoscopic total extraperitoneal inguinal hernia repair, is established through a 2–3 cm crescent-shaped incision made 1–2 cm below the umbilicus, to the right or left of the midline (Fig. 1A). The anterior sheath of the rectus abdominis is opened slightly lateral to the linea alba, allowing passage of a 10 mm trocar. The rectus abdominis fibers are gently retracted laterally with an index finger to expose the preperitoneal space, avoiding peritoneal perforation. The preperitoneal space is dissected bluntly with an index finger and expanded with a balloon dissector, inflated to 20-25 puffs. After expansion, a 1 cm visualization portal is inserted, and CO2 is insufflated to 10-15 mmHg. Visualization is achieved with a 10 mm, 30-degree laparoscope, allowing evaluation of the Retzius space, pubic rami, and symphysis pubis (Fig. 1B).

Since the location of the instrumentation portals would affect the screw trajectory, the optimal entry site was determined under fluoroscopic guidance. For this purpose, in the pelvic inlet view where the superior and inferior pubic rami are superimposed, a 2–3 cm K-wire was axially aligned to represent the screw axis. The point where the K-wire intersected the skin surface was marked as the entry site for the portal (Fig. 1C-D). Subsequently, two instrumentation portals were created at the marked sites under direct endoscopic visualization (Fig. 1E). Hematoma and damaged soft tissues were cleared with a periosteal elevator and laparoscopic suction. If present, the corona mortis vessel was ligated with laparoscopic clips. Symphyseal reduction was achieved using an external fixator system established via external pins placed in the supraacetabular corridor or via a reduction clamp placed through parasymphyseal mini-incisions. Once confirmed, a four-hole symphyseal plate was introduced and temporarily fixed with K-wires (Fig. 1F). After fluoroscopic assessment, the plate was secured with screws using drills and screwdrivers through the laparoscopic ports (Fig. 1G). Final positioning of the plate and screws was confirmed endoscopically and fluoroscopically (Figs. 1H-K). The procedure concluded with irrigation; no drains were used.

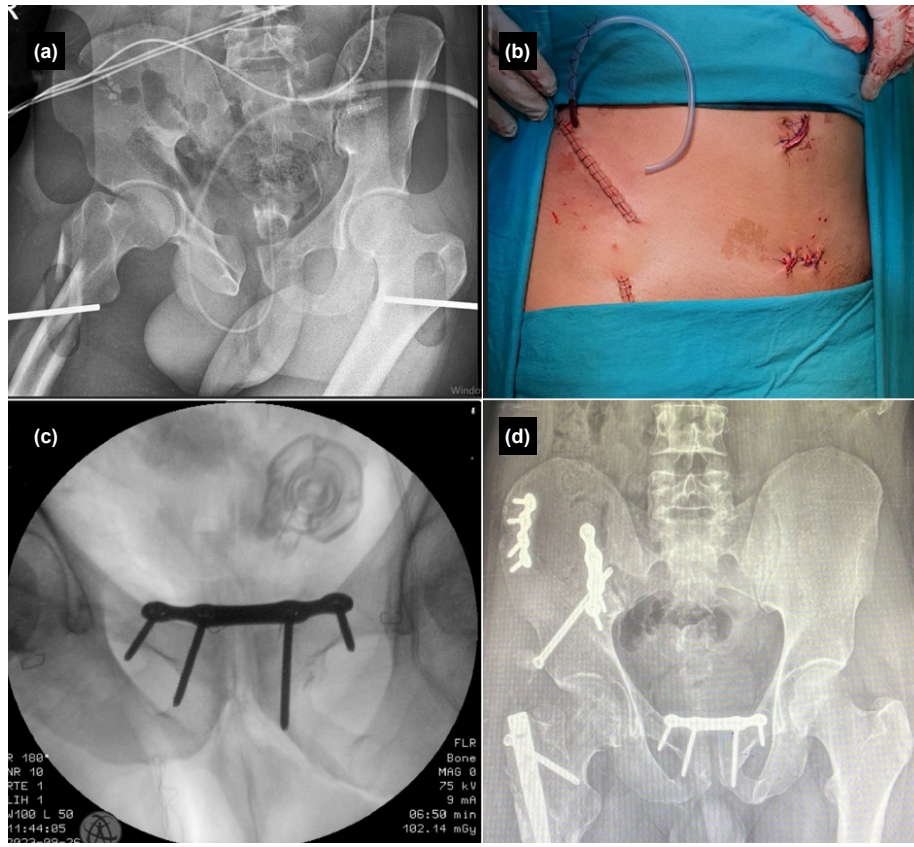

Figure 2. (a) Preoperative pelvis AP radiograph of a patient with an APC1 pelvic ring injury (Young-Burgess classification) and a C1-1AD injury (AO/OTA classification); **(b)** Incisions used during the surgery; **(c)** Fluoroscopic check after the surgical procedure; **(d)** Postoperative 22nd-month pelvis AP radiograph of the patient.

Postoperative Care Protocol

A standardized analgesic protocol was applied: IV tramadol (2 mg/kg, up to 400 mg/day) and IV paracetamol (15 mg/kg, up to 75 mg/kg/day) were given three times daily to ensure consistent pain management. Pain levels were evaluated using VAS scores on postoperative days 1 and 2. Rehabilitation began on the first postoperative day, encouraging early mobilization. Patients with isolated anterior pelvic ring injuries were allowed partial weight-bearing (up to 50% of body weight). For those with additional lower extremity or posterior ring injuries, toe-touch weight-bearing with crutches was permitted for the first 6 weeks, followed by partial weight-bearing for the next 6 weeks. Full weight-bearing and unsupported mobilization began at 3 months, as tolerated.

Postoperative Evaluation and Follow-up

Pelvic radiographs were taken postoperatively and at 1, 3, 6, and 12 months, as well as at the final check-up, to monitor healing and alignment. Clinical and functional outcomes were assessed with Iowa and Majeed Pelvic scores at the final follow-up. Additionally, implant failure, revision needs, and surgery-related complications were evaluated.

Representative Cases

Figures 2–5 illustrate representative cases treated with the O-TEP technique. For each case, preoperative and postoperative pelvic AP radiographs, surgical incision sites, and intraoperative fluoroscopic images are provided. These examples include one case from each classification subtype included in our study, demonstrating the diversity of pelvic ring injuries treated. Figure 2 presents a case classified as APC1 (Young-Burgess classification) and C1-1AD (AO/OTA classification). Figure 3 shows a case with an APC2 injury (Young-Burgess classification) and B2-3D injury (AO/OTA classification). Similarly, Figure 4 depicts another APC2 case, classified as B3-3D (AO/OTA classification). Finally, Figure 5 illustrates a more complex APC3 injury, classified as C1-2D (AO/OTA classification).

Statistical Analysis

Descriptive statistics, including mean, standard deviation, median, minimum, maximum, frequency, and ratio values, were used to summarize the data. All statistical analyses were performed using IBM SPSS 26 (Chicago, IL, USA). The results are presented to provide a clear overview of patient demographics, surgical details, and clinical outcomes, ensuring a comprehensive understanding of the findings.

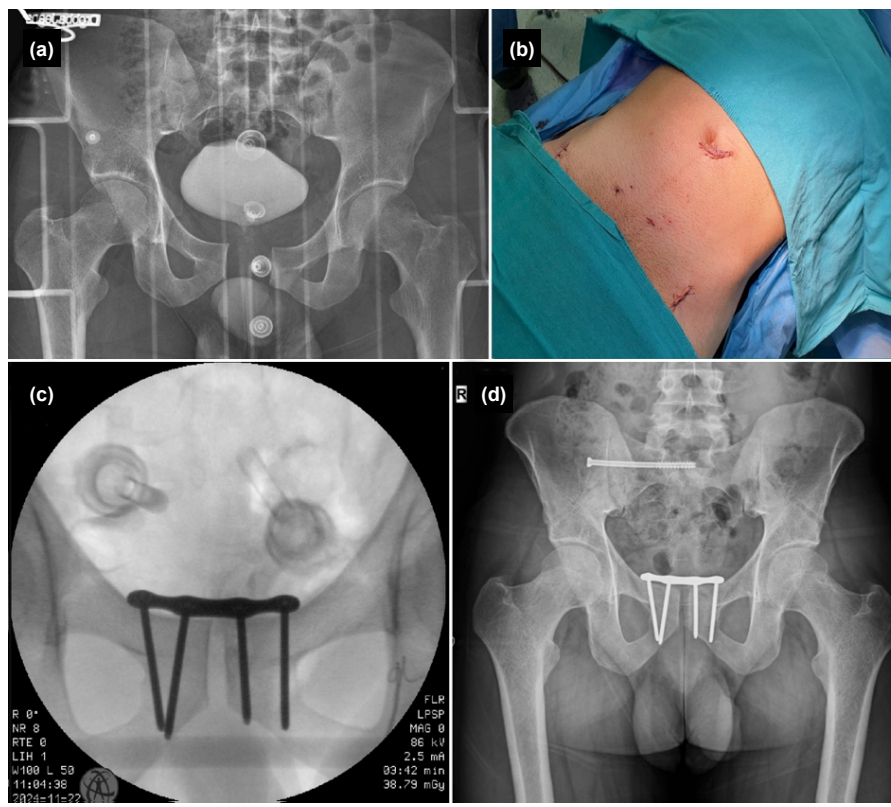

Figure 3. (a) Preoperative pelvis AP radiograph of a patient with an APC2 pelvic ring injury (Young-Burgess classification) and a B2-3D injury (AO/OTA classification); **(b)** Incisions used during the surgery; **(c)** Fluoroscopic check after the surgical procedure; **(d)** Postoperative 14th-month pelvis AP radiograph of the patient.

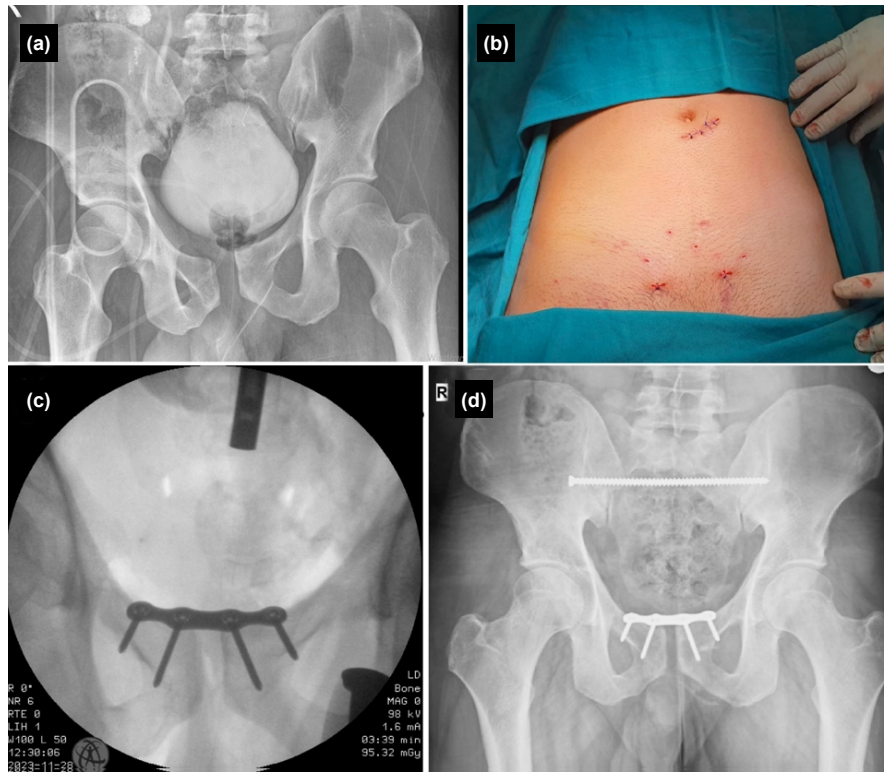

Figure 4. (a) Preoperative pelvis AP radiograph of a patient with an APC2 pelvic ring injury (Young-Burgess classification) and a B3-3D injury (AO/OTA classification); **(b)** Incisions used during the surgery; **(c)** Fluoroscopic check after the surgical procedure; **(d)** Postoperative 20th-month pelvis AP radiograph of the patient.

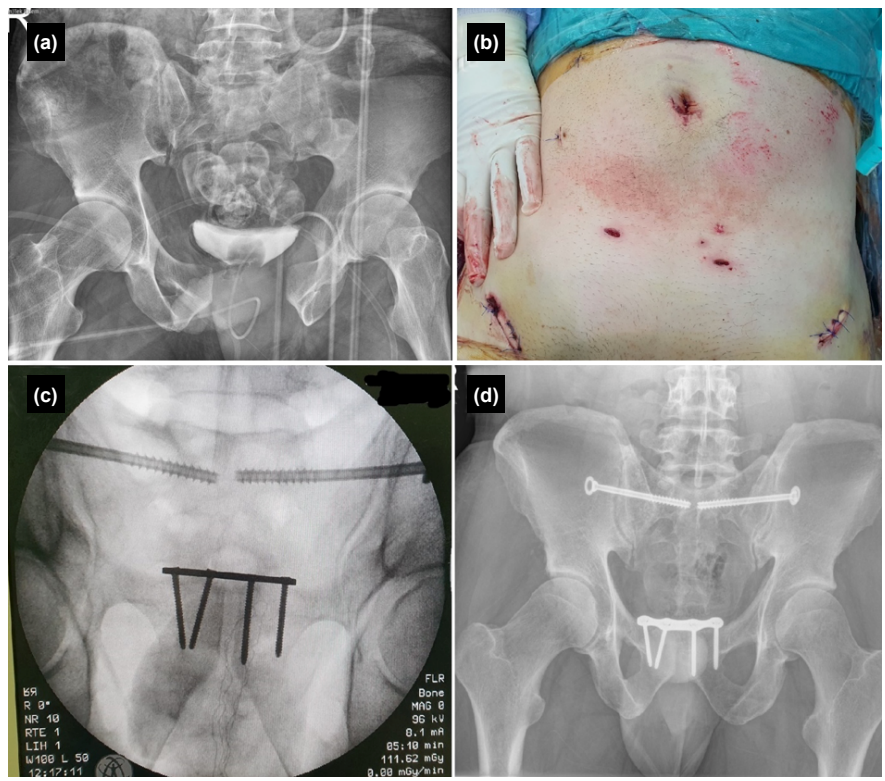

Figure 5. (a) Preoperative pelvis AP radiograph of a patient with an APC3 pelvic ring injury (Young-Burgess classification) and a C1-2D injury (AO/OTA classification); **(b)** Incisions used during the surgery; **(c)** Fluoroscopic check after the surgical procedure; **(d)** Postoperative 16th-month pelvis AP radiograph of the patient.

