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EXPERIMENTAL STUDY

Effect of allopurinol and oxypurinol treatment on apoptosis in an experimental testicular torsion model

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ABSTRACT

BACKGROUND: The aim of this study was to investigate whether allopurinol and oxypurinol treatment could mitigate oxidative stress and germ cell apoptosis in testicular ischemia-reperfusion (IR) injury.

METHODS: Thirty-two male rats were divided into four groups: Group 1 (Sham-Operated, n=8), in which the testicle was exposed but torsion was not performed; Group 2 (IR + Saline, n=8), in which torsion/detorsion was applied to the left testicle and 1 mL of normal saline was administered; Group 3 (IR + Allopurinol, n=8), in which torsion/detorsion was applied to the left testicle and 50 mg/kg allopurinol was administered; and Group 4 (IR + Oxypurinol, n=8), in which torsion/detorsion was applied to the left testicle and 50 mg/kg oxypurinol was administered. On postoperative day 28, left testicular tissue samples were collected, and total antioxidant status (TAS), total oxidant status (TOS), and oxidative stress index (OSI) levels were measured. Additionally, the gene expression levels of Bax, B-cell lymphoma 2 (Bcl-2), endothelial nitric oxide synthase (eNOS), and vascular endothelial growth factor A (VEGF-A) were analyzed.

RESULTS: Allopurinol and oxypurinol significantly decreased OSI levels ($p<0.001$). Oxypurinol was found to be significantly more effective in reducing oxidative stress ($p<0.001$). Both allopurinol and oxypurinol significantly reduced Bax gene expression levels ($p<0.001$). Treatment with allopurinol ($p=0.009$) and oxypurinol ($p=0.001$) significantly increased Bcl-2 levels. Additionally, both agents significantly reduced the apoptosis index ($p<0.001$). Allopurinol ($p_1=0.007$, $p_2<0.001$) and oxypurinol ($p_{1,2}<0.001$) treatments significantly increased eNOS and VEGF-A gene expression levels.

CONCLUSION: Allopurinol and oxypurinol reduce oxidative stress in the testis following IR injury, with oxypurinol demonstrating a greater antioxidant effect. Both treatments also reduce apoptosis by contributing positively to the eNOS and VEGF-A-mediated repair processes. Therefore, allopurinol and oxypurinol may serve as potential therapeutic agents for clinical application in testicular torsion.

Keywords: Sllopurinol; ischemia; oxypurinol; reperfusion; testicular torsion.

INTRODUCTION

Testicular torsion is a serious condition that, if not treated promptly, can lead to long-term consequences such as testicular atrophy and infertility. As the degree of torsion increases, blood flow to the testis decreases, resulting in ischemic damage to the tissue. This condition requires emergency surgical detorsion to prevent further ischemic injury.[1] However, surgical detorsion itself also promotes the generation of reactive oxygen species (ROS), leading to additional tissue dam-

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age. Germ cell apoptosis, which is significantly triggered by oxidative stress, has been detected in experimental models. Testicular germ cell apoptosis plays an important role in determining the prognosis of testicular torsion.[2]

Nitric oxide (NO) is a free radical present in nearly every tissue and plays a crucial role in regulating vascular tone, particularly within the cardiovascular system. Additionally, it exhibits anti-inflammatory and antioxidant properties, enabling it to interact readily with ROS in both physiological and pathological processes. Studies investigating ischemia-reperfusion (IR) injury in various biological systems have shown that NO reduces oxidative damage in tissues by modulating cellular processes that protect cells and tissues from oxidative stress.[3]

There are three distinct isoforms of nitric oxide synthase (NOS), the enzyme responsible for NO synthesis, each encoded by a different gene locus: neuronal (nNOS), inducible (iNOS), and endothelial (eNOS). eNOS is a structural isoform and is localized primarily to the membrane, accounting for approximately 90%. NO synthesized by eNOS in the endothelium diffuses into smooth muscle cells, leading to muscle relaxation. Although eNOS activity has been demonstrated in various tissues and organs (including mast cells, platelets, pancreatic β-cells), its primary source is the vascular endothelial cells.[4] Furthermore, several studies have shown that eNOS is expressed in Leydig and Sertoli cells, as well as in rare degenerated germ cells in the testis. It has also been demonstrated that germ cells in testes overexposed to IR damage express eNOS.[5] The excessive expression of eNOS suggests that NO plays a regulatory role in apoptosis. Recent studies have shown that NO exhibits strong anti-apoptotic activity and exerts tissue-protective effects in damage caused by IR, which represents a highly interesting and potentially significant area of research.[4]

Cell death is one of the fundamental physiological processes occurring in all living organisms. Programmed cell death occurs through three main pathways: apoptotic cell death, autophagic cell death, and necroptotic cell death. Currently, two major pathways have been defined for apoptosis: the extrinsic (death receptor) pathway and the intrinsic (mitochondrial) pathway. Although these two programmed cell death mechanisms are not completely independent, they share similarities in the proteins that regulate the process and can influence one another depending on the stimulus that triggers cell death. The intrinsic pathway is activated by intracellular signals released when cells are under stress and proceeds through the release of proteins from the mitochondrial intermembrane space. B-cell lymphoma 2 (Bcl-2) is a protein with both proapoptotic and antiapoptotic functions that plays a crucial role in the intrinsic apoptotic pathway; approximately 25 different types have been identified to date. Bcl-2 proteins are central regulators of the intrinsic apoptotic pathway and determine whether a cell will undergo apoptosis. Bax (Bcl-2 associated X apoptosis regulator) is a proapoptotic member of the Bcl-2 family capable of forming pores in the outer mitochondrial membrane. These molecules are involved in the initiation of apoptosis.[6,7]

During embryonic development, vascular endothelial growth factor (VEGF) plays a significant role in regulating angiogenesis in various physiological processes, including neovascularization, wound healing, ovulation, the menstrual cycle, blood pressure regulation, and pregnancy. VEGF was first identified as a permeability factor in tumor studies. Since then, it has been shown to be one of the key molecules in endothelial cell proliferation and angiogenesis. It exerts this effect by promoting cell migration and facilitating new vessel formation.[8] VEGF is one of the primary factors responsible for the formation and proliferation of endothelial cells. It also stimulates the expression of anti-apoptotic proteins in endothelial cells. NO plays an important role in the angiogenesis and increased vascular permeability induced by VEGF. A study conducted in mice lacking iNOS and eNOS enzymes demonstrated a reduction in the effectiveness of VEGF.[9]

Allopurinol was initially used for cancer treatment but was found to be ineffective. Later, its role in purine metabolism and its identification as a xanthine oxidase inhibitor led to its approval for the treatment of hyperuricemia and gout in 1966.[10]

Xanthine oxidase converts allopurinol into its main metabolite, oxypurinol. Both compounds are analogs of the purine bases xanthine and hypoxanthine. They inhibit the production of uric acid, the end product of purine catabolism, and reduce superoxide generation by inhibiting xanthine dehydrogenase activity. At low concentrations, allopurinol acts as both a substrate and a competitive inhibitor of the enzyme, whereas at high concentrations, it functions as a non-competitive inhibitor. Oxypurinol, the active metabolite of allopurinol, is a non-competitive inhibitor of the enzyme. The formation of oxypurinol accounts for most of the pharmacological effects of allopurinol, and its prolonged presence in tissues is significant.[10]

Compared to allopurinol, oxypurinol has been shown to possess various properties, including antioxidant, anti-inflammatory, and cell death–preventive effects. Escobar et al.[18] demonstrated that oxypurinol protects against oxidative damage in acute pancreatitis. In an IR study conducted in rats, oxypurinol was shown to have a protective effect on the myocardium.[11]

Effective treatment following testicular torsion may provide protection against the adverse effects of IR injury.[12] In this study, we investigated whether treatment with allopurinol and oxypurinol could reduce oxidative stress and germ cell apoptosis in rat testes following IR.

MATERIALS AND METHODS

The study was approved by the InstitutionalF Review Board for the Care and Use of Laboratory Animals (this study was

approved by the Suleyman Demirel University Animal Experiments Local Ethics Committee date: 12.04.2023, decision no: 148). All procedures were conducted in accordance with the ARRIVE guidelines (Animal Research: Reporting of In Vivo Experiments), the UK Animals (Scientific Procedures) Act 1986 and its associated guidelines, EU Directive 2010/63/EU for animal experimentation, and the National Research Council's Guide for the Care and Use of Laboratory Animals.

Experimental Groups

In this study, 32 male Wistar albino rats weighing between 259 and 465 g were used. The animals were housed under standardized conditions and kept in separate cages. The rats were randomly divided into four groups:

• Group 1 (Sham-Operated, n=8): The testicle was exposed, but torsion was not performed.

• Group 2 (IR-Saline, n=8): Torsion/detorsion was applied to the left testicle, and normal saline was administered.

• Group-3 (IR-Allopurinol, n=8): Torsion/detorsion was applied to the left testicle, and allopurinol was administered.

• Group 4 (IR-Oxypurinol, n=8): Torsion/detorsion was applied to the left testicle, and oxypurinol was administered.

Preparation of Allopurinol and Oxypurinol

The raw materials for the preparation of the parenteral forms of allopurinol (HY-B0219-500) and oxypurinol (HY-19657-200) were obtained from the MedChemExpress LLC (New Jersey, USA). The drugs were prepared under sterile conditions according to the manufacturer's recommendations and were administered at a dose of 50 mg/mL.

Surgical Procedure and Sample Harvesting

After 12 hours of fasting, the rats were weighed and anesthetized via intraperitoneal injection of ketamine hydrochloride (90 mg/kg) and xylazine hydrochloride (10 mg/kg). Using sterile surgical techniques, a midline scrotal incision was made, and the left testicle was exposed. In the IR-Saline, IR-Allopurinol, and IR-Oxypurinol groups, a torsion model was created by rotating the testicle and its cord 720° clockwise for two hours. The testicle was then fixed to the scrotum with a 5/0 silk suture to prevent detorsion, and the scrotum was closed. Thirty minutes before the detorsion procedure, 1 mL of normal saline was administered intraperitoneally to the IR-Saline group, whereas allopurinol and oxypurinol were administered intraperitoneally at a dose of 50 mg/kg to the IR-Allopurinol and IR-Oxypurinol groups, respectively. After two hours of ischemia, the scrotal incision was reopened, detorsion procedure was performed, and the incision was closed in all IR groups. During the reperfusion period, the rats were allowed free access to standard chow and water. On the 28th day of the experiment, all animals were sacrificed, and the left testicle of each animal was harvested and stored at -80°C until further analysis.

Determination of Total Antioxidant Status, Total Oxidant Status, and Oxidative Stress Index

Total antioxidant status (TAS) and total oxidant status (TOS) were measured using colorimetric methods with TAS and TOS kits kit (REL Assay Diagnostics, Türkiye), following the manufacturer's instructions. The TAS assay was calibrated with Trolox, and results were expressed as µmol Trolox equivalent/L (µmol Trolox eq/L). TOS levels were determined based on the oxidation of ferrous ions to ferric ions in an acidic medium in the presence of various oxidative species. The analyses were performed using three different portions of the same tissue sample, and each portion was assessed in three technical replicates.

TAS and TOS results were presented in the graph as fold changes compared to the control group. The oxidative stress index (OSI) values were calculated as the ratio of TOS to TAS.

Quantitative Reverse Transcription Polymerase Chain Reaction (RT-qPCR)

Total RNA was isolated from minced rat testis tissues using the Monarch® Total RNA Miniprep Isolation Kit (New England Biolabs) according to the manufacturer's instructions. RNA purity and quality were measured using a microspectrophotometer (Allsheng). Approximately 500 ng of RNA from each sample was converted into complementary DNA (cDNA) using the iScriptTM cDNA Synthesis Kit (Bio-Rad) following the manufacturer's protocol. qRT-PCR was performed on a CFX Connect Real-Time PCR System (Bio-Rad) using iTaq Universal SYBR® Green Supermix (Bio-Rad) according to the manufacturer's instructions. Primer sequences for rat endothelial nitric oxide synthase (eNOS), vascular endothelial growth factor-A (VEGF-A), Bax, Bcl-2, and glyceraldehyde-3-phosphate dehydrogenase (GAPDH) were generated using the NCBI BLAST interface. Primer sequence information is provided in Table 1. Relative gene expression levels were normalized to GAPDH expression, and quantification was performed using the ΔΔCt method.

Statistical Analysis

Statistical analyses were conducted using SPSS 23.0 (IBM Inc., Chicago, IL, USA). Tukey's Honestly Significant Difference (HSD) test and one-way analysis of variance (ANOVA) were used to compare measurements between the study groups for statistical significance. Normality was assessed using the Kolmogorov-Smirnov test, and homogeneity of variance was evaluated with Levene's test. Continuous variables with normal distribution were presented as mean±standard deviation (SD). The level of statistical significance was set at $p<0.05$.

RESULTS

TAS, TOS, and OSI Levels

A significant increase in TAS levels was observed in the IR-Saline ($p=0.002$), IR-Allopurinol ($p<0.001$), and IR-Oxypurinol ($p<0.001$) groups compared with the sham-operated group.

Table 1. Quantitative real-time polymerase chain reaction (qRT-PCR) primer sequences

Gene	Primer Direction	Primer Sequence
BAX	Forward	5'-GCAGAGGATGATTGCTGATGT-3'
	Reverse	5'-CCTTGAGCACCAGTTTGCTA-3'
BCL2	Forward	5'-GTGGATGACTGAGTACCTGAAC-3'
	Reverse	5'-GAGACAGCCAGGAGAAATCAA-3'
eNOS	Forward	5'-GTGAAGGCGACTATCCTGTATG-3'
	Reverse	5'-CATGCTCTAGGGATACCACATC-3'
VEGF-A	Forward	5'-GGAAGAGAGAGAGAGAGAGAGAC-3'
	Reverse	5'-GACTGGTCCGATGAAAGATCC-3'
GAPDH	Forward	5'-CAAGGTCATCCCAGAGCTGAA-3'
	Reverse	5'-CATGTAGGCCATGAGGTCCAC-3'

Table 2. Total antioxidant status (TAS), total oxidant status (TOS), and oxidative stress index (OSI) values of the groups (values are presented as mean±standard deviation)

Group	TAS (mmol Trolox Eq/L)	TOS (μmol H_2O_2 Eq/L)	OSI
Sham-operated	1.06±0.15^{a}	3.86±1.02^{a}	3.71±1.07^{a}
IR-Saline	1.52±0.11^{b} ($p=0.002$)	31.19±1.88^{b} ($p<0.001$)	20.35±2.19^{b} ($p<0.001$)
IR-Allopurinol	2.41±0.38^{c} ($p<0.001$)	15.93±0.69^{c} ($p<0.001$)	6.72±0.86^{c} ($p<0.001$)
IR-Oxypurinol	3.84±0.15^{d} ($p<0.001$)	10.94±0.90^{d} ($p<0.001$)	2.85±0.27^{a} ($p=0.554$)

^{a,b,c,d} Different superscript letters indicate statistically significant differences. TAS: Total antioxidant status; TOS: Total oxidant status; OSI: Oxidative stress index.

Allopurinol and oxypurinol treatments significantly increased TAS levels compared to the IR-Saline group ($p<0.001$). Oxypurinol increased TAS levels significantly more than allopurinol ($p<0.001$) (Table 2).

Compared to the sham-operated group, TOS levels were significantly higher in all IR groups ($p<0.001$). TOS levels were significantly lower in the IR-Allopurinol and IR-Oxypurinol groups when compared to the IR-Saline group ($p<0.001$). Oxypurinol decreased TOS levels significantly more than allopurinol ($p<0.001$) (Table 2).

Compared to the sham-operated group ($p<0.001$), OSI levels were significantly higher in the IR-Saline and IR-Allopurinol groups. However, no significant difference was observed between the IR-Oxypurinol and sham-operated groups ($p=0.554$). Both allopurinol and oxypurinol treatments significantly reduced OSI values compared to the IR-Saline group ($p<0.001$). Oxypurinol was more effective than allopurinol in reducing oxidative stress ($p<0.001$) (Table 2, Fig. 1).

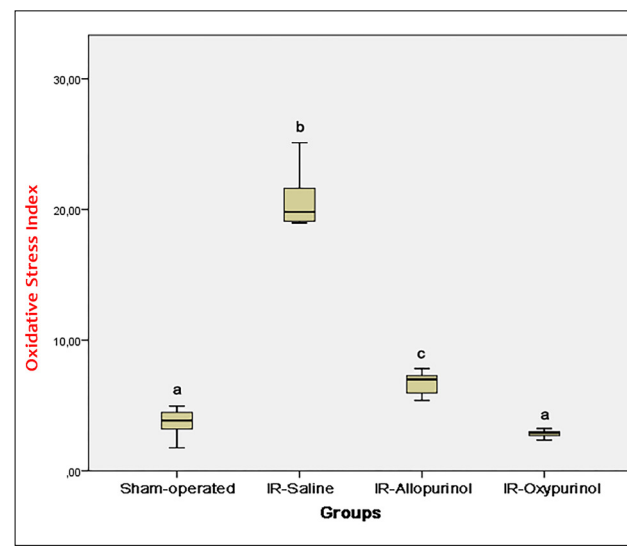

Figure 1. Oxidative stress index (OSI) levels among the groups.

Bax, Bcl-2 Gene Expression Levels, and Bax/Bcl-2 Ratio

Bax gene expression levels were significantly increased in the IR-Saline group compared to the other groups ($p<0.001$). Allopurinol and oxypurinol treatments significantly decreased Bax gene expression levels compared to the IR-Saline group ($p<0.001$). No significant difference was found between the IR-Allopurinol and IR-Oxypurinol groups ($p=0.171$) (Table 3).

Table 3. Bax, Bcl-2 gene expression levels and Bax/Bcl-2 ratios of the groups (values are presented as mean±standard deviation)

Group	Bax	Bcl-2	Bax/Bcl-2
Sham-operated	1.00±0.08[a]	1.00±0.07[a]	1.00±0.10[a]
IR-Saline	1.43±0.13[b] (p<0.001)	0.48±0.08[b] (p=0.002)	3.01±0.48[b] (p<0.001)
IR-Allopurinol	1.10±0.07[a] (p=0.277)	0.92±0.45[a] (p=0.917)	1.40±0.59[a] (p=0.193)
IR-Oxypurinol	0.98±0.13[a] (p=0.990)	1.02±0.21[a] (p=0.999)	0.98±0.09[a] (p=0.999)

[a,b] Different superscript letters indicate statistically significant differences.

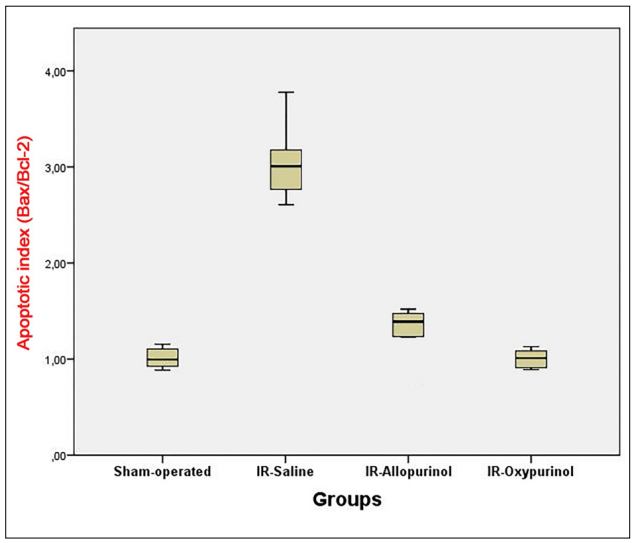

Figure 2. Apoptotic index values among the groups.

Table 4. Endothelial nitric oxide synthase (eNOS) and vascular endothelial growth factor A (VEGF-A) gene expression levels of the groups (values are presented as mean±standard deviation)

Group	eNOS	VEGF-A
Sham-operated	1.00±0.09[a]	1.00±0.08[a]
IR-Saline	1.24±0.16[b] (p=0.006)	1.20±0.18[a] (p=0.342)
IR-Allopurinol	1.48±0.11[c] (p<0.001)	1.74±0.18[b] (p<0.001)
IR-Oxypurinol	1.60±0.16[c] (p<0.001)	2.42±0.27[c] (p<0.001)

[a,b,c] Different superscript letters indicate statistically significant differences.

Bcl-2 gene expression levels were significantly decreased in the IR-Saline group compared to the other groups (p=0.002). Compared to the IR-Saline group, allopurinol (p=0.009) and oxypurinol (p=0.001) treatments significantly increased Bcl-2 gene expression levels. No significant difference was found between the IR-Allopurinol and IR-Oxypurinol groups (p=0.863) (Table 3).

The Bax/Bcl-2 ratio (apoptotic index) was significantly increased in the IR-Saline group compared to the other groups (p<0.001). Compared to the IR-Saline group (p<0.001), both allopurinol and oxypurinol treatments significantly decreased the Bax/Bcl-2 ratio. No significant difference was found between the IR-Allopurinol and IR-Oxypurinol groups (p=0.159) (Table 3, Fig. 2).

eNOS and VEGF-A Gene Expression Levels

Compared to the sham-operated group, eNOS gene expression levels were significantly higher in the IR-Saline (p=0.006), IR-Allopurinol (p<0.001), and IR-Oxypurinol (p<0.001) groups. Allopurinol (p=0.007) and oxypurinol (p<0.001) treatments significantly increased eNOS gene expression levels compared to the IR-Saline group. No significant difference was found between the IR-Allopurinol and IR-Oxypurinol groups (p=0.306) (Table 4).

VEGF-A gene expression levels were significantly higher in the IR-Allopurinol and IR-Oxypurinol groups compared to the sham-operated group (p<0.001), whereas no significant difference was found between the IR-Saline group and sham-operated groups (p=0.342). Allopurinol and oxypurinol treatments significantly increased VEGF-A gene expression levels compared to the IR-Saline group (p<0.001). Oxypurinol increased VEGF-A gene expression levels significantly more than allopurinol (p<0.001) (Table 4).

DISCUSSION

The present study aimed to investigate the protective effects of allopurinol and oxypurinol on germ cell apoptosis induced by testicular IR in rats. The findings indicate that testicular IR significantly induces germ cell apoptosis in rats, whereas allopurinol and oxypurinol activate repair mechanisms by reducing apoptosis.

The testes are highly susceptible to ischemic damage due to the terminal nature of their blood supply and the lack of arterial anastomoses. The duration of testicular torsion is directly proportional to the extent of damage. The salvage rate of the testis is 90% in patients who undergo surgical detorsion within six hours.[13] After this critical period, the salvage rate decreases significantly. However, it is unclear whether

testicular function is fully preserved even after early surgical detorsion. Even a few hours of untreated torsion can damage testicular tissue and lead to functional loss. Experimental studies have shown that when the twisted testis is left in place after unilateral testicular torsion, damage to the blood-testis barrier may occur, affecting both testes and potentially reducing fertility. Testicular torsion followed by detorsion has been shown to induce the formation of ROS, which can result in germ cell apoptosis and DNA damage in the testis. Oxidative stress negatively affects sperm concentration and motility and is therefore considered a significant cause of male infertility. Studies have demonstrated that detorsion can impair the exocrine functions of the testis, cause changes in sperm morphology, and lead to decreased sperm motility and count. Therefore, additional therapeutic strategies are needed following surgical detorsion.[14] Effective treatment following testicular torsion can provide protection against the detrimental effects of IR. Various drugs have been successfully tested in animal models to reduce the adverse effects of IR in testicular torsion.[15] The fundamental mechanism of these agents is the regulation of blood flow after injury, reduction of germ cell apoptosis, and minimization of oxidative stress. These agents have largely been used in experimental torsion models. However, there are also studies in which treatment was administered before torsion.[16] Since testicular torsion is an unpredictable condition, initiating appropriate treatment after torsion is more meaningful in terms of clinical applicability. Testicular torsion is an emergency situation, and in our clinical practice, the time from diagnosis to emergency testicular detorsion is approximately 30 minutes. Therefore, we determined this period based on the assumption that these drugs could be administered immediately after diagnosis and exert a protective effect on the testicles until surgery. Despite the promising results of experimental studies, the greatest challenge is translating one or more of these agents into clinical use. In this context, since allopurinol and oxypurinol, which were used as antioxidants in our study, are already clinically prescribed for conditions such as hyperuricemia and gout, their application in the clinical management of testicular torsion may be more feasible.

Allopurinol, a xanthine oxidase inhibitor, is a urate-lowering drug used in the treatment of hyperuricemia and gout. Various studies have demonstrated the protective effects of allopurinol on the testis after IR in experimental models.[17] Oxypurinol, the active metabolite of allopurinol, has been reported to have stronger biological properties, including antioxidant, anti-inflammatory, and anti-apoptotic activities in various pathological conditions. Oxypurinol protects against oxidative damage in acute pancreatitis and regulates pro-inflammatory genes.[18] Another study showed that oxypurinol protects cardiac tissue from IR damage in rats.[19] In our opinion, no study has yet investigated the effects of allopurinol and oxypurinol on germ cell apoptosis in testicular torsion. Therefore, the results of this study add novel information to the current literature.

The mechanisms underlying testicular damage following IR have not yet been fully elucidated. The main pathophysiological events in testicular torsion are ischemia caused by twisting of the spermatic cord and reperfusion injury resulting from surgical correction of the torsion. IR injury involves neutrophil migration, the formation of pro-inflammatory cytokines and adhesion molecules, lipid peroxidation, apoptosis, anoxia, and changes in microvascular blood flow.[12] The most important factor initiating cytotoxic events after reperfusion is the ROS produced by xanthine oxidase (XO). ROS increases membrane permeability and disrupts membrane integrity through the oxidation of lipids in cellular and mitochondrial membranes[20] Our study showed that allopurinol and oxypurinol, which are XO inhibitors, reduce oxidative stress in the testis after IR, and that oxypurinol is a more effective antioxidant than allopurinol.

Experimental data have shown that germ cells in the testis are highly sensitive to ischemia and are susceptible to damage following IR. The most important pathological mechanism in this injury is germ cell apoptosis. Due to oxidative damage, significant germ cell apoptosis has been observed in experimental testicular torsion/detorsion models. Clinical and animal studies have shown that apoptosis can lead to germ cell loss and reduced spermatogenesis. Apoptosis is a physiological process by which the body eliminates unwanted cells and serves as the primary defense mechanism against damaged cells.[4,5] Various regulatory genes involved in apoptosis have been identified.

Studies have shown that the Bcl-2 protein family, including pro-apoptotic (Bax, Bak, Bid, and Bim) and anti-apoptotic (Bcl-2, Bcl-xL) molecules, plays an important role in regulating germ cell apoptosis.[21] Some studies in various experimental models have revealed that the Bax/Bcl-2 system is crucial for the maintenance of normal spermatogenesis.[22] In addition to their roles in normal testicular physiology, Bax and Bcl-2 proteins have also been found to be significant in the development of various testicular disorders, such as testicular hyperthermia, cryptorchidism, and radiation-induced testicular damage.[[23] In the present study, Bax and Bcl-2 gene expression levels were measured to assess the level of germ cell apoptosis in testicular tissue using qRT-PCR. A significant increase in the apoptotic index was identified in the IR-Saline group compared to the sham-operated group. This result demonstrates that oxidative damage leads to germ cell apoptosis in testicular tissue. The results of the present study also showed that treatment with allopurinol and oxypurinol administered after IR effectively reduces germ cell apoptosis. However, no difference was observed between the two drugs in terms of anti-apoptotic properties.

Nitric oxide, which has dual effects on both cell survival and death, plays a vital role in testicular disorders, including testicular torsion and inflammation. However, the functions of NOS in testicular torsion are currently not well understood. [24] NOS is an enzyme family that catalyzes the production

of NO from L-arginine. There are three subtypes: neuronal NOS (nNOS), endothelial NOS (eNOS), and inducible NOS (iNOS).[25] Previous studies have shown that eNOS, in particular, accelerates angiogenesis under ischemic stress conditions.[26] Phosphorylation of eNOS leads to its activation and NO production. The potential importance of NO in IR stems from its role as an antioxidant in both physiological and pathological processes, as it readily interacts with ROS and reduces oxidative damage in various biological systems.[27] NO has both toxic and protective effects following IR injury. High levels of NO produced by iNOS and nNOS can cause cell damage or death. However, NO produced by eNOS has been shown to reduce oxidative damage in various biological systems. NO has also exhibited anti-inflammatory effects by mediating several inflammatory processes, such as preventing neutrophil infiltration and reducing pro-inflammatory cytokine levels.[28] These anti-inflammatory effects contribute to tissue protection against IR damage. Additionally, degenerative germ cells in the testis have been shown to excessively express eNOS.,[29] suggesting that eNOS and eNOS-mediated NO play a role in germ cell apoptosis. It has also been observed that NO inhibits recombinant human caspases, a family of cysteine proteases that play a critical role in the initiation and execution of apoptosis, in a dose-dependent manner.[30] In this study, eNOS levels were found to be significantly increased in all IR groups compared to the sham-operated group. This result indicates that the tissue enters a repair process after IR. Moreover, allopurinol and oxypurinol increased eNOS levels significantly more than the IR-Saline group. These findings suggest that treatment with allopurinol and oxypurinol after IR may positively contribute to the repair process through antioxidant and anti-apoptotic effects by increasing eNOS-mediated NO production.

Angiogenesis is a physiological process that enables the formation of new vessels from pre-existing vascular structures in response to ischemia. VEGF is the most important factor in the angiogenic process. In previous studies, exogenous local injection of VEGF has been shown to improve neovascularization in both mice and humans.[31] An experimental study on renal IR demonstrated that increased VEGF expression is associated with reduced renal damage through enhanced new blood vessel formation.[32] The presence of VEGF in normal testicular tissue, prostate, and seminal vesicles, as well as its high levels in semen, suggests that it plays an important role in male reproductive physiology.[33] In testicular tissue, VEGF contributes to both angiogenesis and steroidogenesis in Leydig cells. It also maintains the permeability of testicular blood vessels by regulating testicular function.[34] In a study conducted on rats, VEGF protein expression was reported to be significantly decreased in the testicular IR group, while VEGF levels increased in the treatment group, leading to increased vascularization and reduced damage.[35] In the present study, allopurinol and oxypurinol treatment significantly increased VEGF-A gene expression levels compared to the sham-operated and IR-Saline groups. This result suggests that allopurinol and oxypurinol treatment enhances vascularization in testicular tissue after IR. Theoretically, increased vascularization may reduce testicular damage; however, further studies including pathological tissue scoring are needed to confirm this conclusion.

Our study has several limitations. First, as an experimental study, the sample size was limited. Second, testicular size was not measured, as we initially planned to focus on pathology and apoptosis. Histopathological examination could not be performed due to a technical problem. Finally, since hormone levels were not evaluated, we were only able to demonstrate the effects of the drugs on reducing infertility in the long term. Further studies are needed on this issue. We believe that our study may serve as a pioneer for future research.

CONCLUSION

In conclusion, testicular torsion caused a significant increase in germ cell apoptosis due to elevated testicular oxidative stress. Allopurinol and its active metabolite, oxypurinol, were shown to reduce oxidative stress in the testis after IR, and oxypurinol was found to be a more effective antioxidant than allopurinol. Treatment with allopurinol and oxypurinol was also shown to be effective in reducing germ cell apoptosis. In this respect, allopurinol and oxypurinol are potential agents for clinical applications in testicular torsion.

Ethics Committee Approval: This study was approved by the Suleyman Demirel University Animal Experiments Local Ethics Committee (Date: 12.04.2023, Decision No: 148).

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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DENEYSEL ÇALIŞMA - *ÖZ*

Deneysel testis torsiyonu modelinde allopurinol ve oksipurinol tedavisinin apoptozis üzerine etkisi

AMAÇ: Allopurinol ve oksipurinol tedavisinin testis iskemi-reperfüzyonunda (IR) oksidatif stresi ve germ hücre apoptozunu azaltıp azaltamayacağını incelemek.

GEREÇ VE YÖNTEM: Otuz iki erkek sıçan dört gruba ayrıldı: Grup 1 (Sham-Ameliyat, n=8), testis açığa çıkarıldı, ancak torsiyon uygulanmadı; Grup-2 (IR+Salin, n=8), sol testise torsiyon/detorsiyon uygulandı ve 1 ml serum fizyolojik verildi; Grup-3 (IR+Allopurinol, n=8), sol testise torsiyon/detorsiyon uygulandı ve 50 mg/kg allopurinol verildi; Grup 4 (IR+Oksipurinol, n=8), sol testise torsiyon/detorsiyon uygulandı ve 50 mg/kg oksipurinol verildi. Sol testis ameliyat sonrası 28. günde alındı ve dokuda TAS, TOS ve OSI düzeyleri ölçüldü. Ayrıca Bax, Bcl-2, eNOS ve VEGF-A gen ekspresyon düzeyleri incelendi.

BULGULAR: Allopurinol ve oksipurinol, OSI düzeylerini anlamlı şekilde azalttı ($p<0.001$). Oksipurinolün oksidatif stresi azaltmada anlamlı şekilde daha etkili olduğu bulundu ($p<0.001$). Allopurinol ve oksipurinol, Bax gen ekspresyon düzeyini anlamlı şekilde azalttı ($p<0.001$). Allopurinol ($p=0.009$) ve oksipurinol ($p=0.001$) tedavisi Bcl-2 düzeyini anlamlı şekilde artırdı. Allopurinol ve oksipurinol apoptoz indeksini anlamlı şekilde azalttı ($p<0.001$). Allopurinol ($p^1=0.007$, $p^2<0.001$) ve oksipurinol ($p^{1,2}<0.001$) tedavileri, eNOS ve VEGF-A gen ekspresyon seviyelerini anlamlı şekilde artırmıştır.

SONUÇ: Allopurinol ve oksipurinol, IR sonrası testiste oksidatif stresi azaltmada etkilidir ve oksipurinol daha güçlü bir antioksidan etkiye sahiptir. Allopurinol ve oksipurinol tedavisi, eNOS ve VEGF-A aracılı onarım sürecine olumlu katkıda bulunarak apoptozu azaltmada etkilidir. Bu açılardan, allopurinol ve oksipurinol, testis torsiyonunda klinik uygulamalar için potansiyel ajanlardır.

Anahtar sözcükler: Allopurinol; iskemi; oksipurinol; reperfüzyon; testis torsiyonu.

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EXPERIMENTAL STUDY

The potential use of tetracalcium phosphate in vertebral augmentation: A study in a sheep model

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ABSTRACT

BACKGROUND: Percutaneous vertebroplasty (PVP) and percutaneous kyphoplasty (PKP) are widely used to treat vertebral fractures. However, the standard filler material, polymethylmethacrylate (PMMA), presents significant drawbacks, including thermal damage, allergic reactions, and poor biocompatibility. Tetracalcium phosphate (TTCP), a calcium phosphate cement (CPC), has emerged as a promising alternative due to its superior biocompatibility, osteoconductivity, and ability to integrate with natural bone. This study aimed to evaluate the feasibility of TTCP for vertebral augmentation in a preclinical sheep model, focusing on biomechanical stability, biocompatibility, and osteogenic potential.

METHODS: Five Akkaraman sheep underwent PKP with TTCP at three lumbar vertebral levels (L2–L4). Under general anesthesia, TTCP cement was injected into cavities prepared according to the standard PKP procedure. Postoperative care included analgesia and antibiotics. Four animals were followed for 12–14 weeks, and one for 25 weeks. At the end of the study period, the animals were euthanized and vertebrae were harvested for biomechanical testing using a Shimadzu AG-IS 100 kN machine. Histological evaluation was performed to assess ossification stages according to Shapiro's classification. Statistical analysis was conducted using paired t-tests ($p<0.05$).

RESULTS: One animal was euthanized prematurely due to infection, while four completed the study without complications. Biomechanical analysis demonstrated no significant difference in compressive strength between treated and untreated vertebrae ($p>0.05$). Histological examination revealed osteoblastic activity, progressive mineralization, and successful bone integration.

CONCLUSION: TTCP demonstrated promising biomechanical and biophysiological properties for vertebral augmentation. However, its use in infected sites and in the presence of metabolic bone disorders may be limited. Further clinical studies are required to validate its long-term efficacy.

Keywords: Percutaneous vertebroplasty; percutaneous kyphoplasty; tetracalcium phosphate; calcium phosphate cements; polymethylmethacrylate.

INTRODUCTION

Percutaneous vertebroplasty (PVP) and percutaneous kyphoplasty (PKP) are minimally invasive procedures designed to reinforce weakened vertebrae caused by osteoporosis, tumors, or trauma.[1] These interventions involve the percutaneous injection of polymethylmethacrylate (PMMA) into the affected vertebrae to restore structural integrity.[1] First introduced in 1987 by Galibert and Deramond, PVP was initially performed to stabilize a collapsed C2 vertebra affected by a hemangioma through the percutaneous administration of PMMA.[1]

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Over the years, PVP and PKP techniques have been refined to achieve near-optimal clinical outcomes; however, the search for more advanced biomaterials remains ongoing.[2] Numerous studies, including our own,[2] have aimed to develop bone replacement materials that are not only biophysiologically compatible but also capable of overcoming the limitations of existing materials.[3-5] Despite its widespread use, PMMA continues to present several challenges, including the risk of allergic reactions, excessive heat generation during polymerization, biomechanical properties that differ from those of spinal bone, and difficulties in processing.[6] Most notably, the lack of intrinsic biocompatibility of PMMA has prompted continued exploration of alternative materials.[6]

Among the candidate materials under investigation, calcium phosphate cements (CPCs) have emerged as a promising class of biomaterials due to their exceptional biocompatibility and osteoinductive properties.[7-11] These attributes make CPCs particularly suitable for bone repair and replacement applications.[7-11] One of the most extensively studied types of CPC is tetracalcium phosphate (TTCP), which combines a basic TTCP component with an acidic counterpart, such as brushite or monetite.[12] This formulation exhibits a self-setting mechanism in which an acid-base reaction, triggered by the addition of a hardening liquid, results in the formation of calcium-deficient hydroxyapatite.[12] CPCs possess several advantageous properties, including high bioactivity, non-cytotoxicity, and osteoconductivity.[13] Furthermore, their biodegradability allows gradual replacement by newly formed bone tissue following implantation.[13] These characteristics have led to their widespread application in dental implantology, where they have been used to reinforce implant sites and stabilize implants in cases of insufficient bone volume.[13-15]

Given the favorable properties of TTCP and its potential role in bone repair, the present study was designed to evaluate its applicability for vertebral augmentation in a preclinical sheep model. The objective was to determine whether TTCP could serve as a viable alternative to currently used materials for vertebral stabilization, leveraging its superior biocompatibility and osteogenic potential.

MATERIALS AND METHODS

Ethical Approval and Funding

All experimental procedures were approved by the Animal Research Ethics Committee of our university (Decision No: 2023/12) and were conducted in strict accordance with the European Communities Council Directive (86/609/EEC) on animal welfare. Funding was provided by the Scientific Research Projects Fund of Niğde Ömer Halisdemir University (Project No: 2024/4). The study was conducted in compliance with the principles of the Declaration of Helsinki.

Animal Selection and Surgical Preparation

The study included five Akkaraman sheep (2 years of age; 60–70 kg) obtained from the Ayhan Şahenk Agricultural Research and Application Center of Niğde Ömer Halisdemir University (Fig. 1). The animals were fasted for 24 hours prior to surgery. Rectal temperature was monitored to maintain a stable body temperature of 37°C throughout the procedure. All experiments were conducted in a controlled environment under veterinary supervision (H.K.) and surgical supervision (İ.K.) (Fig. 1). General anesthesia was induced intravenously with xylazine hydrochloride (Rompun®, Bayer, İstanbul, Türkiye; 0.1 mg/kg) and ketamine hydrochloride (Ketalar®, Bayer, İstanbul, Türkiye; 2.2 mg/kg). The animals were positioned on their right side to minimize the risk of hypoxia (Fig. 1). Surgical readiness was confirmed by the absence of palpebral and pinch reflexes. Standard aseptic and antiseptic protocols were followed. The surgical field was disinfected with povidone-iodine (Dermosept®, Algilaç, İstanbul, Türkiye) and sterile draping was applied (Fig. 1).

PKP Procedure

For the PKP procedure, the L2–L4 vertebral landmarks (transverse and spinous processes) were identified by palpation. A sterile Jamshidi cannula needle was inserted percutaneously at a 45° angle, 3 cm lateral to the midline, advancing into the cancellous bone of the vertebral body. A drilling device was used to create a 1 cm-deep cavity, which was verified with a probe. Subsequently, 3 mL of TTCP compound, comprising alpha-tricalcium phosphate, dicalcium phosphate, tetracalcium phosphate, and calcium silicate powder mixed with a sodium citrate solution (Grandus® B-One, Permed Health Products, Çanakkale, Türkiye), was injected into the cavity. Each animal underwent PKP at vertebral levels L2–L4 (a total of 15 treated vertebrae). The entry points were closed using sharp-needle 0/0 polypropylene sutures.

Postoperative Care and Follow-up Period

Postoperative pain and inflammation were managed with meloxicam (Maxicam®, Sanovel, İstanbul, Türkiye; 0.5 mg/kg/day for three days). Infection control included oxytetracycline hydrochloride spray (NEO CAF®; Merck Sharp & Dohme [MSD], İstanbul, Türkiye) and antibiotic injections (Reptopen S®, Ceva, İstanbul, Türkiye; 3 mL/day for five days). Animals recovered under close observation and were housed individually for five days before being returned to the flock. They

Figure 1. Study phases.

Figure 2. Appearance of the isolated vertebra and the treated vertebra, along with the biomechanical force-impact testing procedure performed using the Shimadzu Autograph AG-IS 100 machine.

were maintained at the Ayhan Şahenk Agricultural Research and Application Center of Niğde Ömer Halisdemir University with unrestricted access to food and water. One animal was euthanized on postoperative day 10 due to systemic infection secondary to wound contamination, likely resulting from the inability to protect the surgical site from contact with surrounding structures during movement. This animal was excluded from the final analysis. The remaining four animals were followed longitudinally: three were observed for 12–14 weeks, and one for 25 weeks. Sutures were removed two weeks postoperatively. No additional complications or adverse effects were observed, and all remaining animals resumed normal flock activity. At the end of the study period, euthanasia was performed using an overdose of xylazine hydrochloride (Rompun®; Bayer, İstanbul, Türkiye) and ketamine hydrochloride (Ketalar®; Bayer, İstanbul, Türkiye). Vertebrae L1–L5 were dissected for analysis (Fig. 2).

Biomechanical Testing

Biomechanical compressive testing of vertebrae L1, L2, L4, and L5 was performed using a Shimadzu Autograph AG-IS 100 kN testing machine (Shimadzu, Kyoto, Japan). Testing was conducted with a compressive tool at a crosshead displacement rate of 1 mm/min to generate force-stroke curve data in the Hydraulic and Pneumatic Laboratory, Faculty of Engineering, Department of Mechanical Engineering, Niğde Ömer Halisdemir University (Fig. 2). Force-stroke data for each specimen were recorded using the Trapezium software integrated with the Shimadzu testing system. Data analysis was conducted on a computer equipped with an Intel Xeon 2.2 GHz processor, 28 GB RAM, and a 16 GB NVIDIA Tesla P100 GPU. All tests were conducted in air at 20°C under an atmospheric pressure of 656 mmHg. Further biomechanical evaluation of TTCP was considered infeasible due to ethical constraints, limited animal availability, financial limitations, and fundamental anatomical and postural differences inherent to the species.

Histological Processing and Evaluation

The L3 vertebrae were fixed immediately in 10% formalin following dissection of L1-5 for histological analysis. After completion of biomechanical testing, L2 and L4 vertebrae were also fixed in formalin and processed histologically together with L3 at the Department of Pathology, Faculty of Medicine, Niğde Ömer Halisdemir University. Bone specimens underwent decalcification in 3% nitric acid, followed by paraffin embedding, sectioning at 4 µm thickness, and hematoxylin-eosin (H&E) staining. All histological evaluations were performed in a blinded manner by a professional histopathologist (C.Ö.). Microscopic findings related to bone formation were assessed according to the "Classification of Stages of Woven Bone Formation" described by Shapiro et al.[16] (Table 1).

Table 1. "Classification of Stages of Woven Bone Formation" by Shapiro et al.[16]

Stage 1	Highly cellular, densely packed accumulations of differentiating pre-osteoblasts present de novo at sites with no evidence of pre-existing bone tissue. These pre-osteoblasts are derived from the undifferentiated mesenchymal cell pool.
Stage 2	Mesenchymal osteoblasts surround themselves in a 360° arc with randomly oriented matrix fibers: a. The cell area is greater than the matrix area. b. The cell area is equal to the matrix area. c. The matrix area is greater than the cell area.
Stage 3	The matrix is sufficient to act as a scaffold upon which surface osteoblasts begin to synthesize bone in a lamellar configuration.
Stage 4	There is progressive reduction of woven bone within the woven bone/lamellar bone complex. This reduction is relative due to increased synthesis of lamellar bone and absolute due to osteoclastic resorption: a. Woven bone exceeds lamellar bone. b. Woven bone equals lamellar bone. c. Lamellar bone exceeds woven bone.
Stage 5	When the entire bone tissue developmental sequence from undifferentiated mesenchymal cells to exclusively lamellar bone is considered, stage 0 is defined as mesenchymal cell development from undifferentiated elongated cells to progressively differentiating oval cells, whereas Stage V represents the stage at which all bone observed in a region is lamellar.

Table 2. Key parameters of the force-impact curve data obtained using a Shimadzu Autograph AG-IS 100 kN testing machine (Shimadzu, Kyoto, Japan) at a constant test speed of 1 mm/min

Study Groups	Treated Vertebrae (L2, L4)	Control Vertebrae (L1, L5)
Minimum load	10,726.9 N*	10,342.5 N
Maximum load	9,920 N	10,713.8 N
Average maximum load	10,210.4 N	10,528.2 N
Standard deviation	448.436 N	262.549 N

*Newton

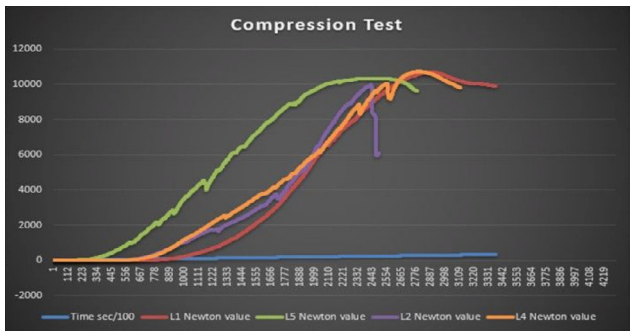

Figure 3. Force-impact test results.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 23 (IBM Corp., Armonk, NY, USA) and Microsoft Excel (version 17). Paired-sample t-tests and percentage analyses were conducted. Statistical significance was defined as $p<0.05$.

RESULTS

Macroscopically, no abnormalities were observed in the vertebrae. The entry points were located within 1–4 mm of the intended target regions (Fig. 2), and a penetration depth of at least 1 cm was achieved in all treated vertebrae.

Regarding mechanical resistance, no statistically significant differences were detected between treated and untreated vertebrae ($p>0.05$) (Table 2, Fig. 3). Despite the anatomical proximity of the vertebrae assigned to the treatment (L2, L4) and control (L1, L5) groups, as well as the inclusion of craniocaudally mixed levels, the comparable force–impact curve profiles observed in both groups suggest that TTCP effectively replicates the load-bearing characteristics of a healthy spine (Table 2, Fig. 3).

Microscopic examination demonstrated osteoblastic activity and mineralization within the bone specimens. The margins of the treated regions were interwoven with native bone tissue, rendering the distinction between treated and untreated areas difficult. Additionally, the material used for ossification appeared as a crystal-like foreign body in certain regions (Figs. 4, 5). Early ossification foci were also observed (Fig. 6). According to Shapiro et al.'s [16] "Classification of Stages of Woven Bone Formation" (Table 1), ossification at three months was classified as Stage 2c, whereas ossification at six months corresponded to Stage 4a (Figs. 4-6). These findings indicate that TTCP undergoes progressive replacement by newly formed bone over time.

DISCUSSION

Since its introduction in 1987 by Galibert and Deramond,[1] PVP and PKP techniques have undergone substantial refinement.[2] Despite numerous advancements, ranging from improvements in Jamshidi cannulas to the development of stent-assisted systems, progress in filler materials has remained largely confined to experimental trials, with PMMA continuing to be the only universally accepted material in clinical practice to date.[2-5] Considering its widespread use, PMMA has several notable limitations, including thermal injury, allergic reactions, difficulties in revision procedures when used in conjunction with implants, incompatibility with subsequent implant placement at treated sites, and, most critically, its lack of biocompatibility.[6,17]

In this context, TTCP, a member of the CPC family, has emerged as a promising alternative for PVP and PKP applications. Its unique properties make it particularly suitable for vertebral augmentation. TTCP hardens through an exothermic reaction at temperatures below 30°C, a process reported to be non-cytotoxic.[18] It achieves 50% of its ultimate compressive strength within one hour and 80% within four hours, thereby providing early mechanical stability and adhesive support in bone defects.[18] A key characteristic of TTCP is its higher calcium-to-phosphorus (Ca/P) ratio compared to hydroxyapatite, the principal mineral component of bone. Specifically, TTCP has a Ca/P ratio of 2.0, whereas hydroxyapatite has a ratio of 1.67.[19] This composition enables TTCP to form hydroxyapatite during the setting process.[19,20] The resulting structure is approximately 50–60% porous and negatively charged, creating an environment conducive to protein binding.[19,20] This, in turn, facilitates the attachment of circulating endogenous growth factors, thereby support-

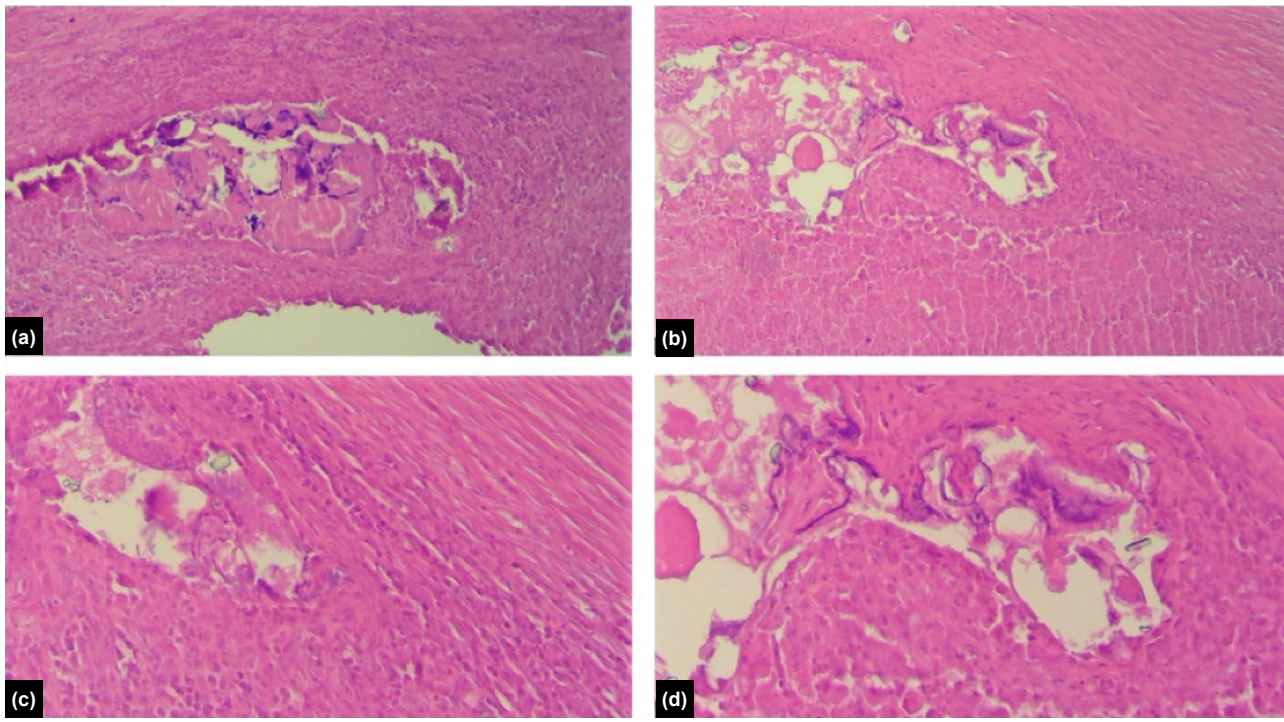

Figure 4. Representative images of microscopic ossification from the 14-week sample (A-B: Hematoxylin and eosin staining, ×100; C-D: Hematoxylin and eosin staining, ×200).

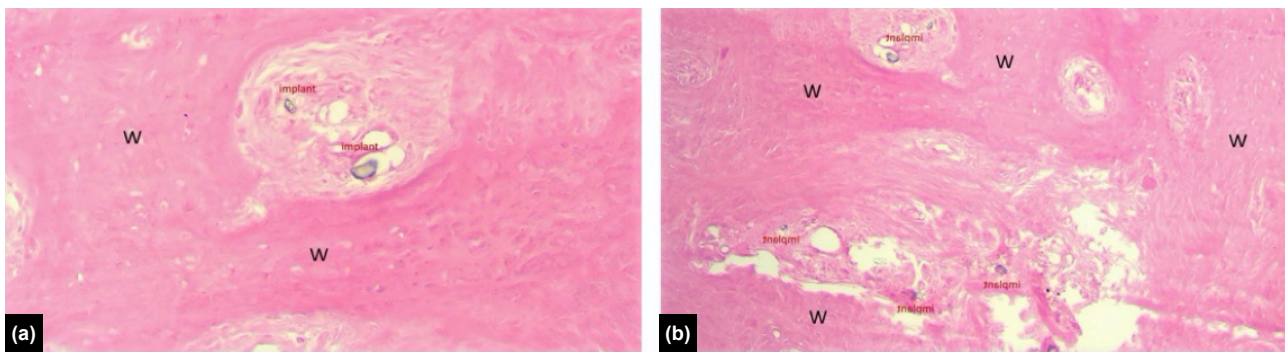

Figure 5. Representative images of woven bone formation with tetracalcium phosphate (TTCP) from the 25-week sample (A: Hematoxylin and eosin staining, ×100; B: Hematoxylin and eosin staining, ×200).

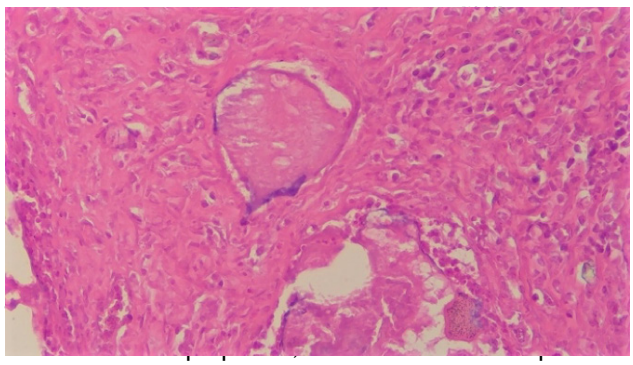

Figure 6. Representative image of an early ossification focus (Hematoxylin and eosin staining, ×200).

advantages and clinical applications. Unlike PMMA,[6] TTCP does not hinder implant placement or removal, as it gradually converts into native bone tissue over time. Additionally, TTCP demonstrates adhesive strength to both metal and bone that is comparable to that of native bone, as evidenced by long-term applications.[21,23] A significant advantage of TTCP cements is their potential to reduce the need for bone grafting, thereby eliminating donor-site morbidity associated with traditional graft materials.[22] Another noteworthy feature of TTCP is the absence of bone-inductive growth factors or osteogenesis-stimulating hormonal components in its formulation, which may render it suitable for use in tumorous pathologies.[24] Furthermore, TTCP is compatible

Table 3. Comparative biophysical properties of grafts[26-28]

Graft Type	TTCP (Tetracalcium Phosphate) Used in the Study	Autograft	Allograft
Hardening time	10 minutes	6 months	6 months
Time to full load-bearing capacity	4 hours (hardens in 10 minutes)	6 months	6 months
Graft resorption time	4-8 months	4-8 months	4-8 months
Volume loss	2%	10%	10%

with the instruments and devices currently used for PVP and PKP procedures with PMMA.[21,25] In our study, TTCP was successfully applied using these techniques in a sheep model characterized predominantly by cancellous vertebral bone, demonstrating its effectiveness. Tomita et al.[26] reported that, in cadaveric vertebral models subjected to PVP and PKP, no statistically significant differences were observed between preliminary tricalcium phosphate cement and PMMA under biomechanical testing conditions identical to those employed in our study, even in the absence of osteoregeneration. These findings suggest that, from a purely mechanical standpoint, advanced TTCP formulations may provide immediate load-bearing capacity comparable to that of PMMA following augmentation procedures.[26] Similarly, our short- and long-term microscopic and biomechanical analyses demonstrated findings comparable to those of normal bone, consistent with previous reports (Table 3).[17,19,21,22,25,27-33]

Despite its advantages, certain limitations of TTCP must be acknowledged. Unlike PMMA, TTCP does not generate high temperatures during polymerization, thereby preventing thermal damage to vascular lesions. Also, in such regions, the presence of blood may alter the liquid-to-powder ratio of the mixture, interfering with its activation.[18-20] Similarly, the use of TTCP is not recommended in infected sites.[34] This limitation is related to its organic composition, which may compromise infection control when implanted into contaminated tissues.[34] Additionally, alterations in the activator ratio may also occur in infected environments, further complicating the clinical use of TTCP under such conditions.[18-20] In these cases, alternative materials may be more appropriate, and research into antibiotic-containing materials is ongoing.[34] Another limitation of TTCP is its inability to achieve bone-level resistance to shear forces until complete replacement by native bone has occurred.[30] Although this limitation is not critical for PVP or PKP procedures, it presents challenges in long-bone reconstruction, where prolonged immobilization may be necessary.[30] Furthermore, TTCP is unsuitable in cases of severe degenerative bone disease (Z-scores below -3), as its primary mechanism relies on remodeling into functional bone tissue.[6] Similarly, conditions that impair osteoblastic activity, such as uncontrolled diabetes, pregnancy, substance or alcohol abuse, and renal failure, may compromise treatment outcomes with TTCP.[35] Conversely, in patients with hypercalcemia, the osteoinductive properties of TTCP may promote excessive deposition, making it unsuitable for use in such conditions.[35] Lastly, TTCP requires a bony scaffold for effective application, rendering it inappropriate for environments involving purely soft-tissue environments.[36]

CONCLUSION

Tetracalcium phosphate emerges as a highly suitable material for PVP and PKP procedures in modern medical practice due to its strong biomechanical and microscopic resemblance to natural bone, along with its faster ossification compared to autografts. However, TTCP has certain limitations, particularly its unsuitability for use in infected tissues or areas containing bodily fluids. Additionally, its effectiveness may be reduced in cases of severe degenerative bone disease, uncontrolled diabetes, hypercalcemia, or other conditions that impair normal bone metabolism. Further large-scale clinical studies are needed to validate its long-term efficacy and safety.

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Ethics Committee Approval: This study was approved by the Niğde Ömer Halisdemir University Animal Research Ethics Committee (Date: 16.10.2023, Decision No: 2023/12).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: İ.K., H.Y., H.K.; Design: İ.K.; Supervision: İ.K., H.Y., H.K., C.Ö.; Resource: İ.K., H.Y., H.K., C.Ö.; Materials: İ.K., H.Y., H.K., C.Ö.; Data collection and/or processing: İ.K., H.Y., H.K.; Analysis and/or interpretation: İ.K., H.Y., H.K., C.Ö.; Literature review: İ.K.; Writing: İ.K.; Critical review: İ.K.

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DENEYSEL ÇALIŞMA - *ÖZ*

Omurga augmentasyonunda tetrakalsiyum fosfatın olası kullanımı: Koyun modeli ile deneysel bir çalışma

AMAÇ: Perkütan vertebroplasti (PVP) ve perkütan kifoplasti (PKP), vertebra kırıklarının tedavisinde yaygın olarak kullanılan minimal invaziv yöntemlerdir. Ancak bu işlemlerde standart dolgu materyali olan polimetilmetakrilatın (PMMA) termal hasar, alerjik reaksiyonlar ve düşük biyouyumluluk gibi önemli dezavantajları bulunmaktadır. Kalsiyum fosfat esaslı bir çimento olan tetrakalsiyum fosfat (TTCP), üstün biyouyumluluğu, osteokondüktivitesi ve doğal kemikle entegrasyon yeteneği sayesinde alternatif bir materyal olarak öne çıkmaktadır. Bu çalışmanın amacı, TTCP'nin vertebra augmentasyonu amacıyla bir koyun modelinde biyomekanik stabilite, biyouyumluluk ve osteojenik potansiyel açısından değerlendirilmesidir.