RESULTS

This study evaluated the clinical and surgical outcomes of patients treated with O-TEP plate-screw fixation for PSD. The mean operative time was 113.3 minutes (range 65-175), with an average blood loss of 127 ml (range 70-300) and a mean hospital stay of 2.7 days (range 2-4). Detailed demographic and injury characteristics are presented in Table 1, while surgical and clinical outcomes are summarized in Table 2. At the final follow-up, the Iowa Pelvic Score was 87.1 (range 80-95) and the Majeed Pelvic Score was 84.9 (range 78-91). No postoperative complications, implant failures, or revision surgeries were observed.

Table 1. Demographic and injury characteristics

	n	%
Sex		
Female	3	23
Male	10	77
Injury mechanism		
Motor vehicle	5	38.4
Fall from height	3	23.1
Occupational accident	3	23.1
Pedestrian	2	15.4
Body mass ındex (BMI)		
Normal (18.5≤BMI<25)	3	23
Overweight (25≤BMI<30)	6	46.1
Moderately Obese (30≤BMI<35)	4	30.7
Additional pathologies		
Femur shaft fracture	2	15.4
Radıus distal fracture	1	7.7
Humerus shaft fracture	1	7.7
Rib fracture	2	15.4
None	7	53.8
Classification (Young Burgess)		
APC 1 (+iliac crescent fx)	1	7.6
APC 2	10	77
APC 3	2	15.4
Classification AO/OTA		
B2 3D	10	77.2
B3 3D	1	7.6
C1 1AD	1	7.6
C1 2D	1	7.6
Age (years)		
Mean±SD	**Median**	**Min/Max**
40±14.8	37	21/61

DISCUSSION

Minimally invasive approaches are gaining importance in orthopedic surgery, becoming popular for their potential to reduce surgical risks and improve recovery times.[1] In treating pubic symphysis diastasis (PSD), open reduction and internal fixation with plates and screws remains the widely accepted standard.[8,10,17] However, various minimally invasive techniques offer alternatives to this traditional approach, with the total extraperitoneal (O-TEP) approach standing out as an innovative option.[16]

The O-TEP technique minimizes the surgical exposure required in standard open reduction and internal fixation, effectively transforming it into a minimally invasive procedure. This study aims to assess the preliminary clinical outcomes of the O-TEP approach for PSD treatment, highlighting its potential advantages and limitations.

Out of the total 19 cases where the procedures were performed, 2 (10%) required conversion to open surgery due to pneumoperitoneum resulting from inadvertent peritoneal perforation, leading to inadequate visualization. After conversion to open surgery, small tears in the peritoneum were observed and primarily repaired. No complications related to this were observed during postoperative follow-ups. Similarly, Küper et al.[11] successfully performed endoscopic symphyseal plating in 4 out of 7 cases using the O-TEP approach. They reported that in 2 cases, they started diagnostically and then planned to convert to open surgery, and in 1 case, they converted to open surgery due to increased end-expiratory CO2 levels. Vinet et al.[18] treated 10 PSD cases with the transabdominal preperitoneal approach (O-TAPP) and reported no conversions to open surgery.

The O-TEP and O-TAPP approaches are innovative adaptations of the total extraperitoneal approach (TEP) and transabdominal preperitoneal approach (TAPP) used by general surgeons for inguinal hernia repair. Beyond Vinet et al.'s study,[18] no other studies on the O-TAPP technique were found in the literature. To our knowledge, our study is the first case series using the O-TEP approach with short-term outcomes. Although these two studies are not sufficient to compare the advantages and disadvantages, the general surgery literature contains many studies on the TEP and TAPP techniques. Overall, these studies indicate that TEP has a higher risk of pneumoperitoneum and conversion to open surgery compared to TAPP. Additionally, the TAPP technique, which involves working in the intraperitoneal space, carries risks such as intraperitoneal organ injury, bowel obstruction, and intraperitoneal adhesions, and requires peritoneal repair.[19–21] Considering that the O-TEP and O-TAPP techniques in orthopedic surgery are adapted from the TEP and TAPP techniques in general surgery, they can be assumed to have similar advantages and disadvantages. The widespread adoption of these techniques in orthopedic surgery will allow for more objective results from an orthopedic perspective.

Table 2. Clinical and surgical outcomes

	Mean±SD	Min / Max	Median
Time to surgery (Days)	3.9±1.14	2/6	4
Surgery duration (minute) (Exclusively for Symphysial Plating)	113.3±36.08	65/175	110
Average blood loss (ml)	127±67.3	70/300	105
Postoperative hospitalization (days)	2.7±0.8	2/4	2.5
Postoperative 1st day VAS	3.7±1.5	1/6	4
Postoperative 2nd day VAS	2.2±1.03	1/4	2
Follow up (months)	21.5±6.9	12/32	21
Iowa pelvic score	87.1±4.7	80/95	86.5
Majeed Pelvic Score	84.9±4.01	78/91	85
	n	%	
Intraoperative complications			
Subcutaneous emphysema	2	15.4	
Postoperative complications	0	0	

In this study, no postoperative complications were observed in any patient during follow-ups. Only two patients experienced intraoperative mild subcutaneous emphysema, which resolved spontaneously during their hospital stay without causing any complaints. In the studies by Küper et al.[11] and Vinet et al.[18] on endoscopic symphyseal plating, no complications were reported. Similarly, Kabir et al., in their technical note on fully endoscopic symphyseal plating using the O-TEP approach, reported one case of subcutaneous emphysema, which resolved spontaneously on the first postoperative day without requiring any treatment.[22]

Regarding patient-related factors, despite the fact that 6 patients (46.1%) were overweight and 4 patients (30.7%) were moderately obese, the O-TEP procedure was successfully performed in all cases. Similarly, Vinet et al.[18] reported no issues related to BMI and successfully applied the O-TAPP technique to obese patients. The general surgery literature also supports the successful application of these approaches to obese patients, with several studies highlighting their advantages over open surgical methods.[23] This suggests that these techniques can be preferred in orthopedic surgery, regardless of BMI.

With respect to operative duration, the average time for endoscopic symphyseal plating alone was found to be 113.3±36.08 minutes (range: 65-175 minutes). Küper et al.[11] reported an average surgical time of 127±52 minutes (range: 30-197 minutes) for symphyseal plating with the O-TEP technique. Vinet et al.[18] reported an average surgical time of 102.5 minutes (range: 60-240 minutes) for symphyseal plating with the O-TAPP technique. Our surgical times are similar to those reported in these studies. Additionally, a recent meta-analysis comparing percutaneous cannulated screw fixation (PCSF) and open reduction and reconstruction plate and screws fixation (RPSF) for PSD treatment reported mean operative times of 37±19.1 minutes for PCSF and 68.9±13.6 minutes for RPSF.[17] Compared to endoscopic techniques, both RPSF and PCSF have shorter operative times, which can be explained by the higher learning curve associated with endoscopic techniques. This observation is consistent with the technical requirements of the O-TEP approach, as the orthopedic surgeon in the present study underwent dedicated training in laparoscopic total extraperitoneal techniques through participation in inguinal hernia procedures and initially performed the first cases with the active involvement of general surgeons, reflecting the inherent complexity and learning demands of this endoscopic technique.

The same meta-analysis reported intraoperative blood loss of 14.9±4.2 mL for PCSF and 162.7±47.6 mL for RPSF.[17] In our study, the average blood loss was 127±67.3 mL (range: 70-300 mL). Küper et al.[11] reported an average blood loss of 129±141 mL (range: 50-400 mL), and Vinet et al.[18] reported an average blood loss of 111 mL. These findings indicate that while endoscopic techniques result in more blood loss compared to percutaneous screw fixation, they result in less blood loss compared to traditional open techniques.

One notable observation from our study was the postoperative hospital stay duration. The presence of additional orthopedic pathologies in patients can impact the length of hospital stay, making the group heterogeneous. However, in our study, the average postoperative hospital stay was 2.7±0.8 days (range: 2-4 days). The literature indicates that minimally invasive methods generally result in shorter hospital stays compared to open techniques.[24–26] Studies with homogenous groups of isolated PSD cases can provide more objective data

on hospital stay durations.

An essential clinical outcome was the VAS score on postoperative days 1 and 2. Under a standardized analgesia protocol, the average VAS score was 3.7±1.5 (range: 1-6) on postoperative day 1 and 2.2±1.03 (range: 1-4) on postoperative day 2. Similarly, Vinet et al.[18] reported an average VAS score of 3 (range: 0-6) on postoperative day 1 and 2 (range: 1-5) on postoperative day 2, noting a reduced need for analgesia. Endoscopic techniques, compared to traditional approaches like the Pfannenstiel or modified Stoppa approach, involve smaller incisions and limited soft tissue dissection, resulting in reduced postoperative analgesia requirements and earlier mobilization.[27]

At the final follow-up, our patients had Majeed Pelvic Scores (MPS) and Iowa Pelvic Scores (IPS) of 84.9±4.01 (range: 78-91) and 87.1±4.7 (range: 80-95), respectively. Vinet et al.[18] reported similar scores in their case series with the O-TAPP technique. Vaidya et al.[28] found comparable Majeed scores of 83.95±15.2 (range: 51-100) for INFIX and 77.67±16.7 (range: 54-100) for plating in a comparative study. Yu et al.[29] reported similar functional outcomes in their comparative study of reconstruction plate screw fixation and percutaneous cannulated screw fixation. These functional scores suggest that endoscopic techniques provide good functional outcomes comparable to other techniques in the literature, making the endoscopic techniques a safe alternative.

While the present findings demonstrate the feasibility and favorable clinical outcomes of the endoscopic approach, they should be interpreted within the methodological limitations of a non-comparative study design. As no control group was included, direct conclusions regarding superiority over established open techniques cannot be drawn. Therefore, rather than suggesting a definitive advantage, the current results indicate that this technique may represent a minimally invasive alternative with comparable clinical outcomes in appropriately selected patients. Given its relatively recent introduction into orthopedic trauma practice, further prospective and comparative studies with larger patient cohorts are warranted to better define its role in relation to conventional open methods.

Limitations

This case series demonstrates the feasibility of the laparoscopic total extraperitoneal (O-TEP) approach for stabilizing pubic symphysis diastasis but lacks a comparative analysis with traditional methods. The small sample size, single-center, retrospective design, and minimum 12-month follow-up may limit the generalizability of the findings and assessment of long-term complications, particularly regarding implant longevity and late-onset issues. In addition, conversion to open surgery due to pneumoperitoneum occurred in 2 cases (10%), representing a technique-related limitation that should be considered when interpreting the results.

Nevertheless, the fact that the majority of cases consisted of APC type II pelvic ring injuries may be considered theoretically encouraging regarding the potential applicability of the technique in this specific injury pattern. However, the very limited number of cases with combined rotationally and vertically unstable pelvic ring injuries means that the applicability of the technique in such more complex injury patterns remains uncertain. Therefore, further studies including a wider variety of pelvic injury models are required.

CONCLUSION

This case series demonstrates that plate-screw fixation via the laparoscopic total extraperitoneal (O-TEP) approach for pubic symphysis diastasis is associated with low complication rates, minimal blood loss, and favorable functional outcomes, making it a promising alternative to open surgery for anterior pelvic ring injuries. The preliminary results indicate that O-TEP provides reduced surgical trauma and quicker recovery times. With continued advancements in technique and technology, O-TEP has the potential to expand minimally invasive options for managing complex pelvic fractures.

Ethics Committee Approval: This study was approved by the Bakırköy Dr. Sadi Konuk Training and Research Hospital Clinical Ethics Committee (Date: 07.08.2023, Decision No: 2023-15-11).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Pubik simfizis diyastazında minimal invaziv ufukların genişletilmesi: Ortopedik cerrahide laparoskopik total ekstraperitoneal yaklaşım (O-TEP)

AMAÇ: Bu çalışma, ortopedik cerrahide laparoskopik total ekstraperitoneal yaklaşım (O-TEP) kullanılarak plak-vida ile tedavi edilen pubik simfizis diyastazı (PSD) olgularının ön klinik ve fonksiyonel sonuçlarını sunmayı amaçlamaktadır.

GEREÇ VE YÖNTEM: Bu retrospektif çalışmaya Mart 2022 ile Mayıs 2025 arasında PSD nedeniyle O-TEP yaklaşımı kullanılarak simfizis pubis plaklaması yapılan ve en az 12 ay takip edilen 13 hasta dahil edildi. Demografik özellikler, yaralanma mekanizmaları, ek patolojiler ve yaralanma sınıflamaları (Young-Burgess ve AO-OTA) kaydedildi. Cerrahi ayrıntılar (süre, kan kaybı, hastanede kalış süresi ve postoperatif takip süresi) değerlendirildi. Klinik ve fonksiyonel sonuçlar, postoperatif VAS skorları ile son kontrolde Iowa Pelvik ve Majeed Pelvik skorları kullanılarak değerlendirildi. Ayrıca implant yetmezliği, revizyon cerrahisi ihtiyacı ve cerrahiye bağlı komplikasyonlar da incelendi.

BULGULAR: Hastaların yaş ortalaması 40±14.8 yıl (21–61) idi. Cinsiyet dağılımı %77 erkek ve %23 kadın idi. Ortalama ameliyat süresi 113±36 dakika (65–175), ortalama kan kaybı 127±67.3 ml (70–300) ve ortalama postoperatif hastanede kalış süresi 2.7±0.8 gün (2–4) olarak bulundu. Enfeksiyon, implant yetmezliği, redüksiyon kaybı veya revizyon ihtiyacı gibi postoperatif komplikasyon görülmedi. Postoperatif 1. ve 2. gün VAS skorları sırasıyla 3.7±1.5 (1–6) ve 2.2±1.03 (1–4) idi. Ortalama takip süresi 21.5±6.9 ay (12–32) olup, ortalama Iowa Pelvik Skoru 87.1±4.7 (80–95), ortalama Majeed Skoru ise 84.9±4.01 (78–91) bulundu.

SONUÇ: Ortopedik cerrahide laparoskopik total ekstraperitoneal yaklaşım (O-TEP), seçilmiş anterior pelvik halka yaralanmalarının cerrahi tedavisinde cerrahların mevcut seçeneklerini genişleten, klinik ve radyolojik olarak tatmin edici sonuçlar sunan yenilikçi bir minimal invaziv yöntemdir.

Anahtar sözcükler: Endoskopi; laparoskopi; ortopedik total ekstraperitoneal yaklaşım (O-TEP); pubik simfizis diyastazı; pelvik halka yaralanması.