GEREÇ VE YÖNTEM: Beş Akkaraman koyununda, L2–L4 lomber vertebra seviyelerinde standart PKP prosedürüyle hazırlanmış boşluklara TTCP enjeksiyonu yapıldı. Genel anestezi altında uygulanan işlem sonrasında analjezik ve antibiyotik tedavileri sağlandı. Dört hayvan 12-14 hafta, bir hayvan ise 25 hafta boyunca gözlemlendi. Takip sonunda ötenazi uygulanan hayvanlardan elde edilen vertebralar, Shimadzu AG-IS 100 kN cihazı ile biyomekanik testlere tabi tutuldu. Histolojik değerlendirme ise Shapiro sınıflamasına göre ossifikasyon evrelerini inceledi. Veriler, eşleştirilmiş t-testi ile analiz edildi ($p<0.05$).

BULGULAR: Bir hayvan enfeksiyon nedeniyle çalışmadan çıkarılırken, diğer dört hayvanda komplikasyon gözlenmedi. Biyomekanik analizler, tedavi edilen ve edilmeyen vertebralar arasında basma dayanımı açısından anlamlı fark olmadığını gösterdi ($p>0.05$). Histolojik incelemeler osteoblastik aktivite, ilerleyici mineralizasyon ve kemik entegrasyonu varlığını doğruladı.

SONUÇ: TTCP, vertebra augmentasyonu için umut verici biyomekanik ve biyofizyolojik özellikler sergilemiştir. Bununla birlikte, enfekte bölgelerde ve metabolik kemik hastalıklarında kullanımı sınırlıdır. Uzun dönem etkinliğini değerlendirmek amacıyla ileri klinik çalışmalara ihtiyaç vardır.

Anahtar sözcükler: Kalsiyum fosfat çimentolar; perkütan vertebroplasti; perkütan kifoplasti; polimetilmetakrilat; tetrakalsiyum fosfat.

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ORIGINAL ARTICLE

Efficacy and safety of empiric transcatheter arterial embolization for acute arterial upper gastrointestinal bleeding: A tertiary-care, single-center experience

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ABSTRACT

BACKGROUND: Upper gastrointestinal bleeding (UGIB) is a significant cause of morbidity and mortality. While endoscopy is the primary treatment modality, transcatheter arterial embolization (TAE) can be an effective alternative when endoscopic treatment fails. This study aims to evaluate the safety and efficacy of empiric TAE for acute UGIB.

METHODS: This retrospective, single-center study reviewed 20 consecutive patients referred to interventional radiology for embolization due to UGIB between August 2021 and November 2024. The mean patient age was 62.3±16.2 years. Clinical success was defined as devascularization of the target area resulting in clinical cessation of bleeding and stabilization of hemoglobin levels. Technical success was defined as occlusion of the feeding vessel and/or absence of extravasation following angiography.

RESULTS: Thirteen patients (65%) had duodenal bleeding and underwent gastroduodenal artery embolization. Seven patients (35%) had gastric bleeding and underwent left gastric artery embolization. Both the technical and clinical success rates of the procedure were 100%. Rebleeding occurred in one patient (5%) and was managed surgically. There was no procedure-related mortality. One major complication (5%), coil migration, was managed conservatively. One minor complication (5%), a groin hematoma, occurred and did not require transfusion.

CONCLUSION: Empiric transcatheter embolization is an effective and safe treatment option for acute upper gastrointestinal bleeding, demonstrating high technical and clinical success rates. The procedure shows favorable outcomes in terms of hemostasis, rebleeding rates, and complication profiles compared to surgical intervention.

Keywords: Transcatheter arterial embolization; upper gastrointestinal bleeding; gastroduodenal artery; therapeutic embolization; interventional radiology.

INTRODUCTION

Upper gastrointestinal hemorrhage (UGIB), originating from anatomical sites superior to the ligament of Treitz, is a significant contributor to morbidity and mortality worldwide.[1] Despite advances in endoscopic interventions and pharmacologic therapy, the mortality rate associated with UGIB remains approximately 5-10%, with no discernible change over the past two decades.[2] The primary causes include peptic

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ulcer disease, erosive gastroduodenal mucosal lesions, Mallory-Weiss syndrome, and neoplastic conditions of the upper gastrointestinal tract.[3]

Endoscopic therapy is the first-line treatment for UGIB. Bleeding can be managed with an 85-95% success rate using endoscopic methods.[4] However, endoscopic management may fail in cases of massive bleeding, anatomically inaccessible lesions, or refractory bleeding despite initial hemostasis. In the past, surgery was considered the standard salvage therapy for failures of endoscopic procedures. However, surgical management is associated with significant morbidity rates ranging from 20% to 40% and mortality rates between 10% and 30%, especially in elderly patients with comorbidities.[5,6] Transcatheter arterial embolization (TAE) has emerged as an alternative to surgery for patients with refractory UGIB. Advances in microcatheter technology, embolic agents, and imaging guidance have improved TAE's technical success and safety profile.[7,8]

Despite the increasing adoption of TAE for UGIB, there remains debate regarding its efficacy compared to surgical intervention, particularly concerning rebleeding rates, long-term outcomes, and specific patient populations who might benefit most from each approach.[9]

This study aimed to assess the technical success, clinical effectiveness, and safety profile of empiric TAE for UGIB and to compare these outcomes with those reported for surgical interventions in the current literature.

MATERIALS AND METHODS

Study Design and Patient Selection

This study was designed as a single-center, retrospective analysis. Ethics committee approval was granted for the study (16.01.2025/E-43012747-050.04-438245). Because of its retrospective design, the study was exempt from the requirement for informed consent. The study was conducted in accordance with the Declaration of Helsinki. We reviewed the electronic medical records of 33 consecutive patients referred to interventional radiology for embolization due to UGIB between August 2021 and November 2024. All patients included in the study were first evaluated with endoscopy. TAE was performed in patients whose bleeding could not be controlled by endoscopic interventions. The files of 33 patients referred to the interventional radiology department by the general surgery service for upper gastrointestinal (GI) bleeding were analyzed. Eight patients who were unsuitable for TAE and five who did not consent to TAE were excluded from the study. Twenty patients (6 males, 14 females) with a mean age of 62.3 years (range: 19-84 years) were included in the study (Fig. 1).

Inclusion criteria were: (1) patients with endoscopically confirmed or clinically suspected UGIB; (2) failure of or contraindication to endoscopic management; (3) referral for interventional radiological management; and (4) patients who gave consent to endovascular treatment.

Exclusion criteria were: (1) lower gastrointestinal bleeding; (2) incomplete medical records; (3) patients who underwent prophylactic embolization before elective surgery; and (4) patients who did not give consent to endovascular treatment.

Data Collection

Patient demographic data, clinical parameters, procedural details, and outcomes were collected from electronic medical records. The following parameters were recorded: age, sex, pre- and post-procedure hemoglobin levels, indication for embolization, target vessel, embolic agent, technical success, clinical success, complications, and endoscopic findings.

Embolization Procedure

All interventions were conducted by experienced interventional radiologists in a specialized angiography suite. Following the administration of local anesthesia, access to the femoral artery was achieved using a 5F femoral sheath (Shunmei, China). An initial abdominal aortography was performed by selective catheterization of the celiac trunk and superior mesenteric artery using a 5-French diagnostic catheter (Performa, Merit Medical, Ireland). Thereafter, super-selective catheterization of the gastroduodenal artery (GDA) or left gastric artery (LGA) was carried out using a microcatheter system (Progreat, Terumo, Japan).

Embolization was performed once the bleeding site was identified or prophylactically based on endoscopic findings. Embolic materials included microcoils (Interlock, Boston Scientific, USA) for the GDA and particles (Embosphere, Merit Medical, Ireland) for the LGA. Clinical success was defined as target-area devascularization resulting in clinical cessation of bleeding and stabilization of hemoglobin levels. Technical success was defined as occlusion of the feeding vessel and/or absence of extravasation following angiography.

Outcome Measures

The primary outcome measures included the rate of technical success (successful placement of embolic agents in the intended vessel) and clinical success (cessation of bleeding without signs of rebleeding within 30 days). Secondary outcome measures encompassed changes in hemoglobin levels, complication rates, duration of hospitalization, and mortality rates within 30 days.

The reporting guidelines established by the Society of Interventional Radiology classified complications as either minor or major. Minor complications were defined as those requiring only observation without intervention or hospitalization. In contrast, major complications were those necessitating prolonged hospitalization, an unplanned increase in the level of patient care, or resulting in sequelae or death. Rebleeding was defined as hematemesis, melena, or a decrease in hemoglobin concentration of ≥2 g/dL following initial stabilization.[10]

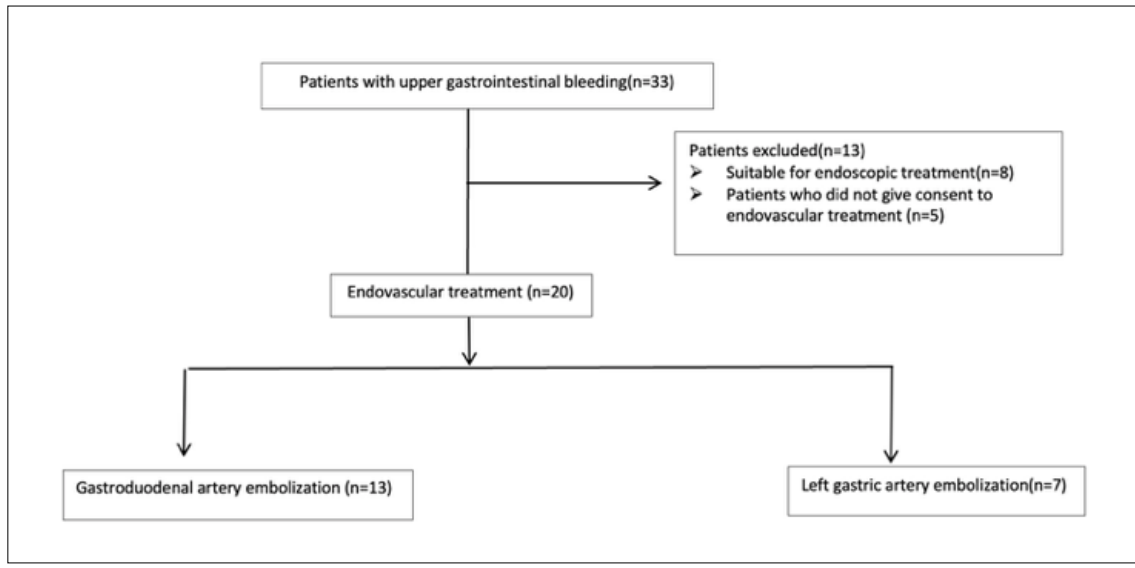

Figure 1. Study flowchart.

Statistical Analysis

Descriptive statistics were employed to describe patient demographics and clinical outcomes. Continuous variables were tested for normality using the Shapiro–Wilk test. As the data did not follow a normal distribution, pre- and post-procedure hemoglobin levels were compared using the Wilcoxon signed-rank test for paired samples. A p-value of <0.05 was considered statistically significant. Continuous variables were presented as mean±standard deviation, depending on distribution. Categorical variables were summarized as counts and percentages. All analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA).

RESULTS

The most common indications for embolization were duodenal ulcers (n=5, 25%), gastric malignancies (n=5, 25%), and gastric ulcers (n=4, 20%). Other indications included esophageal varices with gastric ulcer (n=1, 5%), post-surgical anastomotic bleeding (n=1, 5%), and undocumented indications (n=4, 20%). Table 1 summarizes the baseline characteristics of the study population.

Technical Outcomes

Of the 20 patients who underwent embolization, 13 (65%) had duodenal bleeding, for which gastroduodenal artery embolization was performed. The remaining seven patients (35%) had gastric bleeding and were treated with left gastric artery embolization. The procedure was successful in all patients (100%), achieving both technical and clinical success.

Coils were exclusively used in patients with duodenal bleeding (n=13, 65%), while particles were the embolic agents of choice in all gastric artery embolization cases (n=7, 35%). This approach was tailored to the specific site of bleeding and the vascular anatomy of the patients (Fig. 2).

Rebleeding was observed in one patient (5%) and was managed surgically. A major complication, coil migration, was noted in one patient (5%) and was resolved with conservative management. Additionally, one patient (5%) experienced a minor complication, a groin hematoma, which did not require transfusion. No procedure-related deaths occurred.

Clinical Outcomes

Before the procedure, the average hemoglobin level was 7.9±1.9 g/dL, increasing to 8.3±1.2 g/dL post-procedure, representing a mean increase of 0.4 g/dL (p=0.15). Clinical success, defined as cessation of bleeding without rebleeding within 30 days, was achieved in 19 of the 20 patients (95%), although follow-up data were limited for some patients.

Complications occurred in two patients (10%), including coil migration in one patient (5%) and a groin hematoma in another (5%). These complications did not necessitate further

Table 1. Baseline characteristics of the study population

Characteristic	Value
Pre- and post-procedure hemoglobin levels (g/dL, mean±SD)	7.9±1.9 vs. 8.3±1.2 g/dL (p=0.15)
Indication for embolization, n (%)	
Duodenal ulcer	5 (25%)
Gastric malignancy	5 (25%)
Gastric ulcer	4 (20%)
Esophageal varices with gastric ulcer	1 (5%)
Post-surgical anastomotic bleeding	1 (5%)
Not clearly documented	4 (20%)

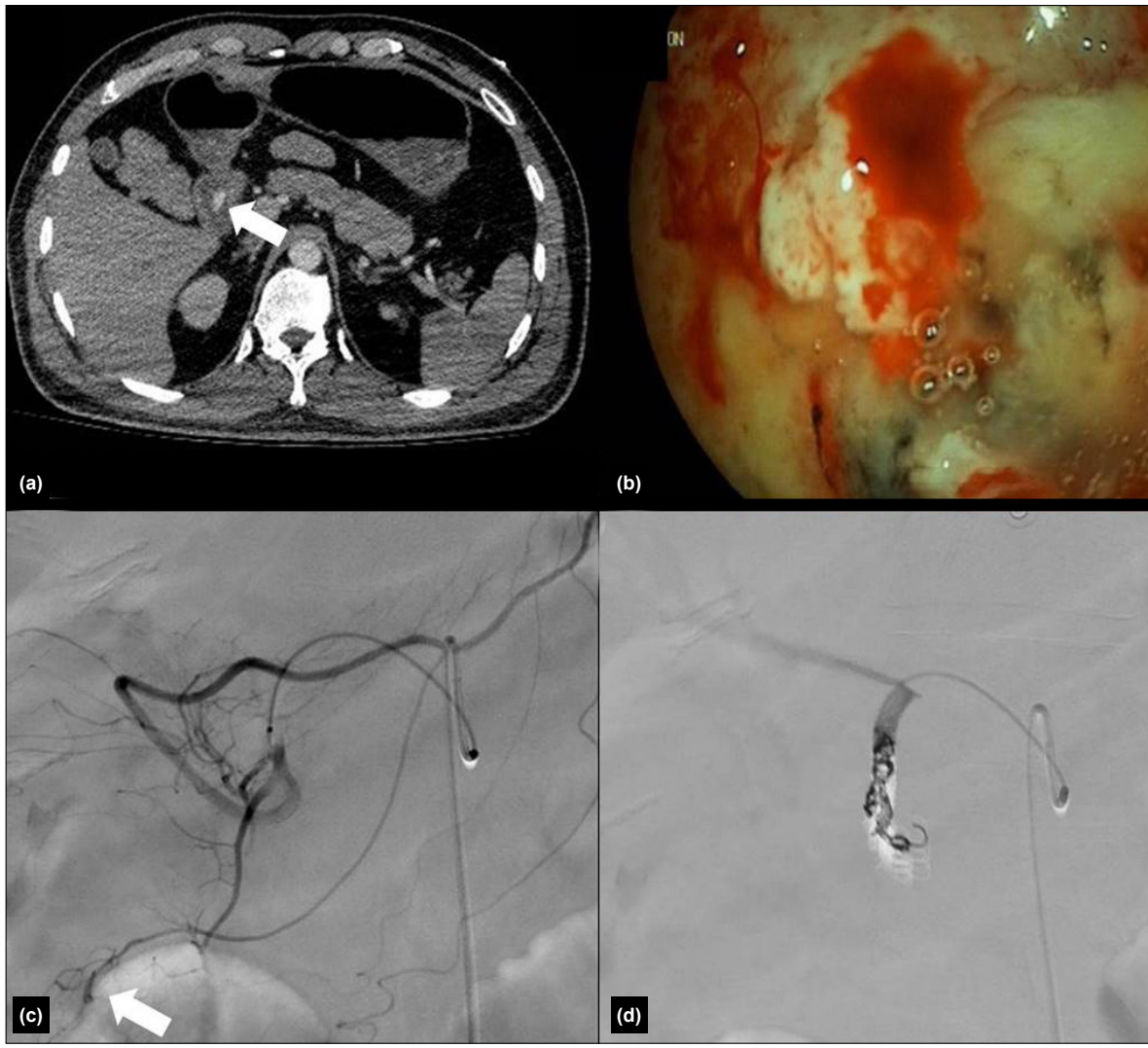

Figure 2. A 73-year-old man presenting with a bleeding duodenal ulcer. An axial contrast-enhanced computed tomography (CT) image **(a)** reveals active bleeding in the duodenum (arrow). Although the bleeding ulcer was identified on endoscopy, attempts to control the hemorrhage were unsuccessful **(b)**. Celiac angiography **(c)** demonstrated active bleeding from the gastroduodenal artery (arrow). The bleeding was successfully managed by embolization of the gastroduodenal artery using microcoils **(d)**.

interventions or result in clinical deterioration. No procedure-related deaths were recorded.

Endoscopic evaluation after the procedure was performed in 12 patients (60%) and demonstrated resolution of active bleeding in all cases, although some patients had persistent ulcers or malignant lesions.

DISCUSSION

This retrospective analysis demonstrates that TAE is an effective and safe treatment for UGIB, showing excellent technical and clinical success rates and a manageable complication profile. A unique aspect of our study is the inclusion of gastroduodenal artery and left gastric artery treatments, as well as the use of both coils and microspheres. Our findings are consistent with previous studies reporting technical success rates ranging from 82% to 100% and clinical success rates from 65% to 93% for TAE in UGIB cases.[11,12]

Our technical success rate of 100% is comparable to other published series. The single technical failure occurred due to instability of a coil in the gastroduodenal artery stump, highlighting the importance of careful coil selection and deployment techniques. Alternative embolic agents, such as gelatin sponge particles or liquid embolic agents, may be employed when coil deployment is challenging.[13]

The clinical success rate of 100% is at the higher end of the range reported in the literature. This may reflect appropriate patient selection, technical expertise, and the use of suitable embolic agents based on bleeding characteristics. The choice of embolic agent remains somewhat controversial, with microcoils preferred for their precision and permanence. At the

same time, particles allow more distal embolization but carry a theoretical risk of ischemic complications.[14]

Regarding safety, our complication rate of 15% is consistent with published rates of 9-20%.[15] The observed complications were related to coil placement and were managed conservatively without clinical sequelae. Our series did not observe major complications such as bowel ischemia, which has been reported in 0-5% of cases in the literature. This may be attributed to careful technique with super-selective catheterization and embolization, preserving collateral circulation.[16]

When comparing TAE with surgery for UGIB, our results suggest that TAE is similarly effective but carries a better safety profile, particularly for high-risk patients. Surgical interventions may have slightly higher technical success rates but are associated with increased morbidity (30-50%) and mortality (5-15%).[17-19] The less invasive nature of TAE makes it an ideal option for elderly patients or those with significant comorbidities who may not be suitable candidates for major surgery.

Numerous studies have sought to identify variables that predict the efficacy or inefficacy of TAE in treating UGIB. Factors such as coagulopathy, multiple comorbid conditions, hemodynamic instability, and corticosteroid use have been associated with increased rebleeding rates after TAE.[20] Appropriate patient selection is paramount, with some authors advocating surgical intervention as the primary treatment modality for young, healthy individuals with significant hemorrhage, while recommending TAE for older patients or those with substantial comorbidities.[21-24]

The anatomical location of bleeding may also influence the success of TAE. Gastroduodenal and left gastric artery embolization have shown higher success rates than embolization of other vessels, likely due to the rich collateral circulation in these regions.[25] In our series, most embolizations involved the gastroduodenal artery, which may have contributed to the favorable outcomes.

Recent innovations in embolization methodologies have further enhanced TAE's effectiveness and safety profile. The use of advanced microcatheters, detachable coils, and liquid embolic agents has improved procedural accuracy. Furthermore, the incorporation of cone-beam computed tomography within the angiography suite facilitates improved visualization of subtle hemorrhage and allows for more precise catheter placement.[26] In addition to methodology, patient selection, pre-procedural evaluation, and post-procedural care are critical to effectiveness and safety.[27]

The minimally invasive approach offers clear benefits, particularly for high-risk patients with comorbidities, compared to the significant physiological stress imposed by traditional surgery. However, it is important to acknowledge the vital role of surgical intervention in the management of upper gastrointestinal hemorrhage. Surgery continues to be an essential treatment option due to its ability to achieve complete and lasting bleeding control through direct intervention at the hemorrhage site, particularly when transcatheter arterial embolization cannot be performed because of anatomical constraints or has failed to achieve the desired outcome. The successful surgical management of the 5% rebleeding rate observed in our study confirms that these two disciplines are not alternatives but complementary. Modern hemorrhage management should adopt a hybrid, patient-tailored approach, recognizing the strengths of both methods and fostering close collaboration between interventional radiology and surgery to achieve optimal patient outcomes.[17,28]

Nevertheless, our study has several limitations. First, its retrospective nature introduces potential selection and information biases. Second, the relatively modest sample size limits statistical power and the ability to extrapolate our findings. Thirdly, follow-up data were not systematically collected for all patients, which may have resulted in underreporting of rebleeding incidences. Fourthly, our comparative analysis of surgical outcomes relied on published literature rather than direct comparisons, which may introduce confounding factors. Finally, the absence of consistent long-term follow-up beyond 30 days precludes the evaluation of late rebleeding or other delayed complications.

CONCLUSION

Transcatheter arterial embolization represents an effective and safe therapeutic modality for patients presenting with upper gastrointestinal hemorrhage, characterized by high technical and clinical success rates and a manageable complication profile. Our findings support the use of TAE as a primary intervention for patients with UGIB who do not respond to endoscopic management, particularly those at high surgical risk.

Ethics Committee Approval: This study was approved by the Sakarya University Ethics Committee (Date: 16.01.2025, Decision No: E-43012747-050.04-438245).

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Akut arteriyel üst gastrointestinal kanamada empirik transkateter arteriyel embolizasyonun etkinliği ve güvenliği: Üçüncü basamak, tek merkez deneyimi

AMAÇ: Üst gastrointestinal sistem kanamaları (UGIB), önemli morbidite ve mortalite nedenlerinden biridir. Endoskopi birinci basamak tedavi yöntemi olmakla birlikte, başarısızlık durumunda transkateter arteriyel embolizasyon (TAE) etkili bir alternatif sunabilir. Bu çalışmada, akut UGIB tedavisinde ampirik TAE yönteminin güvenilirliği ve etkinliği değerlendirilmektedir.

GEREÇ VE YÖNTEM: Bu retrospektif, tek merkezli çalışmada, Ağustos 2021 ile Kasım 2024 tarihleri arasında üst gastrointestinal sistem kanaması nedeniyle girişimsel radyolojiye embolizasyon amacıyla yönlendirilen ardışık 20 hasta değerlendirildi. Hastaların ortalama yaşı 62.3±16.2 idi. Klinik başarı; hedef bölgedeki devaskülarizasyon sonrası kanamanın klinik olarak durması ve hemoglobin düzeyinin stabil hale gelmesi olarak tanımlandı. Teknik başarı ise; besleyici damarların tıkanması ve/veya anjiyografi sonrası ekstravazasyonun izlenmemesi şeklinde tanımlandı.

BULGULAR: On üç hastada (%65) duodenal kanama mevcuttu ve gastroduodenal arter embolizasyonu uygulandı. Yedi hastada (%35) ise gastrik kanama vardı ve sol gastrik arter embolize edildi. İşlemin teknik ve klinik başarı oranı %100 olarak belirlendi. Bir hastada (%5) tekrar kanama gelişti ve cerrahi ile tedavi edildi. İşleme bağlı mortalite saptanmadı. Bir hastada (%5) gelişen ciddi komplikasyon (coil migrasyonu) konservatif olarak yönetildi. Bir diğer hastada (%5) gelişen minör komplikasyon (kasık hematomu) ise transfüzyon gerektirmedi.

SONUÇ: Ampirik transkateter embolizasyon, akut üst gastrointestinal sistem kanamalarının tedavisinde yüksek teknik ve klinik başarı oranlarıyla etkili ve güvenli bir yöntemdir. Hemostaz, tekrar kanama ve komplikasyon profili açısından cerrahi müdahaleye kıyasla avantajlı sonuçlar sunmaktadır.

Anahtar sözcükler: Girişimsel radyoloji; gastroduodenal arter; terapötik embolizasyon; transkateter arteriyel embolizasyon; üst gastrointestinal kanama.

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ORIGINAL ARTICLE

Skin, soft tissue, bone, and joint infections in trauma patients during rehabilitation

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ABSTRACT

BACKGROUND: Infections are a frequent complication of military trauma, occurring not only in the acute phase but also during rehabilitation. However, studies specifically addressing infections in the rehabilitation setting remain scarce. This study aimed to evaluate the incidence, microbiological spectrum, treatment approaches, and outcomes of skin and soft tissue infections (SSTIs) and bone and joint infections (BJIs) in military trauma patients during inpatient rehabilitation.

METHODS: We retrospectively reviewed the medical records of military trauma patients hospitalized at a tertiary rehabilitation hospital between January 2020 and June 2023. Patients who developed SSTIs or BJIs during rehabilitation were included. Demographic and clinical characteristics, laboratory and imaging findings, culture results, antibiotic regimens, surgical interventions, treatment duration, and recurrence rates were analyzed.

RESULTS: Among 1,078 trauma patients, 58 (5.4%) developed SSTIs or BJIs. Stump infection was the most frequent type (44.8%), followed by graft infection (15.5%). *Staphylococcus* species were the predominant pathogens, while multidrug-resistant (MDR) gram-negative organisms were isolated in 24.1% of cases. β-lactam/β-lactamase inhibitor (BL-BLI) therapy was the most common monotherapy, whereas BL-BLI plus a fluoroquinolone was the most frequently used combination regimen. Surgical intervention was required in 34.5% of patients. Recurrent infections occurred in 25.8% of cases. Treatment duration was significantly longer in non-amputee patients ($p<0.05$), primarily due to bone and joint infections. Despite these infectious complications, most lower-limb amputees achieved ambulatory status with prosthetic devices.

CONCLUSION: Military trauma patients remain at risk for SSTIs and BJIs during rehabilitation, with stump infections being the most common. The emergence of MDR organisms underscores the need for appropriate antibiotic selection and strict infection control measures. Despite these complications, relatively favorable functional outcomes can be achieved, particularly in younger trauma populations, highlighting the value of comprehensive rehabilitation programs.

Keywords: Military trauma; rehabilitation; skin and soft tissue infections; bone and joint infections; multidrug-resistant organisms.

INTRODUCTION

Despite changes in warfare tactics and weaponry over thousands of years, combat-related wounds have consistently been characterized by devitalized tissue, foreign bodies, clots, edema, and microbial contamination. Even in the post-antibiotic era, infections arising from such wounds continue to significantly contribute to morbidity and mortality.[1]

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Explosions and other high-energy trauma can lead to extremity amputations or severe injuries with extensive tissue loss; these wounds are often heavily contaminated. In military settings, the use of helmets and body armor effectively protects the head and torso but increases the relative incidence of extremity injuries.[2] Improvements in preventive measures, including body armor and tourniquets, along with advances in wound care, have led to a substantial reduction in combat-related mortality. However, mortality rates and infectious complications associated with post-traumatic wounds have been reported to be increasing.[3,4] Furthermore, the rising prevalence of multidrug-resistant (MDR) organisms in trauma-associated infections poses an increasing challenge for clinicians, particularly with the emergence of carbapenem-resistant Gram-negative bacteria in the management of post-traumatic infections.[4]

Physical therapy and rehabilitation centers provide comprehensive care for patients with multiple trauma, traumatic brain injury, and orthopedic injuries resulting from gunshots or explosions within an interdisciplinary model. In these centers, patients' medical, functional, and quality-of-life needs are addressed from admission to discharge, and, in some cases, lifelong follow-up is provided.[5] In the literature, infections occurring in the acute post-traumatic period have been widely studied, whereas infections arising during the rehabilitation phase remain poorly understood. These infections may delay functional recovery, limit prosthesis use, and prolong hospitalization, underscoring the need for further research. Therefore, this study aimed to evaluate skin and soft tissue infections (SSTIs) and bone and joint infections (BJIs) in patients undergoing rehabilitation in physical therapy and rehabilitation hospitals after military trauma.

MATERIALS AND METHODS

This retrospective study was conducted at a physical therapy and rehabilitation training and research hospital. The study was approved by the Ankara Bilkent City Hospital Ethics Committee (September 12, 2023; approval number E1-23-4017). Patients who developed skin, soft tissue, bone, or joint infections during post-traumatic rehabilitation between January 1, 2020 and June 30, 2023 were included. Patients younger than 18 years of age and those with incomplete medical records were excluded. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Data collected included demographic characteristics, vital signs, prosthesis use, comorbidities, routine laboratory and imaging tests, culture results and resistance profiles of isolated microorganisms, antibiotic regimens, duration of treatment and hospitalization, and recurrent infections. Infections were diagnosed based on detailed anamnesis, physical examination, laboratory findings, and imaging methods (ultrasonography, computed tomography, magnetic resonance imaging, and scintigraphy). Diagnostic criteria were defined according to current international guideline recommendations.[6-8] SSTIs were defined as widespread inflammation or subcutaneous or muscular fluid collection or abscess confirmed by ultrasonography. In patients with suspected osteomyelitis, the diagnosis was supported by radiological examinations such as magnetic resonance imaging or scintigraphy. Infection was confirmed by microbiological culture of soft tissue and/or bone samples whenever available.

Empirical antibiotic therapy was initiated according to the patient's clinical condition, and treatment regimens were adjusted based on wound or tissue culture results when available. Patients requiring surgical intervention were referred to a higher-level center. Data were obtained from both electronic and paper-based hospital records.

Artificial intelligence–based technologies were not used at any stage of this study.

Statistical Analysis

All data were analyzed using IBM SPSS Statistics for Windows, version 27.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics are presented as frequencies, percentages, means±standard deviations, medians, and minimum–maximum values. The normality of quantitative variables was assessed using the Shapiro–Wilk test, skewness and kurtosis values, and graphical methods (histograms, Q–Q plots, stem-and-leaf plots, and boxplots). For normally distributed quantitative variables, the independent-samples t-test was used for between-group comparisons, and the paired-samples t-test was used for within-group comparisons. For non-normally distributed variables, the Mann–Whitney U test was used for between-group comparisons, and the Wilcoxon signed-rank test was used for within-group comparisons. The chi-square test was used to compare categorical variables. A p-value of <0.05 was considered statistically significant.

RESULTS

Of the 1,078 military trauma patients receiving inpatient treatment in the orthopedic rehabilitation clinic, 58 (5.4%) developed SSTIs or BJIs. All patients were male, with a mean age of 33.2±8.9 years. The mean body temperature was 36.3±0.2°C, the mean systolic arterial pressure (SAP) was 108.7±9.8 mmHg, the mean diastolic arterial pressure (DAP) was 70.5±8.8 mmHg, and the mean pulse rate was 79.3±7.2 beats/min.

On physical examination, 75.9% of patients presented with purulent discharge. Thirty-two patients (55.2%) had a history of amputation, most commonly involving the lower extremities. Transtibial amputation (below-knee amputation, BKA) was the most frequent (34.5%), followed by transfemoral amputation (above-knee amputation, AKA) (10.4%). Among amputee patients, 30 (93.7%) were using prostheses. Overall, 44 patients (75.9%) had no comorbidities, while 14 patients (24.1%) most commonly had diabetes mellitus (n=4, 6.9%),

hypertension (n=3, 5.2%), and coronary artery disease (n=3, 5.2%), followed by hypothyroidism (n=2, 3.4%) and other chronic diseases (n=2, 3.4%).

Prior to trauma, all patients were independent ambulators. However, following trauma, amputations, and subsequent complications, significant reductions in ambulation capacity were observed. Among the patients, 44.8% ambulated independently with a prosthesis, 24.1% independently without a prosthesis, 24.1% with walking aids, and 6.9% had limited mobility requiring wheelchair use. The mean Functional Ambulation Scale (FAS) score was 3.7±1.4, with a median of 4 (range: 0–5). A significant correlation was found between amputation level and ambulation status (χ^2=51.3, p<0.001) (Table 1). Specifically, in the subgroup of 28 patients with lower-limb amputations, 26 achieved independent ambulation with a prosthesis, whereas only two required walking aids.

In all patients, the most common infections presented as cellulitis or abscess, with stump infections (44.8%) and graft infections (15.5%) being the predominant types. Nearly all amputee patients developed stump infections, whereas only one case of osteomyelitis was observed. Among non-amputee patients, graft infection was the most frequent finding. Cultures were obtained from 81% of patients, most commonly wound cultures (72.4%). Microbial growth was detected in 30 patients (51.7%). The most frequently isolated microorganisms were methicillin-sensitive *Staphylococcus aureus* (*MSSA*, 17.1%), *Enterobacter aerogenes* (10.4%), and *Pseudomonas aeruginosa* (6.9%). MDR gram-negative organisms were identified in 24.1% of cases according to standard definitions,[9] while methicillin-resistant *Staphylococcus aureus* (MRSA) was detected in a single patient (1.7%) (Table 2).

Table 1. Clinical and functional characteristics of patients with infection

Variable	n (%)
Purulent discharge	44 (75.9)
History of amputation	32 (55.2)
Transtibial BKA	20 (34.5)
Transfemoral AKA	8 (13.9)
Other (upper-limb amputation)	4 (6.8)
Prosthesis use among amputees	30 (93.7)
Comorbid disease (any)	14 (24.1)
Ambulation status after trauma	
Independent ambulation with prosthesis	26 (44.8)
Independent ambulation without prosthesis	14 (24.1)
Ambulation with walking aids	14 (24.1)
Limited mobility/wheelchair-dependent	4 (6.9)
FAS score	Mean 3.7±1.4; Median 4 (0–5)

Correlation between amputation level and ambulation status: χ^2=51.3, p<0.001.SAP: Systolic arterial pressure; DAP: Diastolic arterial pressure; FAS: Functional Ambulation Scale; BKA: Below-knee amputation; AKA: Above-knee amputation; SSTI: Skin and soft tissue infection; BJI: Bone and joint infection.

Table 2. Infection types, microbiological findings, and resistance characteristics

	n (%)
Type of infection developing	
Stump infection	26 (44.8)
Graft infection	9 (15.5)
Cellulitis	6 (10.4)
Osteomyelitis	6 (10.4)
Prosthesis-related infection	4 (6.9)
Surgical site infection	4 (6.9)
Other (decubitus ulcer, lymphangitis, septic arthritis)	3 (5.1)
Type of culture obtained	
Wound culture	42 (72.4)
Tissue culture	4 (6.9)
Wound + tissue culture	1 (1.7)
Isolated microorganisms	
MSSA	10 (17.1)
E. aerogenes	6 (10.4)
P. aeruginosa	4 (6.9)
A. baumanni	3 (5.1)
E. coli	2 (3.4)
Binary growth	2 (3.4)
Other (*K. pneumoniae, MRSA, Proteus spp.*)	3 (5.1)
Resistance status	
MDR organisms	14 (24.1)
Methicillin resistance	1 (1.7)

MSSA: Methicillin-sensitive *Staphylococcus aureus*; MRSA: Methicillin-resistant *Staphylococcus aureus*; MDR: Multidrug resistant.

Evaluation of laboratory results revealed no significant differences in white blood cell counts. However, statistically significant decreases were observed between pre- and post-treatment values for neutrophil percentage, erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP) (Table 3).

Radiological examinations were performed according to clinical findings to determine the type and site of infection. Plain X-rays were obtained for all patients during hospitalization. Ultrasonography was the most frequently used imaging modality (51 patients, 87.9%); fluid collection was detected in 16 patients, fistula formation in four, and both findings in four patients. Scintigraphy was performed in 13 patients (22.4%), revealing osteomyelitis in five cases and soft tissue infection in three cases. Magnetic resonance imaging was performed in

Table 3. Laboratory and imaging test results

Laboratory Findings	Mean±SD	p
White blood cell count		
Pre-treatment	8311.7±3577.2	0.071
Post-treatment	7526.0±2364.1	
Neutrophil percentage		
Pre-treatment	55.9±8.8	<0.05
Post-treatment	53.0±7.2	
ESR		
Pre-treatment	25.2±20.3	<0.05
Post-treatment	16.3±12.5	
CRP		
Pre-treatment	23.0±43.6	<0.05
Post-treatment	7.2±10.0	

ESR: Erythrocyte sedimentation rate; CRP: C-reactive protein.

four patients (6.9%), revealing a fluid collection in one patient and osteomyelitis in another. Computed tomography was performed in one patient (1.7%), with no pathological findings observed.

Half of the patients received monotherapy, most commonly β-lactam/β-lactamase inhibitor (BL-BLI) regimens (17.2%), while the remaining half were treated with combination regimens, most frequently BL-BLI plus a fluoroquinolone (22.4%). Surgical intervention was required in 20 patients (34.5%), with abscess drainage (17.2%) and fistulectomy (6.9%) being the most common procedures.

During the follow-up period, 15 patients (25.8%) developed recurrent infections, comprising 11 SSTIs (73%) and four BJIs (26%). There were no statistically significant differences between amputee and non-amputee groups in terms of recurrence rates or duration of hospitalization. However, treatment duration was significantly longer in the non-amputee group than in the amputee group (24.27±17.42 vs. 15.97±10.14 days, p<0.05) (Table 4).

DISCUSSION

A study evaluating infections after military trauma in the United States reported that SSTIs were the most frequent infections, occurring in 45% of patients (2). In a United States military cohort, 47% of patients with traumatic amputations developed infections, and osteomyelitis was observed in 4.9-8.9% of all trauma patients.[10] Consistent with these findings, 44.8% of our military trauma patients developed stump infections, while 10.4% were diagnosed with osteomyelitis.

In a study from Nigeria, in which approximately 46% of cases involved trauma-related amputations, *Staphylococcus spp*. were the most frequently isolated microorganisms after major lower-limb amputation.[11] The literature also emphasizes that *Staphylococcus spp*. are the most common pathogens in other SSTIs.[8] In line with these reports, *Staphylococcus spp*. were the most frequently identified causative agents in our study, both in post-amputation stump infections and in other SSTIs.

The rising incidence of MDR organisms in trauma-related infections remains a major challenge for clinicians. In a study from the United States evaluating infectious complications after military trauma, MDR organisms were reported in 25% of patients, while another study of trauma patients found a prevalence of 26.8%.[2,4] In line with these findings, MDR organisms were detected in 24.1% of cases in our study.

In our study, similar to previous reports, radiological examinations contributed to assessing the extent of infection and confirming the diagnosis.[12] Ultrasonography was primarily used for the rapid detection of soft tissue infection or abscess, as it is noninvasive, easily performed, and suitable for bedside use. Magnetic resonance imaging and scintigraphy were particularly valuable for identifying osteomyelitis. Decisions regarding surgical intervention were guided by accurate imaging and precise localization of the infected site.

Table 4. Comparison of amputee and non-amputee groups in terms of recurrent infection, treatment duration, and hospital stay

	Extremity Amputation Status		
	Not Amputated (n=26)	Amputated (n=32)	p
Recurrent infection			
Absent	19 (73.1%)	24 (75.0%)	1.000[b]
Present	7 (26.9%)	8 (25.0%)	
Duration of treatment	24.27±17.42	15.97±10.14	<0.05[a]
Duration of hospitalization	43.15±29.17	39.34±31.13	0.635[a]

[a]Independent-samples t test (Mean±SD); [b]Chi-square test (n, %).

Skin and soft tissue infections and BJIs have diverse etiologies. In addition to this heterogeneity, factors such as immune status, recent hospitalization, prior antibiotic exposure, and local resistance patterns are key considerations in selecting appropriate treatment regimens. In our study, the most frequently prescribed antibiotics were BL-BLI, either as monotherapy or in combination with a fluoroquinolone, consistent with the commonly isolated pathogens, observed resistance patterns, infection type, and guideline recommendations.[8,13] The significant decreases in ESR and CRP values at the end of treatment ($p<0.05$) further demonstrated treatment response in our patients.

In their study of major extremity amputations, Dutronc et al.[14] reported that 44% of patients with stump infections required surgical intervention in addition to antibiotic therapy. In our study, this rate was 34.5%. The lower rate of surgical intervention in our cohort compared with the literature may be explained by the inclusion of all trauma patients with SSTIs and BJIs, including both amputees and non-amputees.

Infectious and noninfectious complications of military trauma may occur long after the initial hospitalization, extending into both active-duty and veteran periods. A study from the United States evaluating trauma-related infections after military injuries reported that 76 patients (24%) developed a second infectious episode, most commonly SSTIs and osteomyelitis.[15] Consistent with the literature, 15 patients (25.8%) in our study experienced recurrent infections during the follow-up period, including 11 SSTIs and four BJIs.

The duration of antibiotic therapy is guided by the depth and extent of infection, as well as the patient's immune status. For example, a short five-day course may be sufficient for superficial SSTIs such as cellulitis, whereas deep wound infections often require 1–2 weeks of systemic antibiotic therapy combined with surgical drainage or debridement. Traditional treatment for osteomyelitis generally extends for 4–6 weeks and may be further prolonged in the presence of an orthopedic implant.[16,17] In our study, treatment duration was significantly longer in non-amputee patients compared with amputee patients ($p=0.03$). This difference may be attributed to the higher likelihood of BJIs, such as osteomyelitis, among non-amputee patients, which require longer courses of therapy.

In our cohort, overall ambulation levels following trauma were relatively low. Although 44.8% of patients were able to ambulate independently with a prosthesis and 24.1% required walking aids, nearly all lower-limb amputees ultimately achieved ambulatory status, with only two requiring walking aids. The literature emphasizes that ambulation capacity is strongly influenced by the level and etiology of amputation. For example, among patients undergoing lower-limb amputation due to ischemia or diabetes, prosthetic mobility rates have been reported as 73.5% for transtibial and 40.4% for transfemoral amputations.[18] By contrast, in a Sri Lankan cohort of traumatic amputees, 96% of patients were able to independently perform basic daily activities, and 83% were capable of advanced daily activities.[19] Collectively, these findings suggest that more favorable functional outcomes in military trauma-related amputations may be associated with the younger age and higher physical capacity of this population compared with civilian cohorts.

Limitations

This study has certain limitations. It was retrospective in design and conducted at a single rehabilitation center with a relatively small sample size, which may limit the generalizability of the findings. Detailed clinical data and long-term functional outcomes could not be fully assessed, and molecular analyses of MDR organisms were not performed. Despite these limitations, the study provides valuable insight into infectious complications occurring during the rehabilitation phase of military trauma patients.

CONCLUSION

In this study, stump infections were the most common infectious complication among military trauma patients. *Staphylococcus* species predominated as causative agents, while MDR gram-negative microorganisms were isolated in 24.1% of cases. BL-BLI regimens, either alone or in combination with a fluoroquinolone, were the most commonly used treatments. Treatment duration was longer in non-amputee patients, likely due to the higher incidence of bone and joint infections. Overall, infections remain a major concern during the rehabilitation phase of military trauma patients, particularly SSTIs and stump infections, and the presence of MDR organisms underscores the importance of appropriate antibiotic selection and strict infection control measures. Despite these infectious complications, relatively favorable functional outcomes can be achieved, especially in younger trauma populations, highlighting the essential role of comprehensive rehabilitation programs.

Ethics Committee Approval: This study was approved by the Ankara Bilkent City Hospital Ethics Committee (Date: 12.09.2023, Decision No: E1-23-4017).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Travma rehabilitasyonunda deri, yumuşak doku, kemik ve eklem enfeksiyonları

AMAÇ: Askeri travma hastalarında enfeksiyonlar yalnızca akut dönemde değil, rehabilitasyon sürecinde de sık görülen komplikasyonlardır. Ancak rehabilitasyon döneminde gelişen enfeksiyonlara ilişkin çalışmalar sınırlıdır. Bu çalışmanın amacı, rehabilitasyon sürecinde gelişen deri-yumuşak doku enfeksiyonları (DYDE) ve kemik-eklem enfeksiyonlarının (KEE) insidansını, mikrobiyolojik özelliklerini, tedavi yaklaşımlarını ve sonuçlarını değerlendirmektir.

GEREÇ VE YÖNTEM: Ocak 2020-Haziran 2023 tarihleri arasında üçüncü basamak bir rehabilitasyon hastanesinde yatan askeri travma hastalarının kayıtları retrospektif olarak incelendi. Rehabilitasyon döneminde DYDE veya KEE gelişen hastalar dahil edildi. Demografik ve klinik özellikler, laboratuvar ve görüntüleme bulguları, kültür sonuçları, antibiyotik tedavileri, cerrahi girişimler, tedavi süresi ve nüksler değerlendirildi.

BULGULAR: 1.078 travma hastasının 58'inde (%5.4) DYDE veya KEE gelişti. En sık görülen enfeksiyon güdük enfeksiyonuydu (%44.8), bunu greft enfeksiyonları (%15.5) izledi. Etkenler arasında en sık *Staphylococcus* türleri saptandı; olguların %24.1'inde çoklu ilaca dirençli (ÇİD) gram-negatif mikroorganizmalar izole edildi. En sık kullanılan tedavi β-laktam/β-laktamaz inhibitörü (BL-BLI) monoterapisi, ardından BL-BLI + florokinolon kombinasyonu oldu. Hastaların %34.5'inde cerrahi girişim gerekti. Nüks enfeksiyon oranı %25.8 idi. Ampütasyon geçirmemiş hastalarda tedavi süresi, kemik-eklem enfeksiyonlarının daha sık görülmesine bağlı olarak anlamlı şekilde uzundu ($p<0.05$). Bu enfeksiyöz komplikasyonlara rağmen, alt ekstremite ampütasyonu olan hastaların büyük çoğunluğu protezle ambulasyon sağladı.

SONUÇ: Askeri travma hastaları rehabilitasyon sürecinde DYDE ve KEE açısından risk altındadır; en sık görülen enfeksiyon güdük enfeksiyonlarıdır. ÇİD mikroorganizmaların varlığı uygun antibiyotik seçimi ve sıkı enfeksiyon kontrol önlemlerinin önemini vurgulamaktadır. Bu enfeksiyöz komplikasyonlara rağmen, özellikle genç travma hastalarında görece olumlu fonksiyonel sonuçlar elde edilebilmekte ve kapsamlı rehabilitasyon programlarının önemi bir kez daha ortaya konmaktadır.

Anahtar sözcükler: Askeri travma; çoklu ilaca dirençli mikroorganizmalar; deri ve yumuşak doku enfeksiyonları; kemik ve eklem enfeksiyonları; rehabilitasyon.

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ORIGINAL ARTICLE

Abdominal gunshot wounds: evaluating the role of computed tomography in surgical timing and decision-making

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ABSTRACT

BACKGROUND: Abdominal gunshot wounds contribute significantly to trauma-related morbidity and mortality. Computed tomography (CT) can provide valuable diagnostic information but may potentially delay definitive treatment. This study aimed to evaluate the role of abdominal CT in surgical decision-making and timing among patients with abdominal gunshot injuries.

METHODS: We retrospectively analyzed patients with abdominal gunshot wounds treated at a tertiary university hospital between January 2013 and January 2023. Collected data included demographic characteristics, physiological parameters, trauma scores, CT findings, time intervals (from admission to CT and to surgery), and clinical outcomes. Patients were classified as hemodynamically stable or unstable based on admission parameters and their response to resuscitation. The two groups were compared.

RESULTS: A total of 74 patients were included (94.5% male; median age, 32 years). Of these, 47 (63.5%) were hemodynamically stable at presentation, while 27 (36.5%) were unstable. Abdominal CT was performed in 67 patients (90.5%), with a median time of 28 minutes from admission. The median time to CT was similar between stable (28 minutes) and unstable (30 minutes) patients (p=0.934). Based on CT findings, nonoperative management was feasible in 10 patients (13.5%). Among the unstable group, CT was performed in 7 of 11 nonresponders, of whom six (54.5%) died. Among patients who underwent surgery, the mean time to operation was significantly shorter in unstable patients compared to stable patients (60.4±36.7 vs. 93.2±76.6 minutes; p=0.034). The perioperative mortality rate was 9.3%, with all deaths occurring in hemodynamically unstable nonresponders.

CONCLUSION: Abdominal CT can aid surgical planning without causing significant delays in definitive treatment, even in initially unstable patients who respond to resuscitation. CT findings may support nonoperative management in selected cases and guide targeted surgical interventions in patients requiring operative treatment. However, these findings apply to carefully selected patients and should be interpreted cautiously, as this study does not establish the safety of CT in unselected hemodynamically unstable patients. The proximity of the CT scanner to the resuscitation area facilitated rapid imaging; therefore, the findings may not be generalizable to institutions with remotely located CT facilities.

Keywords: Abdominal gunshot wounds; computed tomography (CT); surgical decision-making; trauma management; hemodynamic instability; time factors.

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INTRODUCTION

Trauma remains a leading cause of mortality worldwide and is the primary cause of death among individuals aged 1–44 years.[1] Penetrating injuries, particularly those caused by firearms, account for a substantial proportion of trauma-related deaths.[2] The management of abdominal gunshot wounds presents unique challenges, requiring rapid assessment and timely decision-making to optimize patient outcomes.

Advanced Trauma Life Support (ATLS) principles emphasize the importance of a primary survey, prompt resuscitation, and timely secondary assessments to identify specific injuries.[3] Traditionally, the management of penetrating abdominal trauma was guided by the principle that any breach of the peritoneal cavity necessitated exploratory laparotomy. However, contemporary evidence suggests that selective nonoperative management may be appropriate in carefully selected patients.[4,5]

The role of diagnostic imaging, particularly computed tomography (CT), in the management of abdominal gunshot wounds continues to evolve. Contrast-enhanced abdominal CT can provide detailed information regarding bullet trajectory, peritoneal violation, organ injuries, and retroperitoneal involvement.[6] Although CT offers valuable diagnostic insight, concerns remain regarding potential delays in definitive treatment, especially in hemodynamically unstable patients.[7]

The "golden hour" concept in trauma care underscores the importance of time in determining patient outcomes. Delays in definitive treatment have been associated with increased mortality, particularly in patients with hemorrhagic shock.[3] However, rapid CT acquisition with modern multidetector scanners may provide critical information without significant time delays when integrated into a well-coordinated trauma system.[8]

Hemodynamic assessment plays a crucial role in trauma management decision-making. Current guidelines categorize patients as hemodynamically stable, responders to resuscitation, transient responders, or nonresponders.[9] While hemodynamic instability has traditionally been considered a contraindication to CT imaging, an increasing body of evidence suggests that selected unstable patients who respond to initial resuscitation (hemodynamically stable patients) may benefit from CT-guided evaluation and management.[10,11]

The balance between diagnostic precision and timely intervention remains a critical consideration in trauma management. Avoiding unnecessary laparotomies through improved diagnostic accuracy must be weighed against the potential risks of delayed intervention.[12] Recent advances in trauma care have led to the development of hybrid operating rooms and rapid imaging protocols aimed at optimizing this balance.[13]

The primary aim of this study was to evaluate the impact of abdominal CT on surgical decision-making in patients with abdominal gunshot wounds. Additionally, we sought to analyze time factors in the management process, including time to CT acquisition and time to definitive treatment, and their relationships with patient outcomes.

MATERIALS AND METHODS

Study Design and Population

We conducted a retrospective analysis of patients with abdominal gunshot wounds treated at the Department of General Surgery, Marmara University Hospital, between January 1, 2013 and January 1, 2023. The study was conducted in accordance with the principles of the Declaration of Helsinki and received approval from the Ethics Committee of Marmara University (approval number: 09.2023.40). The study was reported in line with the STROCSS (Strengthening the Reporting of Cohort, Cross-Sectional and Case-Control Studies in Surgery) guidelines.[14]

Inclusion Criteria

• Patients aged ≥16 years who presented to the emergency department with abdominal gunshot wounds and were evaluated by the general surgery team

• Patients with isolated abdominal injuries or multitrauma patients with abdominal involvement

• The abdominal region was defined as the area between the diaphragm superiorly and the pelvic brim inferiorly, including lower thoracic injuries with diaphragmatic involvement.

Exclusion Criteria

• Patients with incomplete initial or follow-up data

• Patients with isolated extra-abdominal injuries

• Patients who were dead on arrival.

(The patient selection process is summarized in Figure 1.)

Patient records were identified using the *International Classification of Diseases, 10th Revision* (ICD-10) codes (S31.3, S31.4, S31.6, S36, X73, X74, X93, Y22) related to gunshot wounds through the Hospital Information Management System (HIMS).[15] The extracted data included:

1. Demographic characteristics (age, sex)
2. Admission vital signs

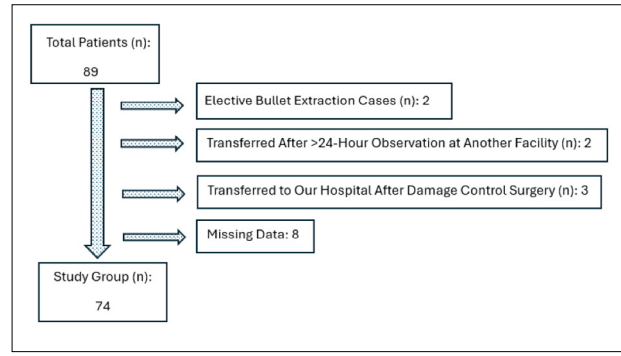

Figure 1. Patient selection flowchart.

3. Laboratory values (hemoglobin, hematocrit, white blood cell count)

4. Resuscitation measures (blood product administration)

5. Imaging studies (timing and findings of abdominal CT)

6. Surgical details (timing, procedures, findings, duration)

7. Trauma scores were assessed according to standardized criteria:

- o Injury Severity Score (ISS)
- o Revised Trauma Score (RTS)
- o Trauma and Injury Severity Score (TRISS).

The ISS evaluates anatomical injury severity, whereas the RTS assesses physiological parameters. The TRISS combines both anatomical and physiological parameters to estimate the probability of survival. The ISS, RTS, and TRISS scores for the patients in this study were calculated using the MDCalc website (https://www.mdcalc.com).[16]

The time intervals were calculated as follows (Fig. 2):

• Time to CT: Time in minutes from admission to completion of CT in the emergency department

• Time to surgery: Time in minutes from admission to entry into the operating room

• Duration of surgery: Time in minutes from incision to closure.

Hemodynamic Classification

Patients were classified based on their hemodynamic status at presentation according to established trauma guidelines:[3]

1. Stable:

- o Systolic blood pressure >90 mmHg
- o Heart rate <100 beats/minute
- o Estimated blood loss <750 mL
- o Normal tissue perfusion

2. Unstable: Presence of:

- o Systolic blood pressure <90 mmHg
- o Heart rate >100 beats/minute
- o Poor tissue perfusion
- o Altered level of consciousness.

Unstable patients were further subcategorized according to their response to initial fluid resuscitation:

• Responders:

- o Normalized blood pressure (>90 mmHg)
- o Decreased heart rate
- o Improved lactate levels
- o Normalized base deficit

• Nonresponders:

- o Persistent hypotension
- o Ongoing tachycardia
- o Worsening metabolic parameters
- o Continued physiological deterioration despite resuscitation.

Patients were grouped accordingly and compared based on these criteria.

Management and Imaging Protocol

Patient management was conducted in accordance with Advanced Trauma Life Support principles. In cases with clear signs of peritonitis (tenderness, rigidity, rebound) or evident hemodynamic instability, immediate surgical intervention was generally preferred. However, in patients with a partial response to resuscitation or inconclusive clinical findings, computed tomography imaging was occasionally performed prior to definitive surgical decision-making. In hemodynamically unstable patients, CT was utilized only when there was a partial response to resuscitation and when it could be performed rapidly without delaying surgical intervention. No patient experienced delayed surgery due to CT scanning. Throughout the study period, our institution adopted a relatively liberal approach to CT utilization, including its use in selected hemodynamically unstable patients when deemed potentially beneficial for assessing organ injuries and bullet trajectories. Additionally, CT imaging was employed to facilitate early notification of relevant specialists—such as cardiovascular surgeons, thoracic surgeons, hepatopancreatobiliary surgeons, and urologists—when complex or multi-organ injuries were suspected. Clinical decision-making was conducted through multidisciplinary collaboration between the emergency department and surgical teams. A single standardized management algorithm was not

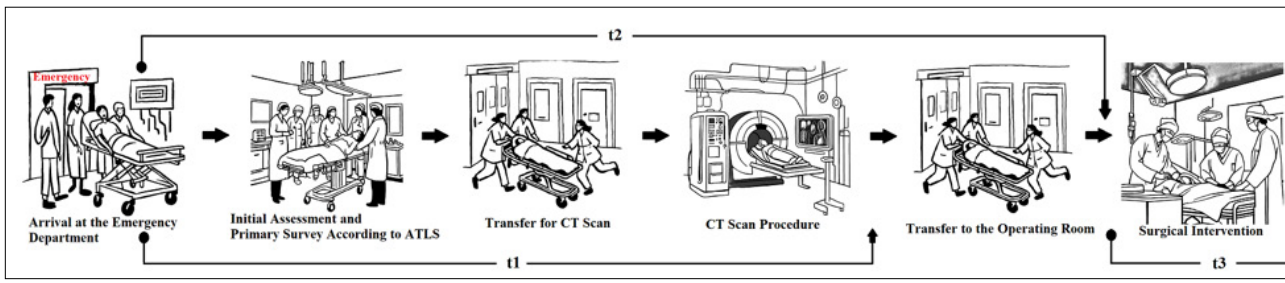

Figure 2. Management process of patients with abdominal gunshot wounds, from emergency department arrival to surgical intervention, highlighting critical time intervals (t1, t2, t3). ATLS: Advanced Trauma Life Support; CT: Computed tomography.

applied consistently throughout the 10-year study period.

The CT examinations performed were intravenous contrast-enhanced, 256-slice multidetector scans. Oral and rectal contrast agents were not routinely administered. Depending on the mechanism of injury, CT imaging also included the thorax and other relevant body regions.

Statistical Analysis

Statistical analyses were performed using SPSS version 25.0 (IBM Corp., Armonk, NY). Data distribution was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Normally distributed variables are presented as means±standard deviations, whereas non-normally distributed variables are expressed as median (interquartile range [IQR]). Categorical variables are presented as frequencies and percentages. Comparisons between groups were performed using Student's t-test or the Mann–Whitney U test for continuous variables, and the chi-square test or Fisher's exact test for categorical variables. A p-value <0.05 was considered statistically significant. Post hoc power analysis was performed using G*Power software (version 3.1.9.7).

RESULTS

Patient Demographics and Clinical Characteristics

A total of 74 patients with abdominal gunshot wounds were included in the analysis, comprising 70 males (94.5%) and four females (5.5%), with a median age of 32 years (IQR: 13). At presentation, 47 patients (63.5%) were hemodynamically stable, whereas 27 (36.5%) were classified as unstable.

Significant differences in vital signs were observed between the stable and unstable groups (Table 1). Mean arterial pressure was significantly lower in the unstable group (median 65 mmHg vs. 89 mmHg; p<0.01). Similarly, systolic blood

Table 1. Patient characteristics and clinical outcomes

Variables	Total	Stable	Unstable	P value
Total number of patients (n, %)	74	47 (63.5)	27 (36.5)	
Age (years), median (IQR)	32 (13)	31 (14)	33 (11)	0.486
Sex (n, %)				
Male	70 (94.6)	45	25	0.620
Female	4 (5.4)	2	2	
MAP (mmHg), median (IQR)	86.1 (24.3)	89 (19.6)	65 (33)	<0.01
SBP (mmHg), (mean±SD)	107.5±21.8	118.2±15.7	89±18.3	<0.01
Heart rate (beats/min), (mean±SD)	100.2±18.5	94±14.3	111±20.3	<0.01
SpO_2 (%), median (IQR)	98 (5)	98 (2)	94 (7)	<0.01
Hgb (g/dL), median (IQR)	14.2 (2.1)	14.2 (1.9)	14.2 (4)	0.437
Hct (%), (mean±SD)	40.6±5.5	41.3±4.2	39.3±7.2	0.146
WBC (10^3/μL), (mean±SD)	13.9±4.6	14.1±4.5	13.6±4.7	0.707
Blood transfusion in emergency department (n, %)	21 (28.4%)	6 (13.3%)	15 (55%)	<0.01
Abdominal CT performed (n, %)	67 (90.5%)	45 (95.7%)	22 (81.4%)	0.092
Time to CT (min), median (IQR)	28 (17.5)	28 (19)	30 (21)	0.934
TRISS (%), median (IQR)	98.54 (1)	96.17 (13.3)	<0.01	
RTS, median (IQR)	7.8 (0.2)	7.84 (0)	7.55 (1.7)	<0.01
ISS, median (IQR)	17 (14)	16 (11)	25 (15)	<0.01
Extra-abdominal injury (n, %)	46 (62.1%)	28 (59.5%)	18 (66.6%)	0.545
Surgery performed (n, %)	64 (86.5%)	38 (80.8%)	26 (96.2%)	0.082
Time to surgery (min), (mean±SD)	73.4±38.1	93.2±76.6	60.4±36.7	0.034
Blood transfusion during surgery (n, %)	24 (37.5%)	6 (66.6%)	18 (38.2%)	<0.01
Perioperative blood loss (mL), median (IQR)	400 (1075)	0 (500)	700 (2500)	0.009
Duration of surgery (min), median (IQR)	121 (65)	99 (68)	150 (60)	0.001
Postoperative length of stay (days), median (IQR)	5 (4)	4 (3)	5.5 (7)	0.034
Perioperative mortality (n, %)	6 (9.3%)	0	6 (22.2%)	<0.01

MAP: Mean arterial pressure; SBP: Systolic blood pressure; Hgb: Hemoglobin; Hct: Hematocrit; WBC: White blood cell count; CT: Computed tomography; TRISS: Trauma and Injury Severity Score; RTS: Revised Trauma Score; ISS: Injury Severity Score.

Table 2. Distribution of injured organs

Small intestine	34 (26.5%)
Colon	19 (14.8%)
Liver	15 (11.7%)
Diaphragm	13 (10.1%)
Stomach	9 (7%)
Mesentery	8 (6.2%)
Major vessels	8 (6.2%)
Kidney	5 (3.9%)
Rectum	4 (3.1%)
Spleen	4 (3.1%)
Pancreas	2 (1.5%)
Duodenum	2 (1.5%)

pressure was lower in unstable patients (mean 89.0±18.3 mmHg vs. 118.2±15.7 mmHg; p<0.01). Unstable patients also had significantly higher heart rates (mean 111.0±20.3 vs. 94.0±14.3 beats/min; p<0.01).

Imaging and Time Factors

Abdominal CT was performed in 67 patients (90.5%), including 45 stable patients (95.7%) and 22 unstable patients (81.4%). The median time from admission to CT completion was 28 minutes (IQR: 19), with no significant difference between stable and unstable patients (28 vs. 30 minutes; p=0.934).

The mean time to surgery was 73.4±38.1 minutes overall and was significantly shorter in unstable patients than in stable patients (60.4±36.7 vs. 93.2±76.6 minutes; p=0.034). The duration of surgery was significantly longer in unstable patients (median 150 vs. 99 minutes; p=0.001).

Management and Outcomes

In our series, the small intestine (26.5%), colon (14.8%), and liver (11.7%) were the most frequently injured abdominal organs due to gunshot wounds (Table 2).

Based on clinical evaluation and CT findings, 10 patients (13.5%) were managed nonoperatively, whereas 64 (86.5%) underwent surgical intervention. One patient presented with evisceration and hemodynamic instability and was taken directly to emergency surgery without undergoing CT imaging. Among the operated patients, the most common procedures were small bowel resection with anastomosis (39.1%), primary small bowel repair (20.3%), and liver laceration repair (23.4%). The negative laparotomy rate was 7.8% (five patients) (Table 3).

Table 3. Types of surgical procedures and patient distribution

Type of Surgery	Number of Patients Treated (n)
Small Bowel Procedures	
Resection + Anastomosis	25 (39.1%)
Primary Repair	13 (20.3%)
Resection + Ileostomy	2 (3.1%)
Colon Procedures	
Primary Repair	8 (12.5%)
Resection + Anastomosis	5 (7.8%)
Resection + Colostomy	5 (7.8%)
Rectal Procedures	
Resection + Colostomy	3 (4.7%)
Primary Repair + Colostomy	1 (1.6%)
Abdominal Organs and Vascular Procedures	
Liver Laceration Repair and Hemorrhage Control	15 (23.4%)
Diaphragm Repair	13 (20.3%)
Major Vessel Repair*	6 (9.4%)
Splenectomy	4 (6.3%)
Primary Stomach Repair	8 (12.5%)
Duodenal Repair	2 (3.1%)
Pancreatic Repair	2 (3.1%)
Nephrectomy	5 (7.8%)
Negative Laparotomy	5 (7.8%)

*Includes repairs of major abdominal vessels such as the inferior vena cava, portal vein, and iliac vessels.

Table 4. Clinical comparison: hemodynamic responders vs. nonresponders

Variables	Nonresponder (n=11)	Responder (n=16)	P value
Age (years) (mean±SD)	35.9±10.9	31.6±6.9	0.232
MAP (mmHg) (mean±SD)	61.2±12.2	75.5±20.3	0.049
SBP (mmHg) (mean±SD)	79.9±11.2	95.2±19.9	0.030
Heart rate (bpm) (mean±SD)	124.5±18.9	101.6±15.7	0.002
Hgb (g/dL) median (IQR)	11.7 (4.4)	14.5 (2.5)	0.087
Hct (%) median (IQR)	34.9 (11)	43.5 (6.6)	0.056
WBC (10^3/μL), (mean±SD)	12±6.1	14.4±3.9	0.289
Blood product administration in ER (n, %)	7 (63.6%)	8 (50%)	0.696
CT performed (n, %)	7 (63.6%)	15 (93.7%)	0.125
Time to CT (min) (mean±SD)	27.4±13.1	30.2±11	0.606
TRISS (%), median (IQR)	73.8 (57.3)	97.7 (2.7)	<0.01
RTS, median (IQR)	6 (2.1)	7.8 (0.2)	<0.01
ISS (mean±SD)	33.1±13.9	20.7±9.1	<0.01
Surgery performed (n, %)	11 (100%)	15 (93.7%)	1
Intraoperative blood product administration (n, %)	10 (90.9%)	8 (50%)	0.042
Intraoperative blood loss (mL) (mean±SD)	2890±1082	1159±998	0.001
Time to OR (min) (mean±SD)	44.7±25.3	67.7±39.6	0.177
Surgery duration (min) median (IQR)	210 (181)	140 (35)	0.002
Extra-abdominal injury (n, %)	7 (63.6%)	11 (68.7%)	0.808
Length of hospital stay (days), median (IQR)	4.5 (8)	6 (6)	0.407
Perioperative mortality (n, %)	6 (54.5%)	0	

MAP: Mean arterial pressure; SBP: Systolic blood pressure; Hgb: Hemoglobin; Hct: Hematocrit; WBC: White blood cell count; CT: Computed tomography; TRISS: Trauma and Injury Severity Score; RTS: Revised Trauma Score; ISS: Injury Severity Score; OR: Operating room; ER: Emergency room; bpm: Beats per minute.

The perioperative mortality rate was 9.3% (six patients), with all deaths occurring in the hemodynamically unstable nonresponder group. No mortality was observed among stable patients or unstable responders.

Subgroup Analysis: Responders vs. Nonresponders

Among the 27 hemodynamically unstable patients, 16 were classified as responders and 11 as nonresponders. Nonresponders demonstrated significantly worse hemodynamic parameters, including lower mean arterial pressure (61.2±12.2 vs. 75.5±20.3 mmHg; p=0.049) and higher heart rate (124.5±18.9 vs. 101.6±15.7 beats/min; p=0.002).

CT scans were performed in seven nonresponders (63.6%) and 15 responders (93.8%), with similar times to CT completion (27.4±13.1 vs. 30.2±11 minutes; p=0.606). All nonresponders and 15 of 16 responders underwent surgical intervention. The time to the operating room was shorter in nonresponders than in responders, although the difference was not statistically significant (44.7±25.3 vs. 67.7±39.6 minutes; p=0.177). The duration of surgery was significantly longer in nonresponders (median 210 vs. 140 minutes; p=0.002) (Table 4).

The mortality rate in the nonresponder group was 5/11 (45.5%), whereas no deaths occurred in the responder group (0/16). Comparison of trauma severity scores revealed significantly higher ISS values (median 48 vs. 25; p=0.03) and lower TRISS values (median 50.3% vs. 89.4%; p=0.03) in deceased nonresponders compared to survivors (Table 5).

Nonoperative Management

Ten patients (13.5%) were managed nonoperatively based on CT findings and clinical evaluation. Nine patients were hemodynamically stable at presentation, and one unstable patient stabilized after resuscitation. CT findings supporting nonoperative management included the following:

1. Back-region trajectories (flank or midline at the L1 vertebral level) (four patients) (Figs. 3, 4)

2. Suspected rectal proximity with normal rectosigmoidoscopy findings (three patients) (Fig. 5)

Table 5. Comparison of deceased and surviving nonresponder patients

Variable	Survived	Deceased	P value	95% CI	Effect Size (Cohen's d)	Post Hoc Power
Total number of patients (n)	5	6				
Age (years) (mean±SD)	41.6±11.6	31.1±8.5	0.121	-2.8 to 23.8	1.03	31%
TRISS (%), median (IQR)	89.4 (26.7)	50.3 (48.9)	0.03	8.2 to 69.9*	1.76	70%
ISS, median (IQR)	25 (16)	48 (21)	0.03	7.5 to 38.5*	1.65	65%
RTS, median (IQR)	7.1 (1.8)	5 (1.9)	0.247	-0.6 to 4.8*	1.12	36%
CT performed	3	4	1		-	-
Not performed	2	2				
Time to CT (min) (mean±SD)	23.6±10.9	30.2±15.5	0.562	-18.6 to 31.8	0.49	10%
Intraoperative blood loss (mL) (mean±SD)	2550±1236	3116±1018	0.450	-963 to 2095	0.51	11%
Surgery duration (min) (mean±SD)	195±102	253±114	0.477	-115 to 231	0.53	11%

TRISS: Trauma and Injury Severity Score; ISS: Injury Severity Score; RTS: Revised Trauma Score; CT: Computed tomography; IQR: Interquartile range; min: Minutes; ml: Milliliters. *Confidence intervals for median differences were estimated using the Hodges-Lehmann method. Statistical significance was defined as p<0.05. However, both statistically significant findings (TRISS and ISS) demonstrated observed power <80%, indicating a potential risk of Type II error. Therefore, these results should be considered preliminary and require validation in larger cohorts.

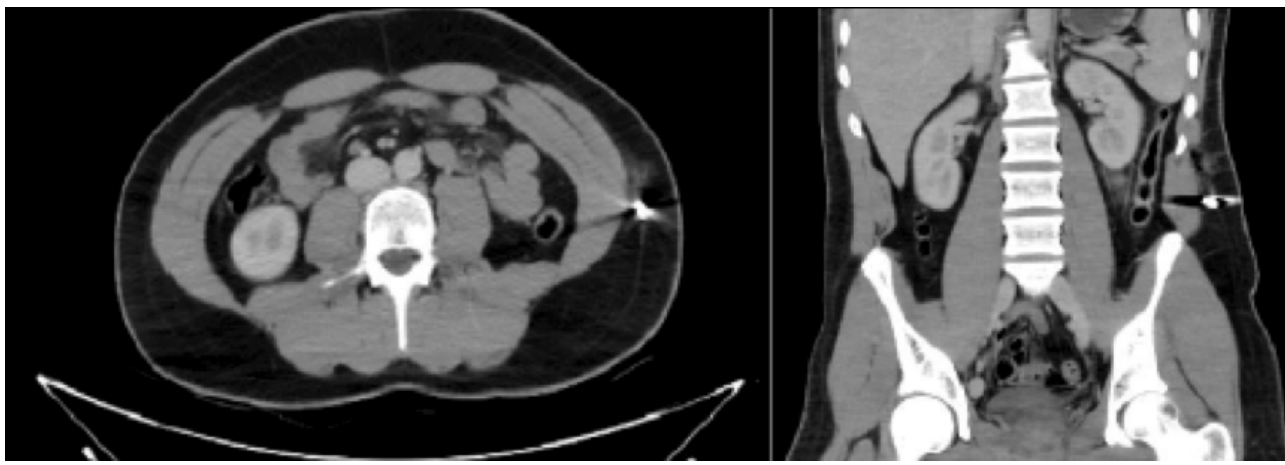

Figure 3. Computed tomography showing a bullet in the left flank without intra-abdominal injury.

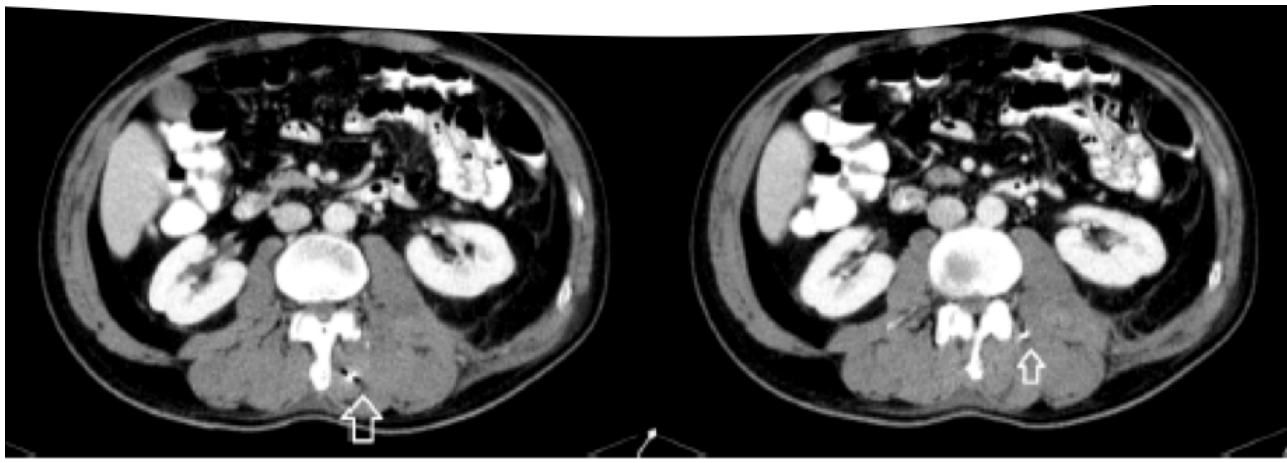

Figure 4. Midline bullet position at the level of the L1 vertebral spinous process.

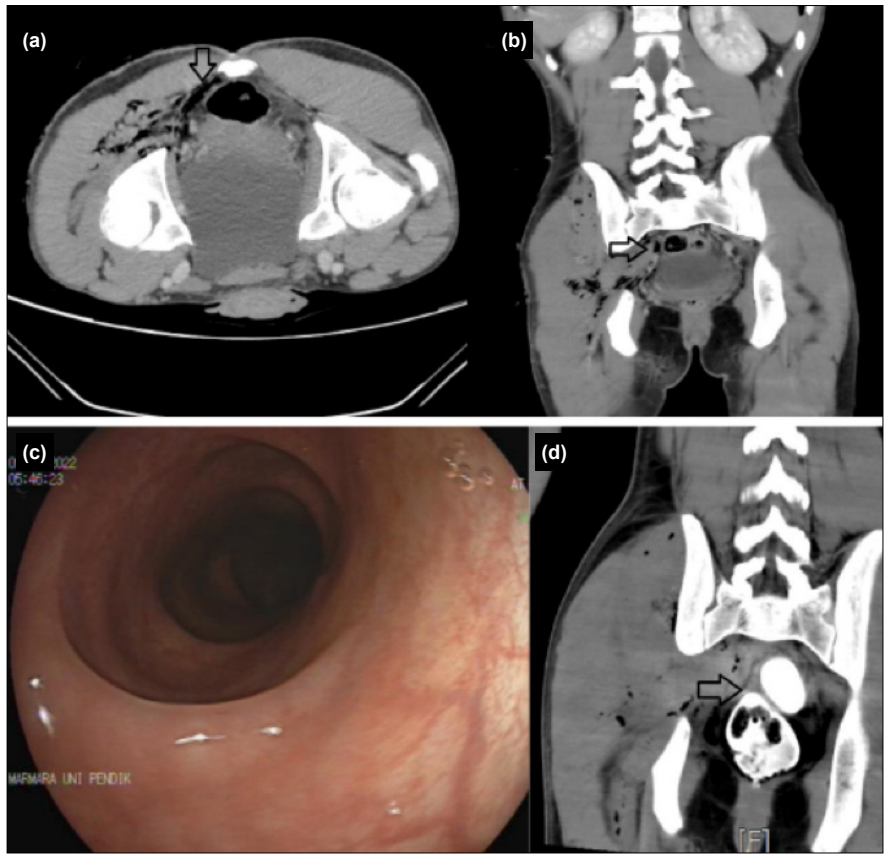

Figure 5. (a) Bullet trajectory and air bubbles in the right pararectal area. **(b)** Bullet trajectory extending from the right gluteal region to the pararectal area. **(c)** Same-day rectosigmoidoscopy showing intact mucosa. **(d)** Pre-discharge rectal contrast-enhanced computed tomography (CT) showing no contrast leakage.

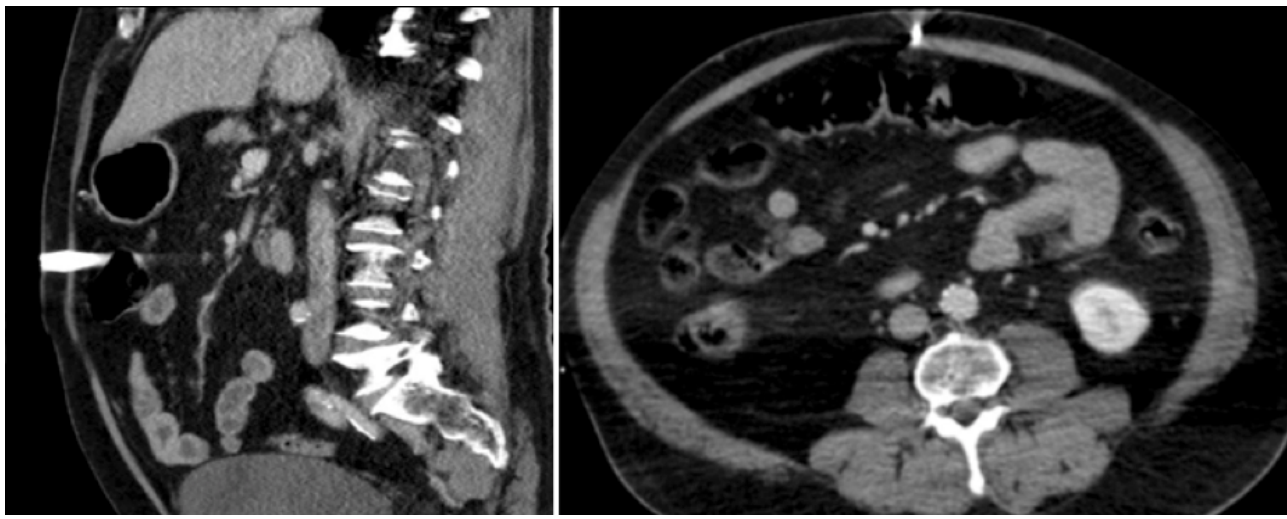

Figure 6. Anterior injury with a subcutaneous bullet trajectory and no peritoneal penetration.

3. Bullet trajectories limited to the subcutaneous tissues without peritoneal penetration (three patients) (Fig. 6).

All nonoperatively managed patients were discharged without complications after 24–48 hours of observation.

DISCUSSION

This study evaluated the impact of abdominal CT on surgical decision-making and time-related factors in patients with abdominal gunshot wounds. Our findings demonstrate that ab-

dominal CT may be safely incorporated into the management algorithm without significantly delaying definitive treatment, even in carefully selected hemodynamically unstable patients who respond to initial resuscitation, particularly when the CT unit is located in close proximity to the trauma resuscitation area.

The efficacy of CT in reducing unnecessary laparotomies is well established in the trauma literature.[17,18] In our cohort, 13.5% (10/74) of patients were successfully managed nonoperatively, with no subsequent surgical intervention required. Among the 64 surgically managed patients, the negative laparotomy rate was 7.8% (n=5), which is higher than the 2.2% reported by Demetriades et al.[19] Our lower nonoperative management rate compared to their reported rate of 29.8% may be attributed to methodological differences: their prospective study applied a standardized protocol with strict criteria for selective nonoperative management, whereas our retrospective analysis relied largely on individual surgeon preference. In our practice, nonoperative management (NOM) was applied to hemodynamically stable patients or those responsive to resuscitation when CT demonstrated limited injury patterns, such as back-region trajectories (flank or midline vertebral level), suspected rectal proximity with normal rectosigmoidoscopy findings, or subcutaneous bullet tracts without peritoneal violation. Notably, in our series of five negative laparotomy cases, CT findings indicated suitability for NOM; however, clinical considerations, such as penetrating abdominal injury or suspected peritonitis, led surgeons to proceed with operative management. This finding suggests that implementation of a standardized NOM protocol could optimize surgical decision-making and reduce unnecessary laparotomies.

In our cohort, the median time from emergency department admission to CT completion was 28 minutes. Fung Kon Jin et al.[20] systematically analyzed time intervals associated with CT use in trauma patients and reported a median of 82 minutes to CT initiation and 105 minutes to CT completion in a high-volume Level I center, with timing influenced by workflow organization and injury severity. When the CT scanner was located within 50 meters of the trauma bay, Huber-Wagner et al.[21] reported a mean admission-to-CT time of 22.7±15.5 minutes. A 10-year analysis from an Australian Level I trauma center demonstrated door-to-CT times ranging from 6 to 299 minutes (mean: 92 minutes), with no significant change over time—underscoring substantial inter-center variability in this metric.[22] This variability is largely attributable to differences in institutional imaging algorithms, CT accessibility, and workflow organization. Notably, most existing literature examines blunt or multitrauma populations, with relatively few studies reporting door-to-CT times specifically for firearm-related injuries. Therefore, our 10-year data may provide a complementary perspective in the context of penetrating trauma.

The proximity of CT scanners to the trauma resuscitation area has a significant positive impact on survival probability in severely injured patients. In our institution, the CT scanner is located approximately 20 meters from the resuscitation room, which contributed to the relatively short imaging acquisition times observed in our study. In the literature, a large multicenter retrospective study by Huber-Wagner et al.[21] demonstrated that locating the CT scanner close to the trauma room improves survival, whereas distances greater than 50 meters negatively affect outcomes. These findings support the concept that the distance between the CT scanner and the resuscitation area directly influences imaging time and the risks associated with potential delays. Shorter distances may facilitate faster imaging and earlier diagnosis, potentially reducing unnecessary delays and associated complication risks.[23]

The use of CT in hemodynamically unstable patients remains a subject of debate in trauma management. Traditional practice advocates immediate surgical intervention in these patients; however, recent evidence has increasingly challenged this approach.[11,24] In our study, 22 of 27 carefully selected unstable patients who responded to initial resuscitation underwent CT imaging without adverse outcomes. This approach was particularly important for facilitating early collaboration with specialty teams, including cardiovascular surgery, thoracic surgery, hepatopancreatobiliary surgery, and urology. In cases where complex or multi-organ injuries were suspected, CT enabled timely notification of these teams, thereby promoting more coordinated and efficient care. Subgroup analysis revealed that CT imaging was associated with favorable outcomes in resuscitation responders with respect to surgical decision-making, whereas in nonresponders, mortality was primarily related to injury severity rather than CT utilization. This finding aligns with multicenter studies suggesting that CT can be safely performed in selected unstable patients who respond to initial resuscitation and may be associated with improved clinical outcomes.[10]

The time from emergency department arrival to operating room entry remains a critical metric in trauma care. Contemporary studies suggest that mortality increases significantly when definitive intervention is delayed beyond 90 minutes in hypotensive trauma patients.[25] Henderson et al.[26] demonstrated that time to emergency trauma laparotomy can serve as an effective audit measure for the clinical governance of a trauma system. In their study, they reported a median time of 127 minutes from the emergency call to operation and 54 minutes from emergency department arrival to operating room entry. In our study, the mean time to surgery was 73.4 minutes overall, 60.4 minutes for unstable patients, and 44.7 minutes for nonresponders, reflecting acceptable performance within currently recommended timeframes. The shorter time to surgery observed in nonresponders highlights appropriate prioritization within our trauma system.

The analysis of trauma scoring systems in our study demonstrated their value in risk stratification. Higher ISS values and

lower TRISS values were strongly correlated with mortality, particularly in the nonresponder group. Although these results should be interpreted cautiously given the small subgroup size, the observed pattern suggests that mortality was more closely related to overall injury severity than to CT utilization. This trend highlights the prognostic value of trauma severity scores and underscores their importance in guiding imaging priorities and the timing of surgical intervention in trauma management. These findings are consistent with recent validation studies of trauma scoring systems.[16]

Limitations

Selection Bias: The retrospective design and the discretion of the initial emergency team and consulting surgeon regarding CT utilization introduce significant selection bias. Our findings apply only to carefully selected unstable patients and do not permit conclusions regarding the safety of CT in unselected hemodynamically unstable populations.

Limited Statistical Power: The small sample size, particularly in the nonresponder group (n=11) and in the mortality analysis (n=6 deaths), limits statistical power and increases the risk of Type II error, thereby precluding definitive conclusions regarding predictors of mortality.

Lack of a Standardized Protocol: The absence of a standardized nonoperative management protocol may have contributed to the relatively low NOM rate (13.5%), reflecting variations in institutional practice and individual surgeon judgment rather than strictly applied evidence-based criteria.

Institutional Infrastructure: The proximity of our CT scanner to the resuscitation room (approximately 20 meters) facilitated rapid imaging. This single-center infrastructure characteristic may limit generalizability to institutions where CT scanners are located farther from trauma bays.

Unassessed Factors: Radiation exposure and cost-effectiveness were not evaluated, limiting the comprehensiveness of our analysis.

CONCLUSION

Abdominal CT may provide valuable diagnostic information to support surgical decision-making in patients with abdominal gunshot wounds and, when applied within a well-coordinated trauma system, may not necessarily result in significant delays in definitive treatment. In selected cases of initially hemodynamically unstable patients who respond to resuscitation, CT imaging appears feasible and may potentially be performed safely without adversely affecting outcomes. Factors such as the proximity of CT scanners to resuscitation areas, continuous patient monitoring during imaging, and appropriate prioritization based on hemodynamic response may contribute to optimizing trauma care. Future prospective studies are warranted to develop standardized protocols for CT utilization in penetrating abdominal trauma, particularly with respect to selection criteria for imaging in unstable patients.

A portion of this study was presented at the 14th National Trauma and Emergency Surgery Congress (November 15-19, 2023, Antalya, Türkiye).

Ethics Committee Approval: This study was approved by the Marmara University Clinical Research Ethics Committee (Date: 06.01.2023, Decision No: 09.2023.40).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: M.İ.A.; Design: M.İ.A.; Supervision: C.Y., Ö.G.; Data collection and/or processing: M.İ.A.; Analysis and/or interpretation: A.S.B., M.E., T.K.U., M.İ.A.; Literature review: A.S.B., M.E., T.K.U., M.İ.A.; Writing: M.İ.A., C.Y.; Critical review: Ö.G., C.Y.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Abdominal ateşli silah yaralanmaları: Cerrahi zamanlama ve karar verme sürecinde bilgisayarlı tomografinin rolünün değerlendirilmesi

AMAÇ: Abdominal ateşli silah yaralanmaları, travmaya bağlı morbidite ve mortalite oranlarında önemli bir paya sahiptir. Bilgisayarlı tomografi (BT), tanısal açıdan değerli bilgiler sağlayabilse de, definitif tedavinin gecikmesine neden olabileceği düşünülmektedir. Bu çalışmanın amacı, abdominal BT'nin cerrahi karar süreci ve zamanlama üzerindeki etkisini değerlendirmektir.

GEREÇ VE YÖNTEM: Ocak 2013 ile Ocak 2023 tarihleri arasında, üçüncü basamak bir üniversite hastanesinde abdominal ateşli silah yaralanması nedeniyle tedavi edilen hastalar retrospektif olarak analiz edildi. Toplanan veriler arasında demografik bilgiler, fizyolojik parametreler, travma skorları, BT bulguları, başvurudan BT ve cerrahiye kadar geçen süreler ile klinik sonuçlar yer aldı. Hastalar, başvuru anındaki hemodinamik durumları ve resüsitasyona verdikleri yanıta göre "stabil" ve "instabil" olarak sınıflandırılarak karşılaştırıldı.

BULGULAR: Toplam 74 hastanın %94.5'i erkekti ve medyan yaş 32 idi. Hastaların 47'si (%63.5) hemodinamik olarak stabil, 27'si (%36.5) instabildi. Abdominal BT 67 hastaya (%90.5) uygulandı ve BT'ye kadar geçen medyan süre 28 dakika olarak saptandı. Stabil (28 dakika) ve instabil (30 dakika) hastalar arasında BT süresi açısından anlamlı fark yoktu (p=0.934). BT bulguları doğrultusunda 10 hastada (%13.5) cerrahi dışı tedavi uygulanabildi. İnstabil grup içinde, 11 yanıtsız hastanın 7'sinde BT çekilmiş olup, bunların 6'sı (%54.5) eksitus olmuştur. Cerrahi uygulanan hastalarda, operasyona kadar geçen ortalama süre instabil hastalarda anlamlı ölçüde daha kısaydı (60.4±36.7 dk vs. 93.2±76.6 dk; p=0.034). Perioperatif mortalite oranı %9.3 idi ve tüm ölümler resüsitasyona yanıt vermeyen instabil hastalarda görüldü.

SONUÇ: Abdominal BT, resüsitasyona yanıt veren başlangıçta instabil hastalarda bile, kesin tedavide anlamlı bir gecikmeye yol açmadan cerrahi planlamaya yardımcı olabilir. BT bulguları, seçilmiş olgularda nonoperatif tedaviyi destekleyebilir ve cerrahi girişim gereken hastalarda hedefe yönelik cerrahi yaklaşımların planlanmasına yardımcı olabilir. Ancak bu bulgular dikkatle seçilmiş hastalara özgüdür ve dikkatli biçimde yorumlanmalıdır; çünkü bu çalışma, BT'nin seçilmemiş hemodinamik olarak instabil hastalarda güvenliğini ortaya koymamaktadır. BT cihazının resüsitasyon alanına yakın konumu hızlı görüntülemeyi kolaylaştırmış olup, bulgular BT'nin uzak konumlandığı kurumlara genellenemeyebilir.

Anahtar sözcükler: Abdominal ateşli silah yaralanmaları; bilgisayarlı tomografi (bt); cerrahi karar verme; travma yönetimi; hemodinamik instabilite; zaman faktörleri.

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ORIGINAL ARTICLE

A new scoring system for the prediction of mortality in Fournier's gangrene: The Eğin score

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ABSTRACT

BACKGROUND: This study aimed to investigate the factors affecting mortality in Fournier's gangrene (FG) and to establish a simplified scoring system that enables practical bedside assessment for clinicians.

METHODS: The medical records of 130 patients treated for FG between February 2012 and January 2025 were retrospectively reviewed. Survivors (Group 1, n=101) were analyzed separately from non-survivors (Group 2, n=29). The collected data included sex, age, infection spread score, Uludag Fournier's Gangrene Severity Index (UFGSI), Fournier's Gangrene Severity Index (FGSI) scores, source of infection, presence of diabetes mellitus (DM), obesity, and other comorbidities. Additional variables included the presence of a diverting stoma, duration of vacuum-assisted closure (VAC) therapy, length of hospital stay, intensive care period (ICP), and isolated bacterial species. Associations between mortality and factors such as age, infection spread score, comorbidities other than DM and obesity (CADO), and ICP were examined.

RESULTS: A significant difference was observed between the groups in terms of age and age score. The infection spread score was significantly higher in Group 2. While 60 patients in Group 1 had CADO, all patients in Group 2 had CADO, demonstrating a statistically significant difference. ICP was also significantly longer among non-survivors. Receiver operating characteristic (ROC) analysis demonstrated that the Eğin score had a sensitivity of 96.6% and a specificity of 63.4% at a threshold value of >3.

CONCLUSION: Age, infection spread score, CADO, and ICP, which constitute the Eğin score, demonstrated significant differences between survivors and non-survivors. These parameters are crucial for predicting mortality in patients with FG.

Keywords: Fournier's gangrene; Fournier's Gangrene Severity Index; Uludag Fournier's Gangrene Severity Index; mortality; vacuum-assisted closure.

INTRODUCTION

Fournier's gangrene (FG) is a polymicrobial, necrotizing infection affecting the anorectal, perineal, and genitourinary regions. It progresses rapidly—at a rate of up to 2 cm per hour—and is associated with high morbidity and mortality rates. As a form of synergistic necrotizing fasciitis, FG causes thrombosis of the subcutaneous vessels, ultimately leading to gangrene of the overlying skin. Because delays in diagnosis and treatment can be fatal, early recognition of symptoms is critical. Prompt and aggressive surgical debridement is essential for management.

The disease often presents abruptly with severe pain and rapidly spreads from the fascia of the anterior abdominal wall to the muscles of the gluteal and femoral regions. FG was first described in 1883 by Jean Alfred Fournier, a French dermatologist and venereologist. Clinical presentation varies depending on the stage at which the patient seeks medical attention. In the early stage, signs may include localized induration, erythema, and swelling in the pelvic region. In advanced stages, sepsis and systemic inflammatory response syndrome may develop. Common clinical findings include localized erythema, hyperemia, pruritus, fever, and scrotal swelling. Early manifestations may be subtle, making diagnosis challenging.

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However, due to the aggressive nature of the disease, more pronounced symptoms, such as cyanosis, malodorous discharge, fecaloid odor, and skin necrosis, can rapidly emerge.[1]

Although FG can occur at any age and in both sexes, it is most prevalent in men between 30 and 60 years of age.[2] Advanced age is a recognized risk factor for the development of FG.[3] The disease is frequently associated with comorbid conditions such as diabetes mellitus (DM), alcoholism, atherosclerosis, peripheral arterial disease, malnutrition, prostate cancer, Human Immunodeficiency Virus (HIV) infection, leukemia, and liver disease.[4] The risk and severity of FG increase in patients with multiple comorbidities.[5]

Fournier's gangrene typically results from synergistic infections involving both aerobic and anaerobic bacteria. Although substantial progress has been made in understanding the etiology and pathophysiology of the disease, mortality rates remain high, ranging from 3% to 45%.[6] Current treatment strategies include hemodynamic stabilization, prompt and aggressive surgical debridement, removal of necrotic tissue, and administration of broad-spectrum intravenous antibiotics.[7] Although recent studies have highlighted the potential benefits of hyperbaric oxygen therapy, its use remains limited due to logistical challenges related to patient transfer and restricted access to specialized treatment facilities.[8]

Several scoring systems have been developed to assess the severity of FG at the time of admission. The Fournier's Gangrene Severity Index (FGSI), introduced by Laor et al. in 1995, was designed to predict mortality.[9] It incorporates nine clinical and laboratory parameters: heart rate, respiratory rate, body temperature, sodium, potassium, creatinine, leukocyte count, hematocrit, and bicarbonate levels. Each parameter is scored from 0 to 4, and the total score reflects disease severity.

In 2010, Yilmazlar et al. developed the Uludag Fournier's Gangrene Severity Index (UFGSI), which incorporates patient age and disease extent into the original FGSI model.[10] They demonstrated that the UFGSI had greater predictive power than the FGSI alone. Lin et al. later proposed a simplified version (SFGSI), including only three variables—serum potassium, creatinine, and hematocrit—to improve usability while maintaining predictive accuracy.[11] However, many of these scoring systems are still too complex for routine bedside application. Clinicians require a simpler and more practical tool.

This study aims to identify mortality-related risk factors in FG and to propose a novel, straightforward scoring system that can be easily applied at the bedside. We hypothesize that age over 60 years, a higher infection spread score, the presence of comorbidities other than DM and obesity (CADO), and a prolonged intensive care period (ICP) are predictors of mortality in patients with FG. The Eğin score, developed based on these variables, is expected to correlate significantly with increased mortality when exceeding a defined threshold.

MATERIALS AND METHODS

A total of 130 patients with FG, aged between 30 and 90 years, were included in the study. Among them, 123 patients received vacuum-assisted closure (VAC) therapy following aggressive surgical debridement, whereas seven patients did not. Patients who were admitted with a preliminary diagnosis of FG but in whom fascial, subcutaneous, or skin necrosis was not detected during debridement were excluded from the study.

Ethical approval was obtained from the Ethics Committee of Prof. Dr. Cemil Taşcıoğlu City Hospital, Istanbul, Türkiye (Approval No: 117, Date: 24.03.2025). All procedures were conducted in accordance with ethical standards and the principles of the Declaration of Helsinki. Data from 130 patients treated for FG between February 2012 and January 2025 at the General Surgery Clinic of Istanbul Prof. Dr. Cemil Taşcıoğlu City Hospital were analyzed. Although the cases were prospectively recorded, the study design was retrospective. Patients were divided into survivors (Group 1, n=101) and non-survivors (Group 2, n=29). The collected variables included sex, age, extent of infection, UFGSI, and FGSI scores, source of infection, presence of diabetes mellitus, obesity, and other comorbidities, presence of a diverting stoma, duration of VAC therapy (days), length of hospital stay (LOHS), intensive care period, and isolated bacterial species.

Based on these data, factors influencing mortality in patients with FG were analyzed. During the surgical management of the cases, four parameters closely associated with mortality were identified:

1. Age and extent of infection have been well established as significant factors in previous studies and were selected as the first two components of the Eğin scoring system.

2. Comorbidities other than DM and obesity (CADO)—including heart failure, chronic obstructive pulmonary disease, hypertension, and malignancies—were observed to correlate with increased mortality. Therefore, the presence of CADO was selected as the third parameter.

3. ICP duration was determined to be a significant predictor of mortality; longer stays were associated with worse outcomes, making it the fourth parameter in the Eğin score.

The scoring criteria were defined as follows:

• Age: <60 years=0 points; ≥60 years=1 point.

• Extent of infection: Limited to the urogenital and/or anorectal region=1 point; limited to the pelvis=2 points; extension beyond the pelvis=6 points.

• CADO: Absent=0 points; present=1 point.

• ICP (days): Below the statistically determined threshold=0 points; above the threshold=1 point.

The diagnosis of FG was based on a physical examination. In suspected cases, soft tissue ultrasonography or pelvic com-

Table 1. Baseline characteristics and clinical variables according to mortality status

	Group 1 (Survivors)	Group 2 (Non-survivors)	p
Sex			
Female	34 (33.7%)	17 (58.6%)	**0.015**
Male	67 (66.3%)	12 (41.4%)	
Age category			
<60 years	65 (64.4%)	7 (24.1%)	<**0.001**
≥60 years	36 (35.6%)	22 (75.9%)	
Infection source			
Urogenital	40 (39.6%)	20 (69.0%)	**0.005**
Anorectal	61 (60.4%)	9 (31.0%)	
Diabetes mellitus (DM)			
No	28 (27.7%)	5 (17.2%)	0.253
Yes	73 (72.3%)	24 (82.8%)	
Comorbidities other than DM and obesity			
No	41 (40.6%)	0 (0.0%)	**<0.001**
Yes	60 (59.4%)	29 (100%)	
Obesity			
No	68 (67.3%)	14 (48.3%)	0.061
Yes	33 (32.7%)	15 (51.7%)	
Isolated bacterial type			
None	54 (53.5%)	12 (41.4%)	0.512
Escherichia coli	38 (37.6%)	14 (48.3%)	
Other organisms	9 (8.9%)	3 (10.3%)	
Definitive closure method			
None	8 (7.9%)	25 (86.2%)	**<0.001**
Primary closure	29 (28.7%)	2 (6.9%)	
Split-thickness skin graft	37 (36.6%)	2 (6.9%)	
V-Y flap	20 (19.8%)	0 (0.0%)	
Rotation flap	7 (6.9%)	0 (0.0%)	
Stoma formation			
No	87 (86.1%)	24 (82.8%)	0.766
Yes	14 (13.9%)	5 (17.2%)	

puted tomography (CT) was performed to detect subcutaneous gas. Upon admission to the emergency department, patients were kept nil per os, and intravenous fluid resuscitation along with broad-spectrum antibiotics was initiated. The surgical team proceeded promptly with extensive debridement to remove necrotic tissue, prevent further spread of infection, and reduce systemic toxicity. Surgical interventions were repeated at 24-48 hour intervals until viable, well-vascularized tissue was achieved and the infection was controlled.

Although there is no universal consensus regarding the use of diverting colostomy, it is often recommended in cases with extensive sphincter damage or large perineal wounds. [12] The decision to perform a colostomy was generally made during the second or third debridement, when inflammation had subsided and the sphincter complex could be more accurately evaluated.

Following aggressive debridement, substantial tissue loss was observed in all patients, making wound management a critical component of FG treatment. VAC therapy, which has gained increasing popularity in recent years, was applied in 123 pa-

Table 2. Mean values and statistical significance of the characteristics across groups

	Group 1 (Survivors)	Group 2 (Non-survivors)	p**
Age (years)	53.97±11.57	68.28±13.15	<**0.001***
Temperature (°C)	36.92±0.57	36.94±0.94	0.339
Heart rate (/min)	0.22±0.63	0.76±0.99	**0.001**
Respiratory rate (/min)	22.79±2.02	24.83±4.52	**0.012**
Serum potassium (mmol/L)	4.21±0.7	4.15±1.01	0.597*
Serum sodium (mmol/L)	134.42±4.95	133.21±7.78	0.439
Serum creatinine (mg/100 mL)	1.21±1.00	1.54±1.35	0.597
Hematocrit (%)	36.56±6.11	31.82±5.54	<**0.001***
White blood cell count (×1000/mm^3)	20.16±8.48	21.19±8.80	0.447
Serum bicarbonate (venous, mmol/L)	22.88±4.83	21.75±7.12	**0.012**
Urea (mg/100 mL)	50.50±32.04	87.24±68.46	**0.002**
VAC therapy duration (days)	26.72±16.61	27.83±20.43	0.942
Length of hospital stay (days)	40.66±23.15	40.48±25.33	0.652
Intensive care period (days)	3.68±8.54	25.07±21.55	<**0.001**

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

tients to promote granulation formation and facilitate wound healing.[13] VAC dressings were changed every 3-4 days. Once adequate granulation tissue had developed, definitive wound closure was achieved using delayed primary suture, V–Y advancement flaps, or-most commonly-split-thickness skin grafts for larger defects.

Among the seven patients who did not receive VAC therapy, five had small, localized defects. Of these, three underwent primary closure after two or more debridements, and two were managed with healing by secondary intention. Of the remaining two patients, one died due to hemorrhage from the open wound, and the other died as a result of malignant invasion of the wound bed.

Statistical Analysis

Statistical analyses were performed using SPSS for Windows, version 15.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were expressed as numbers and percentages for categorical variables and as mean±standard deviation for continuous variables. Group proportions were compared using the chi-square test. For continuous variables, comparisons between two independent groups were conducted using the Student's t-test when the assumption of normality was satisfied and the Mann–Whitney U test when it was not. Receiver operating characteristic (ROC) curve analysis was performed to determine cut-off values. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 130 patients were included in the study, comprising 79 males (60.8%) and 51 females (39.2%). The overall mortality rate was 22.3% (n=29). A statistically significant difference in sex distribution was observed between Group 1 (survivors) and Group 2 (non-survivors) (Table 1).

The mean age of patients in Group 1 was 53.97±11.57 years, which was significantly lower than that of Group 2 (68.28±13.15 years; p<0.001) (Tables 2 and 4). A significant difference was also identified in the age score within the UFGSI parameters (p<0.001) (Tables 3 and 4). The infection spread score was significantly higher in Group 2 (p<0.001) (Tables 3 and 4).

Hematocrit and serum bicarbonate levels (components of both the UFGSI and FGSI) were significantly lower in Group 2 (p<0.001 and p=0.015, respectively) (Table 2). Heart rate and respiratory rate were significantly higher in Group 2 (p=0.001 and p=0.012, respectively) (Table 2). Correspondingly, the scores for temperature, heart rate, respiratory rate, hematocrit, and bicarbonate were significantly elevated in Group 2 (p=0.002, p=0.002, p=0.003, p=0.016, and p<0.001, respectively) (Table 3).

Diabetes mellitus was present in 73 patients in Group 1 and 24 patients in Group 2, with no statistically significant difference between the groups (Table 1). Obesity was identified in 33 patients with DM in Group 1 and in 15 patients in Group 2; again, no significant difference was observed (Table

Table 3. Distribution of scores and statistical significance between groups based on the FGSI and UFGSI scoring systems

		Group 1 (Survivors)	Group 2 (Non-survivors)	p
Temperature score				
36-38.4°C	0	96	22	**0.002**
34-35.9/38.5-38.9°C	1	4	7	
30-31.9/39-40.9°C	3	1	0	
Heart rate score				
70-109	0	90	18	**0.002**
55-69/110-139	2	11	11	
Respiratory rate score				
12-24	0	93	20	**0.003**
10-11/25-34	1	8	9	
Serum potassium score				
3-3.4 mmol/L	0	24	4	0.208
2.5-2.9/3.5-5.4 mmol/L	1	72	21	
5.5-5.9 mmol/L	2	4	3	
<2.5/>6-6.9 mmol/L	4	1	1	
Serum sodium score				
130-149 mmol/L	0	81	19	0.075
120-129/155-159 mmol/L	2	20	9	
110-119/160-179 mmol/L	3	0	1	
Serum creatinine score				
0.6-1.4 mg/100 mL	0	70	13	0.029
<0.6/1.5-1.9 mg/100 mL	2	23	8	
2-3.4 mg/100 mL	3	6	6	
>3.5 mg/100 mL	4	2	2	
Hematocrit score				
30-45%	0	81	17	**0.016**
46-49%	1	4	0	
20-29/50-59%	2	15	12	
<20/>60%	4	1	0	
White blood cell score				
3-14.9 ×1000/mm^3	0	28	6	0.663
15-19.9 ×1000/mm^3	1	29	8	
1-2.9/20-39.9 ×1000/mm^3	2	41	13	
<1/>40 ×1000/mm^3	4	3	2	
Serum bicarbonate score				
22-31 mmol/L	0	73	8	**<0.001**
32-40 mmol/L	1	4	3	
18-21 mmol/L	2	11	12	
15-17/41-51 mmol/L	3	9	3	
<15/>52 mmol/L	4	4	3	
Infection spread score				
Limited to urogenital/anorectal region	1	41	5	**<0.001**
Limited to pelvis	2	43	9	
Extension beyond pelvis	6	17	15	
Age score				
<60 years	0	65	7	**<0.001**
≥60 years	1	36	22	

Table 4. Distribution of age, comorbidities other than diabetes mellitus (DM) and obesity, infection spread score, and intensive care unit stay between the groups

	Group 1 (Survivors)	Group 2 (Non-survivors)	p**
Age (years)	53.97±11.57	68.28±13.15	<**0.001**
Age <60 years (Score 0)	65 (64.4%)	7 (24.1%)	<**0.001**
Age >60 years (Score 1)	36 (35.6%)	22 (75.9%)	
Comorbidities other than DM and obesity			
No	41 (40.6%)	0 (0.0%)	<**0.001**
Yes	60 (59.4%)	29 (100%)	
Infection spread score			
Limited to urogenital/anorectal region (Score 1)	41	5	<**0.001**
Limited to pelvis (Score 2)	43	9	
Extension beyond pelvis (Score 6)	17	15	
Intensive care period (days)	3.68±8.54	25.07±21.55	<**0.001**

Table 5. Univariate analysis of risk factors associated with mortality

	p	OR	95% CI	
Age				
(Ref. <60 years)	<0.001	5.675	2.21	14.57
Infection spread score				
(Ref. Limited to urogenital/anorectal region)	0.001			
Limited to pelvis	0.367	1.716	0.531	5.552
Extension beyond pelvis	0.001	7.235	2.27	23.065
Infection spread score				
(Ref. Limited to pelvis)	0.001			
Limited to urogenital/anorectal region	0.367	0.583	0.18	1.885
Extension beyond pelvis	0.005	4.216	1.552	11.449
Intensive care period (Ref. ≤3 days)				
>3 days	<0.001	43.312	9.591	195.6

1). However, comorbidities other than DM and obesity were present in 60 patients in Group 1 and in all 29 patients in Group 2, demonstrating a significant association with mortality (p<0.001) (Tables 1 and 4). LOHS did not differ significantly between the groups (Table 2).

All 74 patients who developed respiratory failure required mechanical ventilation in the intensive care unit (ICU); 28 of these patients died. The ICP was significantly longer in Group 2 (p<0.001) (Tables 2 and 4).

Bacterial cultures from wound infections were obtained in 64 patients, including 47 in Group 1 and 17 in Group 2. The most frequently isolated organism was Escherichia coli (n=52). Other identified pathogens included Acinetobacter, Streptococcus, Staphylococcus aureus, Pseudomonas, and Klebsiella species, isolated in 12 patients. No statistically significant difference was observed between the groups with respect to the distribution of bacterial species (Table 1).

Age and age score, infection spread score, CADO, and duration of ICP—the components of the Eğin score—demonstrated significant differences between the groups (Table 4). In the univariate analysis, significant risk factors associated with mortality included age, infection spread score, and duration of ICP. Patients older than 60 years had a significantly increased risk of mortality (odds ratio [OR]=5.675; 95% confidence interval [CI]: 2.21–14.57; p<0.001) (Table 5). When the infection spread score was evaluated, the risk of

Table 6. Predictive performance of UFGSI, FGSI, and Eğin score for mortality in patients with Fournier's gangrene

	Threshold 95% CI	Sensitivity	Specificity	Likelihood Ratio	(+) Predictive Value	(-) Predictive Value
UFGSI	≥8	96.4%	61.8%	2.52	41.8%	98.4%
FGSI	≥6	82.8%	69.3%	2.70	43.6%	93.3%
Eğin Score	>3	96.6%	63.4%	2.64	43.1%	98.5%

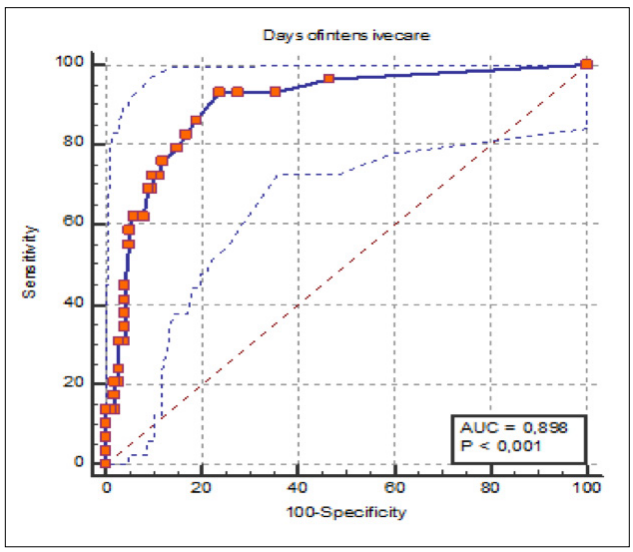

Figure 1. Receiver operating characteristic (ROC) curve or intensive care period duration at a threshold value of > 3 days.

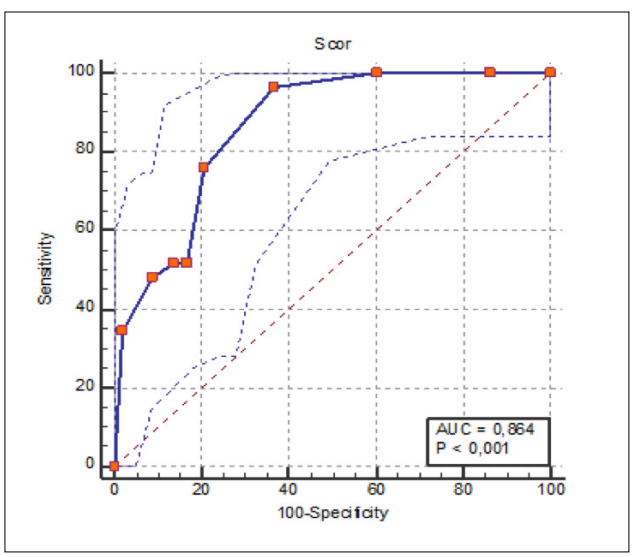

Figure 2. Receiver operating characteristic (ROC) curve of the Eğin score (threshold value: >3).

mortality was significantly higher in patients with infection extending beyond the pelvic boundaries compared with those with infection confined to the urogenital or anorectal regions (OR=7.235; 95% CI: 2.27–23.07; p=0.001) (Table 5). Mortality risk was also significantly elevated in patients with an ICP duration longer than three days (OR=43.312; 95% CI: 9.591–195.6; p<0.001) (Table 5). The presence of diabetes mellitus, obesity, and CADO did not reach statistical significance in the univariate analysis.

In the multivariate analysis, an ICP duration longer than three days (OR=17.505; 95% CI: 3.419–89.611; p=0.001) was identified as an independent predictor of mortality. This finding highlights the critical importance of early recognition and appropriate management of patients requiring prolonged intensive care. Age, obesity, DM, CADO, and infection spread score were not statistically significant in the multivariate model.

ROC analysis of ICP duration demonstrated a sensitivity of 93.1% and a specificity of 76.2% at a cut-off value of >3. The area under the ROC curve (AUC) for ICP days was 0.898 (95% CI: 0.833–0.944) (Fig. 1).

The Eğin score demonstrated a sensitivity of 96.6% and a specificity of 63.4% at a threshold value of >3. The AUC for the Eğin score was 0.864 (95% CI: 0.792–0.917) (Fig. 2). The threshold values, 95% CIs, sensitivity, specificity, odds ratios, positive predictive values, and negative predictive values for all three scoring systems are presented in Table 6.

DISCUSSION

Ongoing debates persist regarding the accurate prediction of mortality in FG. Although several studies have identified contributing factors, the issue remains complex. Among these factors, age has consistently been reported as a significant determinant of mortality.[10,14,15] In line with previous findings, our study demonstrated a significant difference in outcomes between patients older and younger than 60 years (Tables 1–4), with advanced age emerging as an independent predictor of mortality.

Another important finding was the significantly higher infection spread score observed in Group 2 (Tables 3 and 4). Similar to the studies by Yılmazlar et al.,[6,10] our results confirmed a strong correlation between the extent of infection and mortality, reinforcing this parameter as an independent predictive factor.

Numerous previous investigations have examined the impact of comorbidities on FG-related mortality. Although diabetes mellitus is frequently observed in patients with FG, and was present in 73 patients in Group 1 and 24 patients in Group 2

(Table 1), no significant association with mortality was identified in this study. Consistent with the literature, DM alone appears insufficient as a predictor of mortality.[10,14,15] However, while DM and obesity alone were not associated with increased mortality in our cohort, other comorbidities, such as malignancy, heart failure, and respiratory failure, were found to significantly influence mortality (Tables 1 and 4). Therefore, the presence of CADO was identified as a predictive factor.

Length of hospital stay did not differ significantly between the groups; however, the duration of the intensive care period was significantly longer among non-survivors (Tables 2 and 4). An ICP duration longer than 3 days emerged as an independent predictor of mortality in the multivariate regression analysis, rather than merely reflecting disease outcome. This finding, which has not been widely emphasized in the literature, represents an important contribution of the present study.

Although FGSI and UFGSI are widely used tools for predicting mortality in FG, with high reported sensitivity and specificity, their complexity limits their practical use in clinical settings. There remains a need for simpler and more user-friendly predictive models. In our study, age, infection spread score, CADO, and ICP duration—all components of the newly developed Eğin score—differed significantly between survivors and non-survivors (Table 4). In the univariate analysis, age, infection spread score, and ICP duration were identified as significant risk factors for mortality. In contrast, multivariate analysis demonstrated that only ICP duration was an independent predictor of mortality. Among these variables, ICP duration is potentially modifiable. Early diagnosis and prompt, aggressive debridement may limit infection spread, thereby reducing the infection spread score and potentially improving survival. In contrast, age and the presence of CADO are non-modifiable factors but remain essential for risk stratification.

The Eğin score demonstrated a sensitivity of 96.6% and a specificity of 63.4% at a threshold value of >3. In comparison, the reported sensitivities for UFGSI and FGSI were 96.4% and 82.8%, with specificities of 61.8% and 69.3%, respectively. The corresponding threshold values were ≥8 for UFGSI and ≥6 for FGSI. Although the Eğin score showed slightly lower specificity, its comparable sensitivity and simplified structure suggest that it may serve as a practical and reliable tool for bedside use.

Yılmazlar et al.[10] reported a sensitivity of 94% and a specificity of 81% for UFGSI, while Roghmann et al.[14] reported sensitivity and specificity values of 85% and 67%, respectively. In the literature, FGSI sensitivity and specificity values range from 65-100% and 67-88%, respectively. Recently, Çomçalı et al.[16] introduced the Fournier's Gangrene Mortality Prediction Model (FGMPM), which incorporates components of the FGSI, UFGSI, and the Age-Adjusted Charlson Comorbidity Index (ACCI), along with variables such as ICU admission, inotropic support requirement, and neutrophil-to-lymphocyte ratio. They reported AUC values (95% confidence intervals) of 0.788 for ACCI, 0.893 for UFGSI, 0.874 for FGSI, and 0.995 for FGMPM. Although the FGMPM demonstrated the highest predictive performance, its complexity and inclusion of multiple variables may limit its practicality for bedside use. In their multivariate regression analysis, hypoalbuminemia and the need for positive inotropic support were identified as independent risk factors for mortality. The authors therefore suggested that these two parameters might be more practical for mortality prediction than relying solely on the broader parameters included in the UFGSI and FGSI. They also emphasized that easily identifiable variables may be preferable to time-consuming and complex scoring systems. Similarly, the use of readily calculable parameters, as demonstrated in our study, may provide clinicians with a more practical approach to predicting mortality in patients with Fournier's gangrene.

A 2023 meta-analysis evaluating the performance of scoring systems in predicting mortality in Fournier's gangrene demonstrated a clear association between FGSI/UFGSI scores and mortality risk. However, no standardized cut-off value was identified, and mortality rates varied considerably across studies. Preexisting comorbidities, duration of symptoms, and delays in surgical intervention were identified as potential confounding factors. Most studies included in the meta-analysis were retrospective in design, underscoring the need for studies with larger populations to validate these findings. In that analysis, the UFGSI demonstrated the highest predictive accuracy, followed by the FGSI. Future research is required to externally validate newly proposed scoring systems,[17] and those developed in future studies may play a decisive role in improving mortality prediction.

Fecal diversion via sigmoid loop colostomy was performed in 14 patients in Group 1 and five patients in Group 2 (Table 1). No statistically significant association with mortality was observed. As Ozturk et al.[18] suggested, fecal diversion is not recommended unless there is significant sphincter damage or extensive perineal involvement. Delaying the decision until the second or third debridement allows for better sphincter assessment and improved hemodynamic stabilization. During this period, measures such as administering enemas prior to VAC changes, prescribing a low-fiber diet, and using agents such as loperamide hydrochloride to reduce bowel motility may help minimize the need for defecation. VAC therapy offers advantages over traditional dressings, including fewer dressing changes, reduced pain, and comparable costs, while also accelerating granulation tissue formation and wound healing.