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ORIGINAL ARTICLE

Traction radiographs improve evaluation of complex intertrochanteric fractures: Surgeon experience–independent effects in a nationwide simulation-based study

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ABSTRACT

BACKGROUND: The role of traction radiographs in the preoperative evaluation of intertrochanteric femur fractures remains controversial, with inconsistent evidence regarding their impact on fracture classification, stability assessment, and surgical decision-making. This nationwide simulation-based study aimed to investigate how orthopedic trauma surgeons use and interpret traction radiographs and to determine their influence on surgical planning across different levels of clinical experience.

METHODS: A nationwide, cross-sectional simulation-based study was conducted among actively practicing orthopedic and trauma surgeons between October 14 and November 15, 2025, using a structured questionnaire containing simulated cases. The questionnaire included demographic characteristics, clinical experience, perceptions of traction radiographs, and case-based assessments of 15 AO Foundation/Orthopaedic Trauma Association (AO/OTA)-classified intertrochanteric fractures (31-A1, 31-A2, 31-A3). A total of 133 surgeons participated, yielding 1,995 individual case evaluations. Changes in surgical decisions before and after traction radiographs were analyzed using McNemar tests, while independent predictors were identified using generalized estimating equations (GEE).

RESULTS: Traction radiographs were requested in 59.5% of all assessments, with significantly higher request rates in unstable patterns (31-A2: 75%; 31-A3: 68.2%) compared with 31-A1 fractures (30%). Overall, traction imaging resulted in a 12.4% change in surgical planning, increasing to 21% among cases in which traction radiographs were obtained. Decision changes were most common in 31-A2.3 (14.9%) and 31-A3.3 (16.9%) patterns. The most frequent implant transition was from short to long proximal femoral nail (PFN) (40.8%), followed by conversion to arthroplasty (18.8%). GEE analysis demonstrated that both fracture type and requesting traction radiographs were independent predictors of surgical plan modification (odds ratio [OR]=1.55–2.40 for unstable fracture types; OR=1.60 for traction radiograph request; $p<0.05$ for all). Surgeon title, institutional setting, years of experience, and case volume were not associated with decision changes.

CONCLUSION: Traction radiographs provide clearer visualization of fragment configuration and medial and lateral wall integrity, leading to improved recognition of fracture instability and a measurable shift toward more durable fixation strategies. Their impact on surgical planning is most pronounced in complex or borderline-unstable fracture patterns and remains consistent across experience levels. As a low-cost and readily accessible adjunct, traction radiography represents a valuable tool in the preoperative assessment of intertrochanteric fractures. Routine use is recommended, particularly when instability is suspected or when standard radiographs provide insufficient clarity.

Keywords: AO/OTA classification; fracture stability; intertrochanteric femur fracture; traction radiograph; surgical decision-making.

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INTRODUCTION

Intertrochanteric fractures (ITFs) are common injuries in older adults and are largely driven by underlying osteoporosis. Both treatment choice and postoperative prognosis depend heavily on fracture stability; therefore, accurate identification of fracture patterns and stability markers remains essential for appropriate surgical planning.[1] Management is predominantly operative, with proximal femoral nailing (PFN), dynamic hip screw (DHS) fixation, and—when indicated—arthroplasty representing the main treatment options.[2–4] The overarching objective is to achieve stable reduction and reliable fixation that allow early mobilization.

Routine evaluation of ITFs typically includes anteroposterior (AP) pelvis and hip radiographs, along with a cross-table lateral view.[5] However, femoral neck anteversion and deformity caused by the fracture can make these standard projections less clear. In displaced or comminuted fractures, conventional radiographs may not fully depict fragment orientation or the true reducibility of the fracture. Consequently, intraoperative challenges may arise, occasionally leading to suboptimal implant selection or inadequate reduction. Traction radiographs—performed with axial traction and internal rotation of the injured limb during image acquisition—have been described as an adjunct modality to overcome these limitations.[6] In parallel, the use of computed tomography (CT) at initial presentation has also increased in many emergency settings.

Some clinicians have adopted traction radiographs to refine preoperative decision-making.[7] By separating fracture fragments, traction radiographs can provide clearer visualization of the fracture line, comminution pattern, and the integrity of the posteromedial cortex. They have also been shown to significantly improve both interobserver and intraobserver agreement when applying the AO Foundation/Orthopaedic Trauma Association (AO/OTA) classification system for intertrochanteric fractures.[7,8] Particularly in teaching hospitals, these images have been reported as a low-cost, low-morbidity tool that enhances classification accuracy.[9] Conversely, other studies have suggested that traction radiographs do not improve the reliability of AO/OTA classification in pertrochanteric fractures, leaving their true clinical utility somewhat uncertain.[10]

These conflicting findings create uncertainty regarding the true value of traction radiographs in clinical practice and their role in surgical decision-making. To date, no nationwide study has evaluated the impact of traction radiographs on surgical decision-making across varying levels of surgeon experience. In this study, we hypothesized that traction radiographs have a meaningful effect on surgical planning and that this influence increases with fracture complexity, regardless of surgeon experience. Our aim was to investigate how orthopedic trauma surgeons perceive and utilize traction radiographs in the preoperative evaluation of intertrochanteric fractures and to assess their perceived impact on surgical decision-making using a radiology-based, simulation-driven clinical decision-making design.

MATERIALS AND METHODS

Ethical approval for the study was obtained from the Clinical Research Ethics Committee of Koşuyolu Yüksek İhtisas Training and Research Hospital (Date: 14.10.2025, Decision no: KYİEAH-KAEK 2025/17/1274). This study was designed as a nationwide, cross-sectional, case-based online study conducted among actively practicing orthopedic and trauma surgeons. All participants were informed that their responses would be analyzed solely for scientific purposes and reported in an aggregated manner.

A pilot study was conducted with 10 orthopedic surgeons working at Fatih Sultan Mehmet Training and Research Hospital, who independently evaluated 30 fracture cases. Feedback from this phase indicated that an online completion time exceeding 15 minutes reduced response completion rates. Based on the pilot data, a minimum of 15 cases was calculated to provide adequate statistical power, and the final number of questions was adjusted accordingly.

Case Selection and Criteria

Fifteen intertrochanteric fracture cases were selected a priori to represent the AO/OTA 31-A1, 31-A2, and 31-A3 spectrum and common clinical scenarios. Case selection was based on predefined radiographic criteria and image quality rather than clinical outcomes, aiming to minimize selection bias. Two senior orthopedic trauma surgeons independently assigned the reference AO/OTA classification for each case and resolved discrepancies by consensus.

Inclusion Criteria

- Adults aged ≥18 years
- Fracture types AO/OTA 31-A1, 31-A2, and 31-A3
- Radiographs of adequate image quality that clearly demonstrated fracture morphology.

Exclusion Criteria

- Patients aged <18 years
- Fractures of the femoral shaft or distal femur
- Intracapsular fractures (femoral head or femoral neck fractures).

The study population consisted of actively practicing orthopedic and trauma surgeons. Participants were recruited through TOTBİD (Turkish Society of Orthopedics and Traumatology) specialist groups and completed an online questionnaire hosted on Google Forms between October 14, 2025 and November 14, 2025. Data collection was closed on November 15, 2025. Participation was voluntary and anonymous; no directly identifying personal data were collected. The number of surgeons who participated in and completed the case-based online assessment was recorded.

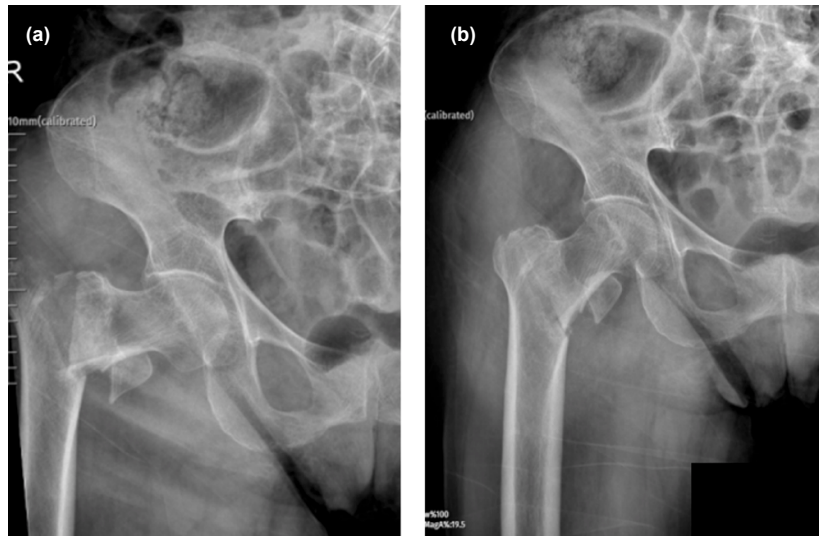

Figure 1. Representative hip radiographs used in the study instrument. **(a)** Standard anteroposterior hip radiograph without traction. **(b)** Traction–internal rotation radiographic view obtained under axial traction.

For each case, participants first reviewed standard preoperative radiographs and recorded (i) whether they would request a traction radiograph and (ii) their initial surgical plan or implant preference. If a traction radiograph was requested (i.e., traction images were viewed), participants then recorded their revised surgical plan (Fig. 1). The primary endpoint was surgical plan change after traction radiography among traction-viewed evaluations, defined as any change in the planned treatment category or implant choice between the pre-traction and post-traction responses. Secondary endpoints included the probability of requesting traction radiography and the direction of decision change (e.g., escalation from extramedullary fixation to cephalomedullary nailing or arthroplasty).

Simulation-Based Clinical Decision-Making Study

All participants evaluated the same standardized radiographic cases via the online platform, ensuring uniform image input across all institutions. The study instrument was structured into three main sections to examine the role of traction radiographs in clinical decision-making from different perspectives:

Demographic Characteristics: This section included participants' job title, type of institution, years of clinical experience, and the frequency with which they treated patients with hip fractures.

1. Questions addressing perceived effectiveness, benefits and drawbacks, associated risk factors, previous training, and the availability of relevant imaging equipment were used to assess participants' perspectives on traction radiographs.

2. Case-Based Surgical Decision-Making: This section analyzed participants' inclination to request traction radiographs, their initial surgical choices, changes in those choices after reviewing traction images, and their preferred surgical approaches.

Item-level missingness was assessed for each variable, and the proportion of missing data was reported for all covariates and outcomes. Because overall missingness was low (133/137 responses; <1% missing data), a complete-case analysis was performed as the primary approach.

Statistical analyses were performed using SPSS (version 24.0, Chicago, Illinois, USA) and Python 3.11. An a priori power analysis indicated that ≥64 respondents were required (two-sided α=0.05, 80% power) to detect a clinically meaningful paired change. Clustering arising from repeated case ratings was accounted for using a design effect, and the final sample (133 participants; 1,995 case evaluations) provided adequate precision for population-averaged estimates. Continuous variables were reported as mean ± standard deviation (SD), while categorical variables were expressed as percentages. Missing data accounted for less than 1%; therefore, no data completion procedures were necessary. The stability of surgical planning before and after traction radiograph evaluation was assessed using Cohen's kappa coefficient (κ), interpreted according to the Landis and Koch classification as 0.00–0.20 (slight), 0.21–0.40 (fair), 0.41–0.60 (moderate), 0.61–0.80 (substantial), and 0.81–1.00 (almost perfect agreement). In this context, kappa was used to measure intra-rater decision stability, assessing the degree of agreement between initial and revised surgical preferences beyond that expected by chance. Factors influencing surgical decision change were analyzed using a generalized estimating equations (GEE) model with a logit link and an exchangeable correlation structure. A significance level of $p<0.05$ was adopted.

RESULTS

Participant Demographics

A total of 133 orthopedic and trauma surgeons participated in the study. The professional distribution included specialists (64%), assistant or associate professors (12%), associate professors (15%), and full professors (9%). Regarding institutional affiliation, 53% were working in university or tertiary-care hospitals, 23% in private hospitals or clinics, 21% in Ministry of Health state hospitals, and 3% in private offices. Clinical experience was broadly distributed as follows: more than 15 years (34%), 11–15 years (19%), 6–10 years (23%), and 0–5 years (24%) (Table 1).

Clinical Profile and Experience

Most respondents (59%) reported routinely managing hip fracture cases. While 21% encountered more than five cases per week, 30% reported monthly exposure, and 11% indicated that they rarely managed such injuries.

Perceptions and Experience with Traction Radiographs

Overall, 72% of participants believed that traction radiographs were useful for assessing fracture stability and fragment alignment (Fig. 2).

When asked about perceived advantages, the most common responses were easier surgical planning (85%) and improved visualization of fracture fragments (65%). Furthermore, 35% agreed that traction radiography reduced the likelihood of fracture characteristics being misclassified or misinterpreted. Reported disadvantages included additional cost and increased time burden (23%), whereas 5% felt that traction imaging offered no meaningful improvement over standard radiographs (Fig. 3).

Table 1. Demographic characteristics of participants

Variable	n	%
Academic title		
Specialist	85	64.0
Assistant professor	16	12.0
Associate professor	20	15.0
Professor	12	9.0
Institution type		
University/tertiary hospital	71	53.4
Private hospital	30	22.6
State hospital	28	21.1
Private office	4	3.0
Clinical experience		
0–5 years	32	24.1
6–10 years	30	22.6
11–15 years	25	18.8
>15 years	46	34.6

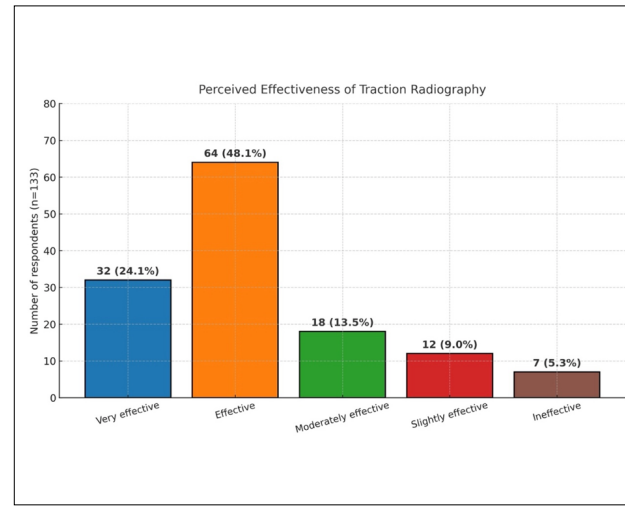

Figure 2. Perceived effectiveness of traction radiographs in assessing intertrochanteric fractures.