The primary limitation of this study is its retrospective design. Another limitation is that, despite the relatively high number of Fournier's gangrene cases treated at our institution, the study was conducted at a single center. Consequently, the findings reflect the patient population, clinical practices, and treatment protocols of our hospital and may not be fully generalizable to centers with different demographic or clinical characteristics. Therefore, the results should be validated through prospectively designed, multicenter studies. The main strength of this study lies in its homogeneous patient population, with all patients managed according to the same therapeutic protocol.

CONCLUSION

These findings support the study hypothesis and demonstrate that the Eğin score is a strong predictor of mortality in patients with FG. An Eğin score greater than 3 was associated with a significantly increased risk of mortality. Therefore, the Eğin score may serve as a practical and reliable bedside tool for identifying high-risk patients with FG and guiding clinical management strategies aimed at reducing mortality.

Ethics Committee Approval: This study was approved by the University of Health Sciences Istanbul Prof. Dr. Cemil Taşcıoğlu City Hospital Clinical Research Ethics Committee (Date: 24.03.2025, Decision No: 117).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Fournier gangreninde mortaliteyi tahmin etmek için yeni bir puanlama sistemi: Eğin Skoru

AMAÇ: Bu çalışmanın amacı Fournier gangreninde (FG) mortaliteyi etkileyen faktörleri araştırmak ve klinisyenler için pratik yatak başı değerlendirmesine olanak tanıyan basitleştirilmiş bir puanlama sistemi oluşturmaktır.

GEREÇ VE YÖNTEM: Şubat 2012 ile Ocak 2025 arasında FG nedeniyle tedavi edilen 130 hastanın tıbbi kayıtları retrospektif olarak incelendi. Sağ kalanlar (Grup 1, n=101) ve sağ kalamayanlar (Grup 2, n=29) iki ayrı grup olarak analiz edildi. Toplanan veriler cinsiyet, yaş, enfeksiyonun yayılma skoru, Uludağ Fournier gangreni şiddet indeksi skoru, Fournier gangreni şiddet indeksi skoru, enfeksiyon kaynağı, diabetes mellitus varlığı, obezite ve diğer eşlik eden hastalıkları içeriyordu. Ek değişkenler arasında saptırıcı stoma varlığı, vakum yardımlı kapatma tedavisinin süresi, hastanede kalış süresi, yoğun bakım süresi ve izole edilmiş bakteri türleri yer alıyordu. Mortalite ile yaş, enfeksiyonun yayılma skoru, diabetes mellitus ve obezite dışındaki komorbiditeler, yoğun bakım süresi gibi faktörler arasındaki ilişkiler incelendi.

BULGULAR: Gruplar arasında yaş ve yaş skoru açısından anlamlı bir fark gözlendi. Enfeksiyonun yayılma skoru Grup 2'de anlamlı olarak daha yüksekti. Grup 1'deki 60 hastada diabetes mellitus ve obezite dışındaki komorbiditeler varken, Grup 2'deki tüm hastalarda vardı ve istatistiksel olarak anlamlı bir fark olduğu görüldü. Yoğun bakım süresi sağ kalamayanlar arasında anlamlı olarak daha yüksekti. Eğin skoru, ROC analizinde >3 eşik değerinde %96.6 duyarlılık ve %63.4 özgüllük gösterdi.

SONUÇ: Eğin skorunu oluşturan yaş, enfeksiyonun yayılma skoru, diabetes mellitus ve obezite dışındaki komorbiditeler, yoğun bakım süresi, sağ kalanlar ve sağ kalamayanlar arasında anlamlı farklılıklar gösterdi. Bu parametreler FG ile ilişkili mortaliteyi tahmin etmede kritik öneme sahiptir.

Anahtar sözcükler: Fournier gangreni; Fournier gangreni şiddet indeksi; mortalite; Uludağ Fournier gangreni şiddet indeksi; vakum yardımlı kapatma.

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ORIGINAL ARTICLE

Comparison of FGSI and HALP scores for mortality prediction in Fournier's Gangrene: A retrospective analysis

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ABSTRACT

BACKGROUND: This study aimed to compare the prognostic performance of the Fournier's Gangrene Severity Index (FGSI) and the hemoglobin–albumin–lymphocyte–platelet (HALP) score in predicting in-hospital mortality among patients diagnosed with Fournier's gangrene. As Fournier's gangrene remains a life-threatening and rapidly progressive soft tissue infection, early risk stratification is critical for improving patient outcomes. Validating practical scoring systems may support timely clinical decision-making and resource allocation.

METHODS: A retrospective analysis was performed on 52 patients who underwent surgical treatment for Fournier's gangrene at a tertiary referral center between December 2022 and June 2025. Demographic, laboratory, and clinical data were collected, and both FGSI and HALP scores were calculated at the time of admission. Receiver Operating Characteristic (ROC) curve analysis and multivariate logistic regression were used to assess the predictive value of both scores for in-hospital mortality.

RESULTS: The mean FGSI was 5.1±2.2, while the mean HALP score was 134.6±100.2. FGSI showed acceptable discrimination (AUC=0.7639; cutoff=5.0), with 72.7% sensitivity and 67.7% specificity. HALP had poor predictive ability (AUC=0.4018). In multivariate analysis, FGSI was an independent predictor (p=0.0146), while HALP was not (p=0.9474).

CONCLUSION: FGSI appears to be a reliable and independent prognostic tool in patients with Fournier's gangrene. HALP, however, does not offer additional prognostic benefit. FGSI should be prioritized in early risk assessment to guide management strategies.

Keywords: Fournier's gangrene; FGSI; HALP; mortality; prognostic score.

INTRODUCTION

Fournier's gangrene (FG) is a rapidly progressing and potentially fatal necrotizing infection that primarily affects the perineal and genital regions. Despite advancements in surgical techniques and intensive care, the condition continues to be associated with high morbidity and mortality, particularly in patients with underlying comorbidities such as diabetes mellitus, chronic kidney disease, or malignancy. Reported mortality rates range from 20% to 40%.[1]

Accurate and early risk stratification is essential in guiding clinical decisions and improving patient outcomes in FG. Among the available prognostic tools, the Fournier's Gangrene Severity Index (FGSI) remains the most widely used disease-specific scoring system. Originally proposed by Laor et al.,[2] FGSI integrates vital signs and laboratory markers to estimate disease severity and predict mortality.

Recently, the hemoglobin-albumin-lymphocyte-platelet (HALP) score has been suggested as a simple, inflammation and nutrition-based prognostic index in various clinical con-

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texts, including oncology and sepsis.[3,4] However, its utility in necrotizing soft tissue infections, particularly in FG, remains unclear.

To date, no study has directly compared the prognostic value of FGSI and HALP in patients with Fournier's gangrene. This study aims to evaluate and compare the predictive performance of FGSI and HALP in estimating in-hospital mortality among patients undergoing surgical treatment for FG.

MATERIALS AND METHODS

Study Design and Patient Population

This retrospective observational study included adult patients diagnosed with Fournier's gangrene (FG) who underwent surgical treatment at a tertiary care center between December 2022 and June 2025. Patients were identified via electronic health records using ICD codes for necrotizing fasciitis of the perineal and genital regions.

Inclusion and Exclusion Criteria

Inclusion criteria:

- Age ≥18 years
- Diagnosis of FG confirmed intraoperatively or via histopathology
- Complete admission clinical and laboratory data

Exclusion criteria:

- Incomplete records
- Necrotizing fasciitis outside the Fournier region
- Patients transferred prior to definitive surgical treatment

The overall patient flow from screening to final analysis is summarized in Figure 1. In brief, 68 records were screened; 16 were excluded (due to missing baseline data, non-Fournier anatomical site, or transfer/early discharge), and 52 patients were eligible and included. All included patients underwent final analysis.

Data Collection

Collected data included:

- **Demographics:** age, sex
- **Comorbidities:** diabetes, hypertension, malignancy, chronic kidney disease
- **Laboratory values:** hemoglobin, albumin, lymphocytes, platelets, hematocrit, sodium, potassium, creatinine, bicarbonate, CRP, and lactate
- **Outcomes:** ICU admission, length of stay, number of debridements, in-hospital mortality

Scoring Systems

Two scoring systems were calculated:

- **HALP score** was calculated as:

$$\text{HALP} = \frac{\text{Hemoglobin (g/L)} \times \text{Albumin (g/L)} \times \text{Lymphocytes (/L)}}{\text{Platelets (/L)}}$$

- **FGSI score** was calculated by assigning individual scores (0–4) to nine physiological and laboratory parameters: body temperature, heart rate, respiratory rate, sodium, potassium, creatinine, bicarbonate, hematocrit, and white blood cell count. The sum of these components yielded the total FGSI.

Statistical Analysis

Statistical analyses were conducted using IBM SPSS Statistics v26.0. Continuous variables were expressed as mean ± standard deviation or median (IQR), while categorical variables were presented as counts and percentages.

Group comparisons (survivors vs. non-survivors) used:

- Student's t-test or Mann–Whitney U test (continuous variables)
- Chi-square or Fisher's exact test (categorical variables)

The discriminatory performance of FGSI and HALP in predicting mortality was evaluated using ROC curve analysis. AUC, sensitivity, specificity, and optimal cutoffs (Youden Index) were reported.

Multivariate logistic regression was performed to identify independent predictors of mortality. FGSI, HALP, gender, age, diabetes mellitus, and chronic kidney disease were included as covariates in the model. A p-value <0.05 was considered statistically significant.

Post-hoc power analysis estimated that the sample size (n=52) provided ~75% power to detect the observed mortality difference based on FGSI scores (α=0.05, two-tailed). The modest sample size and retrospective design are acknowledged as limitations.

Ethical Considerations

The study protocol was approved by the Scientific Research Evaluation and Ethics Committee of Ankara Etlik City Hospital (Approval No: AESH-BADEK2-2025-162, dated 10 June 2025). Given the retrospective design, the requirement for informed consent was waived. The study was conducted in accordance with the Declaration of Helsinki (2013 revision).

RESULTS

A total of 52 patients diagnosed with Fournier's gangrene were included in the final analysis. The mean age was 56.7±13.2 years (range: 21-85), and 61.5% (n=32) were male. The mean length of hospital stay was 9.8±6.4 days (range: 1–35). The mean FGSI score was 5.1±2.2 (median: 5, range: 1–11), and the mean HALP score was 134.6±100.2 (median: 112, range: 7–453) (Table 1).

1. Mortality and Gender Distribution

The overall in-hospital mortality rate was 23.1% (n=12). A

Table 1. Descriptive statistics of the study population

Variable	Mean±SD	Median	Range
Age (years)	56.7±13.2	55	21-85
Hospital stay (days)	9.8±6.4	8	1-35
HALP score	134.6±100.2	112	7-453
FGSI score	5.1±2.2	5	1-11

Table 2. Gender distribution stratified by in-hospital mortality

Gender	Alive n (%)	Deceased n (%)	Total n (%)	p value
Male	29(90.6%)	3(9.4%)	32(61.5%)	
Female	11(55.0%)	9(45.0%)	20(38.5%)	
Total	40(76.9%)	12(23.1%)	52(100%)	0.0086

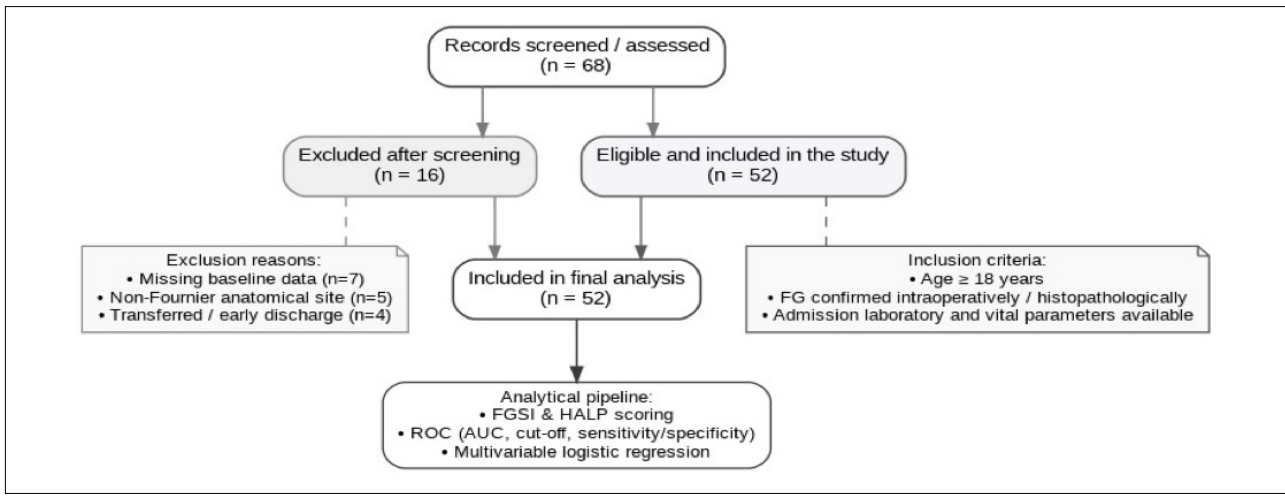

Figure 1. Symmetric study flow diagram. A total of 68 records were screened; 16 were excluded after screening (missing key data, non-Fournier anatomical site, or transfer/early discharge), and 52 patients were eligible and included in the study. All included patients were analyzed. The analytical pipeline comprised FGSI & HALP score calculations (with contextual reference to LRINEC, SOFA, and APACHE II), ROC analysis (AUC and optimal cut-off), and multivariable logistic regression.

significant gender-based difference in mortality was observed:

• Among male patients (n=32), 29 survived (90.6%) and 3 died (9.4%).

• Among female patients (n=20), 11 survived (55.0%) and 9 died (45.0%).

This difference was statistically significant (p=0.0086), indicating markedly higher mortality among female patients (Table 2). No significant differences were found between survivors and non-survivors in terms of age or comorbidities.

2. Severity Scores in Survivors and Non-Survivors

FGSI scores were significantly higher among non-survivors compared to survivors (median: 7 vs. 5, $p<0.05$). In contrast, HALP scores showed no statistically significant difference between the two groups (median: 95 vs. 140, $p>0.05$). Box plots illustrating the distribution of FGSI and HALP scores across survivor groups are shown in Figures 2 and 3, respectively.

3. ROC Curve Analysis

ROC curve analysis demonstrated that FGSI had modest discriminative ability in predicting in-hospital mortality, with an

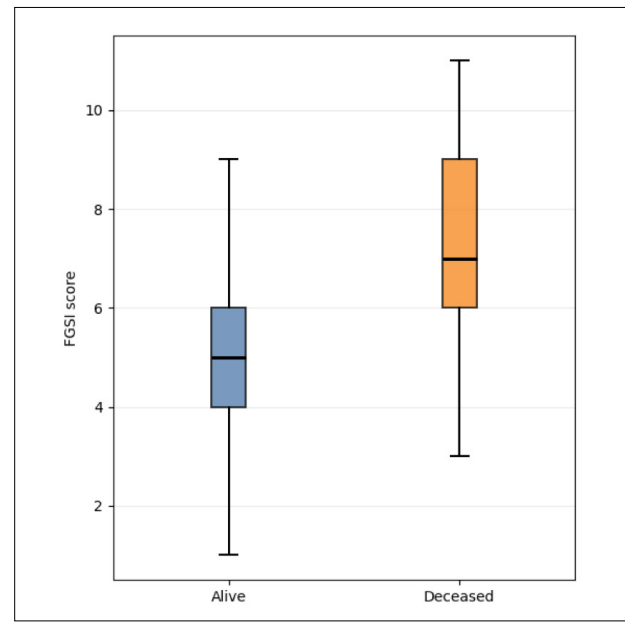

Figure 2. Boxplots of the FGSI stratified by mortality status. Non-survivors exhibited higher FGSI values compared with survivors, consistent with its independent prognostic significance.

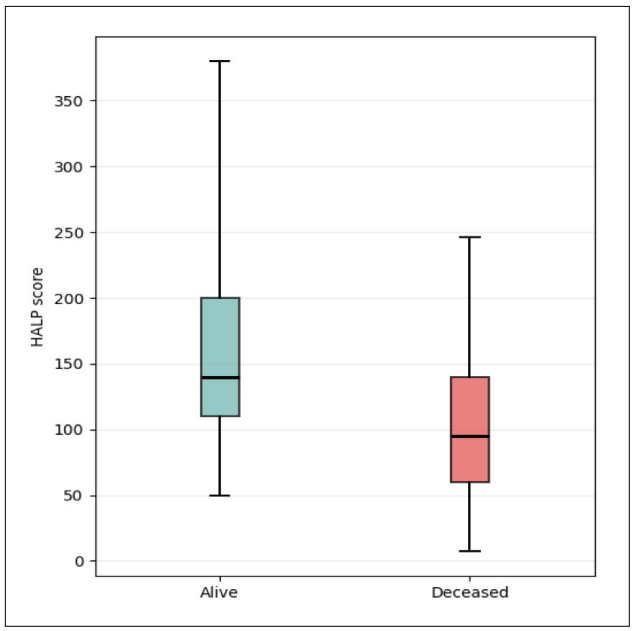

Figure 3. Boxplots of the HALP score stratified by mortality status. HALP distributions showed substantial overlap between groups, in line with its poor prognostic performance.

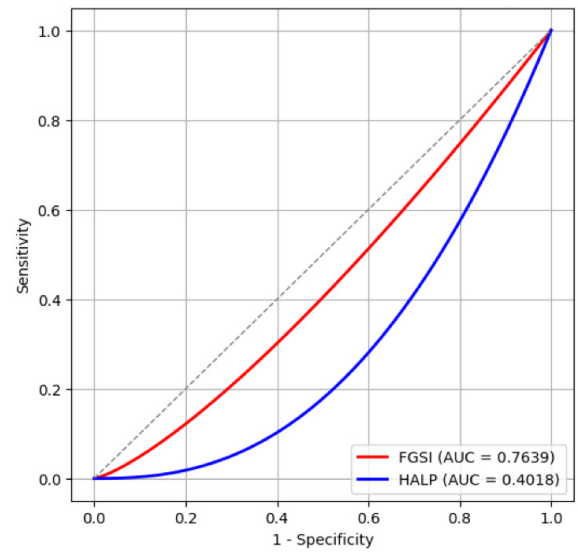

Figure 4. Receiver operating characteristic (ROC) curves of the Fournier's Gangrene Severity Index (FGSI) and the hemoglobin, albumin, lymphocyte, and platelet (HALP) score for predicting in-hospital mortality. FGSI demonstrated acceptable discriminatory ability (AUC=0.7639), whereas HALP did not show predictive significance (AUC=0.4018).

AUC of 0.7639. The optimal cutoff value was determined as 5.0, yielding a sensitivity of 72.7% and specificity of 67.7%.

Conversely, HALP exhibited poor performance in mortality prediction, with an AUC of 0.4018. At its optimal cutoff (246.29), sensitivity was 27.3% and specificity was 87.1% (Table 3, Figure 4).

These findings indicate that FGSI significantly outperformed HALP in predicting patient outcomes.

Table 3. ROC analysis of HALP and FGSI scores

Score	AUC	Cutoff	Sensitivity	Specificity
HALP	0.4018	246.29	27.3%	87.1%
FGSI	0.7639	5.00	72.7%	67.7%

4. Multivariate Logistic Regression Analysis

In multivariate logistic regression analysis that included FGSI, HALP, gender, age, diabetes mellitus, and chronic kidney disease, both FGSI (β=0.411, p=0.016) and female gender (β=1.973, p=0.017) emerged as statistically significant independent predictors of in-hospital mortality. The HALP score remained non-significant (β=–0.0001, p=0.894), and neither age (p=0.540) nor diabetes mellitus (p=0.428) demonstrated a meaningful association with mortality. Chronic kidney disease showed a borderline association (p=0.065). These findings suggest that, after adjusting for major clinical covariates, disease severity as measured by FGSI and patient sex remain the strongest determinants of outcome in this cohort (Table 4).

Table 4. Multivariate Logistic Regression Analysis for In-Hospital Mortality

Variable	β (Beta)	SE (Standard Error)	OR (Odds Ratio)	95% CI for OR	p-value
FGSI	0.411	0.156	1.51	1.11–2.24	0.016
HALP	–0.0001	0.001	0.99	0.98–1.01	0.894
Gender (Female)	1.973	0.812	7.19	1.43–36.1	0.017
Age	0.021	0.035	1.02	0.95–1.11	0.540
Diabetes Mellitus	0.584	0.755	1.79	0.42–7.50	0.428
Chronic Kidney Disease	1.202	0.655	3.33	0.92–12.1	0.065

DISCUSSION

In this study, we compared the prognostic value of two scoring systems, the Fournier's Gangrene Severity Index (FGSI) and the hemoglobin–albumin–lymphocyte–platelet (HALP) score in predicting in-hospital mortality among patients with Fournier's gangrene (FG). Our findings demonstrate that FGSI remains a reliable and statistically significant predictor of mortality, while HALP provides no additional prognostic value in this clinical context.

In our multivariate logistic regression analysis, both FGSI and female gender independently predicted in-hospital mortality, consistent with previous validation studies confirming the independent prognostic strength of FGSI.[2,5] Importantly, FGSI remained statistically significant even after adjusting for sex, age, and comorbidities such as diabetes and chronic kidney disease.[6] This suggests that FGSI provides prognostic value beyond these known risk factors, supporting its role as an independent mortality predictor.[7,8] While previous studies have raised concerns about potential confounding by sex, given the markedly higher mortality rates reported in female patients, our model indicates that FGSI retains its predictive power even when this effect is controlled.[1,9,10]

FGSI, initially developed as a disease-specific severity index, has been validated across multiple studies and remains widely used in clinical practice.[7,11] In our cohort, FGSI demonstrated acceptable discriminatory power (AUC=0.7639), consistent with a recent meta-analysis by Tufano et al.[7] which reported pooled AUC values of 0.90 and reinforced the utility of FGSI and its variants in FG prognosis. FGSI has also been shown to correlate with length of ICU stay and the need for surgical debridement, further supporting its clinical value.[12,13]

In contrast, the HALP score failed to predict mortality in our cohort (AUC=0.4018; p=0.9474), in line with previous findings by Keten et al.[11] Although HALP has shown prognostic significance in cancer and sepsis settings due to its reflection of systemic inflammation and nutritional status,[3,4] its performance in necrotizing soft tissue infections appears limited. The HALP score may not adequately capture the rapid physiologic deterioration and organ dysfunction associated with FG, highlighting the need for more disease-specific models in this context.

A striking observation in our study was the significantly higher in-hospital mortality among female patients compared with males (45.0% vs. 9.4%, p=0.0086). Although FG is far more commonly reported in men, our findings suggest that female patients may experience worse outcomes. Sorensen et al.[1] similarly found higher mortality in women in a large population-based study, despite their lower incidence of FG. In contrast, other studies such as that of Kabay et al.[9] reported higher mortality among male patients, while the low number of female cases precluded meaningful comparisons. Moreover, some series have focused exclusively on male cohorts, as in the study by Dahm et al.,[14] leaving the question of sex-specific differences underexplored. These data highlight a critical gap in the FG literature and support the need for further research into sex-related disparities in disease presentation and outcomes.

Fournier's Gangrene Severity Index (FGSI) remains the most widely utilized and disease-specific scoring system for assessing severity and predicting mortality in patients with FG. Although its performance may vary across different cohorts, its clinical value has been consistently supported by multiple studies.[5] In contrast, general sepsis scores such as the quick Sequential Organ Failure Assessment (qSOFA) and the National Early Warning Score (NEWS) have demonstrated limited prognostic accuracy in FG, largely due to their lack of specificity for necrotizing soft tissue infections. The Charlson Comorbidity Index (CCI) has also been considered as an adjunct to evaluate baseline health status; however, its independent predictive value in FG remains controversial and inconsistent across studies.[8] Taken together, current evidence supports FGSI as the most practical and reliable tool for routine clinical use in this patient population. Future research should aim to refine FG-specific prognostic models and further investigate gender-based disparities to enhance outcome prediction in this high-risk population.

Future prospective studies with larger, multicenter cohorts are needed to validate the prognostic accuracy of FGSI across diverse populations. In addition, combining FGSI with dynamic biomarkers such as lactate or CRP/albumin ratio may yield more robust risk stratification models. The observed gender disparity in mortality also warrants further research to explore potential anatomical, physiological, or health-system related contributors to this outcome gap.

Limitations

This study is limited by its retrospective design and modest sample size, which may affect generalizability. Although a post-hoc power analysis estimated approximately 75% power to detect the observed mortality difference based on FGSI, prospective multicenter studies are warranted to validate these findings. Additionally, only two scoring systems (FGSI and HALP) were compared; other emerging tools may offer further insights if included in future research. FGSI showed modest discriminatory power (AUC = 0.7639), and while statistically significant, its predictive performance may be limited in certain subgroups.

CONCLUSION

FGSI remains a strong and independent predictor of in-hospital mortality in Fournier's gangrene and should continue to serve as a primary tool for early risk stratification. HALP, while useful in other inflammatory conditions, appears inadequate for mortality prediction in this context. The significant mortality disparity observed among female patients requires further clinical and epidemiological investigation.

Ethics Committee Approval: This study was approved by the Scientific Research Evaluation and Ethics Committee of Ankara Etlik City Hospital (Date: 10.06.2025, Decision No: AESH-BADEK2-2025-162).

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Fournier gangreninde mortalite öngörüsünde FGSI ve HALP skorlarının karşılaştırılması: Retrospektif bir analiz

AMAÇ: Bu çalışma, Fournier gangreni tanısı almış hastalarda hastane içi mortaliteyi öngörmede Fournier's Gangrene Severity Index (FGSI) ile hemoglobin–albümin–lenfosit–trombosit (HALP) skorunun prognostik performansını karşılaştırmayı amaçlamaktadır. Fournier gangreni, yaşamı tehdit eden ve hızlı ilerleyen bir yumuşak doku enfeksiyonu olmaya devam ettiğinden, erken risk sınıflandırması hasta sonuçlarını iyileştirmek açısından kritik öneme sahiptir. Pratik skorlama sistemlerinin doğrulanması, zamanında klinik karar alma ve kaynak yönetimini destekleyebilir.

GEREÇ VE YÖNTEM: Aralık 2022 ile Haziran 2025 tarihleri arasında bir üçüncü basamak sağlık merkezinde Fournier gangreni nedeniyle cerrahi tedavi uygulanan 52 hasta retrospektif olarak analiz edildi. Demografik, laboratuvar ve klinik veriler toplanarak, her hasta için FGSI ve HALP skorları başvuru anında hesaplandı. Hastane içi mortaliteyi öngörme açısından her iki skorun prediktif değeri ROC eğrisi analizi ve çok değişkenli lojistik regresyon ile değerlendirildi.

BULGULAR: Ortalama FGSI skoru 5.1±2.2, HALP skoru ise 134.6±100.2 olarak saptandı. FGSI, hastane içi mortalite için kabul edilebilir düzeyde ayırt edicilik gösterdi (AUC=0.7639; eşik değer=5.0; duyarlılık=%72.7; özgüllük=%67.7). HALP skoru ise zayıf prediktif yetenek sergiledi (AUC=0.4018). Çok değişkenli analizde, FGSI istatistiksel olarak anlamlı ve bağımsız bir prediktör olarak belirlendi (p=0.0146); HALP skoru ise anlamlı bulunmadı (p=0.9474).

SONUÇ: FGSI, Fournier gangreni hastalarında güvenilir ve bağımsız bir prognostik araç olarak öne çıkmaktadır. HALP skoru ise ek bir öngörü değeri sağlamamaktadır. Erken risk değerlendirmesinde FGSI'ye öncelik verilmesi, hasta yönetim stratejilerinin yönlendirilmesi açısından önem arz etmektedir.

Anahtar sözcükler: Fournier gangreni; FGSI; HALP; mortalite; prognostik skor.

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ORIGINAL ARTICLE

Abdominal packing in postpartum hemorrhage: A forgotten life-saving technique

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ABSTRACT

BACKGROUND: Postpartum hemorrhage is a major cause of maternal morbidity and mortality. Abdominal packing is a technique used to control bleeding when other methods fail. This study aimed to evaluate the outcomes of patients who underwent abdominal packing for postpartum hemorrhage.

METHODS: This retrospective study included 11 patients who underwent abdominal packing for severe obstetric hemorrhage (10 cases of postpartum hemorrhage and one case of second-trimester pregnancy termination complicated by severe hemorrhage) at Mersin University Faculty of Medicine Hospital between 2005 and 2023. Data were collected from medical records. The primary outcome was the successful immediate control of refractory hemorrhage and temporary stabilization of the patient's hemodynamic status. Secondary outcomes included transfusion requirements, complications, and length of hospital stay.

RESULTS: All 11 patients underwent hysterectomy for postpartum hemorrhage and subsequently required abdominal packing due to persistent bleeding. The median age was 33 years, and the median gravidity was 3. The primary causes of postpartum hemorrhage were uterine atony (54.5%), placenta previa (36.4%), and disseminated intravascular coagulation (9.1%). The median number of packs used was 3, and packs were removed after 24 hours in all cases. Abdominal packing successfully controlled persistent bleeding in all patients following hysterectomy. The median length of hospital stay was 6 days. All patients required blood transfusions. The most common complication was pulmonary edema (90.9%). All patients survived.

CONCLUSION: Abdominal packing may serve as a valuable temporary rescue measure for severe, refractory obstetric hemorrhage in selected cases where conventional methods are insufficient. Careful patient selection and close postoperative monitoring are essential.

Keywords: Abdominal packing; hysterectomy; maternal morbidity; mortality; postpartum hemorrhage.

INTRODUCTION

Postpartum hemorrhage (PPH) remains a leading cause of maternal mortality worldwide, accounting for an estimated 27.1% of all maternal deaths globally.[1] Despite advances in obstetric care and medical management, PPH continues to pose a significant challenge to healthcare providers. Severe cases require prompt and effective intervention to prevent potentially catastrophic outcomes. The time-critical nature of these emergencies often necessitates the implementation of rapid and reliable hemostatic strategies.

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Abdominal packing is a well-recognized procedure in trauma and general surgery, employed as a "damage control technique" in unstable patients with coagulopathy and widespread hemorrhage.[2] This technique was once a mainstay of obstetric and gynecologic surgery prior to the development of modern alternatives. The traditional method involves strategically placing gauze packs to exert pressure on bleeding surfaces, thereby achieving temporary hemostasis until definitive treatment can be undertaken or coagulopathy corrected.[3] However, with the advent of pharmacologic interventions such as uterotonics and hemostatic agents, as well as interventional procedures including arterial embolization and compression sutures, the use of abdominal packing has declined in contemporary obstetric practice.[4-7]

Abdominal packing offers several distinct advantages in emergency situations. It does not require specialized equipment, can be performed in any surgical setting, and provides immediate tamponade of diffuse bleeding surfaces that may be challenging to manage with sutures or focal pressure.[8] Moreover, in resource-limited settings or in cases of catastrophic hemorrhage, packing can serve as a life-saving temporizing measure until definitive treatment becomes available. However, these benefits must be considered alongside potential complications, including infection, adhesion formation, tissue necrosis, and the need for relaparotomy.[9] Furthermore, the pressure exerted by the packs may compromise perfusion to adjacent structures if not carefully monitored.

The aim of this study was to evaluate the characteristics, complications, and outcomes of patients who underwent abdominal packing for severe obstetric hemorrhage at our institution. By analyzing these cases, we sought to determine the contemporary role and efficacy of this technique within the context of modern obstetric hemorrhage management protocols. Although newer techniques have largely replaced abdominal packing in routine practice, we hypothesized that this method remains valuable in specific clinical scenarios where conventional measures are inadequate or unavailable.

MATERIALS AND METHODS

Between January 1, 2005 and December 31, 2023, abdominopelvic packing was successfully performed in 11 patients with persistent postpartum hemorrhage after hysterectomy at Mersin University Medical Faculty Hospital. Ethical approval for the study was obtained from the University Ethics Committee on September 18, 2024 (decision number: 2024/872). The study was conducted in accordance with the principles of the Declaration of Helsinki. Data were collected retrospectively from the hospital's electronic information system and patient records. The indications for abdominopelvic packing included secondary disseminated intravascular coagulation following peripartum hysterectomy, with intact surgical pedicles, and persistent non-arterial hemorrhage originating from venous plexuses, exposed pelvic sidewalls, or other inaccessible regions where traditional suturing or ligation had proven ineffective. For this indication, vascular sources of hemorrhage were excluded.

Patients were included if they experienced refractory PPH that could not be controlled by peripartum hysterectomy and conventional hemostatic measures, or if they developed secondary disseminated intravascular coagulation (DIC) with persistent diffuse oozing. Cases in which bleeding was primarily arterial and required specific ligation, or in which conservative measures (e.g., Bakri balloon) successfully achieved hemostasis, were excluded.

The primary outcome was the effectiveness of abdominopelvic packing in achieving hemostasis without the need for additional interventions. Preoperative and postoperative complete blood counts, transfusion requirements, duration of intensive care unit stay, duration of mechanical ventilation, length of hospitalization, and complications were evaluated. All patients were managed by a multidisciplinary team consisting of experienced obstetricians, anesthesiologists, transfusion medicine specialists, and intensive care physicians.

To prevent potential infectious complications associated with intra-abdominal foreign material, all patients received prophylactic intravenous antibiotic therapy consisting of clindamycin and gentamicin. This regimen was initiated at the time of tamponade and continued throughout the hospital stay.

In cases where conventional methods (uterotonics, compression sutures, or arterial ligation) proved insufficient to stop bleeding, abdominopelvic packing was used as a last-resort (rescue) measure to achieve hemostasis. The aim was to control persistent venous bleeding despite secured surgical pedicles, to gain time for correction of coagulopathy, and to achieve hemodynamic stabilization of the patient.

In cases of vaginal delivery included in the study, when bleeding could not be controlled using routine methods, a hysterectomy was performed first. However, as widespread intra-abdominal bleeding continued after the hysterectomy, transabdominal packing was subsequently applied.

The essential aspect of this technique is to primarily pack the true pelvis (below the pelvic brim) rather than the false pelvis, thereby creating a physical tamponade within the bony structures of the pelvis itself (above the pelvic brim). Packing above the pelvic brim provides minimal tamponade effect, as the primary source of bleeding typically arises from the internal pelvic vessels.

Only X-ray–detectable gauze of larger dimensions (minimum 45 × 45 cm) should be used, and it should be folded in half or into quarters to form rolls. The packs must be positioned securely and uniformly across the exposed bleeding areas of the pelvis and pedicles. In post-hysterectomy hemorrhage, it is crucial to verify that the surgical pedicles are adequately secured. The tamponade effect of abdominopelvic packing provides time for correction of coagulopathy and restoration of hemodynamic stability with blood transfusion.

The patient's blood pressure is stabilized to ensure adequate control of venous hemorrhage. Drains are typically omitted, and primary closure of the rectus sheath is avoided to prevent abdominal compartment syndrome; the skin is approximated only with sutures or staples. Patients are subsequently transferred to the intensive care unit (ICU) for stabilization and correction of any coagulopathy or anemia, and intra-abdominal pack removal is recommended within 24-48 hours. [10] All patients underwent reoperation after 24 hours, during which the packs were removed (Fig. 1).

Statistical Analysis

Statistical analyses were performed using SPSS software (version 22.0; IBM Corp., Armonk, NY, USA). Continuous variables were expressed as median and interquartile range (IQR) due to the small sample size, while categorical variables were presented as numbers and percentages.

RESULTS

During the study period, 10,654 deliveries (3,042 normal vaginal deliveries and 7,612 cesarean deliveries) took place in our hospital, and the prevalence of peripartum hysterectomy was 7.04 per 1,000 deliveries. Eleven women who underwent hysterectomy for postpartum hemorrhage and required abdominal packing due to continued bleeding were included in the study. Patient demographics and clinical characteristics are presented in Table 1. The median age of the patients was 33.0 years (interquartile range [IQR]: 8.0), with a median gravidity of 3.0 (IQR: 1.0) and parity of 2.0 (IQR: 2.0). The median gestational age was 38.0 weeks (IQR: 5.0).

The primary causes of hemorrhage were uterine atony (n=6; 54.5%), placenta previa (n=4; 36.4%), and disseminated intravascular coagulation (n=1; 9.1%). Cesarean section was the predominant mode of delivery (n=10; 90.9%), while only one patient (9.1%) delivered vaginally. Additional procedures performed included hypogastric artery ligation in seven cases (63.6%) and Bakri balloon tamponade in one case (9.1%).

Management strategies and clinical outcomes are summarized in Table 2. The median shock index at the time of the decision to pack was 1.16 (IQR: 0.17). The median number of packs used for abdominal packing was 3 (IQR: 3), with a uniform pack duration of one day for all patients. The median length of hospitalization was 6 days (IQR: 2). Intensive care was required in 10 patients (90.9%), with a median ICU stay of 1.0 day (IQR: 0.5) and a median duration of mechanical ventilation of 30.0 hours (IQR: 8.5). Pulmonary edema was the most common complication, occurring in 10 patients (90.9%).

Table 3 details the hematological parameters and blood product requirements. The median preoperative hemoglobin level was 9.3 g/dL (IQR: 3.1), and the median postoperative hemoglobin level was 8.2 g/dL (IQR: 1.6). The median preoperative hematocrit was 27.1% (IQR: 10%), and the median postoperative hematocrit was 23% (IQR: 6%). The median preoperative platelet count was 101×10^9/L (IQR: 162×10^9/L), and the median postoperative platelet count was 85×10^9/L (IQR: 63×10^9/L).

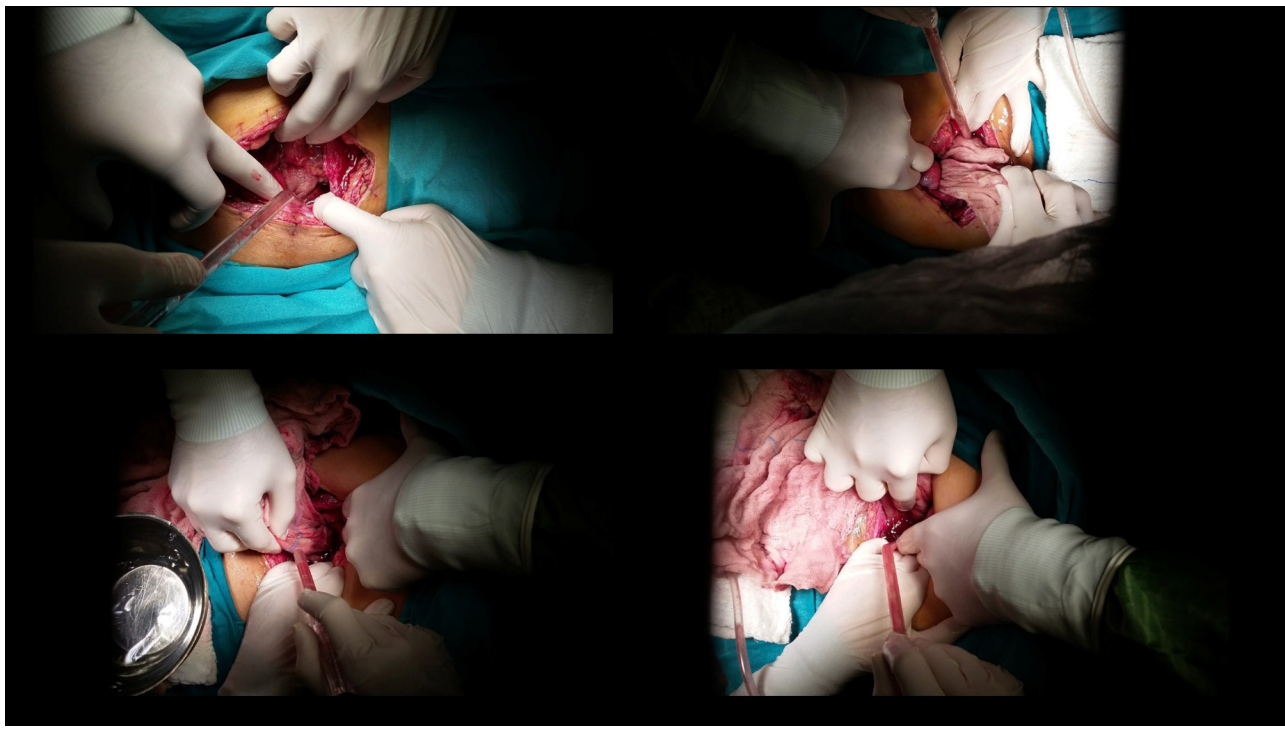

Figure 1. Removed the packs after abdominopelvic packing.

Table 1. Patient characteristics

Case	Age	Gravidity	Parity	BMI (kg/m²)	Gestational Age (weeks)	Previous Surgery	Delivery Route	Cause of Hemorrhage	Additional Procedures Before Packing
1	22	2	1	23.44	19	CS	CS	Second-trimester hemorrhage	Hysterectomy
2	33	3	3	30.44	38	None	CS	Second-trimester hemorrhage	Hysterectomy
3	36	2	2	27.48	38	CS	CS	Placenta previa	Hypogastric artery ligation + hysterectomy
4	31	3	2	22.23	36	CS	CS	Placenta previa	Hysterectomy
5	33	3	2	31.20	38	None	CS	Second-trimester hemorrhage	Hypogastric artery ligation + hysterectomy
6	39	2	1	27.68	37	CS	CS	Second-trimester hemorrhage	Hypogastric artery ligation + hysterectomy
7	43	3	3	25.10	40	Appendectomy	NVD	Second-trimester hemorrhage	Bakri balloon tamponade + hysterectomy
8	33	3	3	35.63	40	None	CS	Second-trimester hemorrhage	Hypogastric artery ligation + hysterectomy
9	39	4	3	Not available	27	None	CS	Placenta previa	Hypogastric artery ligation + hysterectomy
10	38	2	1	Not available	33	None	CS	Placenta previa	Hypogastric artery ligation + hysterectomy
11	30	4	3	29.38	38	CS	CS	DIC	Hypogastric artery ligation + hysterectomy

BMI: Body mass index; CS: Cesarean section; El: Elective; Em: Emergency; NVD: Normal vaginal delivery.

Table 2. Management and outcomes of patients

Case	Shock Index (HR/SBP)	Number of Packs	Pack Duration (days)	Hospital Stay (days)	ICU stay (days)	Duration of Mechanical Ventilation (hours)	Complications
1	1.17	3	1	6	4	48	Pulmonary edema
2	1.29	1	1	10	1	20	Pulmonary edema
3	1.08	2	1	4	2	25	Pulmonary edema
4	1.02	3	1	10	2	30	Pulmonary edema
5	1.30	2	1	5	1	19	Pulmonary edema
6	1.14	6	1	7	2	30	Pulmonary edema
7	1.04	3	1	5	2	36	Pulmonary edema
8	1.16	3	1	5	3	1	None
9	1.26	6	1	6	2	30	Pulmonary edema
10	1.04	5	1	5	3	24	Pulmonary edema
11	1.16	5	1	6	2	30	Pulmonary edema

BP: Blood pressure.

Table 3. Blood product transfusions

Case	Preoperative Hemoglobin	Preoperative Hematocrit	Preoperative Platelets	Postoperative Hemoglobin	Postoperative Hematocrit	Postoperative Platelets	Erythrocyte Suspension Transfusion	Fresh Frozen Plasma Transfusion	Cryoprecipitate Transfusion	Platelet Suspension	Fibrinogen Transfusion (patient level mg/dL)
1	12.9	35.8	101	3.0	9.5	98	10	8	0	2	1 (104)
2	4.9	14.6	40	7.2	21.0	44	8	10	10	5	1 (86)
3	10.9	32.0	121	4.3	12.9	35	5	10	1	1	1 (132)
4	9.3	27.1	105	8.3	23.6	120	5	4	1	4	1 (108)
5	8.4	23.0	76	8.1	23.0	81	4	4	0	1	1 (129)
6	7.9	23.0	77	7.4	22.0	74	5	1	1	2	1 (117)
7	7.8	22.0	60	8.3	23.0	60	6	3	1	0	1 (128)
8	9.7	30.0	231	8.8	27.0	165	4	2	0	0	1 (133)
9	9.4	29.0	236	9.5	29.0	191	8	4	1	0	1 (138)
10	6.5	20.0	28	10.2	29.0	85	5	4	1	1	1 (141)
11	11.1	35.0	222	8.2	24.0	123	8	6	1	1	2 (135)

Blood product transfusions were required in all cases. The median number of erythrocyte suspension transfusions was 5 (IQR: 3), and the median number of fresh frozen plasma transfusions was 4 (IQR: 5). The median number of cryoprecipitate transfusions was 1 (IQR: 0), and the median number of platelet suspension transfusions was 1.5 (IQR: 2.5). The median number of fibrinogen transfusions was 1 (IQR: 0). All patients survived following management with abdominal packing and associated interventions.

DISCUSSION

Postpartum hemorrhage remains a leading cause of maternal morbidity and mortality worldwide. This case series provides valuable insights into the role of abdominal packing in the contemporary management of severe, refractory PPH when conventional methods prove unsuccessful.

Our results demonstrate a 100% survival rate among patients managed with pelvic pressure packing, which compares favorably with the findings of Franchini et al.,[11] who reported mortality rates of 2–4% in severe PPH cases requiring second-line interventions. However, 10 of our 11 patients (90.9%) developed pulmonary edema, a complication rate considerably higher than the 28.6% (2 of 7 patients) reported by Yoong et al.[12] in their study on abdominopelvic packing. This discrepancy underscores the importance of meticulous fluid management protocols when employing this method.

In our study, the median blood product requirements were 5.0 units of packed red blood cells and 4.0 units of fresh frozen plasma. Touhami et al.,[8] in their study on pelvic packing after emergency peripartum hysterectomy, reported a mean transfusion requirement of 19.5 units of packed red blood cells (standard deviation: 7.7). Our median ICU stay of 1.0 day was notably shorter than the 3 days (IQR: 2-6.5) reported by Deffieux et al.[13] in their study on maternal outcomes after abdominal packing for uncontrolled postpartum hemorrhage. This shorter ICU stay, together with the median mechanical ventilation duration of 24 hours (IQR: 24-48) reported by Deffieux et al., suggests potential benefits of our postoperative care approach. Specifically, the shorter ICU stay in our series may be attributed to our practice of reoperating 24 hours after the initial packing procedure.

There are limited data on the use of the shock index in obstetric patients. In a study by Nathan et al., a shock index >0.9 in patients with postpartum hemorrhage was associated with an increased risk of maternal adverse events.[14] Le Bas et al. found that a shock index of 0.7-0.9 in patients with postpartum hemorrhage was associated with a significant increase in blood loss.[15] The median shock index of 1.16 in patients who underwent abdominal packing in this study suggests that these patients were at high risk of hemodynamic instability. The shock index may be a useful tool for assessing hemodynamic status and guiding treatment strategies in patients undergoing abdominal packing.

Based on our findings and a review of the literature, abdominal packing appears most appropriate in specific clinical scenarios: cases of severe PPH refractory to first-line medical management;[9,16] situations in which arterial embolization is unavailable or impractical;[17] when compression sutures have failed;[9] and in resource-limited settings lacking advanced surgical expertise.[9] Specifically, our data suggest that patients with uterine atony or placenta previa who continue to hemorrhage despite conventional measures may derive the greatest benefit from this approach.

This technique is particularly valuable in patients with coagulopathy, such as our patient with DIC, in whom definitive surgical procedures may be complicated by persistent bleeding. As highlighted by Zhou et al.,[18] packing provides temporary hemostasis, allowing correction of coagulopathy before definitive surgery.

Compared to other second-line interventions, abdominal packing offers several distinct advantages. Unlike arterial embolization, which Sentilhes et al.[19] reported to have a technical success rate of 85–95% but requires specialized radiological expertise and facilities, packing can be performed in any surgical setting using readily available materials. The simplicity of the technique contrasts with more complex compression sutures, such as the B-Lynch or Hayman sutures, which Matsubara et al.[20] noted require specific surgical skills and may be challenging to implement in emergency situations.

However, our findings must be considered alongside the advantages of balloon tamponade techniques, which Germano et al.[21] reported to be successful in 99% of cases with ultrasound guidance and 86% without ultrasound guidance. Compared to packing, balloon tamponade techniques are associated with lower complication rates. Therefore, the choice between these methods should take into account institutional resources, provider expertise, and patient-specific factors, such as the source and severity of bleeding.

A notable finding in our study was the high incidence of pulmonary edema, observed in 90.9% of cases. This rate is significantly higher than that reported in standard obstetric cohorts and warrants careful interpretation.[22] It is important to emphasize that all patients in our series experienced massive hemorrhage requiring aggressive fluid resuscitation and multiple blood product transfusions under a massive transfusion protocol. Therefore, we believe that the high rate of pulmonary edema was primarily a manifestation of transfusion-associated circulatory overload and/or transfusion-related acute lung injury, rather than a direct complication of the packing technique itself. Furthermore, abdominal packing is typically reserved for patients in profound shock with coagulopathy; thus, the associated systemic inflammatory response and increased capillary permeability likely contributed to the development of pulmonary edema. Despite this high complication rate, the primary goals of hemorrhage control and hemodynamic stabilization were achieved in all patients, and all cases of pulmonary edema were successfully managed in the intensive care unit without long-term sequelae.

Our study has several limitations. The retrospective nature and small sample size (n=11) limit the generalizability of our findings, and the single-center experience may not reflect outcomes in other healthcare settings. The lack of a control group precludes direct comparison with other management strategies. Finally, the absence of long-term follow-up data, combined with the fact that all patients underwent hysterectomy, prevents evaluation of potential long-term complications such as adhesion formation or effects on subsequent fertility.

Despite these limitations, our study has several strengths. It is one of the few studies to investigate the use of abdominal packing in contemporary practice and provides valuable insights into the technique's potential role in managing severe PPH. Our findings suggest that abdominal packing can be a life-saving intervention for women with refractory PPH, particularly in settings where more advanced interventions may not be immediately available.

CONCLUSION

In conclusion, abdominal packing remains a valuable tool in the management of severe, refractory PPH. When implemented with appropriate patient selection and careful postoperative monitoring, it can serve as a life-saving intervention that bridges the gap between medical management and more invasive surgical procedures. Future research should address the limitations of our study through prospective, multicenter studies comparing modified packing techniques with contemporary interventions such as intrauterine balloon tamponade and endovascular approaches. The development of standardized protocols for patient selection, pack placement, and postoperative management would improve the quality of evidence. Additionally, investigation of modified packing materials that minimize tissue trauma while maintaining efficacy may help reduce complication rates. Long-term follow-up studies examining subsequent pregnancy outcomes and quality of life after abdominal packing for PPH would provide valuable insights into the broader impact of this intervention.

Ethics Committee Approval: This study was approved by the Mersin University Medical Faculty Hospital Ethics Committee (Date: 18.09.2024, Decision No: 2024/872).

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Doğum sonrası kanamada abdominal packing: Unutulmuş bir hayat kurtarma tekniği

AMAÇ: Postpartum kanama maternal morbidite ve mortalitenin önemli bir nedenidir. Abdominal packing, diğer yöntemler başarısız olduğunda kanamayı kontrol etmek için kullanılan bir tekniktir. Bu çalışmanın amacı postpartum kanama nedeniyle abdominal packing tekniği uygulanan hastaların sonuçlarını değerlendirmektir.

GEREÇ VE YÖNTEM: Bu retrospektif çalışmaya 2005-2023 yılları arasında Mersin Üniversitesi Tıp Fakültesi Hastanesi'nde postpartum kanama nedeniyle abdominal packing uygulanan 11 hasta dahil edildi. Veriler tıbbi kayıtlardan toplandı. Birincil sonuç, daha fazla operasyon gerektirmeden abdomino-pelvik packingin etkinliğiydi. İkincil sonuçlar kanama, transfüzyonlar, komplikasyonlar ve hastanede yatış süresini kapsamaktadır.

BULGULAR: 11 hastanın hepsine postpartum kanama nedeniyle histerektomi yapıldı ve devam eden kanama nedeniyle abdominal packing uygulandı. Postpartum kanamanın ana nedenleri uterus atonisi (%54.5), plasenta previa (%36.4) ve dissemine intravasküler koagülasyon (%9.1) idi. Kullanılan ortalama kompres sayısı 3 idi ve tüm hastalara 1 gün süreyle yerleştirildi. Abdominal packing, histerektomi sonrası tüm vakalarda inatçı kanamayı etkili bir şekilde kontrol altına almıştır. Hastanede yatış süresi median 6 gündü. Tüm hastalara kan transfüzyonu gerekmiştir. En yaygın komplikasyon akciğer ödemiydi (%90.9). Tüm hastalar hayatta kaldı.

SONUÇ: Abdominal packing tekniği, özellikle diğer yöntemler başarısız olduğunda, şiddetli postpartum kanama için hayat kurtarıcı bir girişim olabilir. Dikkatli hasta seçimi ve ameliyat sonrası izlem şarttır.

Anahtar sözcükler: Abdominal packing; histerektomi; maternal morbidite; mortalite; postpartum kanama.

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ORIGINAL ARTICLE

Blood urea nitrogen-to-albumin ratio as a predictor of mortality in patients undergoing emergency surgery for obstructive colon cancer

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ABSTRACT

BACKGROUND: Mortality rates are high in patients undergoing emergency surgery for obstructed colon adenocarcinoma. The etiology of mortality is multifactorial, and parameters with high predictive value are still needed. The aim of this study was to investigate the relationship between the blood urea nitrogen-to-serum albumin ratio (BAR) and short-term mortality in patients with obstructed colon cancer undergoing emergency surgery.

METHODS: This retrospective cohort study included patients with obstructed colon adenocarcinoma who underwent emergency surgery at two tertiary care centers between January 2015 and December 2024. Baseline characteristics, laboratory findings, operative details, and clinical data were collected. According to time-dependent receiver operating characteristics (ROC) analysis, the optimal cut-off value for pretreatment BAR was 0.68. Data from patients who died within the first 30 days and those who survived were compared. Univariate and multivariate Cox regression analyses were performed to evaluate the association between BAR and other factors with early mortality.

RESULTS: A total of 173 patients underwent emergency surgery, and 17 (9.8%) experienced early mortality. In multivariate logistic regression analysis, age (≥75 years), lactate level, neutrophil count, and BAR ≥0.68 (odds ratio: 7.053; 95% confidence interval: 1.728-28.785; p=0.006) were identified as significant risk factors for early mortality in patients undergoing emergency surgery for obstructed colon cancer.

CONCLUSION: Mortality in patients undergoing emergency surgery for obstructed colon cancer is high and multifactorial. BAR is a cost-effective, easily measurable, and useful predictor of early mortality.

Keywords: Blood urea nitrogen-to-serum albumin ratio; colon cancer; mortality; obstruction.

INTRODUCTION

In Asia, colorectal cancer (CRC) ranks as the third most frequently diagnosed malignancy, with approximately one million new cases annually, and is as the fourth leading cause of cancer-related mortality.[1] Approximately 20% of colorectal cancer cases require emergency intervention due to colonic obstruction.[2] Most studies have identified emergency surgery as an independent risk factor for early mortality compared with elective surgery. Postoperative mortality and morbidity

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rates in patients with obstructed colon cancer (OCC) are reported to be 8%-15% and 40%, respectively. High morbidity and mortality rates are associated with advanced disease stage, ischemia, perforation, renal failure, advanced age, fluid-electrolyte imbalance, sepsis, and comorbidities.[3-8] Serum albumin concentration is a key marker of nutritional status. The systemic inflammatory response caused by the tumor, together with decreased oral intake due to obstruction, can lead to a progressive decline in albumin levels. Low serum albumin levels markedly prolong hospitalization and increase complication rates, particularly the risk of surgical site infections, enterocutaneous fistulas, and deep vein thrombosis.[9-11] Furthermore, a significant proportion of patients with advanced colon cancer present with malnutrition and hypoalbuminemia, which significantly increase mortality in those undergoing major emergency surgery.[12] Blood urea nitrogen (BUN), a product of protein metabolism, is an important indicator of renal function as well as metabolic and nutritional status, and has been associated with mortality.[13-15] Emerging evidence suggests that an elevated blood urea nitrogen-to-albumin ratio (BAR) is a strong prognostic marker of mortality in various clinical conditions, including upper gastrointestinal bleeding, chronic obstructive pulmonary disease, sepsis, lung cancer, pneumonia, coronavirus disease 2019 (COVID-19), and other critical illnesses.[13,16-21] However, the prognostic role of BAR in predicting early mortality among patients undergoing emergency surgery for OCC has not yet been evaluated. Therefore, the present study aimed to assess the prognostic significance of BAR in predicting mortality in patients with OCC who underwent emergency surgical intervention.

MATERIALS AND METHODS

Study Design and Population

This retrospective cohort study included patients who underwent emergency surgery for OCC at two tertiary care research hospitals. Patients who underwent surgery between January 2015 and December 2024 and had complete electronic medical records were included in the analysis. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Clinical Research Ethics Committee of Dicle University Faculty of Medicine (Approval No: 2025–245). All patient data were anonymized to ensure confidentiality.

Adult patients who underwent surgery within 24 hours of emergency admission for colonic obstruction and had a pathological diagnosis of adenocarcinoma were included. Acute colonic obstruction was confirmed both clinically (obstipation, abdominal distension, nausea, and vomiting) and radiologically (abdominopelvic computed tomography scan with or without contrast). Patients who underwent colectomy for non-adenocarcinoma etiologies, those with rectum-localized obstruction, those treated with bridge therapy using endoscopic stenting, and those managed with medical treatment alone were excluded. In addition, patients with chronic kidney disease, protein-losing nephropathy, or chronic liver disease were excluded.

Data Collection and Outcome Measurement

The following data were collected: demographic characteristics (age, sex, comorbidities, Eastern Cooperative Oncology Group Performance Status [ECOG PS]), symptom duration (days), tumor localization (tumors located in the colon from the cecum to the splenic flexure were defined as proximal, whereas tumors located from the distal splenic flexure to the proximal rectum were defined as distal), intraoperative findings (perforation, presence of metastasis), and surgical details (palliative or curative intent, duration of surgery, etc.). Laboratory parameters recorded at the time of emergency admission included white blood cell count, hemoglobin level, neutrophil count, lactate level, BUN, albumin, creatinine, lactate dehydrogenase (LDH), and C-reactive protein. Time-dependent receiver operating characteristic (ROC) curve analysis for mortality prediction identified 0.68 as the optimal pretreatment BAR threshold, corresponding to a sensitivity of 76.5% and a specificity of 76.9% (area under the curve [AUC]=0.817; p<0.001) (Fig. 1). The predictive cut-off value for mortality for the LDH/albumin ratio was determined to be 5.27.[10] To identify factors associated with hospital mortality following emergency surgery, patients were divided into two groups: those who died and those who survived.

Statistical Analysis

Statistical analyses were performed using jamovi version 2.6 (The jamovi Project, 2025) available at https://www.jamovi.org. Baseline clinical characteristics were analyzed by categorizing patients into early mortality and survival groups. Continuous variables are presented as mean ± standard deviation (SD) or median (range), as appropriate, and categorical vari-

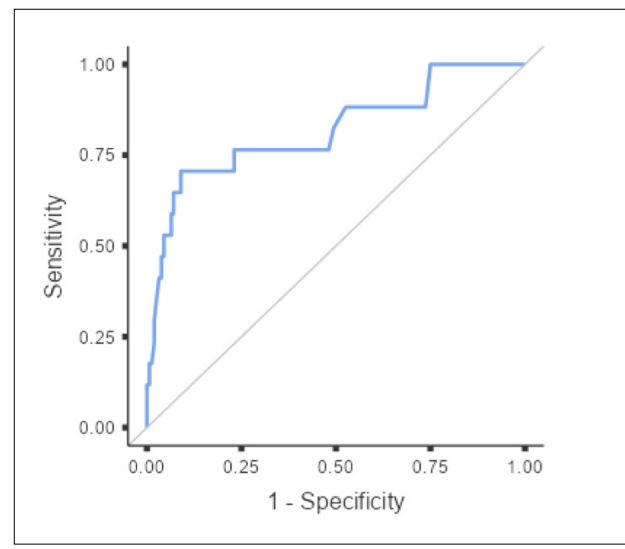

Figure 1. Determination of the optimal cutoff value of the blood urea nitrogen-to-albumin ratio (BAR). The cutoff value was 0.68, yielding a sensitivity of 76.5% and a specificity of 76.9% (area under the receiver operating characteristics curve: 0.817; p=0.001).

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ables as frequencies and percentages. The Shapiro-Wilk test was used to assess normality of numerical data. The Mann–Whitney U test was applied for comparisons of continuous variables, while categorical variables were analyzed using the chi-square test. Subsequently, univariate and multivariate Cox regression analyses were performed to evaluate the association between BAR and short-term mortality in patients with OCC. A two-tailed p value <0.05 was considered statistically significant.

RESULTS

Study Population and Baseline Characteristics

During the 10-year study period, 173 patients underwent emergency surgery for OCC at two tertiary hospitals. The demographic characteristics, operative findings, and clinical outcomes of the patients are presented in Table 1. The median age of the cohort was 61 years (range: 23-96), and 96 patients (55.5%) were male. Seventeen patients (9.8%) expe-

Table 1. Comparison of demographic, clinical, and operative variables between patient groups

Variable	Survivors (n=156)	Non-Survivors (n=17)	Total (n=173)	p-value
Age, years*	60.5 (23-96)	75 (34-89)	61 (23-96)	0.004
Age <75	121 (77.6)	7 (41.2)	128 (74.0)	
Age ≥75	35 (22.4)	10 (58.8)	45 (26.0)	0.003
Sex, n (%)				
Female	66 (42.3)	11 (64.7)	77 (45.5)	0.132
Male	90 (57.7)	6 (35.3)	96 (55.5)	
Comorbidities, n (%)				
Diabetes mellitus	36 (23.1)	3 (17.6)	39 (22.5)	0.766
Coronary artery disease	16 (10.3)	5 (29.4)	5 (29.4)	0.038
Hypertension	46 (29.5)	8 (47.1)	54 (31.2)	0.227
Pulmonary disease	10 (6.4)	2 (11.8)	12 (6.9)	0.334
Heart failure	4 (2.6)	3 (17.6)	7 (4.0)	0.022
ECOG PS, n (%)				
0-1	78 (50.0)	4 (23.5)	82 (47.4)	0.069
≥2	78 (50.0)	13 (76.5)	91 (52.6)	
Duration of symptoms, days				
<3	101 (64.7)	15 (88.2)	116 (67.1)	0.092
≥3	55 (35.3)	2 (11.8)	57 (32.9)	
Tumor location, n (%)				
Proximal colon	48 (30.8)	3 (17.6)	51 (29.5)	0.397
Distal colon	108 (69.2)	14 (82.4)	122 (70.5)	
Perforation, n (%)	15 (9.6)	5 (29.5)	20 (11.6)	0.031
Synchronous liver metastasis, n (%)	25 (16.0)	6 (35.3)	31 (17.9)	0.087
Synchronous peritoneal metastasis, n (%)	8 (5.1)	1 (5.9)	9 (5.2)	1.000
Synchronous lung metastasis, n (%)	3 (1.9)	0 (0.0)	3 (1.7)	1.000
Curative surgery, n (%)	133 (85.3)	10 (58.8)	143 (82.7)	0.013
Surgical procedures, n (%)				
Right/extended right colectomy	37 (23.7)	2 (11.8)	39 (22.5)	0.534
Left/sigmoid colectomy	80 (51.3)	10 (58.8)	90 (52.0)	
Total/subtotal colectomy	39 (25.0)	5 (29.4)	44 (25.4)	
Stoma creation, n (%)	107 (68.6)	16 (94.1)	123 (71.1)	0.026
Blood transfusion, n (%)	25 (16.0)	5 (29.4)	30 (17.3)	0.180
Operative time (minutes, mean±SD)	145.8±51.0	149.4±65.5	146.1±52.4	
Operative time, minutes*	135 (60-310)	135 (80-330)	135 (60-330)	0.868
Anastomotic leak, n (%)	2 (1.3)	1 (5.9)	3 (1.7)	0.268
Relaparotomy, n (%)	2 (1.3)	1 (5.9)	3 (1.7)	0.268

ECOG PS: Eastern Cooperative Oncology Group Performance Status; SD: Standard deviation. *Median (range).

rienced early mortality. Patients in the non-mortality group were younger, with a median age of 61 years (range: 23-96) (p=0.004). Synchronous liver metastasis was the most common metastatic site in both the mortality group (six patients, 35.3%) and the non-mortality group (25 patients, 16.0%). Intestinal perforation detected during surgical exploration was more frequent in the mortality group (29.5%) (p=0.031). Curative surgery with R0 resection was performed in 10 patients (58.8%) in the mortality group and in 133 patients (85.3%) in the non-mortality group, with a statistically significant difference (p=0.013). Sex, comorbidities, performance status, symptom duration, tumor localization, type of surgical procedure, stoma formation, and operative time were similar between the two groups (Table 1).

In the mortality (+) group, BUN, LDH, and lactate levels were higher, whereas albumin levels were significantly lower compared to the non-mortality group (Table 2). Consistent with these findings, both the BAR and LDH/albumin ratios were markedly elevated in the mortality group (p<0.001). The proportion of patients with BAR ≥0.68 was 76.5% in the mortality group and 23.1% in the non-mortality group, and the difference was statistically significant (p=0.003).

Factors Associated with Mortality

In univariate logistic regression analysis, age (≥75 years), ECOG PS ≥2, perforation, elevated lactate, neutrophilia, and BAR ≥0.68 were identified as significant risk factors for early mortality. Multivariate logistic regression analysis was performed including these significant variables (Table 3). In multivariate logistic regression analysis, age (≥75 years), lactate level, neutrophil count, and BAR ≥0.68 (odds ratio [OR]: 7.053; 95% confidence interval [CI]: 1.728-28.785; p=0.006) were identified as significant risk factors for early mortality in patients with OCC undergoing emergency surgery.

DISCUSSION

Despite screening colonoscopy programs, the rate for emergency surgery for OCC is still approximately 15%-20%. In this clinical setting, two major problems stand out for clinicians: i) the high morbidity and mortality associated with emergency surgery and ii) planning the optimal oncologic treatment. Adverse clinical outcomes are common in patients presenting with OCC due to advanced age, fluid-electrolyte imbalance, advanced disease stage, perforation, and frequently accompanying comorbidities.[2,4,6,22] In this study, we investigated the impact of an elevated BAR on mortality in patients with OCC undergoing emergency surgery. Our findings demonstrated that a preoperative BAR value above 0.68 is associated with increased mortality. To our knowledge, this is the first study to evaluate the association between BAR and early mortal-

Table 2. Comparison of initial admission laboratory parameters between survivors group and non-survivors

Variable	Survivors (n=156)	Non-Survivors (n=17)	Total (n=173)	p-value
White blood cell count (10^9/L)	10.5±4.42	12.9±7.28	10.8±4.80	0.322
Hemoglobin (g/dL)	12.0±2.50	11.4±2.29	11.9±2.48	0.380
Platelet count (10^9/L)	319.4±116.3	351.1±192.4	322.5±125.4	0.984
Neutrophil count (10^9/L)	8.16±4.24	10.7±6.93	8.42±4.62	0.214
Lymphocyte count (10^9/L)	1.58±1.17	1.33±0.87	1.55±1.14	0.168
C-reactive protein (mg/L)	46.1±64.3	71.8±102.1	48.7±69.0	0.949
Blood urea nitrogen (mg/dL)	17.5±9.35	29.7±17.0	18.7±10.9	0.001
Creatinine (mg/dL)	0.91±0.62	1.11±0.70	0.93±0.63	0.297
Albumin (g/L)	33.0±7.79	23.5±7.78	32.1±8.27	<0.001
LDH (U/L)	231.2±96.8	328.4±202.5	240.7±114.5	0.028
BUN-to-albumin ratio	0.55±0.34	1.42±0.97	0.64±0.51	<0.001
LDH-to-albumin ratio	7.40±4.11	15.0±10.3	8.15±5.52	<0.001
Lactate level (mmol/L)	1.47±0.65	2.23±1.11	1.54±0.74	0.003
BUN-to-albumin ratio				
<0.68	120 (76.9)	4 (23.5)	124 (71.7)	0.003
≥0.68	36 (23.1)	13 (76.5)	49 (28.3)	
LDH-to-albumin ratio				
<5.27	42 (26.9)	1 (5.9)	43 (24.9)	0.075
≥5.27	114 (73.1)	16 (94.1)	130 (75.1)	

BUN: Blood urea nitrogen; LDH: Lactate dehydrogenase.

Table 3. Univariate and multivariate logistic regression analyses of mortality predictors

	Univariate Analysis		Multivariate Analysis	
Variable	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
Age ≥75 years	4.939 (1.752-13.925)	0.003	6.286 (1.303-30.326)	0.022
Male sex	0.400 (0.141-1.136)	0.085		
ECOG PS ≥2	3.250 (1.015-10.406)	0.047		
Duration of symptoms ≥3 days	0.245 (0.054-1.110)	0.068		
Perforation	3.917 (1.214-12.635)	0.022	2.892 (0.470-17.779)	0.252
Tumor location (distal colon)	2.074 (0.570-7.553)	0.269		
Operative time, minutes	1.001 (0.992-1.011)	0.787		
Blood transfusion	2.183 (0.707-6.742)	0.175		
Lactate level (mmol/L)	2.721 (1.558-4.752)	<0.001	3.999 (1.698-9.421)	0.002
White blood cell count (10^9/L)	1.097 (0.999-1.204)	0.053		
Neutrophil count (10^9/L)	1.109 (1.009-1.219)	0.032	1.141 (1.014-1.283)	0.028
C-reactive protein (mg/dL)	1.004 (0.998-1.010)	0.154		
BUN-to-albumin ratio (≥0.68)	10.833 (3.326-35.288)	<0.001	7.053 (1.728-28.785)	0.006
LDH-to-albumin ratio (≥5.27)	5.895 (0.758-45.837)	0.090		
Anastomotic leak	4.813 (0.413-56.051)	0.210		

BUN: Blood urea nitrogen; CI: Confidence interval; ECOG PS: Eastern Cooperative Oncology Group Performance Status; LDH: Lactate dehydrogenase; OR: Odds ratio.

ity in colon cancer patients undergoing emergency surgery for obstruction. Additionally, we found that age ≥75 years, elevated lactate levels, and increased neutrophil counts were associated with early mortality.

Blood urea nitrogen levels are routinely used in clinical practice because of the ease of measurement as a serum biomarker for assessing renal function. In critically ill patients, particularly those with multiple organ failure and sepsis, renal dysfunction is one of the earliest deteriorating parameters, and elevated BUN levels have been associated with poor clinical outcomes.[19,23] In patients with obstruction, vomiting, reduced oral intake, dehydration, and sepsis secondary to intestinal perforation or ischemia may impair renal function, resulting in increased BUN levels. Previous studies have demonstrated an association between BUN and prognosis or mortality in conditions such as aortic dissection, renal failure, patients undergoing hemodialysis, Escherichia coli bacteremia, lung cancer, and peripheral arterial disease.[13,21,24-27]

Albumin is the principal plasma protein and plays a key role in the distribution of body fluids and maintenance of acid-base balance. It also facilitates the transport of substances such as hormones, bilirubin, and lipids in the blood and helps regulate the inflammatory process.[28] Preoperative hypoalbuminemia, indicating malnutrition, is recognized as being linked to poor outcomes after gastrointestinal surgery. In colorectal surgery patients, hypoalbuminemia significantly increases complications and is considered a predictor of mortality.[12] If there is a serious nutritional risk due to hypoalbuminemia, it is recommended to postpone surgery and administer preoperative nutritional therapy enterally for 10-14 days before surgery, if possible, or parenterally if the enteral route is not adequate.[29] Unfortunately, it is not possible to treat malnutrition in patients undergoing emergency surgery with OCC.

When analyzed in this context, an elevated BAR reflects increased BUN levels combined with reduced albumin concentrations. It has been suggested that a high BAR level may serve as a new prognostic marker for different categories of critically ill patients. Bae et al.[15] examined 914 nontraumatic patients admitted emergently and found that BAR was a predictor of mortality. In another study examining an elderly patient population that included over 1,000 patients, BAR was similarly identified as a powerful predictor of mortality.[16] In critically ill patients requiring intensive care follow-up due to gastrointestinal bleeding, BAR was found to be higher in the group that died.[18] A separate investigation involving 801 patients with sepsis reported a significant positive correlation between BAR levels and both Sequential Organ Failure Assessment (SOFA) and Acute Physiology and Chronic Health Evaluation II (APACHE II) scores. High SOFA and APACHE II scores are recognized markers of greater disease severity and poorer prognosis.[19]

Undoubtedly, our study has some limitations. Its retrospective design and limited number of cases are the most important constraints and may have introduced selection bias.

Because BUN and albumin levels exhibit dynamic variability, supportive therapies may have influenced the results. Additionally, we did not perform external validation; therefore, caution should be exercised when generalizing these findings, and large-scale prospective studies are needed. However, we believe the study is valuable because it includes data from homogeneous patient groups across two centers.

CONCLUSION

In conclusion, BAR at admission is an easily measurable biomarker and an independent predictor of early mortality in patients undergoing emergency surgery for obstructed colon cancer.

Ethics Committee Approval: This study was approved by the Clinical Research Ethics Committee of Dicle University Faculty of Medicine Ethics Committee (Date: 18.06.2025, Decision No: 2025–245).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: U.A., AA, H.Ö.; Design: U.A., A.A.; Supervision: E.G.,E.Gü.; Resource: Ö.S.D., H.Ö.; Materials: U.A., A.A., Ö.S.D., H.Ö., E.G.; Data collection and/or processing: E.G., E.Gü., H.A.; Analysis and/or interpretation: H.A., U.A., A.A.; Literature review: U.A., A.A., H.Ö.; Writing: U.A., A.A., E.G.; Critical review: E.G., E.Gü., U.A.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Tıkayıcı kolon kanseri nedeniyle acil ameliyata alınan hastalarda mortaliteyi öngördüren bir faktör olarak kan üre azotu/albümin oranı

AMAÇ: Tıkalı kolon adenokarsinomunda acil cerrahiye başvuran hastalarda mortalite oranları yüksektir. Mortalitenin etiyolojisi çok faktörlüdür ve yüksek prediktif değere sahip parametreler hala gereklidir. Bu çalışmanın amacı, acil cerrahiye başvuran tıkalı kolon kanseri hastalarında kan üre azotu/serum albümin oranı (BAR) ile kısa dönem mortalite arasındaki ilişkiyi araştırmaktır.
GEREÇ VE YÖNTEM: Bu çalışma, Ocak 2015 ile Aralık 2024 tarihleri arasında iki üçüncü basamak sağlık merkezinde acil cerrahi uygulanan tıkayıcı kolon adenokarsinomu hastalarını kapsayan retrospektif bir kohort çalışmasıdır. Başlangıç özellikleri, laboratuvar, cerrahi ve klinik veriler elde edilmiştir. Zamana bağlı alıcı işletim karakteristikleri (ROC) analizine göre, tedavi öncesi BAR için optimal kesme değeri 0.68 olarak belirlenmiştir. İlk 30 gün içinde mortalite olan ve olmayan hastaların verileri karşılaştırılmıştır. BAR ile erken mortalite arasındaki ilişkiyi araştırmak için tek değişkenli ve çok değişkenli Cox regresyon analizi kullanılmıştır.
BULGULAR: Toplam 173 hasta acil cerrahiye alınmış ve 17'si (%9.8) erken mortaliteye gelişmiştir. Çok değişkenli lojistik regresyon analizinde, yaş (≥75 yıl), laktat düzeyi, nötrofil sayısı ve BAR≥0.68 (odds oranı, 7.053; %95 güven aralığı, 1,728-28,785; p=0.006) tıkayıcı kolon kanseri nedeniyle acil cerrahi geçiren hastalarda erken mortalite için önemli risk faktörleri olarak belirlendi.
SONUÇ: Acil cerrahi gerektiren tıkanmış kolon kanserinde mortalite yüksektir ve çok faktörlüdür. BAR, maliyet etkin, kolayca ölçülebilir ve erken mortalitenin öngörücüsü olarak yararlıdır.

Anahtar sözcükler: Kolon kanseri; tıkanma; kan üre azotu/serum albümin oranı; mortalite.

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ORIGINAL ARTICLE

Functional and quality-of-life outcomes following flap surgery for anal canal stenosis caused by traumatic and non-traumatic factors: A comparative analysis

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ABSTRACT

BACKGROUND: Anal canal stenosis is a functionally disabling condition that results in impaired continence, constipation, and decreased quality of life. Although most cases arise after anorectal surgery, high-energy blast trauma (HEBT) represents a distinct etiology characterized by extensive tissue loss and neuromuscular injury. Long-term outcomes of anoplasty in this setting remain insufficiently described. This retrospective study evaluated functional and quality-of-life outcomes following flap anoplasty for anal stenosis of both postoperative and trauma-related origins.

METHODS: All patients who underwent anoplasty between 2008 and 2015 with ≥12 months of follow-up were included. Functional status was assessed preoperatively and at 12 months postoperatively using the Modified Wexner Score, Wexner Constipation Scale, and the Fecal Incontinence Quality of Life (FIQL) questionnaire. Sphincter morphology was evaluated using endoanal ultrasonography. Statistical analyses included paired tests, effect size calculations, and multivariable logistic regression to identify independent predictors of good continence (Wexner score ≤5).

RESULTS: Thirty-seven patients met the inclusion criteria: 27 with postoperative stenosis and 10 with blast-related trauma. Anoplasty resulted in overall improvement in continence, constipation, and FIQL scores. However, functional recovery differed significantly by etiology: postoperative patients experienced substantial improvement, whereas blast-injured patients achieved only modest gains, reflecting persistent neuromuscular and fibrotic damage. Trauma cases demonstrated lower FIQL scores (14.7 vs. 16.8), higher constipation scores (8.1 vs. 7.2), and increased rates of fecal incontinence (20% vs. 11.1%). Sphincter integrity and shorter stricture length independently predicted good continence, while blast mechanism and advanced age were associated with reduced improvement.

CONCLUSION: Anoplasty provides meaningful functional benefits in patients with anal stenosis; however, recovery is significantly attenuated in survivors of high-energy trauma. These findings underscore the importance of etiology-based planning, thorough sphincter evaluation, and realistic patient counseling.

Keywords: Anal stenosis; fecal incontinence; Fecal Incontinence Quality of Life (FIQL); flap surgery; trauma; mine-blast injury; constipation; Wexner score.

INTRODUCTION

Anal canal stenosis is an uncommon yet functionally disabling condition characterized by narrowing of the anal canal and impaired compliance, leading to defecatory difficulty, pain, and fecal incontinence. It most frequently occurs after anorectal surgery, particularly hemorrhoidectomy or fistulectomy, as a result of progressive cicatrization and loss of pliable anoderm.

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[1,2] The functional consequences extend beyond simple luminal obstruction, as sphincter dysfunction and impairment in quality of life are common.[3-5]

High-energy blast trauma (HEBT) represents a distinct and considerably more complex etiology of anorectal injury.[6-9] Unlike routine postoperative stenosis,[10] blast injuries involve shockwave-induced neuromuscular damage, deep tissue contamination, and extensive soft-tissue loss.[11-12] Management typically requires staged fecal diversion, serial debridement, and delayed reconstruction after maturation of the perineal wound.[13] Consequently, anal stenosis amenable to isolated anoplasty is rare among blast survivors, and long-term functional outcomes in this population remain extremely limited.[14,15]

Multiple anoplasty techniques—including advancement flaps, diamond flaps, and V-Y flaps—have been described to restore anal canal caliber and compliance.[16-23] Although favorable continence outcomes have been well documented in postoperative stenosis, the applicability and success of these techniques in blast-related injuries are less certain due to irreversible neuromuscular damage and pelvic floor fibrosis.[12,14,15]

This study evaluates functional and quality-of-life outcomes following anoplasty for anal stenosis in both blast-injured and elective postoperative patients and identifies key predictors of continence recovery. We hypothesized that, although anoplasty improves outcomes in both groups, blast-injured patients would demonstrate comparatively reduced recovery due to deeper tissue destruction and fibrosis.

MATERIALS AND METHODS

Study Design

This retrospective analysis was conducted using patient data from the General Surgery Department of Gülhane Military Medical Academy (GMMA=GATA) and covered the period from January 2008 to December 2015.

Patient Selection

The study population was created by selecting several hundred patients who were injured in terrorist conflicts (later treated as veterans) and presented to GMMA with perianal injuries over an eleven-year period. These patients were wounded veterans who applied for treatment of anal stenosis, as well as patients who had previously undergone hemorrhoidectomy or whose perianal region had been affected by chronic inflammatory bowel disease, cancer, or radiotherapy. Some of these patients were treated at this hospital, while others were managed at another university hospital where the surgical team continued working after the closure of GMMA.

Among patients who underwent perianal surgery or sustained perineal injuries, 37 individuals who received flap surgery for anal canal stenosis and were followed for at least 12 months were included in the study. Patients were excluded if they had not undergone flap-based anoplasty; presented with severe, destructive, or complex perineal traumatic injuries; had incomplete follow-up documentation; were younger than 17 years of age; or had direct radiation exposure to the perianal region (e.g., secondary to anal malignancy or Paget's disease).

Data Collection and Ethics

Data were extracted from anonymized patient records and digitized for analysis using SPSS. This study was designed as a retrospective analysis utilizing anonymized patient data extracted from existing hospital records. All information used in this research had been routinely documented during standard clinical care, and no additional procedures, interventions, or patient contact were performed for research purposes. The dataset was fully anonymized prior to analysis, and no personal identifiers (such as names, ID numbers, or contact information) were included at any stage of data processing.

In accordance with the principles of the Declaration of Helsinki and relevant national research ethics regulations, studies that rely exclusively on retrospective analysis of anonymized data are exempt from the requirement for formal review or approval by an institutional ethics committee. Therefore, ethical approval for this study was waived, as the research posed no potential risk or burden to human participants, and all data were handled with strict adherence to confidentiality and privacy standards.

Furthermore, the authors confirm that the study complied with all institutional and legal requirements regarding data protection and research integrity. Written informed consent was not required due to the retrospective, non-interventional nature of the study and the complete anonymization of the dataset.

Etiological Groups

Trauma Group: This group included patients injured by high-energy military weapons during terrorist incidents, including high-energy firearms, mine explosions, grenades, rockets, and improvised explosive devices.

Other Etiologies (Non-Trauma Group): This group included patients who developed anal canal stenosis secondary to previous perianal surgical interventions (such as hemorrhoidectomy or fistulectomy), chronic inflammatory bowel diseases (including Crohn's disease and ulcerative colitis), or post-oncologic treatments involving anastomotic strictures or pelvic radiotherapy.

Surgical Technique

All patients underwent one of the following procedures: House flap, Y-V advancement flap, and rhomboid flap surgery. The choice of technique was determined after evaluation of the medical condition, topographic appearance of the anal canal, and the degree of stenosis by at least two experienced surgeons (colorectal and war surgery specialists). Procedures were performed under regional (spinal or epidural) anesthesia in the operating room, most commonly in the prone jackknife

position and occasionally in the lithotomy position. One of the three flap techniques (House, Y-V advancement, or rhomboid) was selected and applied to patients deemed eligible. Trauma patients frequently received therapeutic-dose antibiotics. According to the antibiotic protocol, trauma patients were treated with ciprofloxacin (2×400 mg) and metronidazole (2×500 mg) for five days or longer, with modifications made as clinically indicated. Non-trauma patients received prophylactic ciprofloxacin in accordance with standard perioperative protocols.

Postoperative Follow-up and Assessments

Patients were followed at 1 month, 3 months, and at least 12 months postoperatively. During these visits, both early and late postoperative complications were recorded, and anal canal function was evaluated in terms of defecatory status and continence. Patient satisfaction was assessed using a 5-point Likert scale ranging from 1 (not satisfied) to 5 (fully satisfied). Quality of life was measured using the Fecal Incontinence Quality of Life (FIQL) scale, which addresses lifestyle, coping and behavior, depression and self-perception, and embarrassment. Functional outcomes were further quantified using standardized assessment tools: constipation was evaluated using the Wexner Constipation Score, continence using the Modified Wexner (Jorge) Score, quality of life using the FIQL scale, and patient satisfaction using the Likert scale.

Statistical Analysis

Statistical analyses were performed using SPSS (IBM Corp., NY, USA). Continuous variables were tested for normality using the Shapiro–Wilk test and presented as mean±standard deviation or median (interquartile range), as appropriate. Categorical variables were compared using the χ^2 test or Fisher's exact test. Functional scores were compared using paired parametric or non-parametric tests, and effect size was calculated using Cohen's d. Logistic and linear regression models were applied to evaluate predictors of continence, including trauma mechanism, sphincter status, age, and stricture length. Results were reported as odds ratios (ORs) or β estimates with 95% confidence intervals (Cis). The significance threshold was set at $p<0.05$.

RESULTS

A total of 37 patients were included in the study: 10 (27%) had HEBT, and 27 (73%) had a history of benign anorectal surgery or radiation. The mean follow up duration was 15.2±2.9 months (Table 1).

Clinically Meaningful Outcomes

Continence Status (Modified Wexner/Jorge Score)

The trauma group had a mean continence score of 7.8±2.1, compared to 6.9±1.8 in the non-trauma group. The difference approached statistical significance (p=0.087), with an effect size of d=0.48, suggesting worse continence in the trauma group, although with considerable variability (Table 2 and Table 5).

Fecal Incontinence: Fecal incontinence was observed in 20% (2/10) of trauma patients and 11.1% (3/27) of patients with other etiologies. This difference was statistically significant (p=0.049), indicating a higher risk of incontinence in trauma-related cases, likely due to greater sphincter damage (Table 2, Fig. 1).

Rates of good continence (Wexner ≤5) and clinically meaningful quality-of-life (QOL) improvement (FIQL ≥1) favored non-trauma patients (Fig. 2). Although trauma patients demonstrated improvement, the magnitude of benefit was lower. To assess patients' incontinence status and determine which factors independently influence the achievement of good

Table 1. Demographic and operative characteristics

Variable	Trauma Group (n=10)	Other Etiologies (n=27)	Total (n=37)
Age (mean±SD)	31.4±6.2	44.7±9.8	41.1±10.2
Gender (M/F)	10/0	18/9	28/9
Etiology	Military/mine-blast injury	Hemorrhoidectomy, IBD, radiation, oncologic surgery	—
Flap type	House flap, V-Y advancement flap, rhomboid flap	House flap, V-Y advancement flap, rhomboid flap	House flap, V-Y advancement flap, rhomboid flap
House flap	6	14	20
V-Y advancement flap	3	8	11
Rhomboid flap	1	5	6
Follow-up duration (months)	14.2±3.1	15.6±2.8	15.2±2.9

The trauma group consisted exclusively of male patients injured during military conflicts. All patients had ≥12 months of follow-up and completed the Fecal Incontinence Quality of Life (FIQL) and Wexner assessments.

Table 2. Comparison of functional outcomes at 12 months

Parameter	Trauma (n=10)	Other Etiologies (n=27)	p-value	Effect size (d)
FIQL score	14.7±3.2	16.8±2.9	0.041	0.62
Modified Wexner score	7.8±2.1	6.9±1.8	0.087	0.48
Constipation score	8.1±2.4	7.2±2.0	0.032	0.66
Fecal incontinence	20%	11.1%	0.049	0.58
Satisfaction (Likert)	3.9±0.6	4.3±0.5	0.071	0.51

Functional outcomes were generally worse in trauma patients, particularly with respect to quality of life, constipation severity, and fecal incontinence.

Table 3. Multivariable logistic regression for good continence at 12 months

Variable	Coefficient	Standard Error	z	P>|z|	[0.025	0.975]	OR	OR (low)	OR (high)
Model constant (reference baseline)	28.102	613575.171	0.0	1.0	-1202557.136	1202613.34	1601352770438.773	0.0	inf
Trauma	-26.012	305517.248	-0.0	1.0	-598828.815	598776.791	0.0	0.0	inf
Age (years)	0.134	0.141	0.948	0.343	-0.143	0.411	1.144	0.867	1.509
Stricture length (cm)	-2.017	1.574	-1.281	0.2	-5.102	1.068	0.133	0.006	2.911
Sphincter defect	-27.105	613575.171	-0.0	1.0	-1202612.342	1202558.133	0.0	0.0	inf

Multivariable logistic regression evaluated independent predictors of achieving good continence (Wexner score ≤5) at 12 months post-anoplasty. Odds ratios (OR) with 95% confidence intervals (CI) are presented. Covariates included trauma etiology, age, stricture length, and sphincter defect confirmed by endoanal ultrasonography. Lower OR values indicate reduced odds of good continence. Model convergence was achieved using a reduced covariate structure due to the sample characteristics. The constant term represents the predicted log-odds of good continence for the reference patient (non-trauma, intact sphincter, minimal stricture, average age).

Table 4. Functional outcomes by etiology

Etiology	n	FIQL	Wexner	Constipation	Fecal Incontinence	Flap Necrosis	Satisfaction
Trauma	10	14.7	7.8	8.1	20.0%	10%	3.9
Surgical	9	17.3	6.9	7.2	11.1%	0%	4.2
Pelvic radiation	3	13.5	9.5	9.3	33.3%	0%	3.3
Infection	1	18.5	6.5	6.0	0%	0%	5.0
IBD	4	13.3	9.0	9.5	25.0%	0%	3.5
Other	10	16.2	7.1	7.8	10.0%	0%	4.1

Trauma cases demonstrated inferior functional outcomes compared to surgical etiologies, particularly in continence and quality-of-life (QOL) domains. (Values represent means unless otherwise specified).

clinical continence (Wexner ≤5), multivariate logistic regression analysis was performed across etiological groups, including age, stricture length, and the presence or absence of a sphincter defect as covariates. Despite meticulous patient selection, blast-injured patients remained at higher risk for suboptimal continence recovery, underscoring the importance of sphincter integrity and fibrosis burden in pelvic trauma surgery (Table 3).

Constipation Score (Wexner Constipation Scale)

The trauma group had a mean constipation score of 8.1±2.4, whereas the non-trauma group scored 7.2±2.0. The difference was statistically significant (p=0.032), with a moderate effect size (d=0.66), indicating more pronounced defecatory disturbances in trauma patients (Table 2 and Table 5).

Table 5. Mann-Whitney Test and effect size summary

Parameter	p-value	Effect Size (d)	Interpretation
FIQL	0.041	0.62	Significantly lower in trauma group
Wexner	0.087	0.48	Worse in trauma group; borderline significance
Constipation	0.032	0.66	Significantly worse in trauma group
Fecal incontinence	0.049	0.58	Higher in trauma group
Satisfaction	0.071	0.51	Lower in trauma group

Trauma-induced anal stenosis is associated with poorer functional recovery.

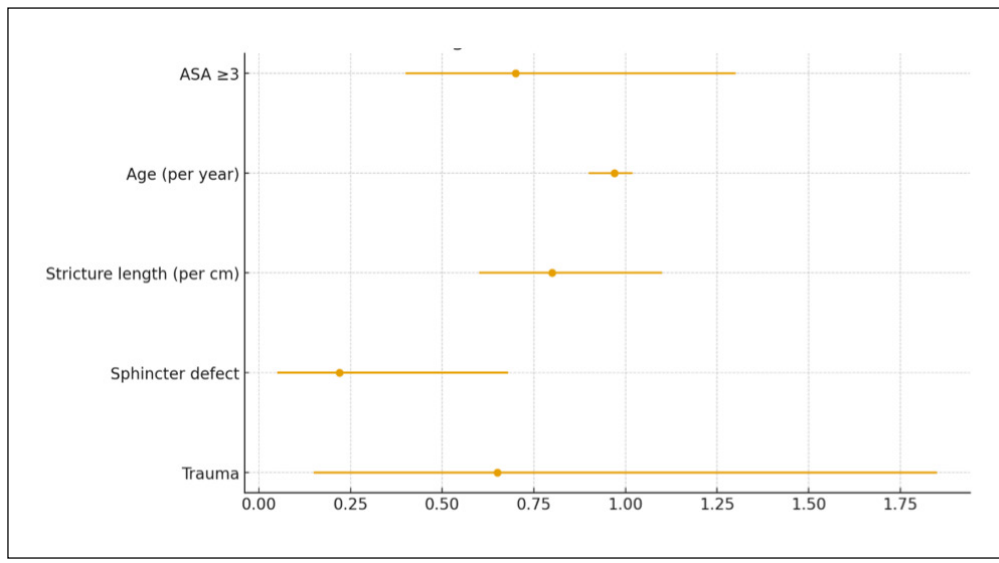

Figure 1. Forest plot of predictors of good continence after anoplasty. Forest plot demonstrating odds ratios (ORs) and 95% confidence intervals for predictors of achieving good continence (Wexner score ≤5) at 12 months. Variables include trauma mechanism, age, stricture length, and the presence of a sphincter defect on endoanal ultrasonography. The vertical reference line represents OR=1. Values <1 indicate a decreased likelihood of achieving good continence. Trauma patients demonstrate a trend toward lower continence recovery, while sphincter integrity remains the strongest independent predictor.

Quality of Life (FIQL Score)

At 12 months postoperatively, the mean FIQL score was 14.7±3.2 in the trauma group and 16.8±2.9 in the non-trauma group. The difference was statistically significant (p=0.041), with a moderate effect size (Cohen's d=0.62), indicating lower quality of life in the trauma group (Table 2).

Patient Satisfaction (Likert Scale)

The mean satisfaction score was 3.9±0.6 in the trauma group and 4.3±0.5 in the non-trauma group. The difference was borderline significant (p=0.071), with an effect size of d=0.51, suggesting lower satisfaction among trauma patients (Table 2).

Etiology-Based Functional Outcomes

In the broader analysis, trauma patients—particularly those with mine-blast injuries—experienced severe anatomical disruption due to high-energy transfer and shock waves. This likely compromised flap viability and continence mechanisms, increased pain scores, and disrupted defecatory patterns. In contrast, patients with surgical etiologies demonstrated better functional recovery, while radiation- and inflammatory bowel disease-related (IBD-related) cases showed lower quality-of-life scores but less severe functional impairment than trauma cases (Table 4).

Summary of Statistical Findings

Given the small sample size, effect sizes (Cohen's d) were emphasized. FIQL and constipation scores were significantly worse in the trauma group. Fecal incontinence was more frequent and statistically significant in trauma patients. Continence and satisfaction scores were also worse in the trauma

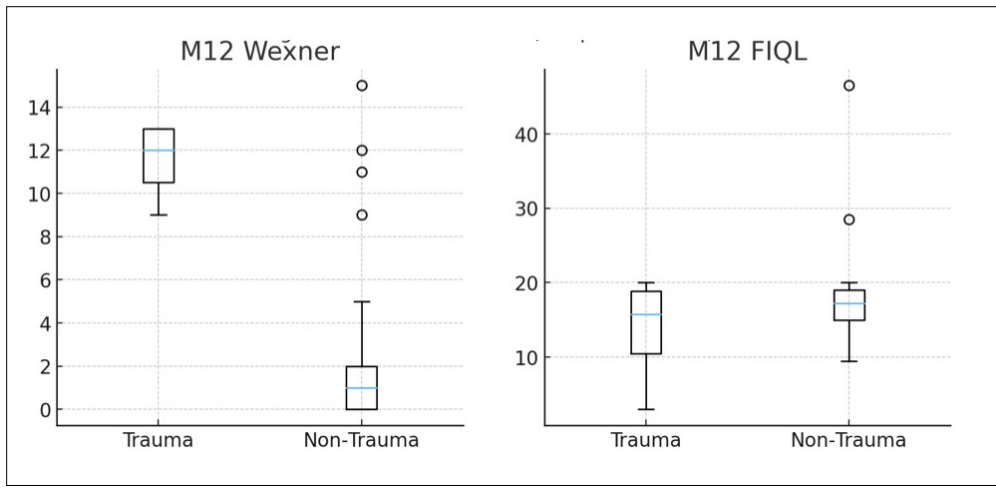

Figure 2. Box-and-whisker plots comparing 12-month (M12) Modified Wexner score and Fecal Incontinence Quality of Life (FIQL) score outcomes in trauma versus non-trauma patients. Box-and-whisker plots comparing 12-month Wexner scores and total FIQL scores between patients with blast-related anal trauma and those with non-traumatic etiologies (e.g., post-hemorrhoidectomy or inflammatory bowel disease–related surgery).

group, although these differences were of borderline statistical significance. Overall, these findings support the study hypothesis both statistically and clinically (Table 5).

DISCUSSION

In this retrospective cohort of patients undergoing anoplasty with flap surgery for anal stenosis, both the surgical and blast-injured (trauma) groups demonstrated significant improvements in continence and QOL parameters. These findings affirm the effectiveness of anoplasty in restoring function when meticulous patient selection, preoperative evaluation, and staged wound optimization are performed. Nonetheless, patients with blast-related injuries experienced less pronounced recovery and significantly poorer functional and quality-of-life outcomes, a result consistent with the complex pathophysiology of high-energy military trauma.

FIQL scores were significantly lower in the trauma group (14.7 vs. 16.8, p=0.041), consistent with findings by Acar et al. and Gallo et al., who reported reduced FIQL scores following traumatic perineal reconstruction.[9,16,17] These results suggest that pelvic floor dysfunction and sphincter damage in trauma patients directly impact quality of life.[15,18]

Fecal incontinence was observed in 20% of trauma patients, aligning with the rates of 24.1–30% reported by Gallo et al.[19-20] Sphincter integrity emerged as the strongest independent predictor of good long-term continence. This finding underscores the essential role of preoperative endoanal ultrasonography, where feasible, particularly in planning reconstructive procedures for patients with traumatic injuries. Some authors, including Brisinda, have emphasized that although sphincter reconstruction may reduce the risk of incontinence, it does not eliminate it entirely.[3,4,24] Blast-induced perineal trauma is rare and complex, typically involving extensive tissue loss and damage to multiple functional structures.[11,14,15] As such, reconstruction often requires advanced, volume-restoring, vascularized techniques beyond isolated anoplasty, which explains the relatively low number of blast-injured patients in this study.

In the present study, continence scores were worse in the trauma group but did not reach statistical significance (p=0.087). Accordingly, the rate of good continence was lower in trauma cases. Reduced improvement in blast-injured patients is likely attributable to combined shock-wave–induced neural injury, dense pelvic fibrosis that impairs reconstruction, delayed staged repair, and the physical and psychological burden of battlefield trauma. This variability is consistent with the findings of Van Oostendorp et al. and others authors, who reported wide-ranging continence outcomes following flap surgery.[23-25]

Constipation scores were significantly higher in the trauma group (8.1 vs. 7.2, p=0.032). Maria et al. linked postoperative constipation to pelvic floor rigidity and anal canal narrowing.[21-23] Our findings suggest that high-energy injuries result in extensive tissue destruction, leading to chronic inflammation, fibrosis, and impaired defecatory patterns.

Satisfaction scores were lower in trauma patients (3.9 vs. 4.3, p=0.071). Sentovich et al. noted that functional recovery, rather than anatomical success alone, is the primary determinant of patient satisfaction.[22]

Flap type and surgical technique are critical to surgical success. Darwish et al. emphasized that flap selection should be based on surgeon experience and the severity of stenosis.[20] In our study, flap types were standardized across groups to isolate the impact of etiology. In trauma patients, severe

topographic deformity and extensive fibrosis were common. Nearly all presented with marked fibrosis, significant narrowing of the anal orifice, irregular traction lines, everted scar patterns, and near-complete loss of perianal elastic tissue. Our surgical algorithm was based on evaluation of circumferential fibrosis, the degree of anal orifice narrowing, and adjacent tissue loss. Following multidisciplinary discussion, reconstruction in nearly all trauma patients was initiated with a House flap, and both trauma patients who developed incontinence had undergone this technique. In some cases, bilateral flaps were used; however, these two patients did not require that approach. In the non-trauma group, three different flap procedures were performed: two rhomboid flaps and one Y-V advancement flap. Importantly, fecal incontinence in some trauma patients may also reflect preexisting sphincter defects related to the initial injury.

Radiation and IBD also negatively affect quality of life; however, trauma cases demonstrated more severe functional impairment. Damian and Mossadegh, as well as Gallo et al., reported similar findings.[4,6,9]

Multicenter studies published in coloproctology journals confirm that surgical outcomes vary by etiology, with trauma-related cases associated with lower quality of life and higher complication rates.[6,8-10,14]

This study has several limitations. Its retrospective design carries an inherent risk of incomplete documentation and selection bias. The small number of blast-injured patients limits statistical power, and the heterogeneity of etiologies may affect generalizability. Follow-up was limited to 12 months, and long-term functional outcomes remain unknown. Although the surgical period extended from 2008 to 2015, the effective follow-up duration appears relatively short because only patients with complete ≥12-month functional data were eligible for inclusion. Long-term records were frequently incomplete due to institutional transitions at the former GMMA and patient transfers—particularly among blast-injured veterans—which reduced the availability of extended outpatient documentation. Nevertheless, the first postoperative year represents the critical period during which continence, constipation patterns, and flap-related outcomes stabilize, making a 12-month follow-up both sufficient and consistent with prior anoplasty literature.

Future studies with larger cohorts, longer follow-up periods, and prospective functional assessments are needed to validate these findings.

CONCLUSION

Flap surgery for trauma-related anal stenosis yields poorer functional and quality-of-life outcomes compared with other etiologies. Constipation, fecal incontinence, and patient-reported satisfaction were notably worse in the trauma cohort, emphasizing the impact of injury mechanism on recovery. Although the trauma patients in our series represented the most favorable survivors of blast injury, their continence outcomes remained inferior to those of non-trauma cases. This finding suggests that profound neuromuscular and fibrotic damage resulting from high-energy trauma persists despite successful surface reconstruction. These results highlight the importance of etiology-based surgical planning and individualized, function-oriented strategies in the management of traumatic anal stenosis.

Ethics Committee Approval: Ethical approval for this study was waived, as the research posed no potential risk or burden to human participants, and all data were handled with strict adherence to confidentiality and privacy standards.

Peer-review: Externally peer-reviewed.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Travmatik ve travmatik olmayan faktörlerin neden olduğu anal kanal darlığı için flep cerrahisi sonrası fonksiyonel ve yaşam kalitesi sonuçları: karşılaştırmalı bir analiz

AMAÇ: Anal kanal darlığı, kontinans ve yaşam kalitesini bozan nadir ancak yıkıcı bir durumdur. Postoperatif fibrozis anorektal cerrahi sonrası en sık neden olmaya devam ederken, yüksek enerjili patlama travmaları, yaygın yumuşak doku kaybı, nöromüsküler hasar ve aşamalı yara yönetimiyle karakterize, farklı bir klinik tablo oluşturmaktadır. Anoplasti sonrası uzun dönem fonksiyonel sonuçlara ilişkin veriler, patlama yaralanması geçirmiş hastalarda sınırlıdır. Bu çalışma, hem elektif anorektal cerrahiye bağlı hem de savaşla ilişkili travmaya bağlı anal darlığı olan hastalarda anoplasti sonrası kontinans ve yaşam kalitesi sonuçlarını değerlendirmeyi amaçladı.

GEREÇ VE YÖNTEM: 2008-2015 yılları arasında anal darlık nedeniyle anoplasti uygulanan ve en az 12 aylık takibi bulunan hastalar çalışmaya dahil edildi. Kontinans ve yaşam kalitesi, ameliyat öncesi ve 12. ayda Modifiye Wexner ve FIQL (Fecal Incontinence Quality of Life) skorları ile değerlendirildi. Sfinkter bütünlüğü endoanal ultrasonografi ile incelendi. İyileşmeyi değerlendirmek için eşleştirilmiş istatistiksel testler ve Cohen's d etki büyüklüğü analizi uygulandı. İyi kontinans (Wexner ≤5) ve postoperatif fonksiyonun öngördürücüleri, lojistik ve lineer regresyon modelleri ile belirlendi.

BULGULAR: Otuz yedi hasta dahil edilme kriterlerini karşıladı. 27'sinde postoperatif darlık, 10'unda ise patlamaya bağlı pelvik travma mevcuttu. Her iki grup da kontinans ve FIQL skorlarında anlamlı iyileşme gösterdi, ancak, fonksiyonel iyileşme etiyolojiye göre önemli ölçüde farklılık gösterdi: ameliyat sonrası hastalar önemli kazanımlar elde ederken, patlama sonucu yaralanan hastalar, kalıcı nöromüsküler ve fibrotik hasarı yansıtan, sadece mütevazı bir iyileşme elde etti. Travma vakaları daha düşük FIQL skorları (14.7'ye karşı 16.8), daha yüksek kabızlık skorları (8.1'e karşı 7.2) ve artmış fekal inkontinans (20%'ye karşı 11.1%) gösterdi. Sfinkter bütünlüğü ve daha kısa darlık uzunluğu, bağımsız olarak iyi kontinansı öngörürken, patlama mekanizması ve ileri yaş, iyileşmenin azalmasıyla ilişkiliydi.

SONUÇ: Anoplasti, anal stenozda anlamlı fonksiyonel fayda sağlar; ancak, yüksek enerjili travma geçirmiş hastalarda iyileşme önemli ölçüde azalır. Bu bulgular, etiyolojiye dayalı planlama, dikkatli sfinkter değerlendirmesi ve gerçekçi hasta danışmanlığı ihtiyacını vurgulamaktadır.

Anahtar sözcükler: Anal darlık, flep cerrahisi, travma, mayın-patlama yaralanması, fekal inkontinans, konstipasyon, FIQL, Wexner skoru.

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ORIGINAL ARTICLE

Predictors of prolonged observation in pregnant trauma patients in the emergency department

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ABSTRACT

BACKGROUND: Trauma during pregnancy presents unique clinical challenges due to physiological adaptations and the need to ensure fetal well-being. Although guidelines recommend a minimum period of maternal and fetal monitoring following trauma, the factors associated with prolonged emergency department (ED) observation in pregnant trauma patients remain insufficiently defined. Identifying these factors may help optimize clinical decision-making and resource utilization in emergency care settings.

METHODS: This retrospective cohort study was conducted in a tertiary-care emergency department between January 2014 and January 2024. Patients were categorized according to ED observation duration as ≤6 hours or >6 hours. Demographic characteristics and clinical variables, including Injury Severity Score (ISS), gestational age, RhD status, trauma characteristics, and consultation requirements, were recorded. Univariate and multivariable logistic regression analyses were performed to identify predictors of prolonged ED observation.

RESULTS: A total of 459 pregnant trauma patients were included in the analysis, of whom 238 (51.9%) were observed in the ED for more than 6 hours. Patients with prolonged observation had a significantly higher gestational age than those observed for ≤6 hours (median 24 weeks [interquartile range (IQR): 15–32] vs. 17 weeks [IQR: 11–23], p<0.001). In multivariable analysis, higher ISS (odds ratio [OR]: 1.20, 95% confidence interval [CI]: 1.08–1.35, p<0.001), advancing gestational age (OR: 1.07 per week, 95% CI: 1.04–1.09, p<0.001), and RhD negativity (OR: 3.84, 95% CI: 1.33–11.14, p=0.013) were independently associated with ED observation exceeding 6 hours. Although the number of consultations was significantly associated with prolonged observation in univariate analysis, it did not remain an independent predictor after multivariable adjustment.

CONCLUSION: Higher ISS, advancing gestational age, and RhD negativity were independently associated with emergency department observation lasting more than 6 hours among pregnant trauma patients.

Keywords: Emergency department; Injury Severity Score; observation duration; pregnancy; Rh alloimmunization; trauma.

INTRODUCTION

Traumatic events during pregnancy represent a significant cause of maternal mortality unrelated to obstetric complications, affecting approximately 6–8% of all pregnancies as a result of accidental or intentional injuries.[1] Furthermore, nearly 4% of pregnant individuals present to the emergency department (ED) for trauma-related reasons during gestation.[2] Motor vehicle collisions, falls, and physical assaults constitute the most common mechanisms of injury in this population.[3]

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The clinical management of pregnant trauma patients requires a distinct approach compared to non-pregnant individuals, primarily due to the profound physiological and anatomical changes associated with pregnancy.[1,2] Focused Assessment with Sonography for Trauma (FAST) remains a widely used modality for the evaluation of intra-abdominal hemorrhage in trauma cases; however, studies conducted in general trauma populations have demonstrated that its sensitivity for detecting intra-abdominal injuries is limited.[4] Moreover, trauma during pregnancy has been associated with an increased risk of adverse maternal and fetal outcomes.[5] These considerations underscore the need for meticulous evaluation and vigilant monitoring of pregnant trauma patients in the emergency department setting.

The primary priority in the resuscitation of pregnant trauma patients is maternal stabilization.[6] Once stabilization has been achieved, a multidisciplinary approach in the emergency department is essential to ensure comprehensive evaluation and management aimed at optimizing outcomes for both the mother and the fetus.[7] Adverse pregnancy outcomes may occur even after minor trauma; therefore, thorough assessment and close observation of all pregnant trauma patients are warranted.[8] International guidelines, including those from the American College of Obstetricians and Gynecologists (ACOG), the Society of Obstetricians and Gynaecologists of Canada (SOGC), and the Eastern Association for the Surgery of Trauma (EAST), recommend an initial period of maternal and fetal assessment following trauma during pregnancy. Continuous fetal monitoring is advised for viable pregnancies, and the need for extended observation is determined based on clinical risk factors.[9-11]

Previous studies examining trauma during pregnancy have reported variable findings regarding the association between clinical or demographic factors and maternal or fetal outcomes.[12,13] Nevertheless, trauma remains a significant contributor to maternal morbidity and mortality throughout pregnancy. Therefore, emergency clinicians must be well-versed in the appropriate evaluation and management of pregnant trauma patients.[14] Despite these recommendations, the lack of consistently reliable predictors continues to hinder the development of standardized management strategies for this population.

This study aimed to identify clinical and demographic factors associated with prolonged emergency department observation among pregnant trauma patients.

MATERIALS AND METHODS

Study Design and Patient Selection

This retrospective study included pregnant trauma patients who presented to the Emergency Department of Gaziantep University Şahinbey Research and Training Hospital between January 2014 and January 2024. The study was conducted in accordance with the principles of the Declaration of Helsinki and received approval from the local ethics committee on May 15, 2024 (Approval number: 2024/121). Detailed reviews of patients' medical records were performed, including laboratory findings, consultation notes, and hemogram parameters.

Of the 563 patient records initially screened, 11 were excluded due to incomplete or insufficient data, and an additional nine patients younger than 18 years were excluded. Patients who developed fetal complications were also excluded, as they were directly admitted to the Department of Obstetrics and Gynecology without undergoing prolonged emergency department observation, making their inclusion inconsistent with the study objective. Furthermore, patients presenting with suicide attempts, toxic exposures, or burn injuries were excluded because these conditions involve substantially different clinical courses, management strategies, and prognoses. Consequently, the final study population comprised patients who sustained trauma due to motor vehicle collisions (including both in-vehicle and pedestrian accidents), physical assaults, or falls.

The SOGC recommends a minimum of 4 hours of fetal monitoring in viable pregnancies following trauma.[9] The EAST recommends at least 6 hours of cardiotocographic monitoring for pregnant trauma patients beyond 20 weeks of gestation.[10] A recent EAST systematic review and meta-analysis further conditionally recommends a formal observation period of 4–6 hours for pregnant trauma patients.[15] In the present study, prolonged observation was defined as emergency department monitoring exceeding 6 hours.

Data Collection

Data were retrospectively extracted from the hospital's electronic medical records for all eligible pregnant trauma patients. The following variables were recorded: maternal age, gestational age at the time of trauma, mechanism of injury (motor vehicle collision, physical assault, or fall), Injury Severity Score (ISS), Rh status, and duration of emergency department observation.

Patients with unstable vital signs or markedly low hemoglobin levels were excluded from the analysis, as these individuals required immediate admission to the intensive care unit or inpatient wards and therefore did not undergo extended observation in the emergency department.

Based on the duration of emergency department observation, patients were categorized into two groups: ≤6 hours (n=221) and >6 hours (n=238). The patient selection process and overall study flow are illustrated in Figure 1.

Emergency Department Management Protocol

Upon presentation to the emergency department, all pregnant trauma patients underwent an initial assessment, including evaluation of vital signs and a primary survey. Focused Assessment with Sonography for Trauma was routinely performed to evaluate for intra-abdominal hemorrhage. In hemodynamically stable patients with minor trauma, consultation with the Department of Obstetrics and Gynecology was requested

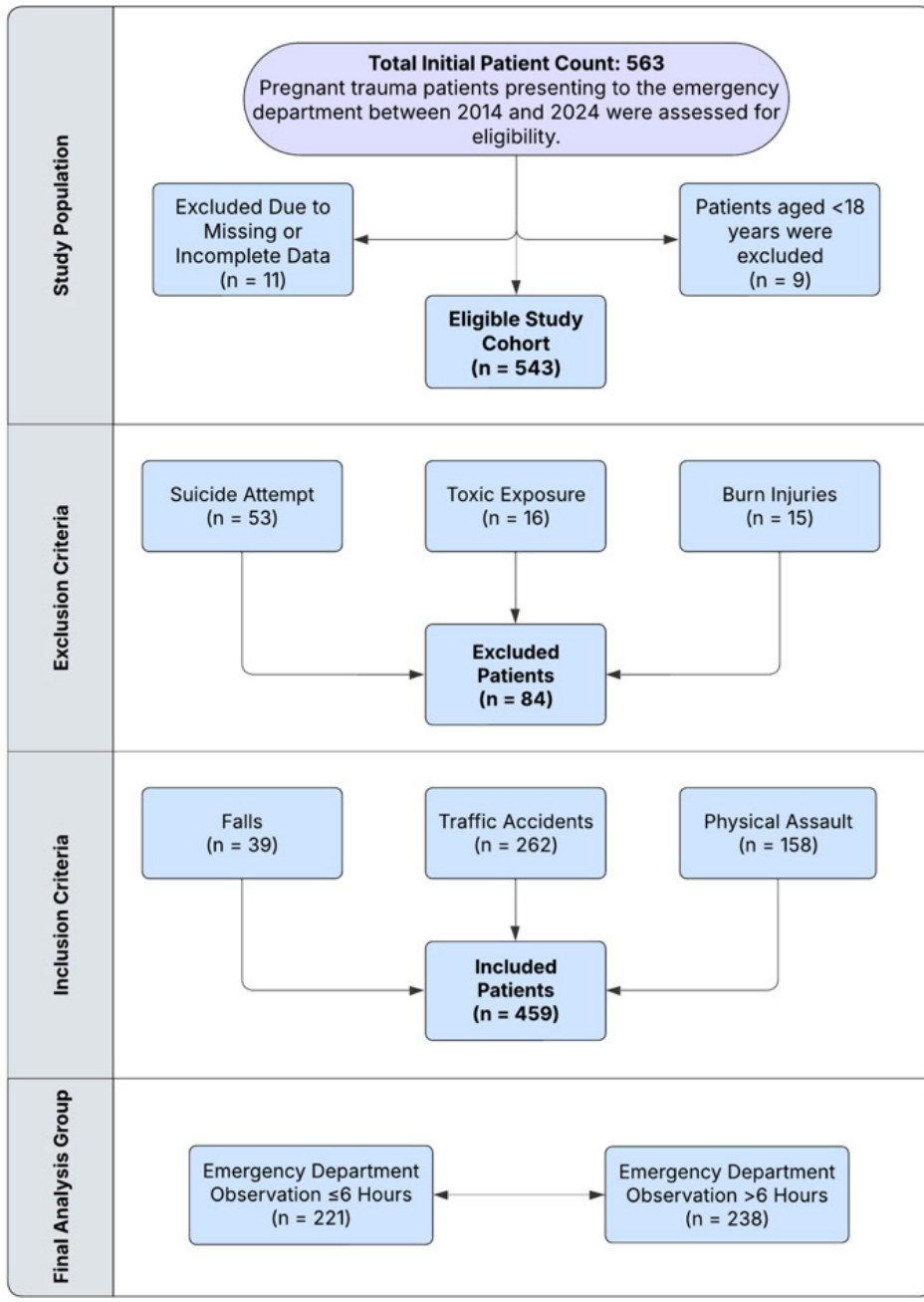

Figure 1. Flowchart of patient selection, exclusion criteria, and final analysis groups.
Legend: Flowchart illustrating the patient selection and exclusion process, inclusion criteria, and final analysis groups of pregnant trauma patients evaluated in the emergency department between 2014 and 2024. Patients were stratified according to emergency department observation duration as ≤6 hours and >6 hours.

primarily for fetal assessment. Based on clinical findings and trauma severity, patients were observed in the emergency department for a clinically determined observation period, in accordance with standard institutional protocols for the management of pregnant trauma patients. Patients who were hemodynamically unstable or sustained severe trauma underwent immediate stabilization in the emergency department and were subsequently transferred to the intensive care units for further management.

Trauma Severity Assessment

The ISS is an anatomically based scoring system used to quantify trauma severity across six body regions: head and neck, face, chest, abdomen, extremities, and external.[16] The ISS is calculated by summing the squares of the scores assigned to the three most severely injured body regions. ISS values range from 1 to 75, with higher scores indicating more severe trauma.

Statistical Analysis

Statistical analyses were conducted using R software (version 4.5.0; R Foundation for Statistical Computing, Vienna, Austria). The distribution of continuous variables was evaluated using the Shapiro–Wilk test. Continuous variables were summarized as medians with interquartile ranges (IQR), whereas categorical variables were expressed as frequencies and percentages.

Patients were stratified into two groups according to emer-

Table 1. Demographic and clinical characteristics of pregnant trauma patients according to emergency department observation duration

Variables	Emergency Department Observation ≤6 Hours (n=221)	Emergency Department Observation >6 Hours (n=238)	p-value
Age, years	25 [22–30]	26.5 [22–31]	0.084
Gestational age (weeks)	17 [11–23]	24 [15–32]	<0.001*
Gravidity	2 [1–4]	2.5 [1–4]	0.118
Parity	1 [0–2]	1 [0–2]	0.305
Number of abortions	0 [0–1]	0 [0–1]	0.258
GCS	15 [15–15]	15 [15–15]	0.370
ISS	1 [1–2]	1 [1–4]	0.004*
Number of consultations	1 [1– 1]	1 [1–1]	0.031*
Trauma mechanism			
Fall	18 (8.1%)	21 (8.8%)	0.625
Physical assault	81 (36.7%)	77 (32.4%)	
Traffic accident	122 (55.2%)	140 (58.8%)	
Type of traffic accident			
In-vehicle	98 (80.3%)	102 (71.3%)	0.120
Out-of-vehicle	24 (19.7%)	41 (28.7%)	
Type of trauma			
Blunt	206 (93.2%)	221 (92.9%)	0.975
Penetrating	12 (5.4%)	14 (5.9%)	
Mixed (blunt + penetrating)	3 (1.4%)	3 (1.3%)	
Extent of trauma			
Isolated injury	165 (74.7%)	165 (69.3%)	0.244
Multitrauma	56 (25.3%)	73 (30.7%)	
Working hours			
In-hours	95 (43.0%)	105 (44.1%)	0.881
Out-of-hours	126 (57.0%)	133 (55.9%)	
Location of trauma			
Head trauma	39 (17.6%)	41 (17.2%)	1.000
Face trauma	12 (5.4%)	15 (6.3%)	0.843
Thoracic trauma	6 (2.7%)	8 (3.4%)	0.896
Abdominopelvic trauma	75 (33.9%)	95 (39.9%)	0.219
Spinal trauma	19 (8.6%)	26 (10.9%)	0.496
Musculoskeletal trauma	50 (22.6%)	58 (24.4%)	0.741
RhD negativity			
Present	5 (2.3%)	18 (7.6%)	0.017*
Absent	216 (97.7%)	220 (92.4%)	

Continuous variables are presented as median [interquartile range]. Categorical variables are presented as n (%). GCS: Glasgow Coma Scale; ISS: Injury Severity Score; IQR: Interquartile range. Bold values indicate statistical significance at p<0.05.

gency department observation duration: ≤6 hours and >6 hours. Group comparisons were performed using the Mann–Whitney U test for continuous variables and the chi-square test or Fisher's exact test for categorical variables, as appropriate.