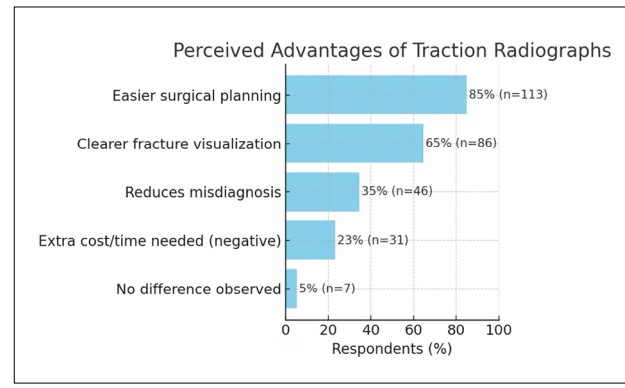

Figure 3. Reported advantages of traction radiographs, including improved surgical planning and enhanced visualization of fracture fragments.

Difficulties Encountered with Traction Radiographs

Patient-related factors were identified as the most common challenge during traction radiography; 80% of participants reported patient discomfort or poor patient cooperation as the primary obstacle. Other barriers included time constraints (42%), lack of adequately trained staff (40%), and limited equipment availability (32%). Only 5% reported experiencing no substantial difficulties (Fig. 4).

Training and Equipment Availability

Formal training in traction radiography was uncommon. More than half of the surgeons (52%) reported learning through on-the-job experience, 20% stated that they had received no training at all, 8% had received only theoretical instruction, and just 19% had undergone comprehensive theoretical and practical training. Equipment accessibility showed a similar pattern: only 13% reported adequate availability, whereas 54% considered their institutional resources inadequate, 24% described them as partially available, and 9% were unsure.

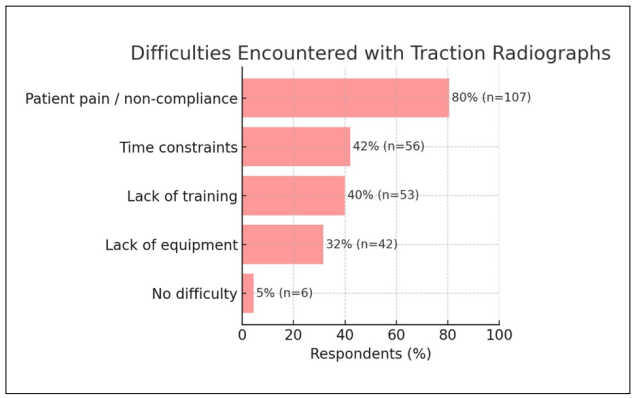

Figure 4. Most commonly encountered challenges during traction radiograph acquisition.

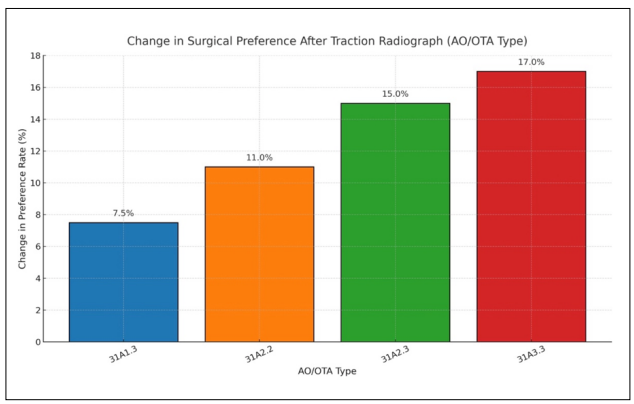

Figure 5. Distribution of surgical plan modifications following review of traction radiographs across AO Foundation/Orthopaedic Trauma Association (AO/OTA) fracture types.

Case-Based Surgical Decision-Making

A total of 1,995 individual observations were obtained from 15 fracture cases. The distribution across the AO/OTA classification system was roughly balanced, with one-third classified as 31-A1, one-third as 31-A2, and the remaining one-third as 31-A3.

Table 2. Distribution of surgical plan changes (n=249) and agreement analysis

Initial preference → Revised preference	Frequency (n)	%
Short PFN → Long PFN	102	40.8
Short PFN → Arthroplasty	47	18.8
Long PFN → Arthroplasty	18	7.2
PFN ↔ DHS	15	6.0
Other transitions	67	27.2
Total changes (out of 1,995 evaluations)	249	100
Cohen's kappa (κ)	0.68	<0.001*

Note: "→" indicates a unidirectional change; "↔" indicates bidirectional changes. PFN: Proximal femoral nail; DHS: Dynamic hip screw. *Statistically significant at p<0.05.

The overall request rate for traction radiography was 59.5%. Fracture type was significantly associated with the probability of obtaining traction imaging (p<0.001). The request rate was 30% for 31-A1 fractures, increasing markedly to 75% for 31-A2 and 68.2% for 31-A3 fractures.

Changes in Surgical Planning

The overall rate of surgical plan modification after reviewing traction radiographs was 12.4%. Among the 1,186 cases for which traction imaging was requested, surgical decisions changed in 249 instances (21%).

Decision changes were most frequent in 31-A2.3 (14.9%) and 31-A3.3 (16.9%) fractures, whereas the rate was lower for 31-A1.3 injuries (7.5%) (Fig. 5). The association between AO/OTA fracture type and decision change was statistically significant ($\chi^2(3)=22.47$, p=0.00035).

Changes in Implant Selection

The most prevalent change among the 249 cases with surgi-

Table 3. Results of generalized estimating equations (GEE) analysis

Variable	OR	95% CI	p-value
31-A2.2 vs. 31-A1.3	1.55	1.10–2.17	0.023
31-A2.3 vs. 31-A1.3	2.10	1.49–2.95	<0.001*
31-A3.3 vs. 31-A1.3	2.40	1.65–3.48	<0.001*
Traction radiograph requested (Yes)	1.60	1.25–2.05	<0.001*
Academic title	–	NS	>0.05
Institution type	–	NS	>0.05
Clinical experience	–	NS	>0.05
Frequency of hip fracture cases	–	NS	>0.05

*Statistically significant at p<0.05. NS: Not significant.

cal plan revision was the transition from a short to a long PFN (40.8%). Other major transitions included switching from short PFN to arthroplasty (18.8%) and from long PFN to arthroplasty (7.2%). Transitions between PFN and DHS fixation occurred in 6% of cases. Overall, 67.1% of decision changes reflected a shift toward a more stable intramedullary construct or arthroplasty (Table 2). The total number of changes (n=249) was consistent with the overall change rate of 12.4% observed across the 1,995 evaluations. To assess the reliability of surgical planning before and after traction radiographs, Cohen's kappa coefficient (κ) was calculated, revealing substantial agreement (kappa=0.68, p<0.001). This finding confirms that the observed shifts in surgical preference were statistically significant and not attributable to chance.

Multivariable Analysis

The generalized estimating equations model demonstrated that requesting a traction radiograph and fracture type were independent predictors of surgical plan change. Compared with 31-A1.3 fractures, the likelihood of decision change was significantly higher in 31-A2.2 (odds ratio [OR]=1.55; 95% confidence interval [CI]: 1.10–2.17; p=0.023), 31-A2.3 (OR=2.10; 95% CI: 1.49–2.95; p<0.001), and 31-A3.3 fractures (OR=2.40; 95% CI: 1.65–3.48; p<0.001) (Table 3).

Requesting traction radiographs increased the odds of a decision change by approximately 60% (OR=1.60; 95% CI: 1.25–2.05; p<0.001). Professional title, institution type, years of experience, and weekly case volume were not statistically significant predictors.

DISCUSSION

The principal finding of this study is that the use of traction radiographs significantly increases the likelihood of revising the surgical plan in intertrochanteric fractures, particularly in cases with unstable fracture patterns. Our results confirm that traction imaging plays an important role in the evaluation of intertrochanteric fractures. During case evaluation, nearly 60% of participants requested traction radiographs, and a substantial proportion subsequently revised their treatment plans, illustrating the role of this imaging modality in clinical decision-making. These results suggest that focused training programs centered on the acquisition and interpretation of traction pictures may enhance surgeon confidence, particularly among those with less experience. This study also provides evidence that traction radiographs influence surgical planning in complex intertrochanteric fractures, independent of surgeon experience.

The rate of traction radiograph requests increased in parallel with the AO/OTA instability grade, and this variable showed a strong association with changes in surgical planning. The rate of decision change was nearly 2.5 times higher in 31-A2.3 and 31-A3.3 fractures than in stable 31-A1.3 fractures. This pattern suggests that surgical plan modifications are concentrated in unstable fracture types and that traction imaging is an important tool for improving treatment strategies in these situations. Our findings support the notion that traction radiographs may elucidate the true stability characteristics of fractures within the AO/OTA 31-A2 subgroup, thereby significantly influencing treatment decisions. The data also suggest that surgeons generally only use traction imaging when they are not sure what to do during the early planning stage. This shows that traction imaging has a selective but important role.

The literature has long documented moderate interobserver agreement for intertrochanteric fracture classification using systems such as Evans/Jensen and AO/OTA, particularly in comminuted patterns.[11–13] Previous reports indicate that adding a traction–internal rotation view improves interobserver reliability.[7] It has also been reported that the addition of an internal rotation traction radiographic view significantly improves radiologist accuracy, diagnostic confidence, and interreader agreement.[14] In one study, 19% of observers revised their assessment of fracture stability—most notably in 31-A2.1 patterns, where 34% of initially "stable" fractures were reclassified as unstable following traction imaging. Our findings contribute to this debate by shifting the focus from classification reliability alone to clinical decision impact. In a standardized national sample of surgeons, traction radiographs were associated with measurable changes in planned treatment, particularly in more complex fracture patterns.

Traction–internal rotation radiographs have been reported to enhance the evaluation of the lateral femoral wall and, in turn, influence implant selection and preoperative planning.[15–17] Consistent with these observations, our cohort demonstrated a 12.4% overall change in implant choice after traction imaging, accompanied by convergence in treatment preferences that suggests improved interobserver agreement. Clinically, this shift in decision-making appears to be driven by the additional information traction views provide regarding case-specific reducibility. In many instances, surgeons revised their initial plans when traction imaging revealed poorer-than-anticipated reduction potential, greater fragment separation, or more pronounced deformity. Importantly, the GEE model supported this interpretation by identifying fracture type and the request for traction radiographs as independent predictors of surgical plan modification, whereas surgeon-related characteristics (professional title and experience) and institution type were not associated with decision change. Collectively, these findings indicate that traction radiographs function less as a "surgeon-dependent" adjunct and more as a standardized decision-support tool that enhances recognition of key fracture determinants across different practice environments. This is particularly relevant when considering the lateral femoral wall, where a thin preoperative wall has been linked to fixation failure and inferior functional outcomes with a dynamic hip screw, underscoring the need for meticulous radiographic assessment.[17] In this study, our results suggest that the perceived value of traction imaging—by facilitating a more confident appraisal of lateral wall adequacy and other instability cues that steer treatment away from DHS when appropriate—reflects a broadly shared awareness

that is largely independent of surgical seniority. Consequently, traction imaging may help harmonize implant selection toward mechanically more stable constructs.

Notably, surgeons were more likely to shift from extramedullary fixation to intramedullary nailing after traction radiographs revealed greater instability. Conversely, transitions from an intramedullary device to a less stable implant following traction imaging were rare. The most frequent change was from a short to a long PFN, followed by conversion to arthroplasty. These trends indicate that the net effect of traction imaging is a shift toward more stable fixation strategies.

In the present study, measured surgeon characteristics (title, years of experience, institution type, and hip fracture volume) were not statistically associated with decision change after adjustment for fracture-related factors. This finding should be interpreted cautiously. Prior work has shown that experience can influence classification reliability and perceived difficulty, and even when p-values are non-significant, clinically meaningful effect sizes may still exist.[9] Therefore, we interpret "experience-independent" to mean that—within the precision of this study—case morphology and traction visualization dominated decision revisions, rather than concluding that experience plays no role in real-world decision-making. Larger or longitudinal study designs, incorporation of confidence ratings, and linkage to operative outcomes are needed to determine whether traction imaging truly standardizes decision-making across different levels of surgeon experience.

When assessing perceived advantages, participants frequently cited several benefits of traction imaging. However, approximately 5% reported practical limitations, primarily related to cost and workflow. Patient-related obstacles, most notably discomfort and limited cooperation, emerged as the most significant challenges during imaging, surpassing institutional or technological constraints.

Training-related findings also deserve attention. Many residents and early-career surgeons report improved confidence in fracture classification and treatment planning when traction imaging is incorporated into their training.[6,9,18] In our study, systematic training was uncommon, with more than half of respondents reporting that they had learned traction radiography informally during clinical practice. Limited access to appropriate equipment was also evident. These findings highlight the need to incorporate traction radiograph acquisition and interpretation into residency training programs and to standardize equipment availability, which may ultimately improve decision-making skills among younger surgeons.

Overall, traction radiograph utilization reached 60% in this cohort and was associated with meaningful changes in surgical planning. These findings suggest that traction imaging may serve as an important complementary tool in the stability assessment of intertrochanteric fractures.

This study has several limitations that should be considered when interpreting the findings. First, the study relies on a case-based, standardized radiograph assessment that captures self-reported diagnostic and treatment preferences rather than real-time bedside decision-making. Therefore, the findings may differ from actual clinical practice, where patient comorbidities, bone quality, functional status, anesthesia risk, and institutional constraints can materially influence implant selection. Second, because the cross-sectional decision-making study was disseminated through professional communication channels and participation was voluntary, the sample represents a convenience cohort. If the total number of eligible surgeons reached is unknown or the response rate is low, nonresponse bias may limit representativeness despite the nationwide scope. Third, traction radiographs were not randomly assigned. Requesting traction imaging likely reflects baseline uncertainty and perceived instability; therefore, associations between traction imaging and decision change should be interpreted as decision-impact associations rather than causal effects. Fourth, only 15 cases were included and were purposefully selected to represent the fracture spectrum. Although this approach supports standardized comparisons, it may not reflect the full national distribution of fracture morphologies, image quality, or borderline patterns, and the results may therefore be sensitive to case selection. Fifth, correlated-data methods reduce—rather than eliminate—analytic concerns in cross-classified study data. Although we modeled within-respondent dependence and performed case-level sensitivity analyses, residual clustering and unmeasured heterogeneity may persist. Finally, the present study does not evaluate whether traction-driven changes in surgical plans translate into improved patient-centered outcomes. Prospective clinical studies linking imaging strategy to intraoperative reducibility, complication rates, and functional recovery are needed.