To identify factors associated with prolonged emergency department observation (>6 hours), univariate logistic regression analyses were initially conducted. Variables demonstrating statistical significance in univariate analysis (p<0.05) were subsequently included in a multivariable logistic regression model. Results were reported as odds ratios (ORs) with 95% confidence intervals (CIs). A two-sided p-value <0.05 was considered statistically significant.

Model calibration, discrimination, and multicollinearity were evaluated using the Hosmer–Lemeshow goodness-of-fit test, receiver operating characteristic (ROC) analysis with calculation of the area under the curve (AUC), and variance inflation factors (VIFs), respectively.

RESULTS

A total of 459 pregnant trauma patients were included in the analysis. Of these, 221 (48.1%) were observed in the emergency department for ≤6 hours, and 238 (51.9%) were observed for >6 hours.

Baseline demographic and clinical characteristics of the study population stratified by emergency department observation duration are presented in Table 1. There were no significant differences between the ≤6-hour and >6-hour observation groups with respect to maternal age, gravidity, parity, number of prior abortions, or Glasgow Coma Scale (GCS) scores (all p>0.05).

Gestational age at presentation was significantly higher among patients observed for >6 hours compared with those observed for ≤6 hours (median 24 weeks [IQR: 15–32] vs. 17 weeks [IQR: 11–23], p<0.001). In addition, the ISS was significantly higher in the >6-hour observation group (median 1 [IQR: 1–4] vs. 1 [IQR: 1–2], p=0.004). The number of consultations required during emergency department evaluation was also greater in patients observed for >6 hours (p=0.031).

No statistically significant differences were observed between the groups regarding trauma mechanism, type of trauma, extent of injury (isolated injury vs. multitrauma), working hours at presentation, or anatomical location of injury (all p>0.05). Similarly, the distribution of traffic accident subtypes did not differ significantly between the two groups.

Rh negativity was more frequently observed in patients with emergency department observation lasting >6 hours than in those observed for ≤6 hours (7.6% vs. 2.3%, p=0.017).

Univariate and multivariable logistic regression analyses were conducted to identify factors associated with prolonged emergency department observation (>6 hours); the results are presented in Table 2.

In univariate analysis, higher ISS (OR: 1.21, 95% CI: 1.10–1.34, p<0.001), advancing gestational age (OR: 1.07, 95% CI: 1.05–1.09, p<0.001), greater number of consultations (OR: 3.00, 95% CI: 1.10–8.20, p=0.031), and Rh negativity (OR: 3.44, 95% CI: 1.24–9.52, p=0.017) were significantly associated with prolonged observation.

In multivariable analysis, ISS (OR: 1.20, 95% CI: 1.08–1.35, p<0.001), gestational age (OR: 1.07 per week, 95% CI: 1.04–1.09, p<0.001), and Rh negativity (OR: 3.84, 95% CI: 1.33–11.14, p=0.013) remained independent predictors of emergency department observation exceeding 6 hours, whereas the number of consultations was no longer statistically significant after adjustment.

Model calibration was evaluated using the Hosmer–Lemeshow goodness-of-fit test, which indicated adequate calibration (χ^2=11.83, df=8, p=0.16). The discriminative ability of the multivariable logistic regression model was assessed using ROC analysis, yielding an AUC of 0.72 (Fig. 2). Multicollinearity among the independent variables was examined using VIFs, and all predictors demonstrated low adjusted VIF values, indicating no evidence of multicollinearity.

Table 2. Univariate and multivariate logistic regression analyses of factors associated with prolonged emergency department observation (>6 hours)

	Univariate Analysis			Multivariate Analysis		
Variables	**OR**	**95% CI**	**p-value**	**OR**	**95% CI**	**p-value**
Injury Severity Score	1.21	1.10–1.34	<0.001	1.20	1.08–1.35	<0.001
Gestational age (weeks)	1.07	1.05–1.09	<0.001	1.07	1.04–1.09	<0.001
Number of consultations	3.00	1.10–8.20	0.031	2.83	0.44–18.33	0.275
RhD negativity (present vs. absent)	3.44	1.24–9.52	0.017	3.84	1.33–11.14	0.013

OR: Odds ratio; CI: Confidence interval.

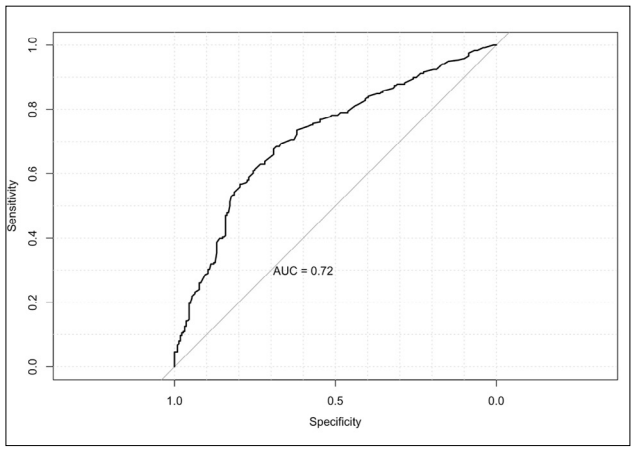

Figure 2. Receiver operating characteristic (ROC) curve of the multivariable logistic regression model predicting prolonged emergency department observation (>6 hours) in pregnant trauma patients. Legend: The area under the curve (AUC) was 0.72, indicating acceptable discriminative ability.

DISCUSSION

In this study, greater trauma severity, as reflected by higher ISS values, was associated with prolonged observation among pregnant trauma patients. Observation duration also tended to increase with advancing gestational age, possibly reflecting heightened attention to fetal monitoring and pregnancy-related considerations in clinical practice. Rh negativity was likewise associated with extended emergency department stays, potentially due to the need for additional evaluation and monitoring in this group. Other clinical variables that demonstrated associations with observation duration in the initial analyses did not remain significant after adjustment for relevant covariates. The adequate model calibration, acceptable discriminative performance (AUC=0.72), and absence of multicollinearity among predictors support the robustness and internal validity of the multivariable model.

The management of pregnant trauma patients in the emergency department is inherently more complex than that of non-pregnant patients because of pregnancy-specific physiological adaptations and fetal considerations.[17] In particular, determining the need for prolonged observation remains a clinical challenge. The literature addressing factors that influence observation duration in this population is limited. Current guidelines recommend at least four hours of fetal monitoring for pregnancies beyond 23 weeks of gestations following trauma;[9] however, standardized criteria for determining the need for extended maternal observation have not been clearly established. Most previous studies have focused primarily on the impact of trauma on pregnancy-related outcomes[18,19] or on indications for hospital admission, rather than on predictors of prolonged emergency department observation. The present study aimed to address this gap by identifying clinical factors associated with extended observation, thereby contributing to a more evidence-based approach to the management of pregnant trauma patients in emergency care settings.

The role of the ISS in predicting obstetric and perinatal adverse outcomes among pregnant trauma patients has long been debated in the literature. Schiff and Holt reported that ISS does not reliably predict adverse pregnancy outcomes such as placental abruption or fetal demise, and that even relatively minor injuries may be associated with unfavorable pregnancy outcomes.[20] Similarly, Dalton et al.[21] found that, among pregnant women sustaining major trauma, ISS may have predictive value at certain threshold levels for severe maternal outcomes, identifying an ISS ≥8 as a discriminative cutoff for serious maternal adverse events. In a cohort study, Genç et al.[22] observed that hospitalization rates were significantly higher among patients with ISS ≥9, while also noting that perinatal complications could still occur even in patients with lower ISS values.

Taken together, these findings suggest that ISS has a limited utility in directly predicting obstetric or perinatal outcomes but may instead function as an indicator of overall trauma severity. Consistent with this interpretation, ISS was significantly associated with prolonged observation duration in our study in both univariate analysis (OR: 1.21, 95% CI: 1.10–1.34, p<0.001) and multivariable logistic regression analysis, in which it remained an independent predictor (multivariable analysis: OR: 1.20, 95% CI: 1.08–1.35, p<0.001). In this context, the association between higher ISS values and prolonged emergency department observation in our cohort likely reflects an increased need for clinical monitoring driven by trauma severity rather than obstetric or perinatal risk per se.

Weiner et al.[23] evaluated 946 pregnant women with minor trauma and reported that those hospitalized for 24-hour observation had a higher gestational age at the time of injury than those managed as outpatients (30.8 vs. 29.1 weeks, p<0.001), despite no differences in obstetric or neonatal outcomes and no cases of placental abruption or intrauterine fetal demise. Similarly, Soysal et al.[24] demonstrated that the likelihood of recommending hospitalization after traffic-related trauma increased with advancing gestational age. Patients with minor trauma who declined hospitalization did not experience adverse outcomes, supporting the notion that extended monitoring in later pregnancy may primarily reflect precautionary clinical practice rather than an inevitable increase in risk. Consistent with these findings, our study demonstrated that advancing gestational age was independently associated with prolonged emergency department observation. Patients observed for ≥6 hours had a significantly higher median gestational age than those observed for <6 hours (24.0 weeks [IQR: 15–32] vs. 17 weeks [IQR: 11–23], p<0.001). Moreover, in multivariable analysis, each additional week of gestation was associated with a 7% increase in the odds of extended observation (OR: 1.07, 95% CI: 1.04–1.09, p<0.001).

Fetomaternal hemorrhage may occur following various types of trauma and can lead to fetal anemia, intrauterine fetal demise, or maternal isoimmunization.[25] International guidelines recommend the administration of anti-D immunoglobulin to RhD-negative pregnant trauma patients. Tests such as the Kleihauer–Betke assay are used to evaluate fetomaternal hemorrhage and guide clinical management, including the consideration of additional dosing when indicated.[9,10]

In the present study, Rh negativity was identified as an independent predictor of prolonged emergency department observation. This association remained significant in both univariate analysis (OR: 3.44, 95% CI: 1.24–9.52, p=0.017) and multivariable logistic regression analysis (OR: 3.84, 95% CI: 1.33–11.14, p=0.013). This association may reflect the additional diagnostic evaluations and clinical precautions required for RhD-negative patients following trauma, including assessment for fetomaternal hemorrhage and confirmation of appropriate anti-D immunoglobulin administration. Accordingly, prolonged observation in this subgroup may be attributable to clinical management considerations rather than to an inherently increased obstetric or perinatal risk.

Although the number of consultations was associated with prolonged observation in univariate analysis, this relationship did not persist after adjustment for trauma severity and gestational age. This finding suggests that consultation frequency reflects the inherently multidisciplinary and precautionary nature of pregnant trauma evaluation rather than serving as an independent determinant of observation duration.[7,14]

This study has several limitations that should be considered when interpreting the results. Owing to its retrospective design, the analysis was restricted to data routinely documented in the emergency department. In addition, the absence of key sociodemographic variables, such as socioeconomic status, race, and ethnicity, limited the assessment of social determinants that may influence observation duration. Data regarding the time interval between the traumatic event and arrival at the emergency department were also unavailable, precluding evaluation of potential delays related to healthcare access. As this was a single-center study conducted at a tertiary referral hospital, the generalizability of the findings to other clinical settings may be limited.

Furthermore, reliance on electronic medical records precluded determination of whether patients discharged after observation subsequently sought care at other institutions. Patients requiring immediate admission to the intensive care unit or management by non-emergency specialties may also have been underrepresented in the study population.

Despite these limitations, this study has several notable strengths. To our knowledge, it is among the first investigations specifically designed to evaluate factors associated with emergency department observation duration in pregnant trauma patients. The inclusion of a 10-year cohort from a high-volume tertiary care center enhances the relevance of the findings to real-world clinical practice. Moreover, the identification of trauma severity, quantified by the ISS, as a predictor of prolonged observation adds to the limited body of literature addressing this issue. These findings may inform future prospective investigations and support the development of more standardized, evidence-based triage and observation strategies for pregnant trauma patients.

CONCLUSION

In summary, greater trauma severity (as reflected by higher ISS), advancing gestational age, and RhD negativity were independently associated with emergency department observation exceeding 6 hours among pregnant trauma patients. Although the number of consultations was significantly associated with prolonged observation in univariate analysis, it did not remain an independent predictor after adjustment in the multivariable model.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Acil serviste travmaya maruz kalan gebe hastalarda gözlem süresinin uzamasını öngören faktörler

AMAÇ: Gebelikte travma, fizyolojik adaptasyonlar ve fetal iyilik hâlinin korunması gerekliliği nedeniyle kendine özgü klinik zorluklar oluşturur. Kılavuzlar travma sonrası anne ve fetüs için asgari bir izlem süresi önermesine rağmen, gebe travma hastalarında acil serviste uzamış gözlem süresi ile ilişkili faktörler yeterince tanımlanmamıştır. Bu faktörlerin belirlenmesi, klinik karar verme süreçlerinin ve acil servis kaynak kullanımının optimize edilmesine katkı sağlayabilir.

GEREÇ VE YÖNTEM: Bu retrospektif kohort çalışma, Ocak 2014-Ocak 2024 tarihleri arasında üçüncü basamak bir acil serviste yürütülmüştür. Hastalar acil serviste gözlem süresine göre ≤6 saat ve >6 saat olarak iki gruba ayrılmıştır. Demografik özellikler ve Travma Şiddet Skoru (Injury Severity Score, ISS), gebelik haftası, RhD durumu, travmanın özellikleri ve konsültasyon gereksinimi gibi klinik değişkenler kaydedilmiştir. Uzamış acil servis gözlem süresini etkileyen faktörleri belirlemek amacıyla tek değişkenli ve çok değişkenli lojistik regresyon analizleri yapılmıştır.

BULGULAR: Toplam 459 gebe travma hastası analiz edilmiştir ve bunların 238'i (%51.9) acil serviste 6 saatten uzun süre gözlenmiştir. Uzamış gözlem grubundaki hastaların gebelik haftası, ≤6 saat gözlenen hastalara göre anlamlı olarak daha yüksektir (medyan 24 [IQR 15–32] hafta vs. 17 [IQR 11–23] hafta, p<0.001). Çok değişkenli analizde, ISS değerlerindeki artış (OR 1.20; %95 GA 1.08–1.35; p<0.001), artan gebelik haftası (hafta başına OR 1.07; %95 GA 1.04–1.09; p<0.001) ve RhD negatifliği (OR 3.84; %95 GA 1.33–11,14; p=0.013) acil serviste 6 saatten uzun gözlem ile bağımsız olarak ilişkili bulunmuştur. Konsültasyon sayısı tek değişkenli analizde uzamış gözlem ile ilişkili olsa da, çok değişkenli analizde bağımsız bir faktör olarak kalmamıştır.

SONUÇ: Artmış ISS, ilerleyen gebelik haftası ve RhD negatifliği, gebe travma hastalarında acil serviste 6 saatten uzun gözlem süresi ile bağımsız olarak ilişkilidir.

Anahtar sözcükler: Acil servis; gebelik; hasta gözlemi; Rh alloimmünizasyonu; travma şiddet skoru; travma.

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ORIGINAL ARTICLE

Clinical characteristics and socioeconomic determinants of unintentional childhood injuries: An emergency department perspective

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ABSTRACT

BACKGROUND: Unintentional childhood injuries (UCIs) are a leading cause of morbidity and mortality among children globally, imposing significant clinical and economic burdens, particularly in low- and middle-income countries. Emergency Departments (EDs) serve not only as the first point of contact for such events but also as the initial entry point for non-fatal UCIs, which represent a hidden and more substantial burden on health services. The primary objective of this study is to comprehensively analyze the clinical and socioeconomic determinants and predictors of unintentional childhood injuries (UCIs) presenting to the emergency department. Based on insights from these empirical data, the study further proposes a multidisciplinary, four-dimensional framework as a conceptual model to enhance systemic prevention and intervention strategies.

METHODS: This is a prospective and cross-sectional study. Data were collected using structured forms and digital medical records, covering demographic, familial, socioeconomic, and injury-related variables. Statistical analyses were performed to examine associations among risk factors, injury mechanisms, clinical outcomes, and mortality predictors.

RESULTS: Falls were the most common cause of UCI (49.8%), followed by traffic accidents (12.4%). Injuries most frequently occurred at home(43.6%), particularly in kitchens and gardens. Male patients constituted 62.7% of the cases. Statistically significant associations were observed between low maternal education, poor economic status, and higher Injury Severity Score (ISS). Multiple trauma(MT) was more common among children aged≥12 years and those with separated parents. Elevatedserum glucose (≥153 mg/dL) and glucose/potassium ratio (≥39.48) were identified as potential clinical markers for assessing mortality risk ($p<0.001$). MT, abdominal and thoracic trauma, and higher ISS were associated with increased mortality.

CONCLUSION: Early identification of high-risk patients using clinical predictors such as serum glucose may improve treatment outcomes. Additionally, the frequent occurrence of head, upper, and lower extremity injuries in the ED indicates that these regions should be carefully examined for potential injuries. The tendency for thoracic and abdominal injuries to co-occur, as well as the higher prevalence of MT among patients with abdominal trauma—and the predictive value of abdominal injuries for adverse clinical outcomes—underscore the need for thorough evaluation of other systems and differentiated clinical monitoring in children identified with abdominal injury. Multidisciplinary and systematic prevention and treatment strategies that address clinical, socioeconomic, and environmental factors remain essential for reducing both the incidence and severity of such injuries. The multidisciplinary, task force-oriented approach proposed in this study—emphasizing the clear definition of roles—may offer significant improvements in this regard.

Keywords: Childhood trauma; clinical prediction rule; emergency medicine; fourth dimension approach; multidisciplinary health team; models; risk factors; theoretical; unintentional injury.

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INTRODUCTION

Unintentional injuries refer to events that are undesired, unplanned, unintended, and not caused deliberately, in other words, accidents. The vast majority of unintentional injuries in children result from incidents such as falls, traffic accidents, burns, and drowning. According to the 2008 WHO/UNICEF World Report on Child Injury Prevention, it is estimated that 100 children die every hour due to such causes. As this projection illustrates, Unintentional Child Injuries (UCI) are among the leading causes of death in the pediatric population worldwide. In fact, as early as 1958, the WHO Regional Office for Europe identified injuries as "the leading cause of death among children in Europe." Despite numerous initiatives developed by governments and international organizations to address UCI, which is a preventable cause of mortality, recent statistics published by the CDC indicate that UCI remains one of the primary causes of childhood deaths. This situation underscores that UCI continues to represent a significant public health challenge requiring sustained international attention and intervention.[1-3]

In addition to mortality, injuries resulting from UCI impose a substantial burden on the healthcare system, particularly on emergency departments (EDs).[4] This is because non-fatal injuries occur far more frequently than deaths, and most affected children first present to the ED. A considerable proportion of these patients subsequently require inpatient treatment. This distribution is commonly illustrated by the injury pyramid.[5] Beyond their physiological and psychological impact on children, UCI also leads to significant anxiety and emotional distress among families and creates a notable socioeconomic burden on society. Research indicates that UCI is the leading cause of disability-adjusted life years (DALYs) lost among children.[6,7] These disabilities may be physical, cognitive, or psychological. Their consequences include school absenteeism, poor academic performance, reduced participation in social activities, and decreased employment opportunities in later life. Considering that approximately 90% of childhood injuries are caused by UCI, affecting tens of millions of children worldwide,[2] it is evident that research and policy interventions targeting the causes of UCI have the potential to produce meaningful reductions in morbidity, an impact that is at least as important as reducing mortality.

It is expected that the risk factors and underlying dynamics associated with non-fatal UCIs differ from those of fatal UCIs. Identifying these risks and implementing targeted interventions has the potential to significantly reduce the number of children who develop disabilities or require long-term care. Considering all these factors, UCIs constitute a substantial portion of the workload in emergency departments. Moreover, given that UCIs are a major source of both mortality and morbidity and that they are largely preventable or at least controllable. UCIs represent an important public health concern. Every child in the world has the right to protection and to live in a safe environment, and even small preventive measures can make a meaningful difference. This study aims to investigate the prevalence, mechanisms, and clinical outcomes of UCIs while identifying key socio-environmental risk factors. Distinct from traditional descriptive analyses, this research utilizes its clinical findings to develop a conceptual multidisciplinary and four-dimensional approach, providing a structured task-force model for public health and emergency medicine integration.

MATERIALS AND METHODS

Study Design

This research was designed as a prospective cross-sectional study. The study population consisted of boys and girls aged 0–18 years who presented to the ED of Konya City Hospital due to unintentional injuries. Hospital records indicated that approximately 9.821 pediatric trauma cases in this age group presented to the ED within one year. Previous studies in the literature have reported that childhood injuries occur with an average prevalence of 30% in this population.[4,8] Taking a population size of 9.821, a prevalence of 30%, a 5% margin of error, and a 90% confidence level, the required sample size was calculated as 222; therefore, a target of 225 participants was determined.

Study Population and Inclusion/Exclusion Criteria

The study included patients aged 0 to 18 years presenting to the emergency department due to unintentional injuries (e.g., falls, traffic accidents, burns). The inclusion criteria were defined as a confirmed history of an unintentional accident and the provision of parental consent. Cases with suspected intentional injury (e.g., physical abuse, assault) and those presenting with non-traumatic etiologies (e.g., infections, acute exacerbations of chronic diseases) were excluded. Furthermore, patients with missing essential data in their medical records, specifically serum glucose/potassium levels or Injury Severity Score (ISS), were excluded from the analysis.

Sampling Strategy

Injury mechanisms and the duration of time spent in various environments (home, school, and outdoors) vary significantly by age group. Considering this variability and to mitigate potential selection bias associated with ED workload and shift patterns, the sampling process was structured to cover the entire 24-hour cycle. Randomization was not restricted to specific hours but was designed to encompass all presentations within the daily loop. In our ED, both ambulatory and ambulance-transported pediatric trauma cases are evaluated in the same examination area. A random number table was applied to the chronological examination order of all admissions, and cases corresponding to the determined sequence numbers were included in the study. Data were collected consecutively from May 15 to June 15, 2025, to ensure a balance between weekday and weekend presentations and to achieve full temporal representation of the sample

Data Collection

A structured information form was used to assess variables including: mother's age, educational status, and employment status, father's age, education, and employment, presence of chronic disease, presence and number of siblings, socioeconomic status, mechanism and location of injury. For this study, clinical parameters such as trauma severity scores and affected body regions were recorded based on standardized diagnostic criteria. Specifically, Abdominal Trauma was defined as injuries to the abdominal wall or intra-abdominal organs (e.g., liver, spleen, intestines) identified via physical examination findings—including tenderness, ecchymosis, or distension—and/or confirmed through radiological imaging such as ultrasonography or computed tomography. Thoracic Trauma encompasses injuries involving the thoracic cage and its internal structures, such as rib fractures, pneumothorax, hemothorax, or parenchymal lung contusion, verified by clinical assessment and radiological findings (chest X-ray or computed tomography). Furthermore, Multisystem Trauma was characterized by the simultaneous involvement of two or more anatomical regions based on the Abbreviated Injury Scale (AIS) (head/neck, face, thorax, abdomen, extremities, and external structures), thereby distinguishing these cases from single-system injuries confined to a single body region. Information such as surgical intervention and survival status during follow-up was obtained from the hospital's digital medical records.

Statistical Analysis

Data obtained from the study were analyzed using IBM SPSS Statistics 23.0 (IBM Corp., Armonk, NY). Frequency, number, and percentage values were used for descriptive analyses of categorical variables. Continuous numerical variables were presented as Mean±Standard Deviation and ordinal variables as median (min–max).

For comparisons, Categorical variables were analyzed using the Chi-square (χ^2) test, and multi-group comparisons using multi-way Chi-square tests. When significant differences were detected, Dunn–Bonferroni post-hoc analysis was performed. Normality of distribution was assessed with the Kolmogorov–Smirnov and Shapiro–Wilk tests. For two-group comparisons of ordinal variables, the Mann–Whitney U test or Student's t-test was applied, depending on distribution characteristics. For comparisons involving more than two ordinal groups, the Kruskal–Wallis H test was used. Post-hoc analyses were conducted using Tukey or Games–Howell tests based on homogeneity of variance. Correlations between variables were evaluated using the Spearman correlation coefficient (ρ).

A p-value of <0.05 was considered statistically significant.

Ethical Approval

Ethical approval for the study was obtained from the University of Health Sciences Hamdiye Scientific Researches Ethics Committee (dated 22.08.2024, decision number 2024/9). Informed consent was obtained from parents or primary caregivers prior to data collection.

The study was conducted in accordance with the principles of the Declaration of Helsinki.

RESULTS

Child-Related Variables

In this study, pediatric patients presenting to the ED due to UCIs were evaluated. UCIs occurred most frequently at age 10, accounting for 11.6% of all injuries. The mean age of injured children was 8.8±4.9 years. The age group with the lowest incidence of injuries was Age ≤2, whereas the group most frequently exposed to injuries was Age ≥12. As age and developmental skills increased, the number of UCIs also rose, and a statistically significant positive correlation was observed between age and UCI occurrence (p=0.04, ρ=0.951). Of the 225 children included in the study, 84 (37.3%) were female and 141 (62.7%) were male. Although boys predominated across all age groups (Age ≤2: males 61.5%, females 38.5%; 3≤ Age ≤6: males 58.9%, females 41.1%; 7≤ Age ≤11: males 60.9%, females 39.1%; Age ≥12: males 67.6%, females 32.4), the difference in gender distribution among age groups was not statistically significant (p=0.752, χ^2=1.204). The median number of siblings among injured children was 1 (Q1=1, Q3=2), and the median birth order was 2 (Q1=1, Q3=3), indicating that most children were the youngest in the family. Additionally, 184 families (81.8%) were identified as having a poor economic status. Sociodemographic characteristics of the children are presented in Table 1

Familial, Socioeconomic, and Environmental Variables

Among the children evaluated in the ED due to UCI, the median age of mothers was 35 years (Q1=30, Q3=40), while the median age of fathers was 38 years (Q1=34, Q3=42). The median floor level of the homes in which the children resided was 2 (Q1=1, Q3=3). A statistically significant relationship was found between maternal education level and the frequency of ED presentations due to UCI; as maternal education decreased, the number of children presenting with UCI increased (p=0.04, ρ=−0.948). Although the association between paternal education level and UCI was not statistically significant (p=0.20), the highest proportion of UCIs occurred among children whose fathers had lower educational attainment. Other familial characteristics of the children are presented in Table 2.

Injury-Related Variables

It was determined that 43.6% (n=98) of UCIs occurred at home, making it the most common location. Among home-related UCIs, the most frequent site was the garden (27%, n=27), followed by the kitchen (24%, n=24).

The most common type of injury was falls, observed in 112 cases (49.8%). Of these, 33 children (29.5%) sustained falls from height, whereas 66 children (58.9%) experienced same-

Table 1. General characteristics of children presenting to the emergency department due to unintentional injuries

Variables	n	%
Age Groups		
Age ≤2	26	11.5
3≤ Age ≤6	56	24.9
7≤ Age ≤11	69	30.7
Age ≥12	74	32.9
Gender		
Girl	84	37.3
Boy	141	62.7
Working Status		
Working	29	12.9
Not working	196	87.1
Chronic Disease		
Present	9	4.0
Absent	216	96.0
Diagnosis of Attention Deficit		
Present	6	2.7
Absent	219	97.3
Family's Economic Status		
Good	41	18.2
Moderate/Poor	184	81.8
Presence of Siblings		
Yes	196	87.1
No	29	12.9
Birth Order (n=196)		
First child	57	25.3
Middle child	35	15.6
Last child	104	46.2

Table 2. Family characteristics of children presenting to the emergency department due to unintentional injuries

Variables	n	%
Mother Alive		
Yes	224	99.6
No	1	0.4
Father Alive		
Yes	219	97.3
No	6	2.7
Mother's Employment Status (n=224)		
Employed	41	18.3
Unemployed	183	81.7
Father's Employment Status (n=219)		
Employed	202	92.2
Unemployed	17	7.8
Mother's Education Level (n=224)		
Primary/Secondary school	137	60.9
High school	48	21.3
University	39	17.3
Father's Education Level (n=224)		
Primary/Secondary school	139	61.8
High school	22	9.8
University	58	25.8
Parental Separation		
Yes	43	19.1
No	182	80.9
Chronic Disease in Mother (n=224)		
Present	27	12.1
Absent	197	87.9
Chronic Disease in Father (n=219)		
Present	19	8.7
Absent	200	91.3
Chronic Disease in Siblings (n=194)		
Present	12	6.2
Absent	182	93.8
Housing Type		
Detached house	68	30.2
Apartment	157	69.8
Home Ownership		
Rented	114	50.7
Owned	111	49.3

level falls. Additionally, 1 child (0.9%) fell from a stroller, and 12 children (10.7%) were injured due to bicycle falls.

Among traffic-related injuries, 11 (4.9%) were pedestrians, 10 (4.4%) were passengers, and 7 (3.1%) were drivers. All UCIs reported as occurring in the workplace involved working children. When injury location was evaluated by age, the following median ages were recorded: Home injuries: median = 5 years (Q1=3, Q3=10), School injuries: median = 10 years (Q1=8, Q3=13), Workplace injuries: median = 15 years (Q1=13, Q3=16), Outdoor injuries: median = 10 years (Q1=6, Q3=15)

Other findings related to injury mechanisms and event characteristics, as well as factors demonstrating statistically significant associations, are presented in Table 3. Post-hoc analysis of Table 3 revealed significant age-dependent variations in injury locations. Children aged ≤2 years and 3–6 years experienced significantly higher rates of home injuries compared to

Table 3. Distribution of injury locations, event types, and related factors in unintentional child injuries

Variables	n	%	Related Factors
Injury Location			
Home	98	43.6	Age Group ($p<0.001$, $\chi^2=56.3$); Maternal chronic disease
School/Daycare	31	13.8	($p=0.03$, $\chi^2=4.37$); Family chronic disease ($p=0.02$, $\chi^2=5.25$);
Workplace	5	2.2	Parental separation ($p=0.037$, $\chi^2=4.35$); Event Type
Outdoor	91	40.4	($p<0.001$, $\chi^2=70.59$
Location of Injuries Occurring at Home (n=98)			
Bedroom	1	1.0	Age Group ($p=0.04$, $\chi^2=42.50$); Home ownership
Children's Room	5	5.1	($p=0.039$, $\chi^2=14.74$); Level of fall ($p<0.001$, $\chi^2=47.58$)
Living Room	22	22.4	
Kitchen	24	24.5	
Sitting Room	4	4.1	
Garden	27	27.6	
Stairs	4	11.2	
Bathroom/Washroom	4	4.1	
Event Type			
Burn	10	4.4	Age Group ($p<0.001$, $\chi^2=60.09$); Child working status
Laceration	8	3.6	($p=0.03$, $\chi^2=13.77$); Maternal employment
Collision / Impact	54	24.0	($p=0.009$, $\chi^2=17.08$); Injury Location ($p<0.001$, $\chi^2=70.59$);
Fall	112	49.8	Single vs. Multiple Trauma ($p=0.07$, $\chi^2=17.76$)
Falling Object	7	3.1	
Traffic Accident	28	12.4	
Animal-related (Cat/Dog)	6	2.7	

the 7–11 and ≥12 age groups, whereas school injuries were predominant in the 7–11 age group. Conversely, outdoor injuries—92.2% of which were traffic-related—were significantly more frequent in adolescents (≥12 years). Working children presented a distinct profile, sustaining significantly more workplace injuries but fewer home, school, and outdoor injuries compared to non-working peers. Workplace injuries were notably associated with advanced maternal/paternal age and larger household size. Furthermore, higher rates of outdoor injuries were observed in children from families with separated parents or chronic familial illnesses.

Regarding specific injury mechanisms, kitchen injuries (44.4%) and burn injuries (60.0%) were significantly clustered in the ≤2-year age group. Most burns (77.8%) occurred in the kitchen, exceeding falls or injuries from falling objects in this location. Garden injuries were most prevalent among children aged 7–11 years (57.1%). Notably, in detached houses, 42.9% of injuries occurred in the garden—where bicycle accidents were more common than falls—whereas in rented households, injuries were more frequent in the child's room. Traffic accidents were the leading cause of injury in the ≥12 age group (67.9%) and among working children. Finally, maternal employment status significantly influenced injury patterns; children of employed mothers had a higher incidence of lacerations (62.5%), while falls were more common (87.4%) among children of unemployed mothers. Clinically, injuries resulting from traffic accidents and falling objects were significantly associated with multisystem involvement.

The distribution of body regions affected by UCI and their frequencies is presented in Figure 1.

Head injuries were significantly more common among children in the Age ≤2 group ($p=0.02$, $\chi^2=14.90$), those with siblings ($p=0.04$, $\chi^2=4.05$), children living in rented homes ($p=0.01$, $\chi^2=5.93$), those who were hospitalized ($p=0.04$, $\chi^2=8.21$), and those who died ($p=0.02$, $\chi^2=5.16$). Conversely, head injury rates were significantly lower in non-operated patients compared with hospitalized patients ($p=0.001$, $\chi^2=13.08$), in first-born children compared with middle and last-born children ($p=0.04$, $\chi^2=7.97$), and in the Age ≥12 group compared with the younger age groups ($p=0.02$, $\chi^2=14.90$).

Neck injuries were significantly more common among children whose caregivers reported attention deficit compared with those without attention deficit ($p<0.001$, $\chi^2=11.02$).

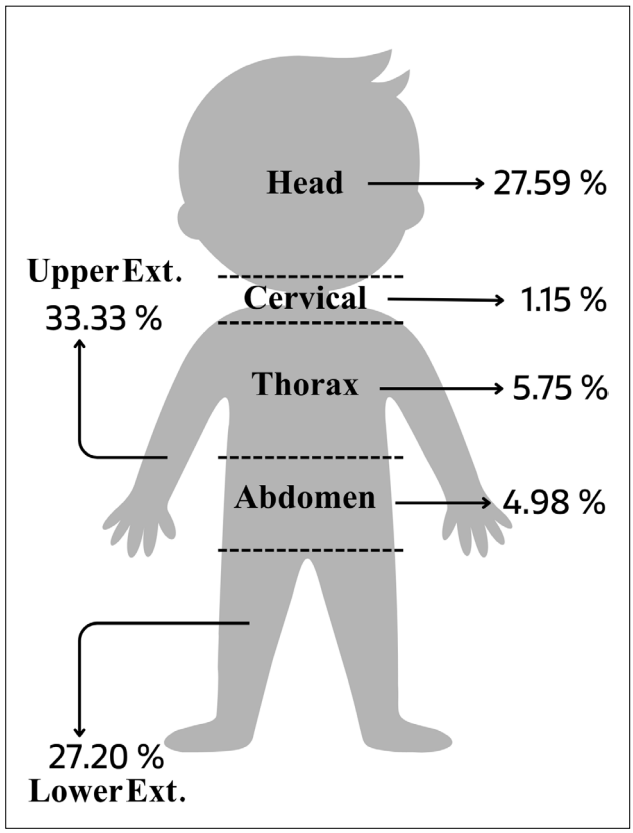

Figure 1. The anatomical distribution and incidence of body region involvement following unintentional childhood injuries. *Ext: Extremity.*

Upper extremity injuries were significantly more frequent in children with siblings than in those without (p=0.03, χ^2=4.53). Working children also had a significantly higher rate of upper extremity trauma (p=0.01, χ^2=5.58), and all workplace injuries involved the upper extremities. Upper extremity trauma in workplace settings was significantly higher than in all other injury mechanisms (p=0.01, χ^2=10.17).

Thoracic injuries were significantly more common in the 7–11 and ≥12 age groups compared with the younger groups (p=0.04, χ^2=13.02), and were markedly higher among children who died compared with survivors (p<0.001, χ^2=48.69).

Abdominal injuries were significantly more frequent in children whose mothers had lower educational levels (p=0.02, χ^2=5.16), in children with thoracic injuries (p<0.001, χ^2=22.41), and among non-survivors compared with survivors (p<0.001, χ^2=18.25).

Lower extremity injuries were significantly more common in fall-related events compared with other mechanisms (p=0.006, χ^2=17.96) and were significantly higher among children in the Age ≥12 group compared with younger groups (p=0.02, χ^2=9.66).

A total of 21 children (9.3%) presented with multisystem trauma. The likelihood of multisystem involvement was significantly higher in children with abdominal injury (p<0.001, χ^2=32.30) and those with thoracic injury (p<0.001, χ^2=77.79).

Among all 225 cases, 66 children (29.3%) required consultation, with a total of 83 consultations performed; 9 patients required consultation from more than one specialty. The remaining 159 children (70.7%) did not require consultation.

The consultations were distributed as follows: Orthopedics: 37 (44.6%), Neurosurgery: 13 (15.7%), Pediatric Surgery: 11 (13.3%), Thoracic Surgery: 8 (9.6%), Otolaryngology: 5 (6.0%), Ophthalmology: 5 (6.0%), Plastic and Reconstructive Surgery: 4 (4.8%),

Two children died in the ED, while among the remaining 223 children, 194 (86.2%) were treated and discharged from the ED. Treatment outcomes and mortality-related findings are presented in Table 4.

According to Table 4, when the Post-hoc analyses were made within the statistically significant variables and the groups that differed significantly were examined. Children in the Age ≥12 accounted for 57.1% of all multisystem traumas, representing a significantly higher proportion compared with other age groups. Among patients with multisystem trauma, the likelihood of parental separation was higher (19.5%) than in those with single-system injuries (7.1%). The need for consultation was also significantly greater among children with multisystem trauma (22.5%) compared with those without (3.8%). Children with multisystem trauma had markedly higher rates of hospital admission (31.0%), surgical intervention, and intensive care unit (ICU) follow-up (66.7%) compared with those with single-system trauma (6.1% and 15.0%, respectively). The mortality rate among children with multisystem UCI was 71.4%, significantly higher than the 7.3% observed in children with isolated injuries.

Injury Severity Score (ISS) among all UCI cases was 3.34±6.39 (min=1, max=45). ISS scores were significantly higher among children with multisystem involvement (p<0.001, U=27.18). A statistically significant difference in ISS was found according to maternal education level (p=0.02, H=9.76), with the significant pairwise difference observed between children of mothers with primary/middle school education (I) and those with university-level education (J) (p=0.03, Mean Difference I–J=3.56). Similarly, ISS varied significantly across age groups (p=0.02, H=9.74). The significant post-hoc difference was between the 7–11 age group (I) and the ≥12 age group (J) (p=0.04, Mean Difference I–J=−2.80). A weak but statistically significant positive correlation was observed between the child's age and ISS (p=0.03, r=0.139), and a negative correlation between maternal education and ISS (p=0.03, r=−0.144). There was a significant difference in ISS according to injury mechanism, driven by comparisons between traffic accidents (I) vs. collision injuries (J) (p=0.001, Mean Difference=5.85) and traffic accidents vs. falls (J) (p=0.01, Mean Difference=4.47). ISS was significantly higher among children who required consultation (p<0.001, U=269.00). Patients treated

Table 4. Multiple system trauma, treatment and mortality outcomes and related factors

Variables	n	%	Related Factors
System Involvement			
Single-system trauma	204	90.7	Age Group (p=0.04, χ^2=7.85); Parental separation (p=0.013, χ^2=6.139); Consultation (p<0.001, χ^2=19.80); Event Type (p=0.07, χ^2=17.76); Ward/ICU follow-up (p<0.001, χ^2=38.10); Discharge/Hospitalization/Surgery (p<0.001, χ^2=21.89); Mortality (p<0.001, χ^2=32.92)
Multi-system trauma	21	9.3	
Treatment and Follow-up (n=223)			
Outpatient treatment	194	86.2	Multisystem trauma (p<0.001, χ^2=38.10); ISS (p<0.001, U=182.0)
Inpatient treatment	29	13.8	
Surgically treated	14	48.2	
Not surgically treated	15	52.8	
Mortality			
Survived	218	96.9	Multipl travma (p<0.001, χ2=32.92), Abdominal travma (p<0.001 χ2=18.25), ISS (p<0.001 U=180.5), Serum Glikoz Seviyesi (p=0.02 U=684.0)
Died	7	3.1	
ED	2	28.6	
ICU	5	71.4	

ED: Emergency Department; ICU: Intensive Care Unit.

as outpatients (I) had significantly lower ISS than those who were hospitalized (J) (p<0.001, Mean Difference=−16.08) or underwent surgery(J) (p<0.001, Mean Difference=−8.27). ISS values were also significantly higher in children with thoracic injuries (p<0.001, U=508.00) and abdominal injuries (p<0.001, U=717.00).

Among non-survivors, ISS (p<0.001, U=180.50), glucose levels (p<0.001, z=−4.500), and the glucose/potassium ratio (p<0.001, z=−4.502) were all significantly higher than in survivors. A moderate, statistically significant positive correlation was found between glucose levels and ISS (p<0.001, r=0.620). Receiver Operating Characteristic (ROC) analysis demonstrated that at ED admission, a blood glucose level ≥153 mg/dL (Youden's Index=1) and a glucose/potassium ratio ≥39.48 (Youden's Index=1) represented clinically meaningful thresholds associated with increased mortality risk.

DISCUSSION

There is considerable variation in the reported ages at which UCIs most commonly occur in children. Some authors have stated that injuries are most frequent at an average age of 5.15±3.79 years, whereas others have reported higher-risk age groups such as 10–14 years.[9,10] In the present study, the mean age of UCI was 8.8±4.9 years, with the highest frequency observed at age 10. Several studies conducted in Türkiye support this finding.[11,12] This variation likely reflects unequal environmental conditions for children and suggests that UCIs have region-specific determinants.

Analysis of age groups revealed that children aged ≤2 years experienced the fewest UCIs, while the ≥12 age group experienced the most. The number of injuries increased with age and developmental progression (p=0.04, ρ=0.951). The observation that falls decrease with age, while home injuries occur more often in the ≤2 and 3–6 age groups, and traffic-related injuries increase in those ≥12, highlights the importance of age-stratified evaluation. These findings underscore the need for etiological studies that compare injury types across developmental stages.

The trends observed may be linked to children's increasing independence during exploration phases, combined with ongoing neurophysiological and psychological maturation. During these stages of heightened curiosity and exploratory behavior, balance and coordination skills are still developing.[13]

In this study, there was no statistically significant association between the child's sex and injury type or outcome. However, boys were more frequently admitted for UCIs across all age groups, consistent with previous reports.[11,14,15] Although physiological and motor development are generally similar between boys and girls—excluding changes during puberty—differences in injury rates may reflect sociocultural norms, gendered behavioral expectations, reinforced gender identity roles, and differences in play patterns, peer interactions, and social learning.[16]

The association of age with multiple variables—including common injury periods, injury location, mechanism, trauma

region, multisystem injury frequency, and ISS—suggests that age may be a stronger determinant than sex in UCI patterns. Nonetheless, both age and sex must be considered when designing injury prevention strategies. Interventions involving parents, digital media, caregivers, peers, teachers, and educational environments play crucial roles. Risk-reduction strategies targeting environmental and physical hazards should also be prioritized.

The most common UCI mechanism in this study was falls (49.8%), consistent with prior literatüre.[17,18] Most injuries occurred at home (43.6%), particularly in the kitchen. Similar to findings reported by Sara Rosenblum et al.,[19] a large proportion of minor UCIs occurred indoors. Previous studies have attributed this to unsafe household environments—especially the kitchen.[20] Although home injuries are often perceived as low-risk, this study identified that "falling objects" were associated with multisystem trauma, clearly demonstrating that the home can sometimes be more hazardous than outdoor environments. This indicates the need for increased safety measures, particularly regarding unsecured household items.[19,21] The association between rented housing and increased head injuries, as well as increased injury frequency in children's rooms, raises questions about whether being a tenant delays safety modifications or reflects socioeconomic disadvantage.[22] Studies assessing repeated childhood injuries may help clarify these findings.[23]

Lower maternal education was associated with higher rates of abdominal trauma and higher ISS scores. In contrast, paternal education showed no such association, possibly because mothers spend more time involved in daily childcare. The high proportion of UCIs among children with fathers of low educational level underscores the need for educational interventions targeting both parents. The statistically significant negative correlation between maternal education and ISS underscores the pivotal role of education in shaping safety awareness and risk perception. These results align with prior research highlighting maternal educational attainment as a key socioeconomic determinant of injury severity and clinical outcomes.[24,25]

Although some studies highlight the impact of advanced parental age and larger family size on injury risk,[14] the association of workplace injuries with older parents in this study may be linked to socioeconomic disadvantage. Older parents may face reduced economic productivity, and larger families often experience financial strain, making child labor more common. The finding that 81.8% of families in this study had low socioeconomic status supports prior evidence that socioeconomic inequity, environmental conditions, and living circumstances are key determinants of UCI.[26,27]

Parental involvement reduces UCI incidence.[28] This study demonstrated that parental separation and parental chronic illness were associated with increased outdoor injuries and higher multisystem trauma rates. These findings suggest that shared, active parental caregiving is essential. Furthermore, parental separation and chronic illness may create psychosocial stress, reduce supervision, and increase injury susceptibility.[14,29,30] Prior literature has similarly reported that low maternal education, mental health issues, smoking, and substance use raise injury risk.[25,31] An important but often overlooked point is that non-parental caregivers (e.g., babysitters, daycare providers) also play critical roles in children's safety.[32] With many children spending substantial time in such environments, preventive programs targeting these groups are essential. In this study, lacerations were more common in children of working mothers, while falls were more common among children whose mothers did not work, suggesting differences in supervision and injury mechanisms during non-parental caregiving.

Although studies are reporting that a higher number of children in the family is associated with an increased incidence of UCI, no studies have been identified that evaluate its impact on the anatomical site of trauma.[14] The presence of siblings increased the likelihood of head injuries and upper-extremity trauma. This may be related to sibling play dynamics or conflict. Younger children being more frequently injured may reflect supervisory challenges or modeling behavior from older siblings. These findings suggest that sibling-focused safety education may be beneficial.

Regarding injury regions, UCIs most commonly affected the upper extremities (33.33%), followed by the head (27.59%) and lower extremities (27.20%), consistent with previous studies.[15] These regions warrant careful examination during ED evaluations. Thoracic and abdominal injuries were associated with multisystem trauma, highlighting the need for thorough systemic assessment in these cases. The association between cervical trauma and attention-deficit symptoms also warrants further investigation. Children presenting with cervical injuries or certain mechanisms should be screened for attention disorders during repeated visits.[33,34]

The majority of UCIs in this study were low-energy and involved single systems: 90.7% affected a single body region, 86.2% were managed on an outpatient basis, and hospitalized cases were primarily managed conservatively. The distribution of injury severity in our study mirrors (Figure 2) the classical injury pyramid described in previous reports.[5,35] While the apex represents a small percentage of mortality and hospitalizations, the vast majority of cases formed the broad base of low-energy, single-system injuries managed on an outpatient basis. However, this massive volume at the base of the pyramid underscores that the clinical burden of UCIs is driven not only by the severity of the few but also by the sheer number of ED presentations, necessitating comprehensive preventive and resource management strategies.

As expected, multisystem trauma and higher ISS scores were associated with increased mortality. Abdominal trauma was also linked to multisystem involvement, emphasizing its

prognostic significance, consistent with previous findings.[36] Biochemical predictors have been studied in relation to trauma outcomes, highlighting their importance in clinical decision-making.[37,38] In this study, elevated glucose levels were associated with increased mortality. Hyperglycemia is well-described as a physiological stress response mediated by catecholamines, cortisol, insulin resistance, and inflammatory cytokines.[39-41] While adult studies show strong evidence for the prognostic value of glucose,[42-47] pediatric evidence remains limited. Some researchers suggest that values exceeding 150 mg/dL, while others propose 200 mg/dL, indicate poor outcomes. In one study, a threshold of 120 mg/dL predicted abnormal CT results.[48,49] Optimal glucose management has been shown to influence mortality outcomes, and similar relationships have been described between ISS and glucose.[50,51] This study supports these findings and suggests that incorporating glucose measurements into scoring systems may improve prognostic accuracy.

UCI prevention requires a multidisciplinary public health approach, including risk identification, hazard reduction, and coordinated interventions. Prevention strategies may be conceptualized using levels such as primordial, primary, secondary, tertiary, and quaternary prevention, traditionally applied to chronic disease but also applicable to UCIs. Health professionals play crucial roles across these levels.[52-54] Many studies have proposed strategies for prevention, yet gaps remain in the knowledge and behavior of healthcare professionals.[6,55-58] Raising awareness among health workers may significantly improve collaboration in UCI prevention.[59] The Haddon Matrix is a useful framework for understanding injury epidemiology, categorizing interventions across pre-event, event, and post-event phases.[5,60,61] Modern approaches, such as the Injury Equity Framework, expand this to include multidisciplinary strategies incorporating 3E (Education, Engineering, Enforcement), 5E (Education, Engineering, Enforcement, Economic incentives, Emergency response), and 7E (Education, Engineering, Enforcement, Economic incentives, Emergency response, Enablement, Ergonomics) models.[5,62,63]

Integrating these frameworks, health protection strategies, the Haddon Matrix, and injury equity models may provide comprehensive insight into modifiable risk factors. A clear definition of interdisciplinary responsibilities is essential, yet often overlooked. As a contribution of this study, the Multidisciplinary Approach of Prevention and Treatment Framework is proposed (Figure 3) to guide future work.

Emergency medicine is the primary point of contact for childhood injuries. Therefore, beyond providing treatment services, emergency physicians play a crucial role in identifying children at risk for recurrent injuries and educating families about prevention, as well as guiding them regarding the requirements of the rehabilitation process. At this strategic intersection, emergency physicians are well-positioned to implement the Multidisciplinary and Four-dimensional Approach, which delineates the responsibilities of emergency medicine across the primordial, primary, secondary, tertiary, and quaternary levels of prevention in childhood injuries. The roles of emergency physicians can be clearly defined at each of these stages. In addressing this problem, emergency medicine physicians must act without delay to foster collaboration not only with family physicians and pediatricians, but also with a broad spectrum of medical and non-medical disciplines.

Limitation

This study focused on the epidemiology of UCIs, emergency department diagnoses, treatment strategies, mortality, and ISS outcomes. Its primary limitation is the single-center design, which may restrict the generalizability of the findings as injury mechanisms and event types vary significantly by region. While the sample size (n=225) was calculated to pro-

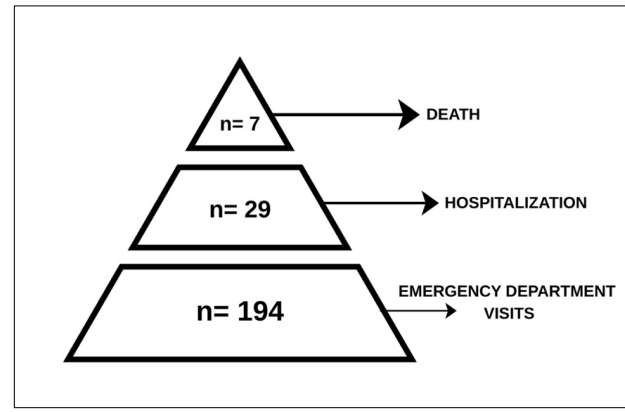

Figure 2. The pediatric injury severity pyramid. The diagram illustrates the distribution of cases based on injury outcome severity within the study population (n=225). The base represents patients discharged after outpatient treatment (n=194), the middle section represents hospitalized patients requiring surgical or conservative management (n=29), and the apex represents mortality (n=7) occurring in the ED or ICU.

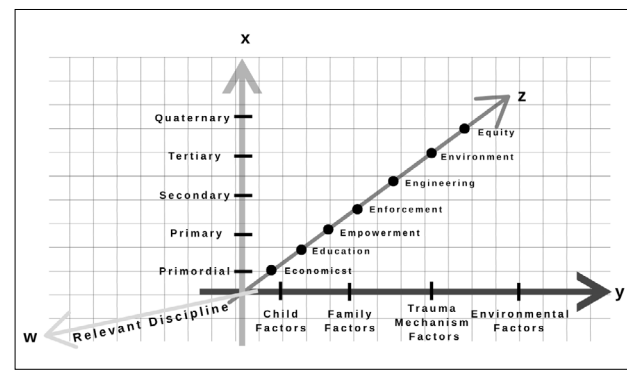

Figure 3. A Multidisciplinary and Four-Dimensional Approach to Unintentional Childhood Injuries. In the figure, the x-axis represents the concept of prevention in healthcare, the y-axis represents accident risk factors, the z-axis denotes the methodology to be followed in addressing risk factors and the clinical approach, and the w-axis indicates the relevant discipline responsible for intervention.

vide baseline insights, it limited the statistical power for more complex subgroup analyses. Most notably, the small number of fatal cases (n=7) in our study population directly affects the reliability and precision of the statistical thresholds. Therefore, the identified cut-off values for serum glucose and the glucose/potassium ratio should be interpreted as potential clinical indicators with limited confidence intervals, rather than definitive prognostic rules. These biochemical findings remain preliminary and necessitate validation in larger, multicenter cohorts with higher mortality rates. Nevertheless, the fundamental aim of this study was to contribute to ongoing efforts to highlight UCIs as a major public health issue. The need for continued action is clear, and each step taken in this direction has the potential to meaningfully improve the health and well-being of children worldwide.

CONCLUSION

This comprehensive analysis of children presenting to the ED following UCIs demonstrates that unintentional childhood injuries impose a significant clinical and socioeconomic burden and remain a major public health concern.

Our findings reveal that injury patterns and severity are shaped by a complex interplay of demographic, socioeconomic, familial, and environmental factors. In particular, low maternal education, poor socioeconomic status, and household-related characteristics were associated with higher injury severity and worse outcomes. These results underscore the potential diagnostic and prognostic value of incorporating sociodemographic factors into the clinical assessment of UCI presentations.

Clinical predictors such as elevated serum glucose and glucose/potassium ratios may offer auxiliary insights during acute triage; however, their application as independent clinical prediction rules requires more robust evidence from broader studies

Multidisciplinary, systematic prevention strategies that consider not only clinical factors but also the broader social context are essential to reducing both the frequency and impact of pediatric injuries. There is an urgent need for targeted interventions that engage families, healthcare providers, educators, and policymakers to strengthen both preventive and therapeutic approaches in the care of children affected by UCIs.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Çocukluk çağı kazalarının klinik özellikleri ve sosyoekonomik belirleyicileri: Acil servis perspektifi

AMAÇ: Kazalar, çocuklar arasında dünya genelinde morbidite ve mortalitenin önde gelen nedenlerinden biridir ve özellikle düşük ve orta gelirli ülkelerde önemli klinik ve ekonomik yükler oluşturmaktadır. Acil servisler (AS), bu tür olaylar için yalnızca ilk başvuru noktası olmakla kalmayıp, aynı zamanda sağlık hizmetlerine daha büyük ve görünmeyen bir yük oluşturan ölümcül olmayan çocukluk çağı kazalarının da ilk başvuru noktasıdır. Bu çalışmanın temel amacı, acil servise (AS) başvuran kazara çocukluk çağı yaralanmalarının klinik ve sosyoekonomik belirleyicilerini ve öngörücülerini kapsamlı bir şekilde analiz etmektir. Elde edilen bu verilerden yola çıkarak çalışma; sistemik önleme ve müdahale stratejilerini güçlendirmek adına, çok disiplinli ve dört boyutlu bir çerçeveyi kavramsal bir model önerisi olarak sunmaktadır

GEREÇ VE YÖNTEM: Bu çalışma, acil servise kaza nedeniyle başvuran hastaları kapsayan prospektif, kesitsel bir çalışmadır. Veriler; demografik, ailevi, sosyoekonomik ve yaralanmayla ilgili değişkenleri içerecek şekilde yapılandırılmış formlar ve dijital tıbbi kayıtlar kullanılarak toplanmıştır. Risk faktörleri, yaralanma mekanizmaları, klinik sonuçlar ve mortalite öngörücüleri arasındaki ilişkileri incelemek için istatistiksel analizler yapılmıştır.

BULGULAR: Çocukluk çağı kazalarının en sık nedeni düşmelerdi (%49.8), bunu trafik kazaları (%12.4) izledi. Yaralanmalar en sık evde (%43,6), özellikle mutfak ve bahçelerde meydana gelmişti. Vakaların %62.7'sini erkek hastalar oluşturuyordu. Düşük anne eğitimi, kötü ekonomik durum ve yüksek Yaralanma Şiddet Skoru (ISS) arasında anlamlı ilişki saptandı. Multipl travmalar, 12 yaş ve üzeri çocuklarda ve ayrı ebeveynli olanlarda daha sık görülmekteydi. AS başvurusunda yüksek serum glukoz düzeyi (≥153 mg/dL) ve glukoz/potasyum oranı (≥39.48) mortalitenin potansiyel öngörücüleri olarak belirlendi ($p<0.001$). Multipl travma, abdominal ve torasik travma ile yüksek ISS artmış mortalite ile ilişkili bulundu.

SONUÇ: Serum glukozu gibi klinik öngörücüler kullanılarak yüksek riskli hastaların erken tespiti tedavi sonuçlarını iyileştirebilir. Ayrıca, acil serviste baş, üst ve alt ekstremite yaralanmalarının sık görülmesi, bu bölgelerin olası yaralanmalar açısından dikkatle incelenmesi gerektiğini göstermektedir. Abdominal yaralanmaların kötü klinik sonuçları öngörmedeki rolü dikkate alındığında, torasik ve abdominal yaralanmaların birlikte görülme eğilimi ve abdominal travmaya sahip hastalarda çoklu travma prevalansının yüksekliği, abdominal yaralanması tespit edilen çocuklarda diğer sistemlerin detaylı değerlendirilmesini ve farklı klinik izlem ve takibi gerektirdiğini göstermektedir. Çocukluk çağı kazaları, sonuçları potansiyel olarak önlenebilir olan önemli bir halk sağlığı sorunudur. Klinik, sosyoekonomik ve çevresel faktörleri ele alan çok disiplinli ve sistematik önleme stratejileri, bu tür yaralanmaların hem insidansını hem de şiddetini azaltmak açısından önemini korumaktadır. Bu çalışmada, elde edilen klinik ve sosyoekonomik bulgular ışığında önerilen görev gücü odaklı çok disiplinli yaklaşım, çocukluk çağı yaralanmalarının yönetiminde sistematik ve etkin bir iyileştirme sağlayabilir

Anahtar sözcükler: Acil tıp; çocuk travmaları; dördüncü boyut yaklaşımı; kazalar; klinik tahmin kuralı; multidisipliner sağlık ekibi; modeller; risk faktörleri; teorik.

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ORIGINAL ARTICLE

Diagnostic Value of immature granulocytes and neutrophil-to-lymphocyte ratio in differentiating epididymo-orchitis from testicular torsion

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ABSTRACT

BACKGROUND: Testicular torsion is an important urologic emergency, and early identification is crucial. This study aimed to evaluate the diagnostic value of hematological parameters—particularly immature granulocytes (IGs) in differentiating epididymo-orchitis from testicular torsion in patients presenting with acute scrotal pain.

METHODS: This retrospective cohort study included 301 male patients presenting with acute scrotal pain between January 2020 and December 2024. Diagnoses were confirmed by Doppler ultrasonography or surgical exploration. Patients were classified into epididymo-orchitis (n=200), testicular torsion (n=37), and control (n=64) groups. Complete blood count parameters (WBC, neutrophil, lymphocyte, platelet, IG, NLR, PLR) were analyzed. Nonparametric tests were used for group comparisons, and ROC curve analyses were performed to determine diagnostic performance. Multivariable logistic regression adjusted for age identified independent predictors.

RESULTS: NLR (cut-off=2.19, AUC=0.644, p<0.001) and IG count (cut-off = 0.06, AUC=0.590, p=0.011) were significantly elevated in epididymo-orchitis compared with controls. No parameter showed diagnostic significance for testicular torsion. In the epididymo-orchitis vs torsion comparison, NLR (AUC=0.781, p<0.001) and IG count (AUC=0.730, p<0.001) demonstrated the best discriminative ability. Multivariable regression confirmed NLR (OR=1.17, 95% CI 1.05–1.31, p=0.005) and IG (OR=2.26, 95% CI 1.10–4.63, p=0.027) as independent predictors of epididymo-orchitis.

CONCLUSION: Immature granulocyte count and NLR are valuable and accessible hematological biomarkers that can assist in differentiating epididymo-orchitis from testicular torsion. Their integration into diagnostic evaluation may enhance clinical decision-making in the emergency management of acute scrotum.

Keywords: Epididymo-Orchitis; immature granulocytes; testicular torsion.

INTRODUCTION

The term acute scrotum refers to the sudden onset of pain and swelling within the scrotal contents and represents a true urological emergency requiring rapid evaluation and management. Several conditions may account for this presentation, such as epididymo-orchitis, torsion of the testicular appendages, testicular torsion, trauma, inguinal herniation, or, more rarely, vasculitic disorders. The wide range of possible causes highlights the need for early and accurate evaluation. Among these, testicular torsion and epididymo-orchitis are the two most frequent causes encountered in emergency departments (EDs) and account for the majority of acute scrotal presentations. Testicular torsion, resulting from twisting of

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the spermatic cord, primarily affects adolescents and young adults and necessitates urgent surgical intervention to restore testicular perfusion. In contrast, epididymoorchitis, an inflammation of the epididymis and testis, is usually of infectious origin and managed conservatively with antibiotic therapy. Despite their distinct etiologies and treatment approaches, both conditions present with similar clinical features, including acute scrotal pain and swelling, which can make accurate differentiation challenging in the emergency setting.[1]

Hematologic indicators, including the neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and immature granulocyte (IGs) count, have gained increasing attention as readily available, cost-effective biomarkers of systemic inflammation and tissue stress.[2] These markers offer potential utility in differentiating between ischemic and infectious pathologies, including acute scrotal conditions. Differentiating testicular torsion from epididymoorchitis is essential due to their divergent management strategies. However, current diagnostic modalities, such as Doppler ultrasonography (US), have limitations, including operator dependency, limited accessibility, and potential delays in time-sensitive cases.[3] While previous studies have investigated the diagnostic roles of NLR and PLR in various inflammatory diseases, their utility in distinguishing between testicular torsion and epididymoorchitis remains inconclusive. Epididymoorchitis, due to its infectious nature, is expected to present with elevated neutrophil counts and NLRs, whereas testicular torsion, an ischemic process, may be associated with less pronounced neutrophilia but relatively increased PLRs or IGs, reflecting early myeloid activation and tissue stress responses.[4] Immature granulocytes are released into the peripheral circulation during acute infectious and inflammatory states as a result of bone marrow stimulation and accelerated myelopoiesis. Pro-inflammatory cytokines such as interleukin-6 and granulocyte colony-stimulating factor promote early release of granulocytic precursors, leading to increased immature granulocyte counts in systemic infections.[5] Among these, IGs, representing early-stage granulocyte precursors, have shown promise in various inflammatory and ischemic conditions but have been not systematically evaluated in the context of acute scrotum.[6] To date, no comprehensive study has systematically assessed the diagnostic potential of IGs in this specific clinical context.

We examined the ability of specific hematologic indicators, with a focus on immature granulocytes, to discriminate between epididymo-orchitis and testicular torsion in patients who presented with acute scrotal complaints.

MATERIALS AND METHODS

Study Design and Setting

This retrospective cohort study was conducted at a tertiary healthcare facility, between January 2020 and December 2024. The study protocol was approved by the Local Clinical Research Ethics Committee (Decision No: 22; Date: February 25, 2025). Given the retrospective design and use of de-identified patient data, the requirement for prospective written informed consent was waived by the ethics committee in accordance with national regulations and the principles of the Declaration of Helsinki.

Study Population, Inclusion and Exclusion Criteria

The study included a total of 301 male patients who were diagnosed with epididymo-orchitis (n=200) or testicular torsion (n=37), along with a control group of 64 individuals. Patient identification was conducted through a systematic electronic medical record query using predefined diagnostic codes for testicular torsion and epididymo-orchitis. The inclusion criteria comprised adult male patients presenting to the ED with acute scrotal pain of less than 12 hours' duration, whose diagnoses were confirmed by review of clinical notes, laboratory findings, scrotal Doppler US, and operative reports when applicable. The control group consisted of patients who presented to the emergency department with acute scrotal pain or discomfort and in whom both infectious and ischemic etiologies were excluded based on clinical assessment, laboratory findings, and scrotal Doppler ultrasonography. These patients were ultimately diagnosed with non-specific or self-limiting scrotal conditions and did not require surgical or antimicrobial treatment (Figure 1). The study included all consecutive eligible patients during the predefined study period. The study period was determined a priori and was not influenced by sample size considerations. No retrospective expansion of the dataset was performed to achieve a target number of cases. A post hoc power analysis was performed solely to describe the statistical power of the final cohort and did not influence study design, case inclusion, or data collection. Exclusion criteria were the presence of chronic scrotal conditions, hematologic disorders, active malignancy, or incomplete medical records.

Data Collection

The primary laboratory variables assessed were leukocyte ($\times10^3/\mu L$), neutrophil ($\times10^3/\mu L$), lymphocyte($\times10^3/\mu L$), platelet($\times10^3/\mu L$), and IG($\times10^3/\mu L$) counts.

Derived hematological ratios were also calculated, including the NLR and PLR. The NLR was calculated as the ratio of absolute neutrophils to lymphocytes, PLR was determined by expressing platelet numbers in relation to lymphocyte counts. The IG count represented the absolute number of immature granulocytes, automatically measured as part of the complete blood count (CBC) analysis.

Clinical data, including age, comorbidity profiles, and current medications, were retrieved from the hospital's electronic medical records. CBC results were generated through an automated hematologic analyzer (Sysmex XN-1000; Sysmex Corporation, Kobe, Japan), with daily calibration and internal quality controls performed according to the manufacturer's recommendations to ensure analytical reliability. Data collec-

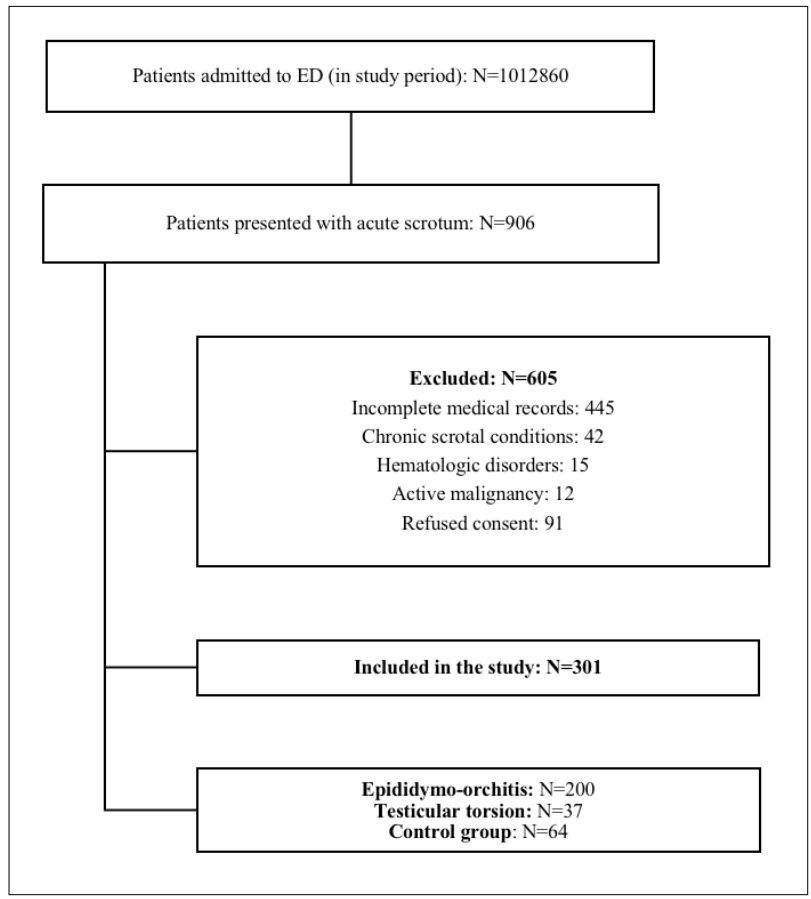

Figure 1. Patient flow diagram.

tion followed a standardized protocol to minimize measurement bias and maintain data integrity.

Statistical Analysis

All statistical procedures were conducted using IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA). Normality of continuous data was assessed with the Shapiro–Wilk test. Since none of the continuous variables followed a normal distribution, results were presented as medians with interquartile ranges (IQRs). Categorical variables were summarized as frequencies and percentages. Comparisons of non-normally distributed continuous data were performed using the Kruskal–Wallis test, and pairwise differences were examined with the Dwass–Steel–Critchlow–Fligner (DSCF) post hoc method. Relationships between categorical variables were evaluated using either the chi-square test or Fisher's exact test, depending on suitability.

Diagnostic accuracy of complete blood count–derived parameters was examined through receiver operating characteristic (ROC) curve analyses, covering age, leukocyte count, neutrophil count, lymphocyte count, platelet count, NLR, PLR, and IG count. For each parameter, the area under the ROC curve (AUC), optimal cut-off point determined by the Youden index, sensitivity, and specificity were calculated together with 95% confidence intervals (CIs). To explore independent predictors distinguishing epididymo-orchitis from testicular torsion, multivariable logistic regression analyses were performed using a backward stepwise elimination strategy, with age retained in all models as a mandatory covariate. Variables yielding $p<0.05$ in univariate testing were entered into the initial multivariable model. Results were reported as odds ratios (ORs) with corresponding 95% CIs.

To identify independent predictors of epididymo-orchitis and testicular torsion, multivariable logistic regression analyses were conducted using a backward stepwise elimination method, with age entered as a forced covariate in all models. Only variables with $p<0.05$ in univariate analyses were included in the initial model. Results were expressed as odds ratios (ORs) with 95% CIs. Model performance was evaluated using the AUC of predicted probabilities and McFadden's pseudo-R^2. Statistical significance was defined as a two-tailed p-value <0.05.

RESULTS

A total of 301 patients were included in the analysis, comprising 200 with epididymo-orchitis, 37 with testicular torsion, and 64 controls. Baseline characteristics of the study groups

Table 1. Baseline characteristics of the study population

Parameter	Total (n=301)	Epididymo-orchitis (n=200)	Testicular torsion	Control (n=37)	p-value* (n=64)
Age (years), median (IQR)	39 (25-58)	43 (28–61)	25 (21–35)	38 (23–49)	<0.001
Leukocyte count (×10³/μL), median (IQR)	10.9 (8.4-14.5)	12.2 (9.3–15.7)	11.1 (8.6–14.9)	8.3 (7.1–9.4)	<0.001
Neutrophil count (×10³/μL), median (IQR)	7.4 (5.0-11.5)	9.0 (5.9–12.3)	7.6 (5.7–12.3)	4.9 (4.1–6.4)	<0.001
Lymphocyte count (×10³/μL), median (IQR)	1.99 (1.48-2.61)	1.90 (1.35-2.56)	1.88 (1.50-2.44)	2.35 (1.77-3.02)	0.012
Platelet count (×10³/μL), median (IQR)	247 (207-292)	253 (217–292)	244 (210–289)	242 (205–278)	0.427
IG (×10³/μL), median (IQR)	0.04 (0.02-0.08)	0.05 (0.02–0.08)	0.04 (0.02–0.06)	0.03 (0.02–0.04)	<0.001
NLR, median (IQR)	3.73 (2.15-6.48)	4.40 (2.59–7.82)	4.37 (2.29–6.43)	2.12 (1.54–3.42)	<0.001
PLR, median (IQR)	127 (92.5-178)	130 (95-186)	136 (110–188)	109 (77–157)	0.029

*One-way ANOVA (Kruskal-Wallis) test; IQR: Inter Quartiler Range; IG: Immature granulocyte; NLR: Neutrophil/lymphocyte ratio; PLR: Platelet/lymphocyte ratio.

Table 2. Diagnostic performance of CBC parameters

Variable	Cut-off (Youden J)	Sensitivity (%)	Specificity (%)	AUC	95% CI	p-value*
Leukocyte count (x10³/μL)						
EO vs C	9.5	70.2	55.0	0.610	0.540–0.680	0.002
TT vs C	9.8	55.0	50.5	0.540	0.450–0.630	0.290
EO vs TT	10.2	69.0	71.0	0.720	0.650–0.790	<0.001
Neutrophil count (x10³/μL)						
EO vs C	7.2	72.0	56.3	0.625	0.555–0.695	0.001
TT vs C	7.0	52.0	56.0	0.532	0.440–0.624	0.320
EO vs TT	8.2	71.2	72.8	0.740	0.670–0.810	<0.001
Platelet count (x10³/μL)						
EO vs C	260.0	52.0	57.5	0.545	0.470–0.620	0.210
TT vs C	258.0	50.0	50.0	0.505	0.420–0.590	0.960
EO vs TT	259.0	56.0	53.0	0.570	0.490–0.650	0.150
NLR						
EO vs C	2.19	83.7	44.9	0.644	0.577–0.711	<0.001
TT vs C	3.83	51.4	49.0	0.501	0.411–0.591	0.983
EO vs TT	3.12	70.1	76.0	0.781	0.705–0.857	<0.001
PLR EO vs C	126.5	60.0	53.1	0.509	0.440–0.579	0.790
TT vs C	106.9	54.0	54.3	0.540	0.455–0.624	0.431
EO vs TT	117.4	59.3	55.8	0.564	0.470–0.658	0.210
IG (x10³/μL)						
EO vs C	0.06	44.5	78.2	0.590	0.523–0.656	0.011
TT vs C	0.12	45.9	60.9	0.531	0.429–0.634	0.539
EO vs TT	0.08	65.8	74.5	0.730	0.642–0.818	<0.001

* ROC Analysis, NLR: Neutrophil/lymphocyte ratio; PLR: Platelet/lymphocyte ratio; IG: Immature granulocyte; AUC: Area Under the Curve; CI: Confidence Interval.

are presented in Table 1. Patients with epididymo-orchitis were significantly older than those with testicular torsion (median 43 vs. 25 years, p<0.001, DSCF post hoc). Both disease groups exhibited higher leukocyte counts, neutrophil

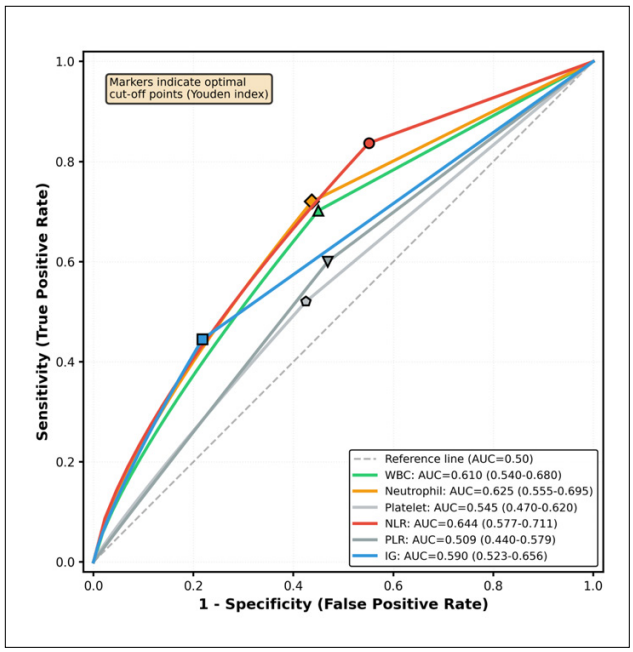

Figure 2. ROC Curves for Epididymo-orchitis vs control.

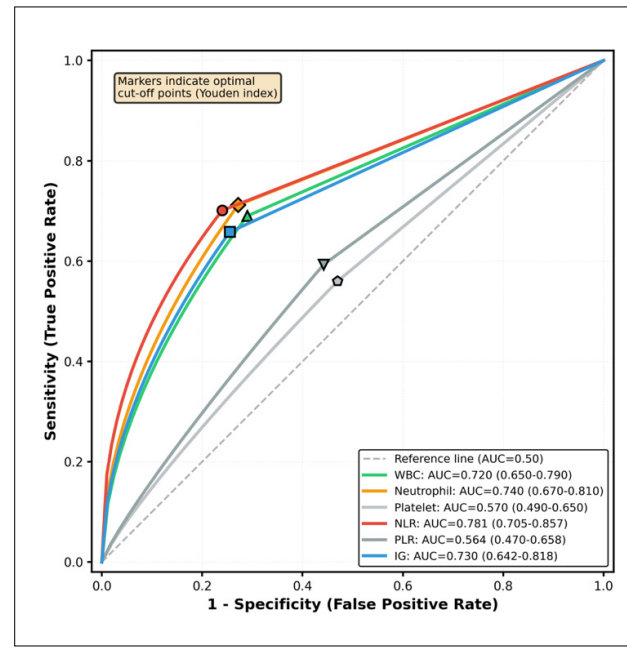

Figure 3. ROC Curves for Epididymo-orchitis vs Testicular Torsion.

counts, and NLR compared with the controls (p<0.001 for all). The IG count was also elevated in the epididymo-orchitis group compared with controls (median 0.05 vs 0.03, p<0.001, DSCF post hoc).

ROC analyses were performed to evaluate the diagnostic performance of CBC-derived parameters in differentiating epididymo-orchitis, testicular torsion, and control groups (Table 2). For epididymo-orchitis vs control, several inflammatory markers demonstrated statistically significant diagnostic accuracy. The NLR (cut-off = 2.19) showed the highest discriminative ability (AUC=0.644 [95% CI 0.577–0.711], p <0.001) with a sensitivity of 83.7% and specificity of 44.9%. This was followed by the neutrophil count (cut-off=7.2×10³/μL, AUC=0.625 [95% CI 0.555–0.695], p=0.001; sensitivity 72.0%, specificity 56.3%). IG count (cut-off=0.06) also demonstrated modest but statistically significant performance (AUC=0.590 [95% CI 0.523–0.656], p=0.011; sensitivity 44.5%, specificity 78.2%). In contrast, platelet count and PLR showed poor discriminatory ability (AUC=0.545 and 0.509, respectively; p>0.05). For testicular torsion vs control, none of the CBC-derived parameters reached statistical significance. All AUC values were close to 0.5, indicating poor diagnostic performance and limited utility for distinguishing torsion from healthy controls. When comparing epididymo-orchitis vs testicular torsion, the pattern was reversed. Both NLR (cut-off=3.12) and IG count (cut-off=0.08) exhibited strong discriminative performance (AUC=0.781

Table 3. Age-adjusted multivariable logistic regression models

Comparison	Variable	β	OR	95% CI	p-value*
Epididymo-orchitis vs Control					
NLR	0.157	1.17	1.05	1.31	0.005
IG count	0.817	2.26	1.10	4.63	0.027
Testicular torsion vs Control					
—	—	—	—	—	>0.05 (ns)
Epididymo-orchitis vs Testicular torsion					
NLR	0.190	1.21	1.09	1.35	<0.001
IG count	1.03	2.80	1.34	5.84	0.006

*Logistic Regression Analysis (age-adjusted), Backward stepwise. Epididymo-orchitis vs Control: AUC=0.76, McFadden R^2=0.21, Testicular torsion vs Control: AUC=0.63, McFadden R^2=0.09, Epididymo-orchitis vs Testicular torsion: AUC=0.83, McFadden R^2=0.26. OR, odds ratio; CI, confidence interval; AUC, area under the curve; R^2, McFadden's pseudo-R^2; IG, immature granulocyte; NLR, neutrophil-to-lymphocyte ratio; ns, not significant.

[95% CI 0.705–0.857] and 0.730 [95% CI 0.642–0.818], respectively; both p<0.001), while WBC, and neutrophil count also achieved good diagnostic accuracy (AUCs=0.720 [95% CI 0.650–0.790], 0.740 [95% CI 0.670–0.810], respectively; p<0.001 for all). PLR and PLT again demonstrated limited or nonsignificant performance. Overall, these findings suggest that NLR and IG count are the most consistent indicators for differentiating infection-related epididymo-orchitis from ischemia-driven testicular torsion, while WBC and neutrophil count may also provide supportive diagnostic information. Routine indices such as PLT and PLR, however, show minimal additional diagnostic value. Figures 2 and 3 present ROC curves for epididymo-orchitis versus control and epididymo-orchitis versus testicular torsion, respectively.

After adjustment for age and backward elimination of non-significant variables, distinct predictors were identified for each comparison (Table 3). For epididymo-orchitis vs control, both NLR (OR=1.17, 95% CI 1.05–1.31, p=0.005) and IG count (OR=2.26, 95% CI 1.10–4.63, p=0.027) remained independently associated with disease presence, whereas other CBC indices lost significance. For testicular torsion vs control, no variable reached statistical significance after age adjustment, indicating limited diagnostic value of CBC-derived parameters for torsion when compared with healthy controls. In contrast, for epididymo-orchitis vs testicular torsion, the NLR (OR=1.21, 95% CI 1.09–1.35, p<0.001) and IG count (OR=2.80, 95% CI 1.34–5.84, p=0.006) independently discriminated infection-related inflammation from ischemic pathology. Model performance was acceptable, with AUCs of predicted probabilities ranging from 0.72 to 0.83 and McFadden's R^2 values between 0.18 and 0.26. These findings suggest that NLR and IG count are the strongest hematologic indicators for differentiating epididymo-orchitis from testicular torsion, while other CBC parameters provide limited additional diagnostic contribution.

DISCUSSION

This study evaluated the diagnostic utility of CBC-derived parameters, particularly IGs, in differentiating epididymo-orchitis from testicular torsion in patients presenting with acute scrotal pain. The principal findings demonstrated that both the NLR and IG count were independently associated with epididymo-orchitis, whereas no CBC-derived variable showed significant diagnostic value for testicular torsion. Furthermore, NLR and IG count achieved the highest discriminative performance in distinguishing infection-related epididymo-orchitis from ischemia-driven torsion, outperforming traditional markers such as leukocyte count, platelet count, and PLR.

Acute scrotum is a time-critical emergency in which accurate differentiation between epididymo-orchitis and testicular torsion is essential to prevent irreversible testicular damage. Although Doppler US is the diagnostic gold standard, its accuracy can be affected by operator experience, equipment quality, and the timing of evaluation, particularly in early or intermittent torsion.[7,8] This study reinforces the emerging role of CBC-derived inflammatory indices as accessible and cost-effective adjuncts to clinical assessment and imaging in acute scrotal conditions. The significant rise of NLR and IG count in the epididymo-orchitis group supports the hypothesis that these markers reflect the early inflammatory cascade associated with infection, whereas their limited elevation in torsion aligns with a primarily ischemic mechanism. These findings are consistent with previous research showing that NLR and IG values correlate more strongly with infectious than ischemic etiologies.[1,2,7,9] Conversely, testicular torsion does not consistently trigger a marked systemic inflammatory response, particularly during the initial ischemic phase. Some studies have reported mild increases in leukocyte or neutrophil counts in testicular torsion, particularly when detorsion or reperfusion occurs, although the evidence remains inconsistent.[2,7] The absence of such changes in our torsion subgroup likely reflects the short symptom duration (< 12 hours) at presentation, before reperfusion injury develops. Although NLR and IG demonstrated moderate diagnostic performance in differentiating epididymo-orchitis from testicular torsion, their AUC values indicate that these markers should not be used as standalone diagnostic tools. Instead, they may serve as supportive adjuncts to clinical evaluation and imaging modalities, particularly in cases where diagnostic uncertainty exists. Importantly, these parameters should not replace clinical judgment or imaging findings in surgical decision-making but may provide additional supportive information in the acute scrotum setting. When comparing testicular torsion with healthy controls, however, no hematologic parameter showed meaningful diagnostic discrimination. This finding is consistent with the pathophysiologic mechanism of the disease. Torsion is primarily an ischemic process; therefore, the associated systemic inflammatory response is limited in the early phase. Some studies have suggested mild increases in inflammatory indices in torsion, mainly during reperfusion or delayed presentations, but these changes are neither specific nor consistent.[2] The relatively short symptom duration (<12 hours) in our patient population may also explain the lack of hematologic response in torsion cases.

In previous studies, PLR did not consistently differentiate testicular torsion from epididymo-orchitis, with some authors reporting no significant differences in PLR between groups, while platelet indices such as mean platelet volume (MPV) appeared more promising in specific settings. Similar observations have been reported in studies, in which PLR failed to demonstrate significant discriminatory power between torsion and epididymo-orchitis, possibly due to its susceptibility to changes in platelet activity during systemic inflammation.[2,4,7,10-13] According to the literature, our study showed that PLR and PLT demonstrated limited or nonsignificant performance.

A key advantage of this study is its comparatively large sam-

ple size, standardized hematologic measurements, and direct comparison between torsion, epididymo-orchitis, and control groups. Even so, some limitations must be recognized. Because the study was retrospective and conducted in a single center, there is a possibility of selection bias, and the smaller number of torsion cases reflects the lower incidence of this condition. Although lower number reflects the real-world incidence of testicular torsion, it may limit statistical power, particularly for ROC curve analyses and multivariable regression models. Therefore, the results should be interpreted with caution, and further studies with larger, multicenter cohorts are warranted to validate our findings. In cases of testicular torsion, patients often present early due to acute and severe pain, which may limit the development of a measurable systemic inflammatory response at the time of admission. Additionally, prior antibiotic use before hospital presentation, particularly in patients with epididymo-orchitis, may alter inflammatory parameters and introduce variability in hematological findings. As information regarding pre-hospital antibiotic use and symptom duration was not consistently available, these factors could not be adjusted for in the analysis and should be considered when interpreting the results. Another methodological consideration is the use of pairwise binary comparisons rather than hierarchical or multinomial modeling. Although appropriate for evaluating marker performance under defined conditions, this approach may not fully reflect the sequential decision-making process in emergency practice, where exclusion of testicular torsion is the primary diagnostic priority. Future multicenter studies with larger cohorts may benefit from hierarchical modeling strategies that better mirror real-world clinical workflows.

CONCLUSION

Hematologic parameters, particularly the NLR and IG, demonstrated moderate diagnostic utility in distinguishing epididymo-orchitis from testicular torsion, but their ability to differentiate testicular torsion was limited. NLR and IG count appear to be practical, accessible, and cost-effective indicators that may help distinguish epididymo-orchitis from testicular torsion. Integrating these hematologic parameters into the early evaluation of patients with acute scrotal symptoms, together with clinical examination and Doppler US, has the potential to improve diagnostic accuracy and support timely decision-making. Future studies should prioritize multicenter studies to validate these findings across diverse populations and healthcare settings. Additionally, research should focus on identifying standardized cutoff values for the NLR and IG, exploring the impact of symptom duration and infection severity, and integrating these markers into comprehensive diagnostic protocols to enhance clinical decision-making.

Ethics Committee Approval: This study was approved by the SBU İstanbul Training and Research Hospital Clinical Research Ethics Committee (Date: 25.02.2025, Decision No: 22).

Peer-review: Externally peer-reviewed.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Epididimo-orşit ile testiküler torsiyonun ayırıcı tanısında immatür granülosit ve nötrofil/lenfosit oranının tanısal değeri

AMAÇ: Testis torsiyonu önemli bir ürolojik acil durumdur ve erken teşhis çok önemlidir. Bu çalışmada, akut skrotum ile başvuran hastalarda epididimo-orşit ve testiküler torsiyonun ayırıcı tanısında hematolojik parametrelerin, özellikle immatür granülosit (IG) düzeyinin tanısal değerini değerlendirmek amaçlandı.

GEREÇ VE YÖNTEM: Bu retrospektif kohort çalışmasına, Ocak 2020–Aralık 2024 tarihleri arasında akut skrotal ağrı nedeniyle başvuran ve Doppler ultrasonografi veya cerrahi eksplorasyon ile tanısı doğrulanan 301 erkek hasta dahil edildi. Hastalar epididimo-orşit (n=200), testiküler torsiyon (n=37) ve kontrol (n=64) olmak üzere üç gruba ayrıldı. Tam kan sayımı parametreleri (lökosit, nötrofil, lenfosit, trombosit, IG, NLR, PLR) değerlendirildi. Gruplar arası karşılaştırmalar Kruskal–Wallis ve Dwass–Steel–Critchlow–Fligner testleri ile yapıldı. ROC analizi ile AUC, duyarlılık ve özgüllük değerleri hesaplandı. Yaşa göre düzeltilmiş çok değişkenli lojistik regresyon analizi ile bağımsız belirteçler tanımlandı.

BULGULAR: Epididimo-orşit grubunda NLR (cut-off=2.19, AUC=0.644, p<0.001) ve IG düzeyleri (cut-off=0.06, AUC=0.590, p=0.011) kontrol grubuna göre anlamlı derecede yüksekti. Torsiyon grubunda hiçbir parametre anlamlı ayırt edici değer göstermedi. Epididimo-orşit ile torsiyon karşılaştırmasında ise NLR (AUC=0.781, p<0.001) ve IG (AUC=0.730, p<0.001) en yüksek tanısal performansa sahipti. Lojistik regresyon analizinde NLR (OR=1.17, 95% GA 1.05–1.31, p=0.005) ve IG (OR=2.26, 95% GA 1.10–4.63, p=0.027) epididimo-orşitin bağımsız belirteçleri olarak bulundu.

SONUÇ: İmmatür granülosit sayısı ve NLR, akut skrotumda epididimo-orşit ile testiküler torsiyonun ayırıcı tanısında yararlı hematolojik biyobelirteçlerdir. Bu kolay erişilebilir parametrelerin klinik değerlendirme ve görüntüleme yöntemlerine eklenmesi, tanısal doğruluğu artırabilir ve acil serviste hızlı karar vermeyi destekleyebilir.

Anahtar sözcükler: Epididimo-orşit; immatür granülosit; testiküler torsiyon.

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ORIGINAL ARTICLE

A retrospective review of patients admitted to a tertiary intensive care unit following the February 6th earthquake in Türkiye

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ABSTRACT

BACKGROUND: The Kahramanmaraş earthquake that occurred in Türkiye in 2023 affected 14 million people, resulting in 53,537 deaths and more than 100,000 injuries. In large-scale disasters, it is crucial to rapidly initiate complex treatment processes in hospitals equipped with tertiary intensive care units following the initial on-site response. In this study, we aimed to retrospectively analyze the types of trauma and the associated surgical and medical treatments of patients affected by the earthquake who were admitted to our level 3 intensive care unit. Our objective was to contribute to future disaster preparedness planning in healthcare institutions and to improve intensive care treatment strategies.

METHODS: This retrospective single-center study was conducted at Mersin City Training and Research Hospital. Clinical data of patients treated in the tertiary intensive care unit were reviewed. The recorded variables included demographic characteristics, time of hospital admission, length of hospital stay, complete blood count, creatine kinase, myoglobin, albumin levels, liver and renal function tests, Acute Physiology and Chronic Health Evaluation II (APACHE II) score, type of trauma, presence of crush syndrome and acute kidney injury, surgical interventions and types of surgery, renal replacement therapy, blood transfusion, fluid therapy, nutritional support, requirement for mechanical ventilation, psychiatric support, hyperbaric oxygen therapy, mortality, and referral to another hospital.

RESULTS: A total of 80 patients were included in the study; 53.8% were female, and the mean age was 49.93 years. The overall mortality rate was 22.5%. The mean age was higher in the mortality group, and lymphocyte count was also significantly higher in this group. The proportion of patients receiving renal replacement therapy was greater in the mortality group compared to survivors (p=0.035). Eleven patients died within the first five days of admission, and 13 of the deceased patients had acute kidney injury. Mechanical ventilation and total parenteral nutrition were more frequently required in the mortality group.

CONCLUSION: Advanced age, the need for total parenteral nutrition, renal replacement therapy, and mechanical ventilation were identified as predictors of mortality among trauma patients followed in a tertiary intensive care unit.

Keywords: Earthquake; intensive care; mortality; renal replacement therapy.

INTRODUCTION

Two major earthquakes (an earthquake doublet occurring within 9 hours, with magnitudes of 7.7 and 7.6 on the Richter scale) struck Türkiye on February 6, 2023. The Kahramanmaraş earthquake sequence directly affected 11 cities. This disaster impacted 14 million people, resulting in 53,537 registered deaths, more than 100,000 injuries, and

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damage to approximately 40,000 buildings, including hospitals.[1] In natural disasters, healthcare services are initiated at the scene, and injured individuals are transported to the nearest healthcare facility. Patients requiring advanced care are subsequently referred to centers capable of providing more complex treatments. Following triage, those in need of critical care are admitted to intensive care units. Patients with multiple trauma often undergo major surgical procedures and require close monitoring in the intensive care unit.[2-5] The localization of trauma, the presence of crush syndrome, and the supportive and resuscitative treatments administered in the intensive care unit, particularly for patients who developed crush syndrome, are considered key determinants of survival and morbidity. Crush syndrome is frequently observed in patients admitted to the intensive care unit after being trapped under debris. Increased vascular permeability and disruption of the cell membrane lead to massive fluid accumulation in the interstitial space.

Compartment syndrome and hypovolemia accompanying trauma are considered important factors that increase mortality, particularly in the presence of acute kidney injury and crush syndrome. The timely implementation of surgical interventions, in addition to appropriate medical treatment, significantly improves prognosis through a multidisciplinary approach.[5-7]

Additionally, service capacity can be enhanced through the safe referral of suitable patients to advanced healthcare institution outside the affected region, allowing qualified beds in large-scale hospitals near the disaster area to remain available for ongoing triage and new admissions.[4] Following the Kahramanmaraş earthquake, our hospital admitted patients both directly and through referral due to its proximity to the disaster region. After triage, patients requiring critical care were admitted to the hospital's intensive care units.

In this study, we aimed to analyze the clinical and demographic characteristics of earthquake victims admitted to our tertiary resuscitation intensive care unit and to compare the features of survivors and non-survivors.

We also aimed to evaluate the admission and treatment algorithms applied in our intensive care unit. Specifically, we examined the contributions of medical and surgical treatments to morbidity in patients with crush syndrome, as well as the types and severity of trauma observed. Based on the data obtained, we sought to generate analyses that may help develop strategies to reduce morbidity and mortality in similar natural disasters and to guide best practices for hospitals with tertiary intensive care units.

MATERIALS AND METHODS

After obtaining approval from the Mersin University Clinical Research University Clinical Research Ethics Committee (20/03/2024-06-283), the medical records of patients admitted to the tertiary intensive care unit of Mersin City Training and Research Hospital between February 6, 2023 and March 6, 2023, who had been referred from the earthquake region, were analyzed using the hospital information management system (HIMS). Patients who were transferred to another center immediately after initial admission were excluded from the study. The following data were recorded: demographic characteristics, time of hospital admission, length of hospital stay, laboratory parameters at admission and on the third day of intensive care (complete blood count [CBC], creatine kinase [CK], myoglobin, albumin levels, liver and renal function tests [creatinine, glomerular filtration rate (GFR)]), Acute Physiology and Chronic Health Evaluation II (APACHE II) score, type of trauma, presence of crush syndrome and acute kidney injury, surgical interventions and types of surgery, renal replacement therapy, blood product use, daily fluid therapy, nutritional support, requirement for mechanical ventilation, psychiatric support, use of hyperbaric oxygen therapy, mortality, and referral to another healthcare facility. Informed consent for treatment was obtained from the patients or their first-degree relatives. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Statistical Analysis

The distribution of variables was assessed using the one-sample Kolmogorov-Smirnov test. Qualitative data were presented as numbers and percentage, while quantitative data were expressed as mean±standard deviation. Group comparisons were performed using the Mann-Whitney U test or Student's t-test. Categorical data were compared using the Chi-square test and presented as numbers and percentages.

Significant predictors of mortality were determined using binary logistic regression analysis. All analyses were performed using the Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL), version 20. Statistical significance was set at $p<0.05$ for all analyses.

RESULTS

After the initial enrollment of 120 cases, 40 patients who were referred to other healthcare facilities in the region were excluded from the study. A total of 80 patients, including 43 females, were included in the final analysis (Table 1). The mean age was 49.93 years. The overall mortality rate was 22.5%. In the mortality group, the mean age and lymphocyte count were significantly higher compared to the survivor group ($p=0.013$ and $p=0.022$, respectively) (Table 2). On day 1, blood creatinine levels, age, and APACHE II scores were significantly higher in the mortality group than in the survivor group ($p=0.04$, $p=0.013$, and $p=0.000159$, respectively) (Table 3). Renal replacement therapy was administered to 50% of patients in the mortality group, which was significantly higher compared to 24.2% in the survivor group ($p=0.035$) (Table 4). In the mortality group, age, total parenteral nutrition (TPN) use, and renal replacement therapy were significantly more frequent ($p=0.020$ and $p=0.006$) (Table 5). Acute kidney injury was reported as the cause of death in 11 of the 18 de-

Table 1. Demographic characteristics of patients

Variable	Mortality (n=18) Mean±SD	Survival (n=62) Mean±SD	p-value
Age (years)	54.00±19.98	41.00±18.74	**0.013***
WBC (Day 1)	19.17±8.50	16.64±10.69	0.359
NEU (Day 1)	16.00±6.68	13.92±9.90	0.407
PLT (Day 1)	25.20±11.42	24.78±10.97	0.876
Albumin (Day 1)	3.18±0.58	3.12±0.52	0.693
Monocytes (Day 1)	1.00±0.69	0.82±0.51	0.227
Neu/Lym (Day 1)	12.32±7.14	13.37±8.87	0.647
Plt/Lym (Day 1)	210.70±137.75	250.87±156.32	0.232
Mon/Lym (Day 1)	0.72±0.44	0.79±0.51	0.594
Daily fluid volume (L)	4.61±1.68	4.69±1.44	0.838
Time from trauma to ICU (days)	6.56±5.74	4.39±4.53	0.097
ICU length of stay (days)	8.28±9.65	6.16±6.05	0.262

*P<0.05; aStudent's t-test; bChi-square test; *Non-homogeneous variable.

Table 2. Regression analysis

Variable	Mortality (n=18) Median (95% CI)	Survival (n=62) Median (95% CI)	p
LYM (Day 1)*	1.26 (0.85–2.82)	1.04 (0.84–1.37)	0.022*
CK (Day 1)*	10,000 (180–10,000)	10,000 (489–10,000)	0.465
Myoglobin (Day 1)*	10,000 (609–10,000)	10,000 (337–10,000)	0.090

Table 3. Comparison of kidney function tests

Variable	Survivors (n=62)	Mortality (n=18)	p
Age (years)	41.00±18.74	54.00±19.98	**0.013***
GFR1	80.4±57.71	60.69±42.49	0.051
GFR2	93.95±58.21	59.76±44.19	0.09
Creatinine 1	1.66±1.49	2±1.67	**0.04***
Creatinine 2	1.51±1.59	1.75±1.1	0.173
APACHE II score	14.15±7.51	21.15±9.9	**0.000159***
Female gender, n (%)	33 (53.2)	10 (55.6)	0.861

p<0.05; Mann-Whitney U test; GFR1 (first-day GFR); GFR2 (third-day GFR); Creatinine 1 (first-day creatinine); Creatinine 2 (third-day creatinine).

Table 4. Intensive care unit characteristics

Variable	Mortality (n=18) N (%)	Survival (n=62) N (%)	p
Male gender, % (n)	44.4 (8)	46.8 (29)	0.861
Renal replacement therapy, % (n)	50 (9)	24.2 (15)	0.035*
Head injury, % (n)	16.7 (3)	16.1 (10)	0.957
Extremity injury, % (n)	61.1 (11)	79 (49)	0.122
Trunk injury, % (n)	38.9 (7)	43.5 (27)	0.725
Mechanical ventilation	94.4 (17)	22.6 (14)	<0.001*
FFP transfusion	27.8 (5)	14.5 (9)	0.192
ES transfusion	44.4 (8)	58.1 (36)	0.307
TS transfusion	11.1 (2)	0 (0)	0.192
Psychiatric support	0 (0)	25.8 (16)	N/A
Surgery	38.9 (7)	54.8 (34)	0.233
External referral	0 (0)	16.1 (10)	0.957
Crush syndrome	61.1 (11)	45.2 (28)	0.233
AKI	61.1 (11)	46.8 (29)	0.284
Hyperbaric therapy	11.1 (2)	9.7 (6)	0.858
Oral nutrition	38.9 (7)	88.7 (55)	<0.001*
Enteral nutrition	11.1 (2)	9.7 (6)	0.858
Total parenteral nutrition	94.4 (17)	59.7 (37)	0.006*
Inotropic support	100 (18)	0 (0)	N/A

*P<0.05; aStudent's t-test. FFP: Fresh frozen plasma; ES: Erythrocyte suspension; PS: Platelet suspension; AKI: Acute kidney injury.

Table 5. Multivariate analysis

Variable	OR	95% CI	P value
Year	1.038	1.006–1.071	0.020*
Lymphocyte count	1.032	0.614–1.245	0.158
TPN	9.591	1.139–79.553	0.006*
Renal replacement therapy	1.968	0.466–8.310	0.035*
Mechanical ventilation	39.58	4.632–338.247	<0.001*

p<0.05; Mann-Whitney U test; GFR1 (first-day GFR); GFR2 (third-day GFR); Creatinine 1 (first-day creatinine); Creatinine 2 (third-day creatinine).

ceased patients (61.1%). (Tables 6 and 7). Fasciotomy was the most commonly performed trauma-related surgery (17.8%). Additionally, a cesarean section was performed on one pregnant patient with extremity trauma (Table 8).

DISCUSSION

This study demonstrated that the higher rate of hemodialysis in the mortality group indicates that crush syndrome is a major contributor to mortality, and the need for renal replacement therapy (RRT) has predictive value for mortality. Furthermore, the requirement for mechanical ventilation was also found to be a predictor of mortality. At admission, lymphocyte counts were significantly higher in survivors.

Similar to the February 6, 2023 Kahramanmaraş earthquake in Türkiye, large-scale natural disasters worldwide have dem-

Table 6. Causes of death among deceased patients

Diagnosis	Sequence No	Day of Admission	Length of Stay
ARDS	1	1	15
Acute kidney injury	2	2	3
ARDS	3	1	10
Acute kidney injury	4	2	2
Acute kidney injury	5	3	1
Acute kidney injury	6	3	8
Acute kidney injury	7	17	4
Sepsis	8	13	41
Head trauma	9	2	5
Acute kidney injury	10	16	1
Acute kidney injury	11	3	1
Head trauma	12	6	17
ARDS	13	17	3
Acute kidney injury	14	3	1
ARDS	15	11	13
Acute kidney injury	16	7	6
Acute kidney injury	17	3	12
Acute kidney injury	18	5	6

Table 7. Mortality rates

Diagnosis	N=18 n (%)
AKI	11 (61.11%)
ARDS	4 (22.22%)
Head trauma	2 (11.11%)
Sepsis	1 (5.55%)

onstrated that well-organized rescue operations at the disaster site and within the rubble are of critical importance. Additionally, survival rates can be increased and morbidity reduced through a rapid and well-coordinated advanced frontline healthcare organization.[2,3,5,8,9] An emergency alarm was issued on the morning of February 6 in accordance with the administrative decision of our hospital management. Patients who were eligible for discharge or transfer from the intensive care unit were evacuated, and 300 hospital beds in total (100 of which were intensive care beds) were allocated for potential patients from the disaster area.

In this regard, the study by Kulakoğlu et al., which included data from Kilis State Hospital in the earthquake region, reported that while the bed occupancy rate was 72.7% before the disaster, it was reduced to 12% following triage under the declared state of emergency, thereby making beds available for emergency management.[10]

It was anticipated that the need for tertiary intensive care beds for earthquake victims at our hospital would gradually increase starting from the first day. Patients who were treated and stabilized but still required tertiary intensive care were referred from our hospital to centers outside the affected region. Ultimately, 18 earthquake victims were successfully transferred from our tertiary intensive care unit by ground and air ambulance. Previous relevant studies have not provided detailed information regarding intercity transfers of patients from one intensive care unit to another.

Similar to findings from studies conducted after the 1999 Marmara earthquake, early access to healthcare services was shown to have a positive impact on survival rates and to reduce complications.[7,10] In his study, Koyuncu reported that the time from entrapment under the rubble to arrival at a healthcare facility ranged between 4 and 36 hours, with a mean of 8 hours.[11] Gürü et al. stated that the highest number of patient admissions occurred on the third and fourth days at a hospital in Ankara, which served as a distant referral center after the February 6 earthquake.[12] Similarly, Bulut et al., reporting their experience after the Marmara earthquake, indicated that the highest number of admissions occurred on

Table 8. Types of surgical procedures in mortality and survival groups

Type of Surgery	Total (n=80) n (%)	Mortality (n=18)	Survival (n=62)
Fasciotomy	13 (17.8%)	2	11
Laparotomy	2 (2.7%)	1	1
Tube thoracostomy	11 (15.4%)	3	8
Amputation	7 (9.58%)	1	6
Lower extremity fracture	12 (16.4%)	3	9
Upper extremity fracture	4 (5.47%)	2	2
Debridement	10 (13.6%)	-	10
Flap	2 (2.7%)	-	2
Grafting	2 (2.7%)	-	2
Pelvic fracture repair	3 (4.1%)	-	3
Cesarean section	1 (1.36%)	-	1
Splenectomy	1 (1.36%)	-	1
Vertebral fracture	4 (5.47%)	1	3
Perianal repair	1 (1.36%)	1	-
Total	73 (100%)	14	59

the third and fourth days.[13] In our study, 50 earthquake victims (62.5%) admitted to the intensive care were hospitalized within the first three days. Due to our hospital's proximity to Hatay by sea and air, the number of admissions from this region was higher during the first three days. Although there was no statistically significant difference between survivors and non-survivors in terms of intensive care unit admission after trauma, survivors tended to arrive earlier (4-39 days), whereas deceased patients were admitted later (6-56 days).

Furthermore, the platelet-to-lymphocyte ratio (PLR), neutrophile-to-lymphocyte ratio (NLR), and monocyte-to-lymphocyte ratio (MLR) are associated with inflammatory processes related to trauma, immune response, infection, and blood vessel wall inflammation. Several studies have investigated whether elevated levels of these ratios are associated with increased morbidity and mortality.[14-17] In our analysis, NLR, MLR, and PLR values calculated from admission blood samples were lower in the deceased patient group; however, no statistically significant difference was observed between survivors and non-survivors. When lymphocyte count was evaluated, it was higher in survivors.

Previous studies have shown that extremity, trunk, head, and spinal injuries are the most common types of trauma among earthquake victims. It has also been reported that patients frequently present to emergency departments in severe clinical conditions, including crush syndrome, hemorrhage, hemorrhagic diathesis, respiratory failure, and central nervous system injury.[3,8,11] The study by Kundakçı et al. reported that head and neck injuries, as well as extremity traumas, were associated with increased mortality.[18] In our study, extremity trauma was the most common type of injury among patients admitted to our tertiary intensive care unit, whereas head trauma was the least common. No difference was found between survivors and non-survivors in terms of the anatomical location of trauma.

Among 32 patients treated by Li et al. in a tent intensive care unit following the 2008 Wenchuan earthquake, 17 were diagnosed with crush syndrome, nine with acute renal failure (ARF), and four with multiple organ dysfunction syndrome (MODS). Six patients (18.75%) died: four due to MODS and two due to ARF.[2]

In a review conducted by Erek et al., which included 639 earthquake victims hospitalized in 35 different centers after the 1999 Marmara earthquake, 512 patients had extremity injuries, 100 had thoracic or abdominal trauma, and 323 underwent fasciotomy. The study reported that 477 patients (74.6%) with acute kidney injury secondary to crush syndrome received dialysis treatment one or more times, while 147 patients recovered without dialysis.[19] In their study, Buyurgan et al. analyzed 1,110 earthquake victims who presented to the emergency department as either directly or via transfer. They reported that 18.8% of patients developed crush syndrome and 3% developed acute kidney injury. These patients were hospitalized and treated with emergency inter-

ventions, RRT, amputation, fasciotomy, and fluid therapy as indicated.[20] Similarly, Huang's study on the Chi-Chi earthquake emphasized the importance of fluid therapy, as well as timely fasciotomy and amputation when necessary, in the management of crush syndrome.[21] In the study by Demirkan et al., conducted at a center where 18 trauma patients were treated following the Marmara earthquake, 12 patients required mechanic ventilator support. Seven patients underwent fasciotomy due to extremity trauma, six underwent amputation, seven received RRT, and six received continuous renal replacement therapy (CRRT). ARF developed in 13 patients. Five patients died due to multiple organ failure (MOF), and two died due to sepsis.[7] Similarly, Bulut et al., in their report on experiences after the Marmara earthquake, identified crush syndrome as the most frequent cause of death.[13] These studies demonstrated that crush syndrome and acute kidney injury had a significant impact on mortality and morbidity among earthquake victims.[2,7,18-20] It was also reported that, within the first 24 hours, fluid resuscitation combined with prompt surgical intervention was implemented under close monitoring.[2,5,7]

In our study, 60 of the 80 earthquake victims admitted to our tertiary intensive care unit had extremity trauma. During follow-up, 39 patients developed crush syndrome and 40 developed acute kidney injury (AKI). Patients received fluid therapy consisting of 20% mannitol (150 mL) and 0.9% NaCl buffered with bicarbonate, administered up to a total of 4-6 liters per day. Among the 40 patients who developed acute kidney injury, renal replacement therapy was initiated when indicated, in addition to fluid resuscitation. Considering the high number of admissions during the first days after the earthquake, the predominance of young and middle-aged patients, and the fact that these were primary admissions to our hospital, creatinine levels were used as the primary indicator of renal function in this dynamic intensive care setting. Accordingly, acute kidney injury was defined based on serum creatinine levels in accordance with the KDIGO (Kidney Disease: Improving Global Outcomes) guidelines to assess renal function in our study, as the role of GFR in AKI staging has not yet been clearly established.[22] Patients with renal injury were classified into two groups: Stage 1-2 (mild to moderate AKI) and Stage 3 (severe AKI). Since baseline creatinine levels were unknown, increases in creatinine were estimated based on patient age and overall clinical condition. Patients with Stage 3 AKI required renal replacement therapy and had serum creatinine levels above 4. Pre-earthquake health records, hospital system data, and e-Pulse records could not be accessed due to lack of authorization. Therefore, creatinine levels were assumed to be normal in most young patients without comorbidities. If creatinine levels were within the normal range at initial presentation, AKI classification was based on subsequent increases in creatinine levels over time.

A total of 41 patients underwent surgical procedures. The three most common operations were fasciotomy, lower extremity fracture repair, and tube thoracostomy. Cesarean section, perianal repair, and splenectomy were each performed in one patient. In the mortality group, limb fracture surgery was performed in 5 of the 18 deceased patients.

Amputation was performed in seven patients overall and was the fifth most common surgical procedure after debridement. Hyperbaric oxygen therapy was administered to eight patients with severe extremity injuries. Thirty-one patients required mechanical ventilation.

APACHE II scores were higher in the mortality group. Eleven of the 18 patients who died had acute kidney injury, and 11 patients died within the first five days of admission. Regarding causes of death, one patient died of sepsis, two of head trauma, and four of acute respiratory distress syndrome (ARDS). Our results showed that 11 of the 18 deceased patients were diagnosed with crush syndrome-associated AKI and received RRT; all were classified as Stage 3 AKI. There was no significant difference in the prevalence of crush syndrome between non-survivors and survivors. However, crush syndrome was associated with an increased need for RRT and higher mortality. In addition, the requirement for mechanical ventilation was found to be a predictor of mortality.

The number of operated patients was higher among survivors, and the most common procedures were fasciotomy and amputation. The higher rate of surgical interventions in this group suggests that timely surgical management may have contributed to survival and allowed for additional corrective procedures as patients' survival time increased.

In the study by Koyuncu et al., 123 earthquake victims received erythrocyte suspension (ES), 69 received fresh frozen plasma (FFP), and a total 1,008 units of blood products were administered.[11] In our study, ES, FFP, and platelet suspension (PS) were the most frequently transfused blood products. Among survivors, FFP was administered to nine patients and ES to 36 patients. In the mortality group, FFP was administered to five patients, ES to eight patients, and PS to two patients. Platelet suspension was administered only to two patients in the mortality group. The higher proportion of FFP and PS transfusions in the mortality group suggests that coagulation disorders were more severe among deceased patients.

When analyzing nutritional support in patients treated at our tertiary intensive care unit, an aspect not widely addressed in the studies we reviewed, we found that total parenteral nutrition was the most commonly used method. In the mortality group, nutrition was provided exclusively via TPN, as gastrointestinal feeding was not feasible due to the requirement for inotropic support in all deceased patients. In contrast, patients in the survivor group were predominantly able to resume oral feeding after a short period of TPN. There are very few studies reporting psychiatric support provided in intensive care units during disaster periods. In our study, four patients received psychiatric support during their ICU stay. Only one of these patients required pharmacological treat-

ment, which was initiated after psychiatric evaluation. All four patients received psychotherapy and were encouraged to maintain family contact more frequently than other patients.

After initial treatment in the intensive care unit, 40 of the 120 stabilized patients whose treatment was expected to be prolonged and who were deemed suitable for transfer were referred to hospitals outside the province by ground ambulance. These transfers were confirmed in advance in order to free intensive care beds for new patients expected to arrive.

Limitations

This study had certain limitations. First, no information could be obtained regarding the clinical outcomes of the referred patients, as follow-up data were not accessible. Additionally, there were missing data in the medical records of the earthquake victims, particularly regarding renal function from the time of the disaster until hospital admission. Therefore, detailed analyses of these parameters could not be performed.

CONCLUSION

Effective organization of emergency healthcare service lines in disaster areas after an earthquake, the rapid completion of each stage of care, and the treatments applied in the intensive care unit are significant factors that influence survival and serve as key determinants of prognosis. Compartment syndrome, which is frequently encountered in such injuries, is managed with fasciotomy, amputation, fluid resuscitation, renal replacement therapy, and antibiotic treatment. Ventilatory and nutritional support are also important components that directly affect prognosis. It should be emphasized that the safe referral of stabilized earthquake victims to advanced healthcare institutions enables the admission of new patients to available intensive care beds. To ensure that these processes are carried out accurately and systematically, we believe that hospitals should establish disaster plans and develop written protocols for post-disaster patient management. Such structured preparation may assist physicians in patient follow-up during future disasters. Further detailed research is needed to develop management algorithms.

Ethics Committee Approval: This study was approved by the Mersin University Clinical Research University Clinical Research Ethics Committee (Date: 20.03.2024, Decision No: 2024-06-283).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Türkiye'de 6 Şubat depreminde üçüncü basamak yoğun bakım ünitesinde tedavi edilen hastaların retrospektif olarak incelenmesi

AMAÇ: Türkiye'de 2023 yılında meydana gelen Kahramanmaraş depremi 14 milyon insanı etkilemiştir. Deprem 53.537 kişinin ölümüne ve 100.000'den fazla yaralının geride kalmasına neden olmuştur. Bu tür büyük afetlerde, sahada ilk müdahaleyi takiben gelişmiş yoğun bakım ünitesine sahip hastanelerde komplike tedavi süreçlerinin hızla başlatılması çok önemlidir. Bu çalışmada, depremden etkilenen ve 3. seviye yoğun bakım ünitemize kabul edilen hastaların travma türlerini, ilişkili cerrahi ve tıbbi tedavilerini retrospektif olarak analiz etmeyi planladık. Sonuç olarak, sağlık kurumlarında doğal afetlere yönelik hazırlıklar ve yoğun bakım ünitesindeki tedavi stratejileri hakkında ileriye dönük yapılacak planlamalara ilham olmayı amaçladık

GEREÇ VE YÖNTEM: Bu retrospektif tek merkezli çalışma, Mersin Şehir Eğitim ve Araştırma Hastanesi'nin üçüncü basamak yoğun bakım ünitesinde tedavi gören hastaların klinik bilgilerinin toplandığı bir çalışmadır. Hastaların demografik verileri, hastaneye geliş zamanı, hastanede kalış süresi, tam kan sayımı, kreatin kinaz, miyoglobin, albümin düzeyleri, karaciğer ve böbrek fonksiyon testleri, APACHE II skoru, travma tipi, ezilme sendromu, akut böbrek hasarı varlığı, cerrahi girişim, cerrahi tipleri, renal replasman tedavisi, kan transfüzyonu, sıvı tedavisi, beslenme desteği, mekanik ventilasyon ihtiyacı, psikiyatrik destek, hiperbarik oksijen tedavisi, mortalite, başka bir hastaneye sevk edilme durumları kaydedildi.

BULGULAR: Bu çalışmaya %53.8'i kadın olan ve yaş ortalaması 49.93 olan 80 hasta dahil edilmiştir. Mortalite oranı %22.5 olup ortalama yaş daha yüksektir, aynı şekilde lenfosit sayısı da anlamlı derecede yüksek bulunmuştur. Mortalite grubunda renal replasman tedavisi alan hasta yüzdesi sağ kalan gruba göre daha yüksekti. (p=0.035) Ölen hastaların 13'ünde akut böbrek hasarı mevcuttu ve 11 hasta ilk beş gün içinde öldü. Mekanik ventilasyon ve total parenteral beslenme uygulanan hastalar ölüm grubunda daha yaygındı.

SONUÇ: Üçüncü basamak yoğun bakım ünitesinde takip edilen travma hastalarında ileri yaş, total parenteral beslenme, renal replasman tedavisi ve mekanik ventilasyon varlığı mortalite için prediktör olarak bulunmuştur.

Anahtar sözcükler: Deprem; mortalite; renal replasman tedavisi; yoğun bakım.

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ORIGINAL ARTICLE

Treatment method selection for perianal abscesses: Bedside or operating room? a single-center retrospective study

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ABSTRACT

BACKGROUND: This study aims to evaluate the effect of the type of intervention (bedside vs. operating room incision and drainage) on clinical outcomes in the treatment of perianal abscess and to identify predictive factors that may be effective in determining the type of intervention.

METHODS: A retrospective study was conducted on 213 patients who underwent incision and drainage (I&D) for cryptoglandular perianal abscess. Patients were divided into "bedside I&D" and "operating room I&D" groups according to the type of intervention. Demographic characteristics, laboratory values, abscess size, early complications, and long-term fistula development were compared. Receiver operating characteristic (ROC) analysis was performed to determine cut-off values for white blood cell count (WBC), C-reactive protein (CRP), and abscess size; subsequently, logistic regression analyses were performed using these parameters.

RESULTS: WBC count, CRP levels, and abscess size were statistically significantly higher in the operating room group ($p<0.001$). According to ROC analysis, cut-off values were determined as 14.68×10^9/L for WBC, 55.7 mg/L for CRP, and 29.5 mm for abscess size. While CRP lost statistical significance in univariate regression analysis, WBC and abscess size were identified as independent predictive factors for determining the intervention site in multivariate analysis. During long-term follow-up, fistula development was observed significantly more frequently in the operating room group ($p=0.002$).

CONCLUSION: WBC level and abscess size may be valuable predictors in deciding the type of intervention for perianal abscess treatment. Bedside I&D can be safely performed in low-risk cases, whereas operating room intervention should be preferred in patients with high inflammatory markers and larger abscesses.

Keywords: Bedside; incision and drainage; operating room; perianal abscess.

INTRODUCTION

Perianal abscesses are common anorectal conditions, with an estimated 100,000 cases of anorectal abscesses occurring annually in the United States.[1] Although the vast majority are reported to be of cryptoglandular origin, Crohn's disease, male sex, diabetes, and smoking are among the best-defined risk factors.[2] Treatment of perianal abscesses requires surgical intervention, usually performed through incision and drainage (I&D). However, current guidelines do not provide a clear recommendation regarding the most appropriate intervention setting (bedside or operating room) for the treatment of perianal abscesses.[3-5]

The predictive risk factors that should be considered when determining the type of intervention (bedside or operating room) for perianal abscess treatment have not been clearly defined in the literature.[6] It is thought that interventions performed in the operating room (OR) setting allow greater precision, thus providing better results, such as lower ab-

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scess recurrence and reduced fistula formation.[7] However, although no definite difference has been demonstrated between incision and drainage procedures performed at the bedside and those performed in the OR in terms of cost and bed usage time, it has been reported that drainage procedures performed in the OR within the scope of day surgery may be more advantageous in terms of both cost and bed utilization rates.[6,8,9] Nevertheless, the effects of both types of interventions on clinical outcomes and whether there are differences in long-term complications remain controversial in the literature.

This study aimed to compare the effects of the type of intervention (bedside vs. OR) on clinical outcomes in the treatment of perianal abscess and to identify the advantages and disadvantages of these two methods, thereby contributing to the determination of objective criteria for treatment selection.

MATERIALS AND METHODS

The data of patients who underwent perianal abscess incision and drainage at Istanbul Çam and Sakura City Hospital between September 2021 and September 2024 were evaluated retrospectively. The inclusion criteria were patients with cryptoglandular perianal abscess who were 18 years of age or older and whose data were fully accessible in the hospital database. The exclusion criteria were a history of anorectal abscess or perianal fistula; inflammatory bowel disease; diagnosis of hidradenitis suppurativa; history of anorectal trauma; anal or rectal malignancy; Fournier gangrene or complex abscess (supralevator or horseshoe abscess); receipt of immunosuppressive therapy or presence of immunosuppressive disease; fistula detected at the time of hospital admission; and lack of blood parameters or imaging data. A total of 213 patients meeting the specified criteria were included in the study. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Başakşehir Çam Sakura City Hospital Scientific Research Ethics Committee (2024-07).