CONCLUSION

In conclusion, traction radiographs improve visualization of fracture configuration and instability markers, leading to changes in surgical planning, particularly in complex or borderline unstable intertrochanteric fractures. This effect is consistent across different levels of surgical experience. Traction radiography may therefore serve as a useful adjunct in preoperative assessment when standard radiographs provide limited information.

Ethics Committee Approval: This study was approved by the Koşuyolu Yüksek İhtisas Training and Research Hospital Ethics Committee (Date: 14.10.2025, Decision No: KYİEAH-KAEK 2025/17/1274).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: B.E.K., H.Ç.K.; Design: H.Ç.K., B.E.K.; Supervision: B.E.K.; Resource: O.G.;

Materials: O.Y.; Data collection and/or processing: H.F.E., O.Y.; Analysis and/or interpretation: H.Ç.K., O.G.; Literature review: H.Ç.K., B.E.K.; Writing: H.Ç.K., O.G.; Critical review: B.E.K., B.Y.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Traksiyon grafileri kompleks intertrokanterik kırıkların değerlendirilmesini iyileştirir: Cerrah deneyiminden bağımsız etkiler gösteren ulusal ölçekli simülasyon temelli çalışma

AMAÇ: Traksiyon grafilerinin intertrokanterik femur kırıklarının preoperatif değerlendirilmesindeki yeri halen tartışmalıdır. Literatürde kırık sınıflandırması, stabilite değerlendirmesi ve cerrahi planlama üzerindeki etkisine ilişkin bulgular kesinleşmemiştir. Bu ulusal ölçekli çalışma, ortopedi ve travmatoloji uzmanlarının traksiyon grafisi kullanımına yönelik yaklaşımlarını ve bu görüntülemenin cerrahi karar verme sürecine etkisini, klinik deneyimden bağımsız olarak değerlendirmeyi amaçlamıştır.

GEREÇ VE YÖNTEM: 14 Ekim–15 Kasım 2025 tarihleri arasında aktif olarak çalışan ortopedi ve travmatoloji hekimlerine çevrimiçi vaka temelli bir değerlendirme uygulanmıştır. Bu değerlendirme; demografik bilgiler, klinik deneyim, traksiyon grafisine yönelik algı ve 15 AO/OTA sınıflandırılmış intertrokanterik kırık vakasına (31-A1, A2, A3) ilişkin vaka temelli soruları içermiştir. Toplam 133 katılımcıdan 1995 gözlem elde edilmiştir. Cerrahi karar değişiklikleri McNemar testi ile analiz edilmiş, bağımsız belirleyiciler Genelleştirilmiş Tahmin Denklemleri (GEE) ile değerlendirilmiştir.

BULGULAR: Traksiyon grafisi istem oranı tüm değerlendirmelerin %59.5'ini oluşturmuş olup, bu oran instabil kırık tiplerinde anlamlı biçimde yükselmiştir (31-A2: %75; 31-A3: %68.2; 31-A1: %30). Traksiyon grafisi sonrası genel cerrahi plan değişikliği oranı %12.4, traksiyon grafisi istenen olgularda ise %21 olarak bulunmuştur. Karar değişikliği özellikle 31-A2.3 (%14.9) ve 31-A3.3 (%16.9) kırıklarında belirginleşmiştir. En sık implant geçişi kısa PFN'den uzun PFN'ye (%40.8), ardından artroplastiye geçiş (%18.8) şeklinde olmuştur. GEE analizinde kırık tipi ve traksiyon grafisi istemi cerrahi karar değişikliğinin bağımsız belirleyicileri olarak saptanmıştır (OR=1.55–2.40 ve OR=1.60; p<0.05). Katılımcının unvanı, kurum tipi, deneyim yılı ve vaka hacminin karar değişikliği üzerinde anlamlı etkisi bulunmamıştır.

SONUÇ: Traksiyon grafileri fragman konfigürasyonunun ve medial/lateral duvar bütünlüğünün daha net değerlendirilmesine olanak sağlayarak kırık instabilitesinin daha doğru tanınmasına ve daha dayanıklı implant tercihlerine yönelimde artışa neden olmaktadır. Bu etkinin özellikle kompleks veya sınırda instabil kırıklarda belirgin olduğu ve cerrahi deneyiminden bağımsız olarak korunduğu gösterilmiştir. Traksiyon grafisinin düşük maliyetli, uygulanabilir ve klinik karar sürecine anlamlı katkı sağlayan bir yöntem olarak intertrokanterik kırıkların preoperatif değerlendirilmesinde rutin kullanımının, özellikle instabiliteden şüphelenilen durumlarda, faydalı olabileceği düşünülmektedir.

Anahtar sözcükler: AO/OTA sınıflandırması; cerrahi karar verme; intertrokanterik femur kırığı; kırık stabilitesi; traksiyon grafisi.

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CASE REPORT

Incidental detection of congenital absence of the long head of the biceps tendon during shoulder arthroscopy: A case report

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ABSTRACT

Although congenital variations of the biceps brachii are relatively common, agenesis of the long head is exceedingly rare. Due to the absence of clinical symptoms and notable physical examination findings, its diagnosis is challenging. The absence of the long head represents one such variant, although it has only rarely been reported in arthroscopic and imaging studies. As this anomaly does not result in functional impairment, congenital biceps agenesis is often incidentally detected on shoulder magnetic resonance imaging performed for other reasons. In this case report, we present a 42-year-old industrial worker with a two-year history of persistent pain who underwent rotator cuff repair, during which an absent long head of the biceps tendon was incidentally identified. Current evidence suggests that the absence of the long head of the biceps tendon is not a risk factor for rotator cuff rupture or labral pathology. Additionally, when evaluating patients with an absent long head of the biceps tendon, it is essential to consider any previous surgical interventions. If the long head cannot be identified, the distal portion of the tendon should be carefully assessed, as the most common cause of its absence near the shoulder is not a congenital condition but rather a complete tear causing the tendon to retract downward. This condition represents an incidental anatomical variation and does not contribute to the functional impairment observed in these conditions.

Keywords: Agenesis; arthroscopy; biceps; tendon; shoulder.

INTRODUCTION

The biceps brachii is a two-headed muscle consisting of a short head and a long head that spans two joints. The long head originates from the supraglenoid tubercle, while the short head originates from the coracoid process, with its distal attachment at the radial tuberosity. Functioning as a powerful supinator and flexor of the elbow, the biceps also plays an important role in stabilizing the shoulder—particularly during abduction and internal rotation.[1] Congenital variations of the long head of the biceps tendon (LHBT) were once thought to be extremely rare;[2,3] however, advancements in magnetic resonance imaging (MRI) and arthroscopy have significantly increased both the detection rate and the recognized diversity of LHBT variations. The absence of the LHBT represents one such variant, although it has only rarely been reported in arthroscopic and imaging studies.[4]

Owing to its rarity, lack of awareness, variable clinical presentation, absence of specific clinical signs, and the limitations of conventional MRI, clinical diagnosis remains extremely challenging, if not impossible.[5] Moreover, congenital absence of the LHBT is rare, and its prevalence is unknown. Reports describing bilateral absence of the LHBT are also limited.[6] In this case report, we present the arthroscopic findings of a patient who presented with shoulder pain and was found to have an absent left LHBT during rotator cuff surgery.

CASE REPORT

A 42-year-old male industrial worker presented to the or-

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thopedic outpatient clinic with a two-year history of gradually worsening shoulder pain. On physical examination, Jobe's, Neer, and Hawkins tests were positive, while upper extremity strength was 5/5. The patient's shoulder exhibited no signs of laxity or hypermobility, and the "Popeye" sign was absent. Additionally, both the O'Brien and Speed tests were negative, with no clinical or physical evidence suggesting biceps pathology. With a preliminary diagnosis of a rotator cuff tear and impingement, radiographs and an MRI were obtained. MRI evaluation revealed an empty bicipital groove (Fig. 1) and a partial tear of the supraspinatus tendon. In the absence of a Popeye sign and any history of trauma, the finding was interpreted as agenesis rather than rupture of the biceps tendon. Because the patient's symptoms persisted despite physical therapy for the partial supraspinatus tear, shoulder arthroscopy was subsequently recommended. Intraoperatively, examination confirmed that the supraglenoid area was completely bare, with no identifiable LHBT—findings consistent with biceps agenesis (Fig. 2). The labrum was intact, and no intraoperative instability was observed. The rotator cuff tear was successfully repaired using a double-row technique.

DISCUSSION

Initially, Diplock et al.[7] argued that the LHBT was a functionally insignificant vestigial structure. However, current evidence indicates that the LHBT plays a crucial role as a dynamic stabilizer of the shoulder by depressing the humeral head and elevating the superior glenoid labrum.[8] Congenital absence of the LHBT is a rare anomaly, with unilateral absence associated with other skeletal and extraskeletal congenital anomalies in 57% of cases.[9] In 1997, Mariani et al.[10] published the first case report documenting arthroscopic absence of the LHBT in a patient with no history of trauma. Since then, numerous case reports and case series have documented the absence of the LHBT.[11] Shoulder arthroscopy is the most reliable method for establishing a definitive diagnosis. Its key diagnostic feature is the failure to identify the intra-articular portion of the LHBT in the presence of a shallow or absent bicipital groove.[2] The present case represents the first reported instance of biceps agenesis encountered in a patient undergoing rotator cuff repair. In 2009, Dierickx introduced a comprehensive classification of congenital anatomical variations of the LHBT. This classification delineates three possible pathoanatomical variants observable on shoulder arthroscopy and MRI in cases of LHBT absence: the absent type (ABS), the adherent type to the capsule–labrum complex (ADH-CL), and the adherent type confluent with the rotator cuff (ADH-CO) types. The ABS variant is characterized by the complete absence of both the intra-articular and extra-articular portions of the LHBT.

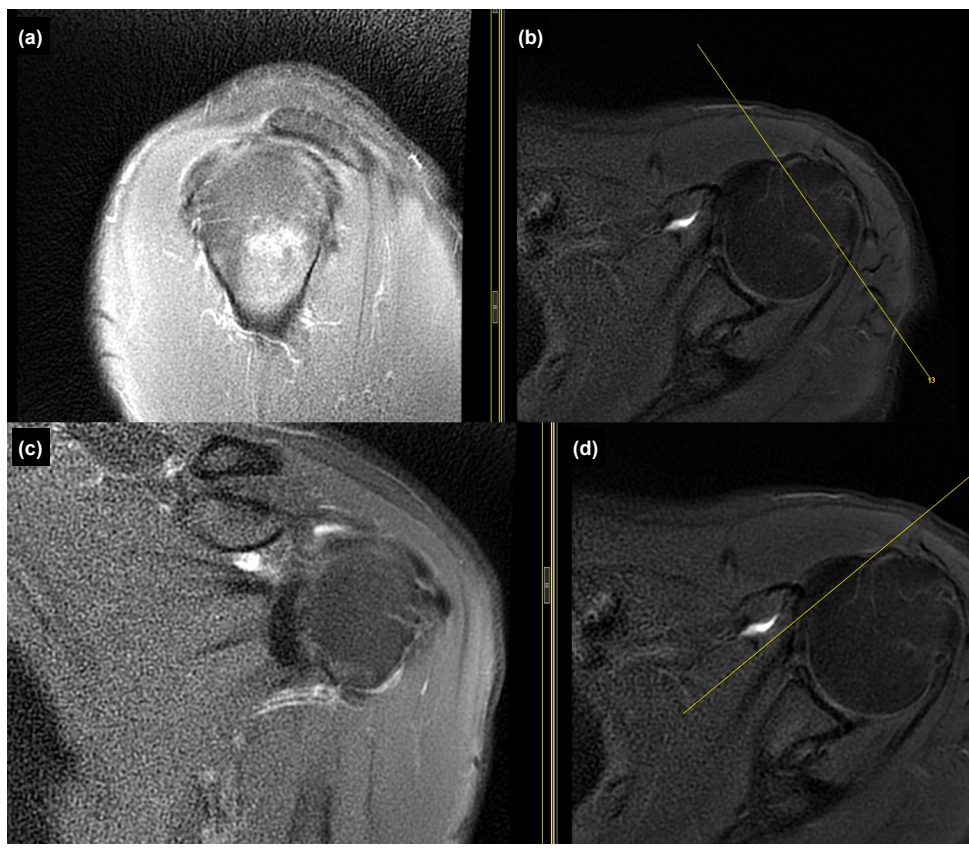

Figure 1. Axial, coronal, and sagittal magnetic resonance imaging (MRI) sections demonstrating the absence of the intra-articular portion of the long head of the biceps tendon.

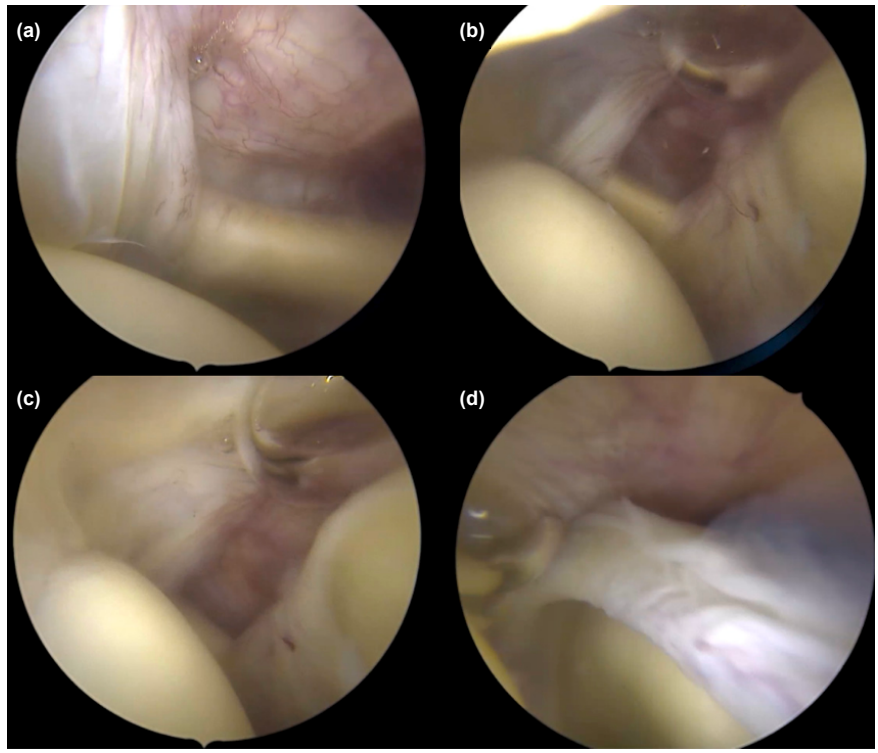

Figure 2. Arthroscopic views of the right shoulder demonstrating the absence of the long head of the biceps tendon (LHBT). **(a)** The subscapularis tendon is visualized together with the absent bicipital groove. **(b)** The subscapularis tendon, superior glenoid, and humeral head are visualized, with no identifiable LHBT. **(c)** A distant view of the subscapularis, superior glenoid, and humeral head again demonstrating the absence of the LHBT. **(d)** The normal attachment site of the LHBT on the superior glenoid is empty, while the superior labrum appears intact without disruption.

In the ADH-CL variant, the LHBT normally attaches to the labrum or supraglenoid tubercle but adheres to the inferior surface of the tendon (i.e., fixed at one end). In the ADH-CO variant, the LHBT is completely confluent with the cuff without distinct fixed ends.[5] The current case represents an ABS-type biceps agenesis, with no evidence of attachment to either the labrum or the supraglenoid area.

It is important to assess the distal portion of the tendon if the LHBT cannot be identified, as the most common cause of its absence near the shoulder is not a congenital condition but a complete tear causing the tendon to retract downward.[12] A full-thickness tear of the tendon may produce a visible "Popeye" sign on examination, presenting as a soft-tissue bulge due to downward displacement of the biceps muscle after detachment and disruption of normal tension within the tendon.[9] Additionally, when evaluating patients with an absent LHBT, it is essential to consider any previous surgical interventions (e.g., tenotomy or tenodesis).

CONCLUSION

In conclusion, current evidence suggests that the absence of the LHBT is not a predisposing factor for rotator cuff tears or labral pathology. Rather, it is an incidental anatomical variation that does not contribute to the functional impairment observed in these conditions.

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OLGU SUNUMU - *ÖZ*

Omuz artroskopisi sırasında tesadüfen saptanan biseps tendonunun uzun başının konjenital yokluğu: Bir olgu sunumu

Biseps brakii kasının konjenital varyasyonları nispeten yaygın olmakla birlikte, biceps brakii kasının uzun başın agenezisi son derece nadir görülen bir durumdur. Klinik semptomların ve belirgin fizik muayene bulgularının bulunmaması nedeniyle tanı koymak oldukça zordur. Biceps brakii kasının uzun baş tendonunun yokluğu, bu varyasyonlardan biridir ve artroskopik ya da görüntüleme çalışmalarında nadiren bildirilmiştir. Fonksiyonel bir bozukluğa yol açmadığı için, konjenital biseps tendon agenezisi genellikle başka nedenlerle yapılan omuz manyetik rezonans görüntülemeleri sırasında tesadüfen saptanır. Bu olgu sunumunda, iki yıldır devam eden omuz ağrısı olan 42 yaşındaki bir endüstri işçisinde yapılan fizik muayenede biceps tendonu ile ilişkili muayene bulguları negatifti. Artroskopik rotator manşet onarımı sırasında, bisepsin tendonunun uzun başının yokluğu tesadüfen belirlenmiştir. Güncel literatür, bisepsin uzun baş tendonunun yokluğunun, rotator manşet yırtığı veya labral patoloji açısından bir risk faktörü oluşturmadığını göstermektedir. Bisepsin uzun başı olmayan hastalar değerlendirilirken, daha önce geçirilmiş cerrahi girişimlerin (örneğin tenotomi veya tenodez) mutlaka göz önünde bulundurulması gerekmektedir. Eğer tendonun uzun başı tespit edilemiyorsa, distal kısmı mutlaka değerlendirilmelidir; çünkü omuz çevresindeki yokluğun en yaygın nedeni konjenital agenezis değil, tendonda oluşan tam kat yırtık sonrası aşağıya doğru retraksiyondur. Bu durum, ilgili klinik tabloya katkıda bulunmayan, tesadüfi bir anatomik varyasyon olarak kabul edilmektedir.
Anahtar sözcükler: Agenesi biseps; artroskopi; omuz; tendon.

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CASE REPORT

Rare and fatal late-term complication of endovascular aneurysm repair: Migration of the endograft into the duodenum

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ABSTRACT

Endovascular aneurysm repair (EVAR) is a treatment method that has become increasingly popular for abdominal aortic aneurysms (AAA) due to its ease of application, reduced hospital stay, and its suitability as an alternative for patients who cannot tolerate open surgery. Although the early outcomes of EVAR are better than those of open surgery, complications such as endoleak, migration, thrombosis or kinking of the endograft limbs, graft infection, and secondary rupture may occur. In this study, we present a patient who underwent EVAR at another institution approximately 10 years earlier and was admitted to our clinic with complaints of deterioration in general condition, fever, and melena. Laboratory examination of 73-year-old man revealed a white blood cell (WBC) count of 17,100, hemoglobin level of 9.5 g/dL, and C-reactive protein (CRP) level of 261 g/L. Computed tomography (CT) revealed thrombosis within the EVAR graft, free air surrounding the graft, fractures in the graft stents, and displacement of the right limb beyond the aorta at the level of the iliac bifurcation. The endograft was observed to have migrated toward the duodenum and formed a fistula. The patient, who presented with sepsis, underwent emergency surgery. Initially, a left axillofemoral bypass was performed to relieve ischemia in the left leg. Subsequently, a laparotomy was performed with the joint participation of the general surgery and cardiovascular surgery departments. Intra-abdominal fecal contamination and rupture of the sigmoid colon were observed. The abdomen was lavaged, the sigmoid colon and rectum were excised, and a colostomy was created. An aortotomy was then performed, and the main body of the graft and its left limb were removed. The duodenum was opened, and the fistulized right limb of the endograft was also removed. No additional vascular intervention was required due to abdominal contamination, adequate collateral circulation in the right leg, likely due to the chronic nature of the process, and the absence of ischemia. The aorta was ligated at the infrarenal level, and the patient, who required high-dose inotropic support, was transferred to the intensive care unit. The patient died in the eighth postoperative hour. To our knowledge, this case represents a rare and unique complication that has not been previously reported in the literature. By presenting this case, we aim to draw attention to the long-term complications of EVAR and emphasize the importance of open surgery in patients with a high life expectancy.

Keywords: Abdominal aortic aneurysm; endovascular aneurysm repair; long-term complication.

INTRODUCTION

Today, approximately 80% of patients indicated for surgery for abdominal aortic aneurysm (AAA) undergo endovascular aneurysm repair (EVAR), while open aneurysm repair (OAR) is preferred in younger patients with a longer life expectancy and fewer comorbidities. The 30-day mortality is significantly lower with EVAR compared to OAR. However, periodic post-EVAR imaging has reported reintervention rates as high as 18%.[1]

The most common complication after EVAR, often requir-

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ing reintervention, is endoleak. Other complications include stent migration, endograft infection, limb kinking or occlusion, and endograft collapse. Additionally, ischemia of the extremities, kidneys, intestines, pelvic organs, and spinal cord may occur. Serious complications such as secondary aneurysm rupture have also been reported.[2] Studies have shown that OAR provides better long-term outcomes in terms of aneurysm-related mortality, reintervention rates, and secondary rupture compared to EVAR.[3,4] In light of these data, the choice of method for patients undergoing AAA surgery is critically important. In this study, we present a complication that, to our knowledge, has not been previously reported in the literature. The case involves a patient who previously underwent EVAR and subsequently developed thrombosis in the body of the endograft and the iliac limbs, leading to secondary rupture of the right iliac limb. The endograft then became detached, curled, and fistulized into the duodenum, eventually floating within the duodenal lumen.

CASE REPORT

A 73-year-old male patient presented to our hospital with complaints of worsening general condition, melena, fever, and ischemia in the left leg for three days. On admission, the patient had a temperature of 39°C, was tachycardic (130 bpm) and tachypneic (30 breaths/min), and showed a decline in consciousness. Physical examination revealed diffuse abdominal tenderness with guarding. Rectal examination was positive for melena. From the patient's medical history, it was learned that he had undergone EVAR for an AAA at an external center 10 years earlier and had been receiving antiplatelet therapy. Laboratory findings were as follows: white blood cell count (WBC) 17,100, hemoglobin 9.5 g/dL, and C-reactive protein (CRP) 261 mg/L. Computed tomography (CT) demonstrated thrombosis of the EVAR graft, free air around the graft, fracture of the graft stents, and the aorta extending outside the graft at the level of the right iliac bifurcation. The graft was located infrarenally and the renal arteries were observed to be patent. It was determined that the endograft had migrated toward the duodenum, forming a fistula, entering the duodenal lumen, and floating within it (Fig. 1).

Informed consent was obtained for the scientific publication of this case, with assurance that the patient's personal information would remain confidential.

The patient, who was in a state of sepsis, first underwent a left axillofemoral bypass to address ischemia in the left lower extremity. Subsequently, the patient was taken for emergency abdominal surgery with the simultaneous participation of the cardiovascular surgery and general surgery teams. A median laparotomy was performed, and abdominal exploration revealed a rupture in the sigmoid colon with fecal contamination. After irrigation, the sigmoid colon and rectum were resected, and a colostomy was created. The aorta was freed, and a cross-clamp was placed inferior to the renal arteries. An aortotomy was performed, and the endograft was found to be completely thrombosed and infected. The main body and left limb of the endograft were removed. An aortoduodenal fistula was present at the distal aorta, at the level of

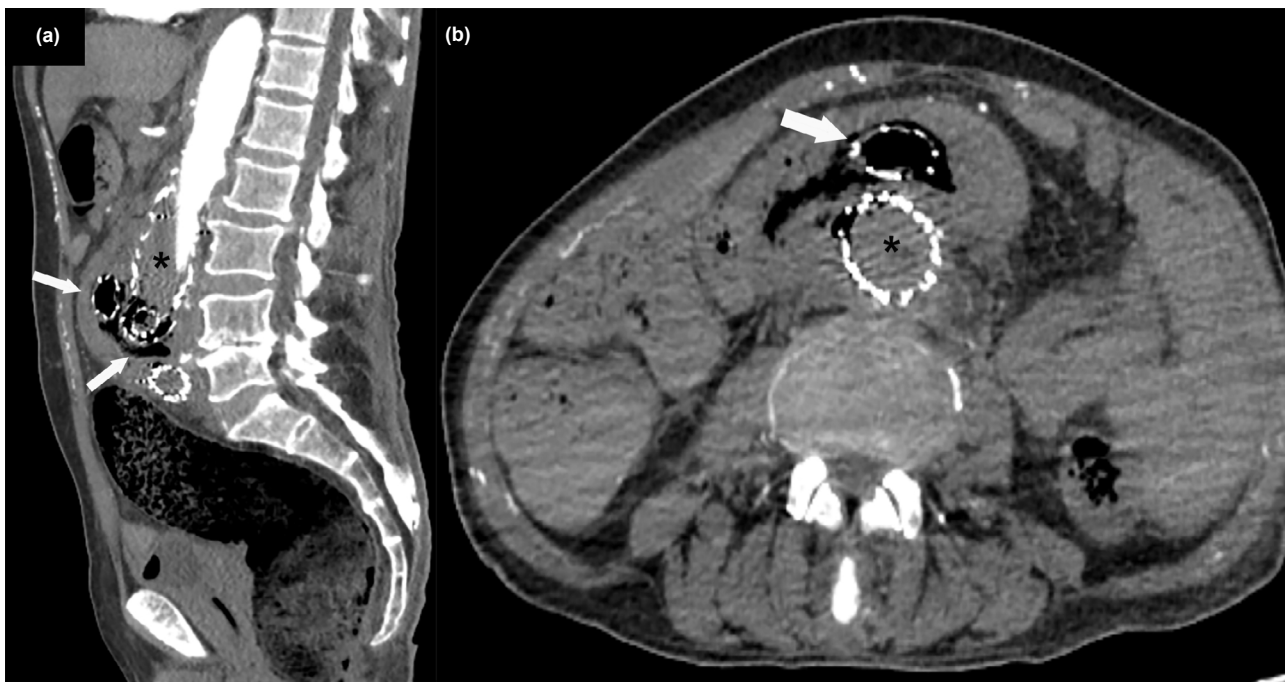

Figure 1. Sagittal **(a)** and axial **(b)** computed tomography (CT) angiography images obtained at the level of the duodenum and aorta show the aortic endograft filled with air and coursing into the duodenal lu**m**en (white arrows in a and b). Note the total occlusion of the aorta at the level of the stomach (black asterisks in a and b).

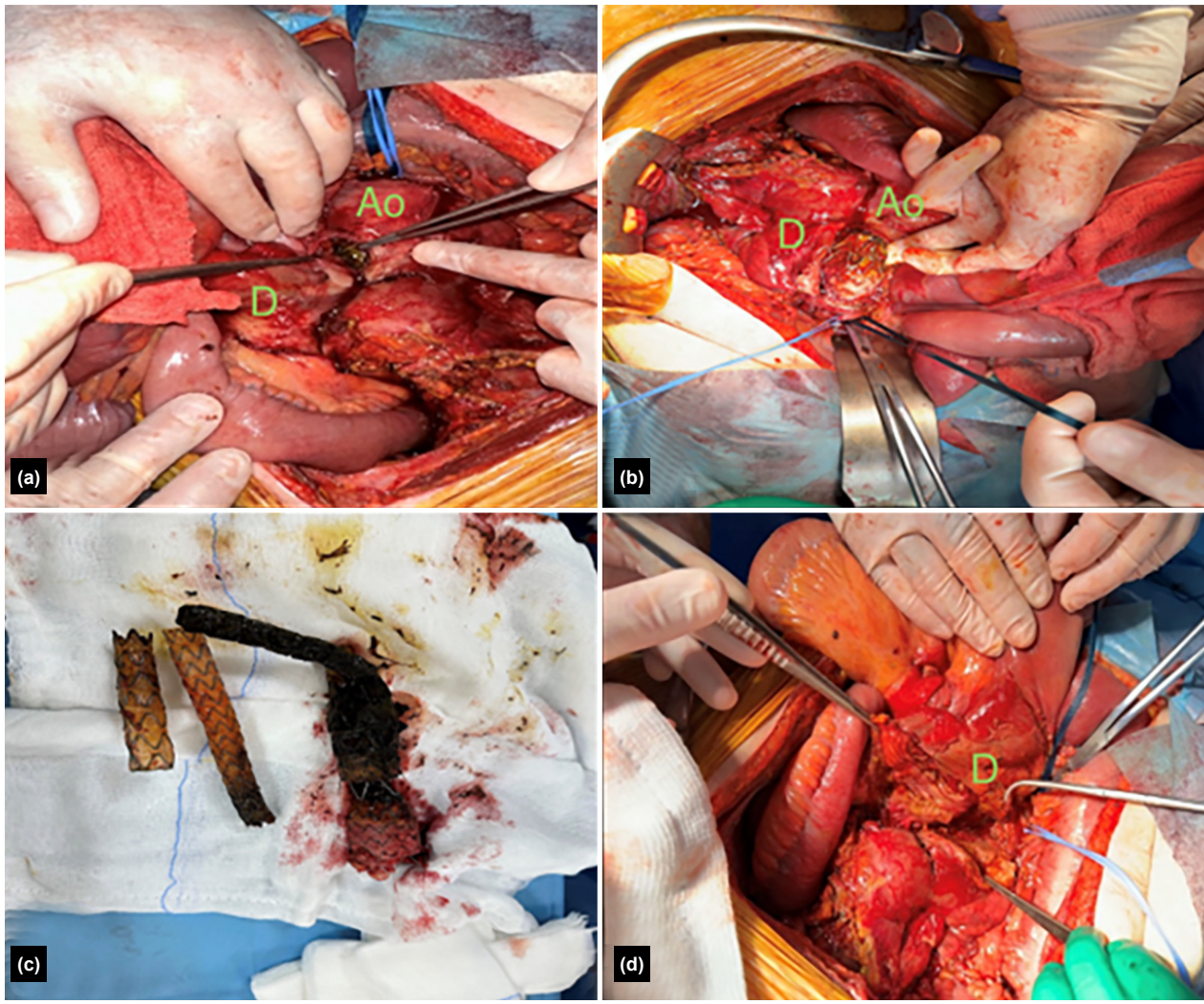

Figure 2. Intraoperative photographs show a fistula between the aorta and duodenum **(a and b)**. Postoperative view of the extracted endograft **(c)**. Direct visualization of the duodenal lumen **(d)**. Ao refers to the aorta, and D refers to the duodenum.

the right iliac bifurcation. The duodenum was opened, and the right limb of the endograft, extending upward within the lumen, was removed. It was determined that the ampulla of Vater was intact and that a Whipple procedure was not necessary; therefore, the duodenum was primarily repaired (Fig. 2). Since there was no distal ischemia in the right lower extremity and the abdomen was heavily infected, we avoided placing an additional vascular graft and ligated the aorta at the infrarenal level. The patient was admitted to the intensive care unit with high inotropic support. Unfortunately, the patient, who remained in septic shock, died 8 hours after surgery.

DISCUSSION

An abdominal aortic aneurysm can be defined as a pathological dilation of the aorta. It is a serious health problem affecting 4.8% of the population (6.0% in men and 1.6% in women) and may result in death due to the risk of rupture. It is most commonly observed in individuals aged 65-74 years.[5] Although the clinical presentation is generally silent, symptoms related to compression of surrounding organs and distal embolization may also occur. In cases of rupture, more dramatic findings such as abdominal or back pain, abdominal swelling, pallor, agitation, and hemodynamic shock may develop. Intervention is recommended for men with an abdominal aortic diameter ≥55 mm and for women with ≥50 mm.[6]

Currently, approximately 80% of patients undergoing intervention for AAA are treated with EVAR, while OAR is performed less frequently.[1] The main reason for this is that early survival outcomes are better in patients treated with EVAR. Antoniou et al.[4] reported that the 30-day mortality rate was 1.2% for EVAR and 3.1% for OAR, concluding that EVAR is superior to OAR in terms of 30-day mortality. EVAR has many advantages, such as being less invasive than OAR, allowing early mobilization, reducing the duration of hospital stay, being feasible under sedation without the need for gen-

eral anesthesia, and causing less postoperative pain. These advantages make EVAR a good treatment alternative for patients at high risk for open surgery. In the high-risk group of ruptured AAAs, approximately 80% of women and about 70% of men die.[1] Therefore, EVAR should be considered the primary approach in the treatment of ruptured AAAs.[1,6] The Management of Abdominal Aorto-iliac Aneurysms guidelines published by the European Society for Vascular Surgery (ESVS) in 2024 recommend an endovascular approach as the first-line treatment option for patients with AAA rupture and suitable anatomy (Class I, Level of Evidence A).

Unfortunately, the early advantages of EVAR do not necessarily translate into favorable long-term outcomes. Complications such as endoleak, endograft migration, endograft infection, endograft collapse, limb kinking or occlusion, and secondary aneurysm rupture negatively affect the long-term results of EVAR. Among these complications, the most common one is endoleak, which is also the condition that most frequently requires reintervention. Compared to OAR, long-term mortality rates, reintervention rates, and secondary rupture rates are significantly higher after EVAR. In other words, EVAR may become disadvantageous in the long term for the treatment of AAA. Therefore, when deciding on the procedure for elective AAA surgery, the patient's age and accompanying comorbidities should be the primary considerations. In a meta-analysis by Ben Li et al.,[3] at 5-9 years of follow-up, all-cause mortality was significantly higher in EVAR patients (27.3% vs. 24.7%), while reintervention rates were 17.6% versus 14.9%, and secondary rupture rates were 2.0% versus 0.6%. Current ESVS guidelines also recommend OAR for elective AAA treatment in patients with long life expectancy and low comorbidity (Class IIa, Level of Evidence B).[6]

Aortoenteric fistula after EVAR is a rare but fatal complication. Erosion caused by the endograft in the aortic wall has been reported as the most common mechanism for fistula development. Inflammation in the aneurysmal aortic wall after EVAR and primary infection of the endograft are other important causes of aortoenteric fistula. In some cases, however, a distinct etiological mechanism cannot be identified. Patients generally present with abdominal or back pain, nausea, vomiting, and gastrointestinal (GI) bleeding. Sometimes atypical findings such as fever, weight loss, or septic shock may also be present.[7] We believe that the aortoduodenal fistula in this case developed due to graft thrombosis and migration, followed by infection. Because the graft was thrombosed from the main body, the patient did not experience massive GI bleeding; instead, melena was present and the septic condition was predominant.

The case we present was lost due to this rare and fatal complication that developed in the long term. Reflecting on this case, the question of whether the decision for the index AAA intervention would have been more appropriate in favor of OAR inevitably arose. Although there is no definitive answer to this question, we recognize the need for a much more detailed, meticulous, and comprehensive evaluation when deciding which intervention to apply in similar cases. We believe that, compared with the previous decade, greater consideration should be given to OAR and its long-term advantages.

In conclusion, the preference for EVAR in patients with long life expectancy who are also suitable candidates for OAR may lead to an increase in long-term complications. To reduce such complications, patient selection should be performed meticulously and the most appropriate method should be chosen for each patient. In particular, centers with extensive experience in open surgery should consider OAR over EVAR in patient groups with long life expectancy. By presenting this rare and fatal EVAR complication, we hope to contribute to decision-making in the treatment of AAA.

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Conflict of Interest: None declared.

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OLGU SUNUMU - *ÖZ*

Endovasküler anevrizma onarımının nadir ve ölümcül geç dönem komplikasyonu: Endogreftin duedonuma göçü

Endovasküler anevrizma onarımı (EVAR), uygulama kolaylığı, hastanede kalış süresinin kısalması ve açık cerrahiyi tolere edemeyen hastalar için iyi bir alternatif olması nedeniyle abdominal aort anevrizmaları (AAA) için giderek popülerlik kazanan bir tedavi yöntemidir. EVAR'ın erken dönem sonuçları açık cerrahiye göre daha iyi olmakla birlikte, endoleak, migrasyon, endogreft uzuvlarında tromboz/kıvrılma, greft enfeksiyonu ve sekonder rüptür gibi komplikasyonlar görülebilir. Bu çalışmada, yaklaşık 10 yıl önce başka bir kurumda EVAR uygulanan ve genel durumunda bozulma, ateş ve melena şikayetleriyle kliniğimize başvuran bir hastayı sunuyoruz. 73 yaşında erkek hastanın laboratuvar incelemesinde beyaz kan hücresi (WBC) sayısı 17100, hemoglobin düzeyi 9.5 g/dL ve C-reaktif protein (CRP) düzeyi 261 g/L olarak bulundu. Bilgisayarlı tomografi (BT), EVAR greftinde tromboz, greft etrafında serbest hava, greft stentlerinde kırıklar ve sağ bacağın iliak bifurkasyon seviyesinde aortun dışına yer değiştirdiğini gösterdi. Endogreftin duodenuma doğru göç ettiği ve fistülleştiği görüldü. Sepsis ile başvuran hasta acil ameliyata alındı. İlk olarak sol bacaktaki iskemiyi gidermek için sol aksillofemoral baypas yapıldı. Daha sonra genel cerrahi ve kalp damar cerrahisi bölümlerinin ortak katılımıyla laparotomi yapıldı. Karın içi fekal kontaminasyon ve sigmoid kolon rüptürü görüldü. Karın yıkandı, sigmoid kolon ve rektum eksize edildi ve kolostomi oluşturuldu. Daha sonra aortotomi yapılarak greftin ana gövdesi ve sol bacağı çıkarıldı. Duodenum açıldı ve fistülize olmuş sağ bacak endogrefti de çıkarıldı. Karın içi kontaminasyon, sağ bacakta muhtemelen kronik sürece bağlı yeterli kollateral dolaşım ve iskemi olmaması nedeniyle ek vasküler girişime gerek duyulmadı. Aort infrarenal seviyede bağlandı ve hasta yüksek inotropik destek alarak yoğun bakım ünitesine alındı. Hasta, postoperatif 8. saatte kaybedildi. Bilgilerimize göre, literatürde daha önce bildirilmemiş bu nadir ve benzersiz olguyu sunmamızın amacı, EVAR'ın uzun dönem komplikasyonlarına dikkat çekmek ve yüksek yaşam beklentisi olan hastalarda açık cerrahinin önemini vurgulamaktır.

Anahtar sözcükler: Abdominal aort anevrizması; endovascular anevrizma onarımı; uzun dönem komplikasyon.

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CASE REPORT

Subacute post-traumatic ascending myelopathy after cervical spinal cord injury: a rare and fatal complication

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ABSTRACT

Subacute post-traumatic ascending myelopathy (SPAM) is a rare but devastating complication of spinal cord injury (SCI). It is characterized by progressive neurological deterioration extending several segments above the primary lesion within days to weeks after trauma. The underlying pathophysiology remains uncertain, and treatment strategies are not standardized. A 38-year-old man sustained traumatic C6–7 spondylolisthesis with bilateral facet dislocation following a motorcycle accident. Initial magnetic resonance imaging (MRI) demonstrated cord contusion and edema extending from C5 to C7. After traction and reduction, the patient underwent anterior C6 corpectomy with placement of an expandable cage and C5–7 plating, followed by C5–6 total laminectomy and C4–7 posterior instrumentation. Postoperatively, partial neurological recovery was observed. However, on postoperative day 10, the patient developed quadriparesis rapidly progressing to quadriplegia, accompanied by spinal shock and respiratory failure requiring mechanical ventilation. Imaging studies excluded hematoma and implant failure, although postoperative MRI was limited by metallic artifacts. Differential diagnoses, including pulmonary embolism, cardiac dysfunction, and sepsis, were ruled out. Based on the clinical progression and exclusion of alternative causes, a diagnosis of ascending myelopathy was established. Despite intensive supportive care, the patient died on the fourth day of mechanical ventilation. SPAM remains an unpredictable and fatal complication of SCI. Limitations in postoperative imaging, particularly metal-related artifacts, may hinder diagnosis, underscoring the importance of correlating clinical and radiological findings. Vigilant monitoring and continued reporting of cases are essential to improve recognition, refine diagnostic strategies, and guide management of this rare entity.

Keywords: Ascending myelopathy; cervical trauma; complication; spinal cord injury; subacute post-traumatic ascending myelopathy (SPAM).

INTRODUCTION

Spinal cord injury (SCI) is a devastating condition associated with severe neurological impairment and high morbidity.[1] Although neurological deterioration immediately following trauma is not uncommon, progression of deficits to levels above the initial site of injury represents an unusual and alarming clinical phenomenon.[2]

Subacute post-traumatic ascending myelopathy (SPAM) is one such complication, characterized by unexpected cranial extension of neurological deficits within days to weeks after the initial insult.[3] The condition is poorly understood, with proposed mechanisms including vascular ischemia, cerebrospinal fluid (CSF) flow disturbances, inflammatory processes, and secondary injury cascades.[4-6]

No standardized treatment has been established, and management remains largely supportive.[7] We present the case of a patient with traumatic C6–7 spondylolisthesis and bilateral facet dislocation who, despite undergoing anterior and posterior decompression and stabilization, developed fatal ascending myelopathy in the postoperative period.

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CASE REPORT

A 38-year-old man with no significant past medical history was admitted to our emergency department following a motorcycle accident. On arrival, neurological examination revealed bilateral upper extremity weakness (grade 3/5), complete paraplegia of the lower extremities, loss of anal tone, and anesthesia below the C6 level. He was also in spinal shock, presenting with bradycardia and hypotension.

This study was conducted in accordance with the ethical standards of the institutional and national research committees and with the Declaration of Helsinki. Written informed consent was obtained from the patient for publication of this case and any accompanying images.

Initial radiological evaluation demonstrated C6–7 traumatic spondylolisthesis with bilateral facet dislocation and facet interlocking (Figure 1), along with spinal cord contusion and edema extending from C5 to C7 (Figure 2). The patient was placed in cervical traction, achieving reduction. He subsequently underwent an anterior C6 corpectomy with placement of an expandable cage and C5–7 anterior plating, followed by a C5–6 total laminectomy and C4–7 posterior instrumentation and fusion.

High-dose corticosteroid therapy was initiated according to the NASCIS II (National Acute Spinal Cord Injury Study II) protocol, consisting of an intravenous loading dose of 30 mg/kg methylprednisolone administered over one hour, followed by a continuous infusion of 5.4 mg/kg/hour for the subsequent 23 hours. This regimen was continued in the postoperative period as part of anti-edema and neuroprotective management.

In the immediate postoperative period, neurological status improved: upper extremity strength increased to 4/5, and minimal movement (1/5) was noted in the lower extremities. Despite this partial recovery and ongoing high-dose corticosteroid therapy, on postoperative day 10 the patient developed quadriparesis, which rapidly progressed to quadriplegia. At that time, the level of anesthesia, initially below C6, had ascended into the upper cervical dermatomes to the C3 level, consistent with ascending myelopathy. Features of spinal shock reappeared, accompanied by respiratory depression consistent with diaphragmatic palsy, necessitating intubation and mechanical ventilation.

Repeat cranial and cervical imaging excluded intracranial pathology, implant malposition, or postoperative hematoma (Figure 3). Although magnetic resonance imaging (MRI) was limited by metallic artifacts, no new compressive lesion was identified (Figure 4). Extensive investigations were subsequently performed to exclude other potential causes of deterioration. Thoracic computed tomography (CT) angiography ruled out pulmonary embolism, transthoracic echocardiography demonstrated normal cardiac function, and laboratory analyses, including complete blood count, electrolytes, renal and hepatic profiles, and infection markers, were within normal limits. As no alternative pathology was identified, and given the characteristic ascending neurological progression, a diagnosis of subacute post-traumatic ascending myelopathy was made. Despite intensive supportive treatment, the patient succumbed on the fourth day of mechanical ventilation.

DISCUSSION

Subacute post-traumatic ascending myelopathy is an uncommon but devastating complication of spinal cord injury. It is defined as progressive neurological deterioration extending four or more segments above the initial lesion, usually within days to weeks after trauma.[8] Although early neurological worsening by one or two levels is frequently observed in SCI,[2] the distinctive cranial extension seen in SPAM is rare and often associated with respiratory compromise and high mortality.[9]

Since Frankel's initial description in 1969,[10] only a limited number of cases and small series have been reported. Yablon et al.[11] demonstrated that ascending neurological deficits were more frequent among conservatively managed patients

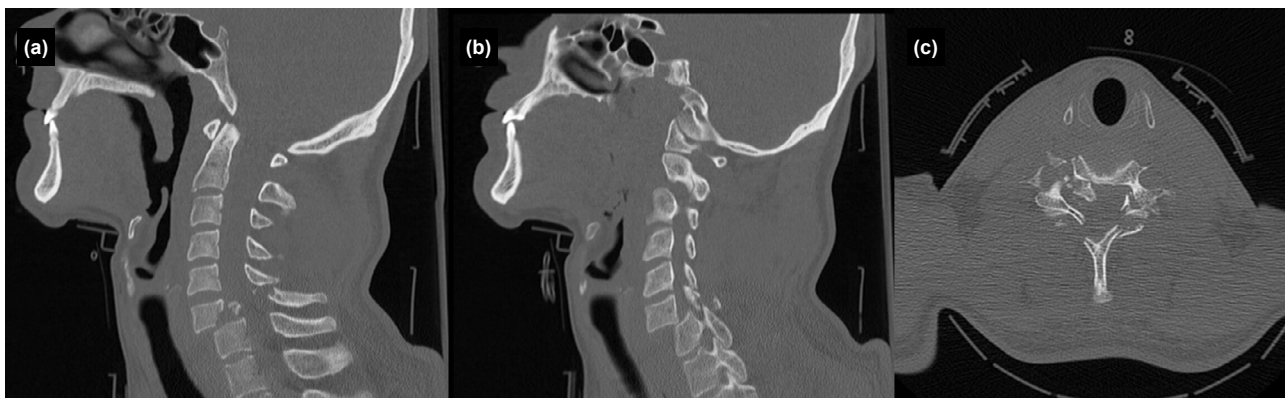

Figure 1. Preoperative cervical computed tomography (CT) images. **(a)** Sagittal reconstruction showing traumatic C6–7 dislocation. **(b)** Sagittal view demonstrating bilateral facet interlocking at C6–7. **(c)** Axial image confirming bilateral facet dislocation with locked facets.

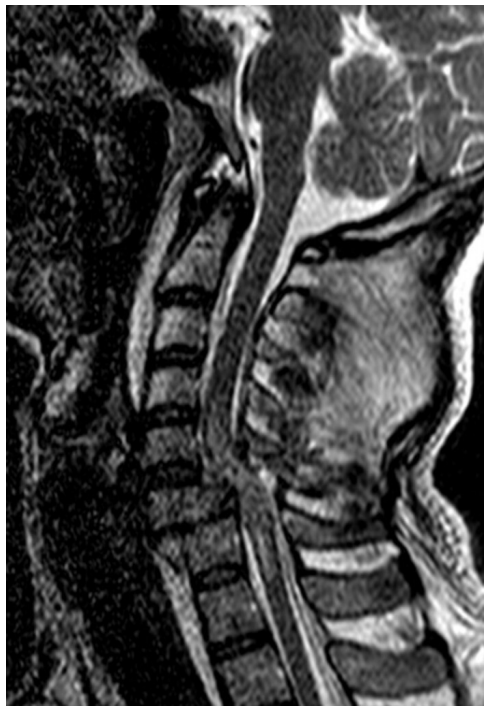

Figure 2. Preoperative sagittal T2-weighted magnetic resonance imaging (MRI) of the cervical spine demonstrating C6–7 dislocation with associated spinal cord contusion and edema extending from C5 to C7.

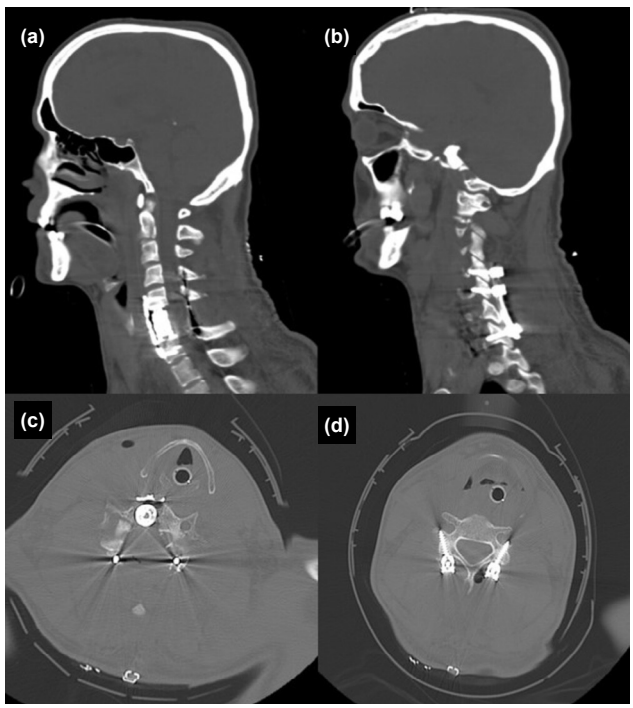

Figure 3. Postoperative cervical computed tomography (CT) images. **(a)** Sagittal reconstruction showing anterior C6 corpectomy with expandable cage placement and C5–7 anterior plating. **(b)** Sagittal view demonstrating posterior instrumentation from C4 to C7 with laminectomy at C5–6. **(c)** Axial CT image at the C6 level showing the anterior cage and plate construct. **(d)** Axial CT image at the C5 level showing posterior lateral mass screw fixation.

than among those who underwent surgical stabilization, suggesting that stabilization may play a protective role. Belanger et al.[3] subsequently defined SPAM as a distinct clinical entity, while Planner et al.[5] described characteristic MRI features, including cranially ascending T2 hyperintensity and cord swelling. More recent reviews, such as Zhang and Wang, confirm its estimated incidence of 0.4–1% and emphasize that no unifying mechanism has been established (Table 1).[7]

The proposed pathophysiology remains multifactorial, encompassing vascular ischemia or venous hypertension, cerebrospinal fluid flow obstruction, autoimmune inflammation, and reperfusion injury.[4,7] Pathological studies have identified cord edema, infarction, and apoptotic changes above the index injury, supporting both vascular and secondary injury hypotheses.[6] Clinically, SPAM often presents with stepwise or rapid deterioration, sometimes preceded by low-grade fever, pain, or autonomic instability.[5,12]

Therapeutic strategies are not standardized. High-dose corticosteroids, anticoagulation, and surgical approaches such as duraplasty or cord untethering have been attempted, with inconsistent results.[3,7,13] Supportive management, including hemodynamic stabilization, ventilatory support, and rehabilitation, remains the cornerstone of care.[7,9] Despite aggressive combined anterior and posterior decompression and stabilization in our case, the patient deteriorated neurologically on postoperative day 10, culminating in quadriplegia and respiratory failure.

A particular limitation of our case was the inability to radiologically demonstrate ascending myelopathy due to signifi-

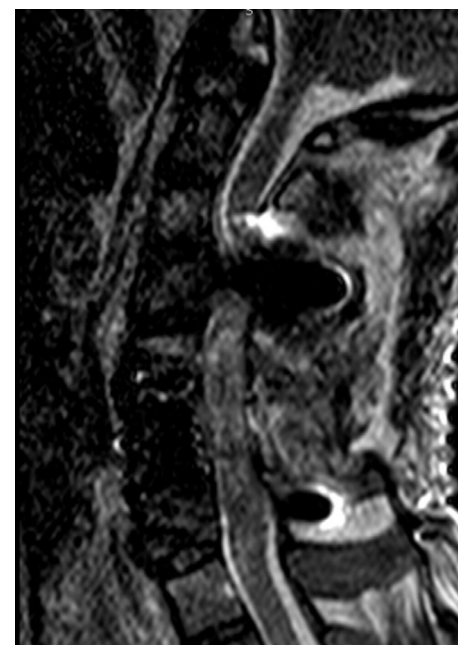

Figure 4. Postoperative sagittal T2-weighted magnetic resonance imaging (MRI) of the cervical spine. Metallic artifact from anterior and posterior instrumentation limits evaluation; however, no definite new compressive lesion is observed.

Table 1. Key reports of subacute post-traumatic ascending myelopathy (SPAM) after spinal cord injury

Author/Year	Study Design	N (Patients)	Pathology/ Proposed Mechanism	Location of Pathology	Levels Ascended	Outcome	Follow-up Duration
Frankel, 1969[10]	Case report	1	Early ascending cord lesion	Thoracic to cervical	12 levels	Fatal	17 days
Yablon et al., 1989[11]	Cohort study	134 (14 with SPAM)	Acute ascending myelopathy; higher risk with non-operative management	Various (cervical/thoracic)	1–4+	Variable; some fatal	Inpatient/early
Aito et al., 1999[9]	Case series	Several	Ascending myelopathy in early SCI	Cervical and thoracic	3–6	High morbidity	Short-term
Belanger et al., 2000[3]	Case series	3	SPAM defined as a distinct clinical entity	Thoracic and cervical	4–8	Two improved, one deteriorated	Months
Schmidt, 2006[4]	Case report	1	Vascular mechanism (venous hypertension, ischemia)	Lumbar → thoracic	5	Partial recovery	3 months
Planner et al., 2008[5]	Retrospective review	Multiple	MRI: cranially ascending T2 hyperintensity, cord swelling	Cervical/thoracic	≥4	Most stabilized; some residual deficits	Variable
Kumar et al., 2010[12]	Case report	1	Post-traumatic SPAM	Thoracic (T12) → higher levels	6	Survived with deficits	6 months
Al-Ghatany et al., 2005[6]	Case report with pathology	1	Infarction, edema, apoptosis the above lesion	Thoracic cord	Fatal 5–6	Autopsy	
Zhang & Wang, 2017[7]	Literature review	60+ (reviewed)	Multifactorial mechanisms	Poor prognosis;			
Biswas et al., 2022[8]	Case report	1	Ascending paralysis after SCI	Thoracolumbar to upper thoracic	8	Survived with deficits	6 months

The table summarizes study design, number of patients, proposed pathology or mechanism, anatomical location of the pathology, number of spinal levels ascended, clinical outcomes, and follow-up duration. SPAM: Subacute post-traumatic ascending myelopathy; SCI: Spinal cord injury; CSF: Cerebrospinal fluid; MRI: Magnetic resonance imaging.

cant metallic artifacts from instrumentation on postoperative MRI. Although no new compressive lesion or hematoma was identified, the artifact precluded optimal evaluation of intramedullary changes. Thus, the diagnosis of SPAM relied on the characteristic clinical progression and the exclusion of alternative etiologies such as pulmonary embolism, cardiac dysfunction, or sepsis. This limitation underscores the importance of correlating imaging with clinical findings and highlights the potential value of artifact-reducing MRI sequences or CT myelography in similar scenarios.

Overall, our case highlights the unpredictable course of SPAM, its high mortality despite timely surgical stabilization, and the diagnostic challenges posed by postoperative imaging limitations.

CONCLUSION

Subacute post-traumatic ascending myelopathy remains a rare but devastating complication of spinal cord injury, characterized by rapid neurological deterioration and high mortality. Its pathophysiology is still unclear; imaging may be limited in the postoperative setting, and no standardized treatment exists. Supportive care, therefore, remains the cornerstone of management, while vigilant neurological monitoring and continued reporting of cases are essential to improve early recognition, refine diagnostic strategies, and guide future therapeutic approaches.

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OLGU SUNUMU - *ÖZ*

Servikal omurga travması sonrası gelişen subakut posttravmatik asendan myelopati: Nadir ve ölümcül bir komplikasyon

Subakut posttravmatik asendan myelopati (SPAM), omurilik yaralanmalarının nadir fakat yıkıcı komplikasyonlarından biridir. Travmadan sonraki günler veya haftalar içinde, başlangıç lezyonunun birkaç segment üzerinde nörolojik kötüleşme ile kendini gösterir. Patofizyolojisi tam olarak bilinmemekte olup standart bir tedavi yaklaşımı yoktur. Otuz sekiz yaşındaki erkek hasta motosiklet kazası sonrası acil servise getirildi. Başlangıç radyolojik incelemelerde C6–7 düzeyinde travmatik spondilolistezis, bilateral faset dislokasyonu ve C5–7 düzeyinde medulla spinalis kontüzyonu ile ödem saptandı. Redüksiyon sonrası anterior C6 korpektomi, ekspandibl kafes ve C5–7 plak yerleştirilmesi yapıldı, ardından C5–6 total laminektomi ve C4–7 posterior enstrümantasyon uygulandı. Postoperatif dönemde kısmi nörolojik düzelme izlendi. Ancak 10. günde kuadriparezi hızla kuadriplejiye ilerledi; spinal şok bulguları ve solunum depresyonu gelişti. Kontrol görüntülemelerinde hematom veya implant malpozisyonu saptanmadı, ancak manyetik artefakt nedeniyle medulla intrensek patolojisi net değerlendirilemedi. Pulmoner emboli, kardiyak disfonksiyon ve sepsis gibi ayırıcı tanılar ekarte edildi. Klinik seyir asendan myelopati ile uyumlu değerlendirildi ve yoğun destek tedavisine rağmen hasta kaybedildi. SPAM, servikal omurga travmalarının nadir fakat ölümcül bir komplikasyonudur. Postoperatif dönemde metalik artefakt nedeniyle radyolojik tanı sınırlı olabilir. Bu nedenle klinik-radyolojik korelasyon, dikkatli nörolojik takip ve yeni vaka bildirimleri bu nadir sendromun daha iyi anlaşılması ve yönetimi açısından kritik öneme sahiptir.

Anahtar sözcükler: Asendan miyelopati; servikal travma; komplikasyon; omurilik yaralanması; SPAM.

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