Clinical characteristics of the patients, including age, sex, presence of diabetes mellitus, smoking status, fever status, time from symptom onset to hospital admission, blood parameter results, imaging data, type of intervention, need for surgery due to inadequate drainage or recurrent abscess within 30 days, and development of perianal fistula during long-term follow-up, were evaluated.

The time from symptom onset to hospital admission was classified as "early admission" If it was less than 72 hours and as "late admission" if it was more than 72 hours. Patients with moderate-grade fever or higher were considered to have "high fever." White blood cell (WBC) and C-reactive protein (CRP) levels were evaluated in blood tests. Abscess size was defined as the diameter of the abscess on imaging performed before I&D.

Patients were divided into two groups according to the location where the index I&D procedure for perianal abscess was performed: bedside I&D and OR I&D. In addition, patients were grouped according to the presence or absence of early complications, and parameters were analyzed between these groups.

Surgical Procedure

All patients received intravenous antibiotics for prophylactic purposes before the procedure. Antibiotic selection was based on infection risk and patient characteristics. In all I&D procedures, the incision was made as close to the anal verge as possible to minimize the potential length of fistula formation, ensure adequate drainage, and prevent sphincter damage. Packing of the abscess cavity varied according to the surgeon's preference. All procedures were performed either by the senior surgeon or by a general surgery resident under the supervision of a senior surgeon. During the follow-up period, physical examinations were performed by senior surgeons, and dressings were performed by general surgery residents.

All patients who underwent bedside I&D had the procedure performed at the bedside in the emergency department. Patients were positioned in the Sims position during the procedure, and local anesthesia was administered after vascular access was established. After the procedure, patients' pain levels were evaluated, and intravenous analgesics were administered if necessary. All patients received oral empirical antibiotics after the procedure and were followed up in the outpatient clinic.

OR I&D procedures were performed in the lithotomy position under spinal anesthesia. All patients received empirical antibiotics and were followed up in the outpatient clinic after discharge.

Statistical Analysis

Statistical analysis of the data was performed using IBM SPSS Statistics for Windows version 25.0 (IBM Corp., Armonk, New York, USA). The normality of data distribution was evaluated using the Kolmogorov-Smirnov test. Since the variables were not normally distributed, the nonparametric Mann-Whitney U test was applied. Categorical measurements are expressed as number (n) and percentage (%), and continuous measurements are expressed as median (M), 25th percentile (Q1), and 75th percentile (Q3). The Pearson chi-square test was used for comparisons of ratios. Receiver operating characteristic (ROC) analysis was performed to determine cut-off values for parameters showing statistical significance. Parameters grouped according to ROC-derived cut-off values were included in logistic regression analysis to identify independent predictive factors for the selection of the I&D setting. Variables found to be statistically significant in univariate analysis were included in the multivariate logistic regression model. Logistic regression results are presented as odds ratios (ORs) with 95% confidence intervals (95% CI). A p-value <0.05 was considered statistically significant.

RESULTS

The median age of the patients was 38 years (range: 26-49), and 76.99% (213 patients) were male. Diabetes mellitus was present in 24.41% of patients, and 34.74% were smokers. The incidence of high fever was 4.67% in patients who underwent bedside I&D and 57.14% in those who underwent OR I&D, with the difference being statistically significant (p<0.001).

A significant difference was also observed between the two groups in terms of abscess size. Abscess size was larger in the OR I&D group (median 35 mm, Q1: 29.75, Q3: 40) compared to the bedside I&D group (median 22 mm, Q1: 17, Q3: 28) (p<0.001). In blood parameters, WBC count and CRP levels were significantly higher in the OR I&D group compared to the bedside I&D group (p<0.001). The early complication rate was similar between the bedside I&D and OR I&D groups, with no statistically significant difference (p=0.542). However, during long-term follow-up, perianal fistula development was more common in the OR I&D group (45.23% vs. 21.63%, p=0.002). Comparisons of clinical features and outcomes between patients who underwent bedside and OR I&D are summarized in Table 1. The most commonly used imaging method was transperineal ultrasonography, which was performed in 90.61% (193 patients) of patients. The median hospital stay of patients who underwent OR I&D was one day (Q1: 1, Q3: 1.25). No unexpected situations were encountered after bedside I&D procedures.

ROC analysis was performed to determine cut-off values for WBC count, CRP level, and abscess size (Fig. 1, Table 2). The cut-off value for WBC was 14.68×10^9/L, which was statistically significant, with 85% sensitivity and 84.9% specificity (area under the curve [AUC]=0.917; p<0.001). The cut-off value for CRP was 55.7 mg/L, with 70% sensitivity and 69.8% specificity (AUC=0.759; p<0.001). The cut-off value for abscess size was 29.5 mm, which was statistically significant, with 80% sensitivity and 77.4% specificity (AUC=0.818; p<0.001). These cut-off values were used to categorize the metric variables, which were then subjected to logistic regression analysis.

Table 1. Comparison of clinical characteristics and outcomes of patients undergoing bedside and operative incision and drainage (I&D)

	Total (n=213)	Bedside I&D (n=171)	Operative I&D (n=42)	p value
Age# (Years)	38 (26-49)	38 (26-50)	39.5 (26-46.25)	0.823
Sex* (Male)	164 (76.99)	128 (74.85)	36 (85.71)	0.134
Symptom onset* (Early presentation)	116 (54.46)	96 (56.14)	20 (47.61)	0.32
Diabetes* (Yes)	52 (24.41)	41 (23.97)	11 (26.19)	0.765
Smoking status* (Current smoker)	74 (34.74)	60 (35.08)	14 (33.33)	0.831
High fever* (Present)	32 (15.02)	8 (4.67)	24 (57.14)	<0.001
Abscess size# (mm)	24 (18-32)	22 (17-28)	35 (29.75-40)	<0.001
WBC# (10^9/L)	12.88 (10.29-15.19)	11.99 (9.88-14.09)	16.68 (15.38-17.71)	<0.001
CRP# (mg/L)	44.5 (23.42-70.82)	41.8 (21-60.07)	86.9 (45.6-151.62)	<0.001
Early complications* (Present)	34 (15.96)	26 (15.2)	8 (19.04)	0.542
Perianal fistula* (Present)	56 (26.29)	37 (21.63)	19 (45.23)	0.002

*n (%); #median (Q1-Q3); WBC: White blood cell count; CRP: C-reactive protein.

Table 2. Receiver operating characteristic (ROC) analysis of factors influencing the choice between bedside and operative incision and drainage (I&D)

	AUC (95%)	p value	Cut-off value	Sensitivity (%)	Specificity (%)
WBC (10^9/L)	0.917 (0.874-0.961)	<0.001	14.68	85	84.9
CRP (mg/L)	0.759 (0.668-0.851)	<0.001	55.7	70	69.8
Abscess size (mm)	0.818 (0.743-0.893)	<0.001	29.5	80	77.4

WBC: White blood cell count; CRP: C-reactive protein; AUC: Area under the curve.

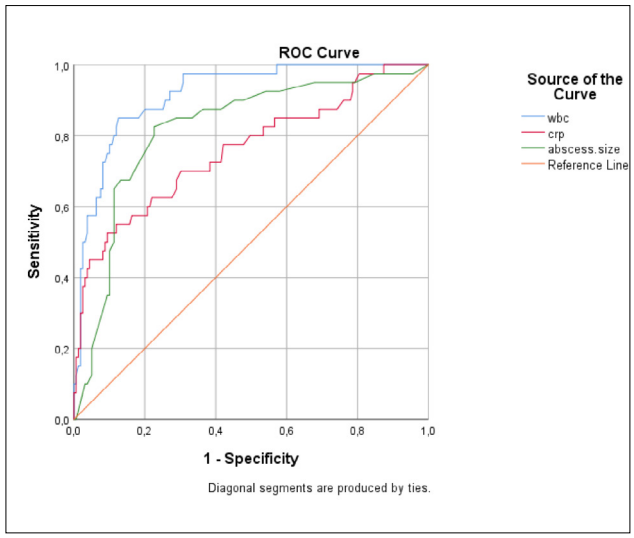

Figure 1. Receiver operating characteristic (ROC) curves of white blood cell count, C-reactive protein, and abscess size in determining the choice between bedside and operative incision and drainage (blue line: white blood cell count, red line: C-reactive protein, green line: abscess size).

In univariate analysis, high WBC (hazard ratio [HR]: 35.04, 95% CI: 13.38–91.77, p<0.001), high CRP (HR: 5.44, 95% CI: 2.56–11.60, p<0.001), and large abscess size (HR: 11.12, 95% CI: 5.01–24.65, p<0.001) were significant predictors for OR drainage selection. However, in multivariate Cox regression analysis, the CRP group was no longer statistically significant (HR: 1.92, 95% CI: 0.69–5.36, p=0.214). High WBC (HR: 20.88, 95% CI: 7.16–60.87, p<0.001) and large abscess size (HR: 8.47, 95% CI: 2.99–23.95, p<0.001) were identified as independent significant predictors. These findings indicate that WBC count and abscess size are clinically important independent determinants in choosing the setting for drainage (Table 3).

The clinical characteristics of patients with early complications are summarized in Table 4. In the group with early complications, WBC values were statistically significantly higher [12.2 (9.89–14.54) vs. 14.78 (13.38–16.07), p<0.001]. No statistically significant differences were found in the other evaluated parameters.

Table 3. Univariate and multivariate logistic regression analysis of study parameters

	HR (95% CI) Univariate	p value Univariate	HR (95% CI) Multivariate	p value Multivariate
WBC (>14.68×10^9/L)	35.04 (13.38–91.77)	<0.001	20.88 (7.16–60.87)	<0.001
CRP (>55.7 mg/L)	5.44 (2.56–11.6)	<0.001	1.92 (0.69–5.36)	0.214
Abscess size (>29.5 mm)	11.12 (5.01–24.65)	<0.001	8.47 (2.99–23.95)	<0.001

HR: Hazard ratio; WBC: White blood cell count; CRP: C-reactive protein.

Table 4. Comparison of clinical features of patients with and without early complications

	No early complications (n=179)	Early complications (n= 34)	p value
Age# (Years)	38 (26-49)	36.5 (26.5-50.5)	0.883
Sex* (Male)	134 (74.86)	30 (88.23)	0.089
Symptom onset* (Early presentation)	101 (56.42)	15 (44.11)	0.187
Diabetes* (Yes)	43 (24.02)	9 (26.47)	0.761
Smoking status* (Current smoker)	64 (35.75)	10 (29.41)	0.476
High fever* (Present)	24 (13.4)	8 (23.52)	0.13
Abscess size# (mm)	23.5 (18-30.25)	27 (20-38.5)	0.065
WBC# (109/L)	12.2 (9.89-14.54)	14.78 (13.38-16.07)	<0.001
CRP# (mg/L)	45 (23.67-68.82)	42.9 (21-91.32)	0.735
Perianal fistula* (Present)	47 (26.25)	9 (26.47)	0.979

*n (%); #median (Q1-Q3); WBC: White blood cell count; CRP: C-reactive protein.

DISCUSSION

In this study, we evaluated different treatment strategies used in the management of perianal abscess. The literature describes various approaches regarding where and under what conditions I&D should be performed for the treatment of perianal abscesses.[6,8] Current guidelines recommend drainage of the abscess but do not clearly specify whether this procedure should be performed at the bedside in the emergency department or under anesthesia in the OR.[3-5] We believe that the most critical step in making this decision is a detailed examination and clinical evaluation of the patient by the surgeon. The fundamental approach is to guide the decision by requesting additional blood tests and imaging studies, particularly in cases with signs of sepsis, additional risk factors, or atypical presentations.[3,5] Our findings show that higher WBC counts, larger abscess size, and increased CRP levels are significantly associated with operative I&D. In multivariate regression analysis, WBC count and abscess size emerged as independent predictors, whereas CRP lost its statistical significance.

In the current literature, studies directly comparing bedside and OR I&D are quite limited.[6] Most existing studies compare outpatient incision and drainage procedures, usually performed as day surgery, with surgical drainage methods requiring hospitalization.[8-10] It has been reported that even day surgery contributes significantly to reducing healthcare system costs.[8-9] In a study by Swift et al.[9] conducted in England, a total of 42,568 bed days were used for emergency perianal abscess surgery, with a mean hospital stay of 1.2 days. The study also predicted that if a targeted 90% transition to day surgery was achieved, approximately 28,114 bed days could be saved over three years.[9] In our study, no statistically significant difference was found between the groups in terms of early complication rates. This finding suggests that I&D procedures performed at the bedside in the emergency department may be a safe and advantageous option in carefully selected cases. It should be emphasized that patients with complex abscesses, severe systemic disease, or signs of sepsis were excluded from this study. In a study by Sho et al.,[10] it was reported that even among patients undergoing day surgery, reoperation and rehospitalization rates were not negligible.

Our study is among the first in the literature to focus on identifying parameters that predict the type of intervention (bedside or OR) in the treatment of perianal abscess. WBC level and abscess size were identified as independent predictors of intervention type in multivariate regression analysis. In particular, a WBC level above 14.68×10^9/L was significantly associated with OR I&D (odds ratio [OR]: 4.91, 95% CI: 2.2–10.9) and emerged as an independent variable in the regression model. This finding suggests that leukocytosis reflects not only systemic inflammation but also the local severity of disease. Although no studies in the current literature have evaluated leukocytosis as a determinant of intervention type (bedside vs. OR) in perianal abscess treatment, leukocytosis has been shown to be associated with disease severity and with both early postoperative and long-term complications.[11,12] In a study by Dong et al.,[11] a significant association was found between larger abscess cavity size and higher WBC levels. In the same study, although a statistically significant association was observed between WBC levels and postoperative recurrence in univariate analysis, WBC was not identified as an independent risk factor in multivariate analysis.[11] Similarly, Elhadidi et al.[12] reported that WBC levels of 18×10^9/L or higher were significantly associated with severe anorectal sepsis.

As with WBC levels, studies directly assessing the impact of abscess size on the choice of intervention type (bedside vs. OR) are rare. The current literature reports that abscess cavity size is associated with postoperative recurrence, and an increase in abscess diameter has also been identified as an independent predictor of conservative treatment failure in the pediatric population.[11,13] These findings indicate that abscess size is a parameter that should not be overlooked when deciding on the type of intervention. Our study demonstrates that abscess size can be considered a guiding factor not only for treatment success but also in the surgical decision-making process regarding intervention type (bedside vs. OR).

Although CRP level showed a statistically significant association in univariate analysis for determining the type of intervention in the treatment of perianal abscess, it was not identified as an independent risk factor in multivariate regression analysis. While there are no definitive studies in the current literature evaluating CRP levels in selecting the intervention type, elevated CRP has been reported to be associated with anorectal sepsis and fistula development.[12,14]

One of the important findings of our study is that early complication rates were similar between the two groups, whereas perianal fistula formation was more frequently detected in the OR group during long-term follow-up. Considering that larger and potentially more complex abscesses undergo OR I&D, as emphasized by Narayanan et al.,[7] the baseline risk of perianal fistula is already higher in these cases and may be associated with the higher detection rate of fistulas during OR I&D. In addition, the identification of minor fistula tracts during more detailed exploration in the OR and their subsequent clinical detection during follow-up may be another reason for the higher fistula frequency observed in the group that underwent OR surgery. Although some studies in the literature suggest that treating intraoperatively detected fistulas with fistulectomy reduces inadequate drainage and abscess recurrence, other studies have reported conflicting results, indicating that an early aggressive approach may increase the risk of sphincter damage or other complications.[10,15] This contradiction highlights the complexity of perianal anatomy and underscores the need to tailor diagnostic and treatment strategies to individual patient factors.

Our study has certain limitations. First, the single-center, retrospective design carries a potential risk of selection bias. Second, because perianal abscess I&D is a painful procedure, patients' pain scores and discomfort levels during the procedure could not be compared between groups due to missing data. Furthermore, the more severe clinical presentation of patients in the OR I&D group limits direct comparison between the groups. In addition, reliance on clinical examination and imaging for perianal fistula detection may have resulted in a higher reported perianal fistula rate in this group due to easier identification of subclinical tracts during more detailed examinations in the OR.

CONCLUSION

Our results suggest that bedside I&D may be a safe and effective option in selected cases; however, more comprehensive evaluation and OR I&D may be required for patients with pronounced inflammatory findings or larger abscesses. In this context, incorporating WBC level and abscess size into clinical decision-making algorithms may support an individualized and resource-efficient approach. Future multicenter prospective studies are needed to strengthen the generalizability of these findings.

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Ethics Committee Approval: This study was approved by the Başakşehir Çam Sakura City Hospital Scientific Research Ethics Committee (Date: 25.09.2024, Decision No: 2024-07).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Perianal apseler için tedavi yöntemi seçimi: yatak başında mı ameliyathanede mi? tek merkezli, retrospektif çalışma

AMAÇ: Bu çalışmanın amacı perianal apse tedavisinde müdahale tipinin (yatak başı, ameliyathane insizyon ve drenaj) klinik sonuçlar üzerine etkisini değerlendirmek ve müdahale tipinin belirlenmesinde etkili olabilecek prediktif faktörleri saptamaktır.
GEREÇ VE YÖNTEM: Kriptoglandüler perianal apse nedeniyle insizyon ve drenaj (İ&D) uygulanan 213 hasta retrospektif olarak değerlendirildi. Hastalar müdahale türüne göre "yatak başı I&D" ve "ameliyathane I&D" gruplarına ayrıldı. Demografik özellikler, laboratuvar değerleri, apse boyutu, erken komplikasyonlar ve uzun vadeli fistül gelişimi karşılaştırıldı. Beyaz kan hücresi (WBC), C-reaktif protein (CRP) ve apse boyutu için cut-off değeri belirlemek amacıyla ROC analizi yapıldı; ardından bu parametreler üzerinde lojistik regresyon analizleri yapıldı.
BULGULAR: WBC, CRP düzeyleri ve apse boyutu, ameliyathane grubunda istatistiksel olarak anlamlı şekilde daha yüksek bulundu ($p<0.001$). ROC analizine göre belirlenen cut-off değerleri; WBC için 14.68×10^9/L, CRP için 55.7 mg/L ve apse boyutu için 29.5 mm olarak tespit edildi. Univaryant regresyon analizinde CRP istatistiksel anlamlılığını kaybederken, çok değişkenli analizde WBC ve apse boyutunun müdahale yerini belirlemede bağımsız prediktif faktörler olduğu saptandı. Uzun dönem takipte, fistül gelişimi ameliyathane grubunda anlamlı olarak daha sık gözlendi ($p=0.002$).
SONUÇ: WBC düzeyi ve apse boyutu, perianal apse tedavisinde müdahale türüne karar vermede değerli öngörücüler olabilir. Yatak başı İ&D düşük riskli vakalarda güvenle gerçekleştirilebilirken, yüksek inflamatuar belirteçleri ve büyük apse boyutu olan hastalarda ameliyathane müdahalesi tercih edilmelidir.

Anahtar sözcükler: Ameliyathane; insizyon ve drenaj; perianal apse; yatak başı.

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ORIGINAL ARTICLE

Management of pediatric splenic trauma

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ABSTRACT

BACKGROUND: In this study, we aimed to present the management and treatment processes of patients with splenic trauma, discuss nonoperative treatment approaches, and share our institutional experience.

METHODS: A total of 244 patients hospitalized for splenic trauma between January 2010 and January 2020 were retrospectively analyzed.

RESULTS: Splenic injury was present in 22% of trauma patients who presented to the emergency department and were consulted by pediatric surgery. The most common cause of splenic injury was falls (60%). Forty-three percent of patients were of school age. Ninety percent of patients had Grade I-III splenic injuries. The mean age at presentation was 7.90 years. The mean hematocrit level was 32% and the mean hemoglobin level was 10.90. Blood transfusion was administered to 29% of patients. Additional injuries were present in 45.9% of cases, with the lung being the most frequently affected organ. The mean length of hospital stay was 6.03 days. Mortality occurred in five patients, and morbidity was observed in five patients. There was a statistically significant correlation between blood pressure, urine output, and mortality. A statistically significant association was also found between platelet-to-lymphocyte ratio, blood transfusion, hemoglobin level, Glasgow Coma Scale (GCS) score, and mortality ($p<0.001$). Furthermore, significant correlations were identified between GCS score, length of hospital stay, neutrophil count, and the presence of additional injuries ($p<0.001$). A strong negative correlation was observed between lactate levels and blood transfusion ($r=-0.610$), as well as between lactate levels and GCS score ($r=-0.645$). In the ROC analysis evaluating lactate as a predictor of additional injury, a sensitivity of 58% and specificity of 83% were identified at a cutoff value of 1.9.

CONCLUSION: We recommend nonoperative management for patients with splenic injury, as it reduces mortality, morbidity, and healthcare costs. Treatment protocols for these patients should be scientifically standardized.

Keywords: Nonoperative treatment; pediatric splenic trauma.

INTRODUCTION

Trauma remains the leading cause of mortality and morbidity in the pediatric population worldwide. In 2015, trauma caused more deaths and morbidity burden in the United States than all other childhood diseases combined.[1] After injuries to the head and extremities, the abdomen is the third most frequently affected region. Each year, 1 in 10,000 children in the United States experiences abdominal trauma.[2] A study conducted in the United States reported that 3% of all trauma cases presenting between 1994 and 2014 involved splenic injuries, of which 79.6% were isolated splenic injuries.[3]

In 2000, due to variability in the management of pediatric

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abdominal traumas, the trauma committee of the American Pediatric Surgical Association published guidelines and criteria for the management of solid organ injuries.[4] As the management of intra-abdominal solid organ injuries became standardized, hospital length of stay decreased and the success rate of nonoperative management increased.[4,5] Over time, these guidelines have been periodically updated, with the most recent systematic review published in 2019. Recent evidence suggests that shorter hospital stays, followed by a reduced period of bed rest after discharge, are safe.[5] The primary advantage of nonoperative management is the avoidance of postoperative complications. Patients managed nonoperatively have demonstrated shorter hospital stays, fewer blood transfusions, and improved quality of life.[6] Current scientific data indicates that the success rate of nonoperative management exceeds 90%.

Although nonoperative management is widely accepted for hemodynamically stable patients, there remains ongoing debate regarding the optimal management and follow-up of hemodynamically unstable patients. Additionally, there is no clear consensus on the role of angiographic interventions in splenic trauma.

In this study, we aimed to retrospectively review the management and treatment processes of patients who were followed in our intensive care unit for splenic trauma between January 2010 and January 2020, to discuss nonoperative management strategies, and to evaluate our institutional experience.

MATERIALS AND METHODS

Between January 2010 and December 2019, all patients who presented to the emergency department due to trauma and were referred to the pediatric surgery department were examined. A total of 244 patients with splenic trauma were included in the study. Eight patients with splenic trauma whose medical records were inaccessible were excluded.

This study was conducted in accordance with the principles of the Declaration of Helsinki. Approval was obtained from the Academic Committee of the Department of Pediatric Surgery (19/05/2021). Subsequently, ethical approval was granted by the Ethics Committee (15/12/2021-86).

The following variables were analyzed: demographic characteristics, mechanism of injury, injury grade, presence of comorbidities, need for blood transfusion, length of hospital stay, and presence of concomitant injuries. Blood pressure, hematocrit (HCT), hemoglobin (Hb), platelet (PLT), neutrophil (NEU), lymphocyte (LYM), and lactate levels were recorded. The neutrophil-to-lymphocyte ratio (NLR) and platelet-to-lymphocyte ratio (PLR) were calculated. Glasgow Coma Scale (GCS) scores, urine output, mortality, morbidity, radiological investigations performed, and treatment approaches were also assessed.

Initial patient data were obtained from emergency department records at the time of admission. In cases with additional injuries, consultations from relevant specialties were reviewed. The clinical course of all patients during hospitalization was evaluated.

Statistical Analysis

Statistical analyses were performed using SPSS Statistics for Windows, version 18.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were presented as frequency, percentage, mean, and standard deviation. The normality of data distribution was assessed. The Pearson chi-square test was used to compare qualitative data. The independent samples t-test was applied for comparisons of normally distributed quantitative data. For variables that did not follow a normal distribution, the Mann–Whitney U test was used. Spearman correlation analysis was performed to evaluate correlations between variables. Receiver operating characteristic (ROC) curve analysis was conducted to determine sensitivity and specificity. A p-value of ≤0.05 was considered statistically significant for all analyses.

RESULTS

Between January 2010 and December 2019, splenic injury was identified in 22% of pediatric patients admitted to the emergency department due to trauma. Among patients with splenic trauma, 43% were between 7 and 12 years of age. The most common mechanism of injury was falls, accounting for 60% of cases, and 74.2% of the patients were male. The distribution of age, sex, and mechanisms of injury are presented in Table 1.

Table 1. Age distribution, sex, and mechanism of trauma

	n	%
Age (years)		
0-3	40	16.4
4-6	59	24.2
7-12	105	43
13-17	40	16.4
Sex		
Male	181	74.8
Female	63	25.2
Mechanism of trauma		
Fall	148	60.3
Motor vehicle accident (MVA)	46	18.9
Road traffic accident (RTA)	21	8.9
Bicycle crash accident (BCA)	15	6.1
Blunt abdominal trauma (BAT)	8	3.3
Penetrating trauma (PT)	3	1.2
Gunshot wound (GSW)	3	1.2

Table 2. Distribution of injury grades

Injury Grade	n	%
I	86	35.2
II	84	34.4
III	50	20.5
IV	19	7.8
V	5	2.0
Total	244	100

Focused Assessment with Sonography for Trauma (FAST) was performed in 235 patients, and computed tomography (CT) was performed in 182 patients. It was assumed that patients who did not undergo CT at our institution had previously undergone CT at the referring hospital; however, these imaging data were not accessible.

The most common injury grade was Grade I, accounting for 35.2% of cases. The distribution of injury grades is presented in Table 2.

The mean age of the patients was 7.9 years. The descriptive characteristics of the study population are presented in Table 3.

Isolated splenic injuries accounted for 54.2% of cases, while 45.9% of patients had concomitant injuries. The lungs were the most frequently affected additional organ (21%). The distribution of associated injuries is shown in Table 4.

Three patients (1%) had comorbidities. One female patient with iron deficiency anemia presented with a Grade I splenic injury following a fall. No additional injuries were identified. Her HCT was 29.27% and Hb was 9.13 g/dL. She did not receive a transfusion and was discharged after nonoperative management. The second patient, a female with depression and behavioral disorder, presented with a Grade I splenic injury due to a gunshot wound. She had bilateral pneumothorax, right-sided hemothorax, and a Grade II liver injury. A total of three units of erythrocyte suspension (ES) were administered. She was discharged following nonoperative management. The third patient, a male with acute myeloid leukemia, presented with a Grade I splenic injury after a fall. No additional injuries were detected. Although his HCT and Hb levels were within normal limits, thrombocytopenia was present. He did not receive ES and was discharged with nonoperative management.

The mean length of hospital stay was 6.03 days. The distribution of hospital stay according to injury grade and mechanism of trauma is presented in Tables 5 and 6, respectively.

Twenty-six patients were hypotensive, while 218 were normotensive at presentation. Decreased urine output was observed in 15 patients. The relationship between blood pressure, urine output, and mortality is shown in Table 7.

A statistically significant association was found between both blood pressure and urine output and mortality ($p<0.001$).

A total of five patients died, three of whom died in the emergency department. One patient died during the surgical procedure, and another died in the postoperative period. Among these patients, three had Grade V splenic injuries and two had Grade IV splenic injuries. Four of the five deceased patients had concomitant high-grade liver injuries.

Five patients experienced morbidity. One patient discontinued school and developed substance abuse following the

Table 3. Characteristics of the patients

	Minimum	Maximum	Mean	Standard Deviation
Age (years)	1	17	7.9	4.133
Blood transfusion	1	6	1.64	1.110
HCT (%)	13.9	46.44	32.90487	5.4390932
Hb (g/dL)	7	14	10.90	2.283
GCS	3	15	14.37	1.934
Lactate (mmol/L)	0.6	14	2.377083	2.4192701

Table 4. Distribution of concomitant injuries

Injured Organ	n	%
Lung	50	21%
Skeletal system	49	20%
Liver	27	11%
Cranial injury	25	10%
Kidney	21	8%
Adrenal gland	6	2%
Intestinal injury	2	0.8%

Table 5. Length of hospital stay according to injury grade

Injury Grade	n	Mean	Standard Deviation	Minimum	Maximum
I	86	5.36	2.361	2	17
II	84	6.00	2.630	3	21
III	50	6.48	1.705	5	13
IV	19	8.05	3.504	2	17
V	5	6.00	7.071	1	16
Total	244	6.03	2.674	1	21

Table 6. Trauma mechanism and length of hospital stay

Trauma Mechanism	Mean	Standard Deviation	Minimum	Maximum
Fall	5.79	2.155	1	17
MCA	6.52	2.676	4	12
RTA	6.13	2.729	1	16
BCA	5.33	1.799	4	9
PT	4.00	1.732	2	5
BAT	7.88	5.866	3	21
GSW	13.67	4.933	8	17
Total	6.03	2.674	1	21

trauma, suggestive of post-traumatic stress disorder (PTSD). One patient underwent splenectomy due to instability and was subsequently treated for post-traumatic anxiety disorder. One patient developed a left ocular contracture. Another developed paraparesis. One patient developed atrophy of the left kidney.

Six patients underwent surgical intervention, two of whom died. Of the remaining four patients, three underwent splenectomy for Grade V splenic injuries. One patient with a Grade II splenic injury underwent surgery for a ureteral injury, during which splenic laceration repair was performed.

The mechanisms of trauma and the patients who underwent surgery are presented in Table 8. A statistically significant association was found between the mechanism of trauma and the need for surgery ($p<0.001$).

Patients involved in traffic accidents and gunshot wounds had significantly higher rates of additional injuries (Table 9). A statistically significant association was identified between the

Table 7. Association between blood pressure, urine output, and mortality

	Mortality	Total
Blood pressure		
Hypotensive	5	26
Normotensive	0	218
Total	5	244
Urine output		
Decreased	5	17
Normal	0	227
Total	5	244

Table 8. Association between trauma mechanism and surgical intervention

Trauma Mechanism	Surgery	Total
Fall	3	148
RTA I	46	
MCA	0	21
BCA	0	15
BAT	0	8
PT	0	3
GSW	2	3
Total	6	244

Table 9. Association between trauma mechanism and additional injury

Trauma Mechanism	Additional Injury	Total
Fall 60	148	
MCA	28	46
RTA	14	21
BCA	3	15
BAT	3	8
PT	1	3
GSW	3	3
Total	112	244

Table 10. Variables associated with mortality

Mortality	p Value
PLR	0.000
Blood transfusion	0.000
Hb	0.000
GCS	0.000
NLR	0.013
Lactate	0.001

Table 11. Variables associated with additional injury

Additional Injury	p Value
Blood transfusion	0.014
Hospital stay	0.000
GCS	0.000
NEU	0.000
NLR	0.001
Lactate	0.023

mechanism of trauma and the presence of additional injuries ($p<0.01$).

No significant association was found between platelet count, neutrophil count, or patient age and mortality. However, significant associations were observed between NLR, lactate level, PLR, blood transfusion requirement, Hb level, and GCS score and mortality ($p<0.05$). Additionally, the presence of additional injuries was significantly associated with mortality ($p<0.05$) (Table 10).

A statistically significant association was identified between blood transfusion requirement and lactate levels and the presence of additional injuries ($p<0.05$). A statistically significant association was also found between NLR and the presence of additional injuries ($p<0.01$). Furthermore, GCS score, length of hospital stay, and neutrophil count were significantly associated with the presence of additional injuries ($p<0.001$) (Table 11).

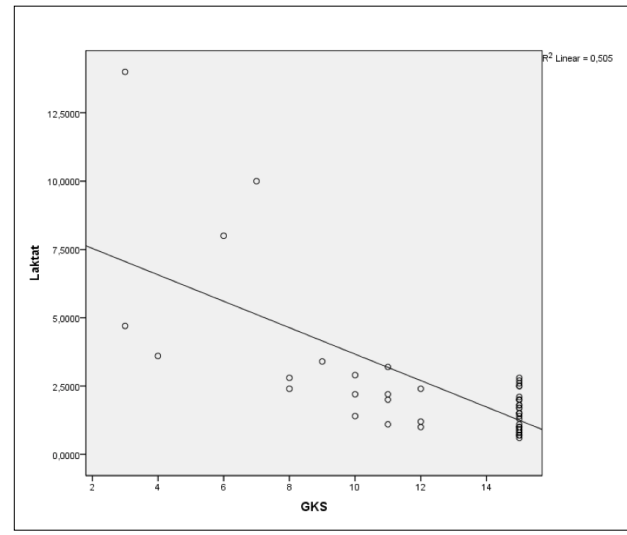

Figure 1. Correlation curve between lactate level and Glasgow Coma Scale (GCS) score

A strong negative correlation was observed between lactate level and GCS score ($r=-0.610$), as well as between blood transfusion requirement and GCS score ($r=-0.645$). A moderate negative correlation was found between lactate level and Hb ($r=-0.594$) and between blood transfusion requirement and Hb ($r=-0.517$). A moderate positive correlation was observed between NEU and lactate level ($r=0.419$). Additionally, a moderate negative correlation was identified between lactate level and HCT ($r=-0.595$), while a moderate positive correlation was found between lactate level and blood transfusion requirement ($r=0.446$). No statistically significant correlations were found between length of hospital stay, age, PLT, LYM, NLR, or PLR and other variables. The correlation curve between lactate level and GCS score is presented in Figure 1.

In the ROC analysis evaluating lactate level as a predictor of additional injuries, a cutoff value of 1.9 yielded a sensitivity of 58% and a specificity of 83% (area under the curve [AUC]: 72%).

DISCUSSION

In our study, 97% of patients with splenic injuries were successfully managed nonoperatively. Patients continue to be followed up, and no complications have been detected to date. Therefore, we recommend nonoperative management for patients with splenic injuries, as it reduces mortality, morbidity, and healthcare costs.

Most splenic traumas are isolated injuries. Falls are the most common mechanism of trauma, and boys are more frequently affected than girls. The majority of patients present with low-grade injuries. As the injury grade increases, the need for blood transfusion also rises.

Due to socioeconomic differences, the mechanisms of trauma vary among countries. In our study, falls were the most common cause of splenic trauma in children. In the literature, Rialon et al.[7] reported that traffic accidents were the leading cause of splenic injury, whereas Aoki et al.[8] identified falls as the most common mechanism, particularly in high-grade splenic injuries. We hypothesize that sleeping on rooftops in rural areas during the summer may be an important contributing factor to fall-related splenic injuries. Additionally, children in our region spend most of their time outdoors during the summer months, which may increase the incidence of falls.

Rialon et al.[7] reported a mean age of 12 years among children presenting with splenic injuries, Leeper et al.[9] reported a mean age of 11 years, Aoki et al.[8] found a mean age of 10 years, and Knight et al.[10] reported a mean age of 14 years. In our study, the median age was lower (7.89 years). We believe this may be attributable to socioeconomic factors, including increased outdoor activity during the summer and insufficient traffic safety measures for children.

In our cohort, 35.2% of patients had Grade I splenic injuries, 34.4% had Grade II, 20.5% had Grade III, 7.8% had Grade IV, and 2% had Grade V injuries. Approximately 90% of patients had Grade I-III injuries. In the American Pediatric Surgical Association (APSA) systematic review, most patients were reported to have Grade II-IV injuries.[11] We believe that the higher proportion of Grade I injuries in our study may be related to the predominance of fall-related trauma, particularly during the summer months, when lower-grade splenic injuries are more common.

In our study, 29% of patients received blood transfusions. The transfusion rates according to injury grade were 6% for Grade I, 15% for Grade II, 56% for Grade III, 94% for Grade IV, and 100% for Grade V splenic injuries. A statistically significant association was demonstrated between blood transfusion requirement and injury grade ($p<0.001$). In the literature, the reported need for blood transfusion in patients with splenic injuries ranges from 10% to 20%. We believe that the higher transfusions rate observed in our study may be attributed to the high prevalence of concomitant traumatic injuries. Seventy-two patients had Hb levels between 8-10 at admission; however, transfusion became necessary as Hb levels decreased due to ongoing bleeding, particularly in patients with additional injuries. Another contributing factor may be our transfusion threshold for unstable patients, which was set at an Hb level of 8, consistent with recommendations in the literature. Previous studies report an Hb threshold between 7.5-9.5 as an indication for transfusion in critically ill patients.[12,13] The ATOMAC (American Pediatric Surgical Association (APSA) Outcomes and Transfusion in the Management of Pediatric Solid Organ Injury) guidelines and several publications recommend transfusion at an Hb level below 7. However, in patients with high-grade splenic injuries or concomitant injuries, Hb levels may decline during follow-up due to ongoing bleeding. We also consider an Hb level below 7 as an indication for transfusion in stable patients, while supporting transfusion at Hb levels below 8 in unstable patients with ongoing bleeding (e.g., high-grade or vascular injuries).

The mean length of hospital stay in our study was 6.03 days. In the literature, Rialon et al.[7] reported a mean stay of 4 days, Aoki et al.[8] reported 10 days for high-grade injuries, McDonald et al.[14] reported 5.5 days, and the APSA systematic review reported 3.9 days.[11] Cost-effective treatment strategies are becoming increasingly important worldwide, and prolonged hospital stay is a well-established factor associated with increased healthcare costs. We believe that the longer hospital stay observed in our study may be related to the presence of additional injuries. However, when compared with the literature, particularly studies published after the 2019 APSA systematic review, our length of stay is consistent with reported data.

In our study, the mortality rate was 2% (5/244). Although some studies in the literature report no mortality, Rialon et al.[7] reported a mortality rate of 4%. Among the deceased patients in our study, three were involved in road traffic accidents (RTAs) and two sustained injuries due to falls. All deceased patients had concomitant injuries and were unstable upon arrival at the emergency department. Due to the small number of deaths, it was not possible to conduct comprehensive statistical analyses to evaluate risk factors for mortality. However, in the analyses performed, statistically significant associations were identified between NLR, lactate level, PLR, blood transfusion requirement, Hb level, and GCS score and mortality. Therefore, admission GCS score and laboratory parameters such as Hb, lactate, neutrophil, lymphocyte, and platelet counts are clinically valuable, particularly in the management of high-risk patients. As the number of patients increases, more robust scientific data will be obtained in future studies.

Given the statistically significant association between the mechanism of trauma and the presence of additional injuries, it should be emphasized that nearly 60% of patients involved in traffic accidents had concomitant injuries. Additional injuries should be carefully evaluated using CT and managed with a multidisciplinary approach. Schalamon et al.[15] reported that 68% of children with multiple trauma presented following traffic accidents. In our study, a statistically significant association was found between GCS score and neutrophil count and the presence of additional injuries. Therefore, elevated neutrophil levels on complete blood count (CBC) may serve as an indicator of concomitant injuries.

In our correlation analysis, a strong negative correlation was observed between lactate level and GCS score, as well as between blood transfusion requirement and GCS score. As GCS decreases, the likelihood of transfusion increases. Therefore, in patients presenting with low GCS scores, it may be beneficial to prepare ES immediately upon admission while laboratory evaluations are ongoing.

In our ROC analysis evaluating lactate level as a predictor of

additional injuries, a cutoff value of 1.9 demonstrated a sensitivity of 58% and a specificity of 83%. Careful interpretation of blood gas analysis, which is the fastest available diagnostic test, is essential. Patients with lactate levels above 1.9 are more likely to have concomitant injuries. In these cases, ES should be prepared promptly, CT should be performed without delay for diagnostic evaluation, and consultations with the relevant specialties should be initiated immediately.

As we did not encounter any complications requiring angiographic embolization, this intervention was not utilized in our cohort. Furthermore, angiographic embolization has not been shown to preserve splenic function. Given the high success rate of nonoperative management, even in high-grade injuries, further scientific studies are needed to better define the role of angiographic embolization.

Limitations

The principal limitation of this study is its retrospective design. Access to much of the data was challenging. Because some patients were referred from other hospitals, certain data were inaccessible. As this was a single-center study, the findings, particularly those related to mortality and morbidity risk factors, should be evaluated in multicenter studies with larger patient populations. Additionally, the absence of complications in our cohort may be related to the sample size, and as the number of patients increases, we may be able to present new data on complication management, particularly regarding angiographic embolization.

CONCLUSION

A multidisciplinary approach grounded in current scientific evidence is the most critical factor in ensuring survival in pediatric trauma patients. From the moment of admission to the emergency department, management should follow a standardized protocol based on scientific data. All injuries must be systematically identified, and treatment should be initiated without delay. Multicenter scientific studies will further strengthen the existing body of evidence, supporting the nonoperative management of most patients and facilitating discharge without long-term sequelae.

Ethics Committee Approval: This study was approved by the Dicle University Non-Interventional Studies Ethics Committee (Date: 15.12.2021, Decision No: 86).

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Çocuklarda dalak travmalarının yönetimi

AMAÇ: Dalak travmalı hastaların yönetim ve tedavi süreçlerini sunmayı, nonoperatif tedavi yönetimini tartışmayı ve deneyimlerimizi paylaşmayı amaçlıyoruz.
GEREÇ VE YÖNTEM: Ocak 2010 ile Aralık 2019 tarihleri arasında dalak travması nedeniyle hastaneye yatırılan 244 hasta çalışmaya dahil edildi ve retrospektif olarak analiz edildi.
BULGULAR: Acil servise başvuran ve çocuk cerrahisi ile konsülte edilen travma hastalarının %22'sinde dalak yaralanması mevcuttu. Dalak yaralanmasının en sık nedeni düşme (%60) idi. Hastaların %43'ü okul çağındaydı. Hastaların %90'ında evre 1-2-3 dalak yaralanması vardı. Başvuru anında ortalama yaş 7.90, ortalama hematokrit 32, ortalama hemoglobin 10,90 idi. Hastaların %29'una transfüzyon yapıldı. Hastaların %45.9'unda ek yaralanma vardı ve en sık yaralanan organ akciğerdi. Ortalama hastanede kalış süresi 6,03 gündü. 5 hastada mortalite, 5 hastada ise morbidite görüldü. Kan basıncı ve idrar çıkışı ile mortalite arasında istatistiksel olarak anlamlı bir ilişki vardı. ($p<0.05$) Trombosit/lenfosit oranı, kan transfüzyonu, hemoglobin ve GCS ile mortalite arasında istatistiksel olarak anlamlı bir ilişki bulundu. ($p<0.001$) GCS, hastanede kalış süresi, nötrofil sayısı ve ek yaralanma arasında istatistiksel olarak anlamlı ilişki bulundu. ($p<0.001$) Laktat ve kan transfüzyonu ile GKS arasında yüksek düzeyde negatif korelasyon olduğu görüldü. (sırasıyla r=-0,610 ve r=-0,645) Laktat ile ek yaralanma için yapılan ROC analizinde laktat cut off değeri 1,9'da duyarlılık %58, özgüllük %83 olarak belirlendi.
SONUÇ: Dalak yaralanmalı hastalara ameliyatsız tedaviyi hem mortaliteyi, hem morbiditeyi hem de maliyeti azalttığı için öneriyoruz. Hastaların tedavi yönetimi bilimsel olarak standardize edilmelidir.

Anahtar sözcükler: Çocuklarda dalak travmaları; nonoperatif tedavi; pediatrik travma.

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ORIGINAL ARTICLE

Management of undisplaced or minimally displaced distal radius fractures in adults: immobilization with circumferential casting versus plaster splinting

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ABSTRACT

BACKGROUND: Distal radius fractures (DRFs) are among the most common fractures in adults, with a significant proportion being stable, non-displaced, or minimally displaced. These fractures generally have a low risk of secondary displacement. This study aimed to compare the clinical and radiological outcomes of short-arm circular casting and volar splint application in the conservative treatment of stable distal radius fractures. Additionally, the study evaluated complication rates, patient comfort, and the feasibility of these two immobilization techniques in emergency department settings.

METHODS: This retrospective study reviewed the medical records of 170 patients diagnosed with stable, non-displaced, or minimally displaced distal radius fractures at two emergency departments between January 2020 and January 2023. Fracture stability was assessed using Lindstrom's criteria. Among the participants, 88 patients were treated with short-arm circular casting, while 82 received volar splint application. Immobilization was maintained for four weeks, followed by a six-month follow-up period. Radiographic parameters (radial height, radial inclination, palmar tilt, and articular surface step-off) were measured at baseline and during follow-up visits. Clinical and functional outcomes were assessed using the Quick Disabilities of the Arm, Shoulder, and Hand (qDASH) and Patient-Rated Wrist Evaluation (PRWE) scales. Complication rates and patient satisfaction were also analyzed.

RESULTS: The study included 170 patients (mean age: 46.9±11.4 years). No statistically significant differences were observed between the casting and splint groups in terms of radiological parameters at baseline or six months post-treatment ($p>0.05$). Similarly, clinical and functional outcomes, including qDASH and PRWE scores, were comparable between the two groups ($p>0.05$). Complication rates were 5.7% in the cast group and 4.8% in the splint group, with no significant difference ($p>0.05$). The volar splint technique demonstrated advantages in terms of ease of application and patient comfort.

CONCLUSION: Short-arm circular casting and volar splinting provide equivalent clinical and functional outcomes in the management of stable distal radius fractures. Given its ease of application and greater patient comfort, volar splinting can be considered a practical alternative in emergency department settings, particularly for selected patient populations.

Keywords: Distal radius fracture; stable fractures; short-arm cast; volar splint; conservative treatment.

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INTRODUCTION

Distal radius fractures (DRFs) represent one of the most common fracture types in adults, comprising approximately 17% of all adult fractures. A substantial proportion (between 10% and 35%) of these fractures are nondisplaced or minimally displaced and typically exhibit a low risk of secondary displacement owing to their intrinsic stability.[1] Short-arm circular cast immobilization is frequently used for the treatment of stable distal radius fractures.[2] This method is intended to maintain fracture alignment and prevent displacement, malunion, and subsequent functional impairment. However, in cases of initially displaced fractures, a notable risk of re-displacement following circular cast application has been reported, raising ongoing debate regarding the efficacy and appropriateness of this treatment approach.[3]

Short-arm splinting, a commonly used form of immobilization, offers several advantages, including ease of application, the ability to accommodate edema, and enhanced patient comfort.[4] Moreover, studies have shown that immobilization with removable wrist splints yields favorable clinical and functional outcomes in the management of stable distal radius fractures.[5] However, the efficacy of splint applications relative to circular casts, as well as their impact on complication rates and patient satisfaction, has not been clearly established.

In recent years, a growing body of research has focused on identifying the optimal duration of immobilization for distal radius fractures.[6, 7] Although traditional protocols advocate a minimum of four weeks of immobilization, particularly for displaced fractures, emerging evidence suggests that immobilization may be unnecessary for stable distal radius fractures.[8] This evolving perspective has raised questions regarding the necessity of rigid immobilization for inherently stable injuries.[9,10] Within this context, volar splinting, a less restrictive alternative to circumferential casting, has been hypothesized to provide adequate immobilization for the conservative management of stable distal radius fractures. This study aims to compare the clinical and radiological outcomes of short-arm circular casting and volar splinting in the conservative management of stable distal radius fractures. It is hypothesized that volar splinting provides outcomes comparable to those of circular casting in terms of fracture stability, complication rates, and functional recovery, thereby supporting its use as a less restrictive treatment alternative.

MATERIALS AND METHODS

This retrospective study was conducted in accordance with the Declaration of Helsinki and was approved by the local ethics committee (AEŞH-EK1-2023-499). Patient records from the emergency departments of two distinct hospitals were reviewed for the diagnosis of acute distal radius fractures between January 2020 and January 2023. This study exclusively included patients with stable, nondisplaced, or minimally displaced distal radius fractures. Fractures that were potentially unstable or required reduction were excluded from the analysis. Stability criteria were established according to Lindstrom's descriptions as follows: dorsal angulation <15°, volar tilt <20°, radial inclination >15°, ulnar variance <5 mm, and articular surface step-off <2 mm.[11] Inclusion criteria were age ≥18 years, fractures not requiring manipulation, isolated upper extremity injuries, absence of a prior wrist fracture history, and compliance with a six-month follow-up period. This study included fractures categorized as Frykman types 1, 3, 5, and 7.

Exclusion criteria were inadequate or low-quality radiographs, fractures with dorsal comminution, concomitant fractures (such as ulnar styloid fractures), pre-existing anatomical deformities, open injuries, fractures requiring reduction, and inability to complete the six-month follow-up.

Circular cast applications (Alban®, Ağaoğlu Medical, Türkiye) were performed by orthopedic and traumatology residents or specialists, whereas volar splints were custom-molded and applied by experienced casting professionals using moldable thermoplastic material (Ilgaz®, Ongun Medical, Türkiye). Casting generally required a higher level of technical expertise and precise application to maintain alignment and ensure appropriate pressure distribution. In contrast, volar splinting was a simpler and more practical technique that could be efficiently applied by trained personnel, particularly in high-volume emergency department settings. Both methods were used to stabilize the wrist in a neutral position of rotation, deviation, and flexion. The volar splint was applied to the volar aspect of the forearm and wrist and secured using an elastic bandage (Fig. 1). In this study, patients were treated at two different institutions. All stable distal radius fractures

Figure 1. Illustration demonstrating immobilization of the wrist in a neutral position using a circular cast (left) and a plaster splint (right).

presenting to the secondary care hospital were managed with volar splints, whereas those admitted to the tertiary care center received circular cast treatment. This allocation reflected institutional practice patterns rather than randomization. All patients were immobilized for a standard period of four weeks.

Regular clinical and radiographic evaluations were performed in both groups before and after treatment. Wrist radiographs were obtained in anteroposterior and lateral views during the initial assessment in the emergency department, as well as at weeks 2 (first follow-up), 4 (termination of immobilization), 8, and 6 months (final follow-up). Radiographic parameters included radial height (mm), radial inclination (°), dorsal/volar tilt (°), and articular surface step-off. All radiographs were digitized using Picture Archiving and Communication System (PACS) software (PiViewStar®; Infinite Technology, Seoul, Korea). The software included a digital goniometer and additional measurement tools with a precision of 1/1000. This standardization eliminated potential magnification and measurement errors.

Patients were monitored for early complications, such as edema, neurovascular compromise, and signs of compartment syndrome, throughout the follow-up period. Clinical assessments of swelling and vascular status (including capillary refill, skin color, and temperature) were performed at each follow-up visit. However, no quantitative grading system (e.g., circumference measurement or a standardized edema scale) was used to document swelling. In addition, complications such as displacement, complex regional pain syndrome (CRPS), and tendon rupture were recorded during the study period.

At the six-month follow-up, functional outcomes and patient-reported satisfaction were assessed using two standardized instruments. Patient function was evaluated using Quick Disabilities of the Arm, Shoulder, and Hand (qDASH) and Patient-Rated Wrist Evaluation (PRWE) questionnaires. Wrist range of motion was quantified using a goniometer to assess volar and dorsal flexion, radial and ulnar deviation, and pronation and supination. The PRWE scale, comprising 15 items, is a self-administered questionnaire, with higher scores indicating greater functional limitations.[12] The qDASH, which consists of 11 items, evaluates pain and functional impairment, with higher scores indicating greater functional loss.[13]

Radiographs obtained at the six-month follow-up were evaluated for fracture union, delayed union, malunion, and degenerative joint changes. Radiographic measurements were independently performed by two orthopedic surgeons, demonstrating excellent interobserver reliability (intraclass correlation coefficient [ICC] >0.90). To ensure consistency, measurements obtained by the more experienced evaluator were used for analysis. Functional outcomes, including range of motion, PRWE, and qDASH scores, were assessed by two additional orthopedic specialists. All evaluators were blinded to treatment group allocation during the assessment process.

Statistical Analysis

Statistical analyses were conducted using SPSS version 25 (IBM Corp., Armonk, NY, USA). The Kolmogorov-Smirnov test was used to evaluate data distribution. Comparisons of normally distributed continuous variables between the two groups were performed using the independent samples t-test, with statistical significance defined as $p<0.05$. Nominal variables were assessed using the chi-square test or Fisher's exact test, depending on the data format. Subgroup comparisons across the four predefined categories (cast with nondisplaced fractures, cast with minimally displaced fractures, splint with nondisplaced fractures, and splint with minimally displaced fractures) were conducted using multivariate analysis of variance (MANOVA). The effect size, as determined by Cohen's d, was 0.45, indicating a moderate difference between the groups. Additionally, a power analysis conducted on 170 data points demonstrated a statistical power of 0.9, confirming that the analyses had sufficient sample size and reliability.

RESULTS

A total of 170 patients were included in this study, comprising 88 patients in the cast group and 82 patients in the splint group. As presented in Table 1, no significant differences were observed between the two treatment groups in terms of demographic variables, including age, sex, hand dominance, and smoking status ($p>0.05$). Similarly, no statistically significant differences were found in demographic characteristics between the nondisplaced and minimally displaced fracture groups.

Radiological assessments yielded comparable results for both treatment groups when baseline measurements were compared with those recorded six months post-treatment. No statistically significant differences were observed between the initial and six-month measurements for radial height, radial inclination, palmar tilt, or articular surface step-off ($p>0.05$). Table 2 presents the detailed radiological findings. The rate of loss of reduction in minimally displaced fractures was 3.5% (n=2) in the cast group and 5.6% (n=3) in the splint group; however, this difference did not result in significant variations in clinical or radiological outcomes ($p=0.386$).

At the six-month follow-up, clinical and functional evaluations included qDASH and PRWE scores, as well as measurements of joint range of motion. No statistically significant differences were observed in functional outcomes between the cast and splint groups. The qDASH and PRWE scores were comparable between the two groups ($p>0.05$), and no differences were observed in joint range of motion, including flexion, extension, pronation, and supination (Table 3). Comparison of the nondisplaced and minimally displaced fracture subgroups also revealed no statistically significant differences in functional outcomes.

The complication rates during the six-month post-fracture follow-up were 5.7% (n=5) in the cast group and 4.8% (n=4)

Table 1. Comparison of demographic characteristics between the study groups

	Cast (n=88)	Splint (n=82)	p-value
Age (years)	45.6±10.3	48.5±12.6	0.086
Sex (Male/Female)	32/56	27/55	0.638
Dominant side injured (Yes/No)	56/32	54/28	0.762
Frykman classification			0.519
Type 1	38	38	
Type 3	23	15	
Type 5	17	15	
Type 7	10	14	
Displacement (Minimal/None)	57/31	54/28	0.967
Smoking status (Yes/No)	29/59	34/48	0.251

Table 2. Comparison of initial and final radiological measurements according to treatment modality (cast vs. splint) and fracture displacement type (nondisplaced vs. minimally displaced)

Parameter (unit)	Cast		Splint		p-value
	Nondisplaced (n=57)	Minimally Displaced (n=31)	Nondisplaced (n=54)	Minimally Displaced (n=28)	
Radial Inclination (°)					
Initial	23.41±2.74	23.15±1.90	23.69±2.15	24.08±1.85	0.420
Final	22.97±3.58	23.14±1.91	23.09±3.06	24.08±1.85	0.400
Radial Height (mm)					
Initial	12.33±1.64	12.26±1.32	12.07±1.75	12.44±1.70	0.755
Final	11.98±2.02	12.39±1.45	11.64±2.33	12.43±1.70	0.244
Palmar Tilt (°)					
Initial	11.21±1.66	11.35±1.68	11.48±1.45	11.54±1.42	0.754
Final	10.96±1.98	11.32±1.68	11.07±2.22	11.50±1.42	0.628
Articular Step-off (mm)					
Initial	0.16±0.37	0.19±0.40	0.17±0.38	0.14±0.36	0.960
Final	0.21±0.45	0.19±0.40	0.22±0.42	0.14±0.36	0.869

in the splint group. The incidence of complications did not differ significantly between the two groups (p=0.386). In the cast group, two patients experienced fracture displacement, two were diagnosed with complex regional pain syndrome, and one required carpal tunnel release surgery. Among patients diagnosed with CRPS, one individual had a history of hand numbness related to neuropathic sensitivity, while another demonstrated a predisposition to microvascular complications attributable to a history of tobacco use (Fig. 2). The splint group reported three cases of fracture displacement and one instance of rupture of the extensor pollicis longus (EPL) tendon. In cases of nondisplaced fractures, no subsequent displacement was observed (Fig. 3). As previously described, displacement findings were limited to minimally displaced fractures. These events were not significantly associated with clinical or functional outcomes. Patients with displacement were aged 64 and 60 years in the cast group and 68, 66, and 45 years in the splint group. A 45-year-old patient with displacement underwent surgical intervention, whereas the remaining patients were managed conservatively.

Table 3. Comparison of joint range of motion and patient-reported outcome measures (DASH and PRWE) at the 6-month follow-up across subgroups defined by treatment modality (cast vs. splint) and fracture displacement type (nondisplaced vs. minimally displaced)

Parameter (unit)	Cast		Splint		p-value
	Nondisplaced (n=57)	Minimally Displaced (n=31)	Nondisplaced (n=54)	Minimally Displaced (n=28)	
Range of Motion (°)					
Flexion	62.65±8.70	60.87±8.15	62.83±9.75	60.82±9.12	0.637
Extension	44.53±9.92	43.48±7.74	46.39±6.93	46.68±6.08	0.279
Radial Deviation	18.09±2.82	17.97±2.73	18.61±3.47	18.46±3.73	0.758
Ulnar Deviation	21.25±2.71	21.68±2.80	21.26±2.34	22.21±2.44	0.346
Supination	69.72±4.40	68.61±3.62	68.56±3.42	68.43±3.32	0.301
Pronation	81.16±3.76	81.77±4.59	80.72±3.63	81.68±4.35	0.609
Patient-Reported Outcomes					
PRWE	12.18±5.72	12.94±4.45	11.15±4.64	10.86±4.54	0.280
DASH	13.56±6.78	13.94±6.21	13.34±6.42	13.01±6.79	0.955

Figure 2. Posteroanterior radiographs of a Frykman type III nondisplaced distal radius fracture showing the initial stable fracture (left) and diffuse demineralization consistent with complex regional pain syndrome (right) at the third-month follow-up after four weeks of immobilization.

Figure 3. Posteroanterior radiographs of a Frykman type I distal radius fracture showing initial immobilization with a volar splint (left) and the six-month follow-up image demonstrating complete radiographic healing (right).

DISCUSSION

In this study, the clinical and radiological outcomes of circular casting versus volar splint application in the management of stable, nondisplaced, and minimally displaced distal radius fractures revealed that both techniques provide safe and effective treatment options. Comparable complication rates and functional outcomes support the viability of both approaches in the conservative management of stable fractures. This study evaluated Frykman types 1, 3, 5, and 7 fractures, with stability assessed according to Lindstrom criteria. The Frykman classification provides a framework for categorizing fracture patterns; however, incorporating additional factors such as age, dorsal comminution, angular deformity, and ulnar styloid fracture may enhance the prediction of instability.[14] Patients with ulnar styloid fractures were excluded from our study due to their association with distal radioulnar joint instability, which can adversely affect treatment outcomes.[15] Given the heightened risk of instability associated with ulnar styloid fractures involving the basal fragment, our objective was to obtain a more homogeneous patient cohort.

The literature indicates that stable distal radius fractures have received less attention than unstable fractures, with recent discussions primarily focusing on the duration of immobilization.[7] Traditional guidelines recommend 4-6 weeks of immobilization; however, recent studies suggest that shorter durations may be sufficient. The risk of fracture redisplacement is highest within the first two weeks and subsequently decreases to approximately 7–8%.[16,17] Recent research emphasizes reduced immobilization durations, with growing evidence supporting three weeks as sufficient.[18]

The four-week immobilization period used in this study was

selected to balance the risk of early fracture redisplacement with the need to minimize adverse outcomes, such as wrist stiffness and restricted range of motion associated with prolonged immobilization. This decision also reflected standard institutional practice at both participating centers, ensuring protocol consistency across study groups. While our findings demonstrated the clinical and radiological effectiveness of a four-week duration, future comparative studies are warranted to evaluate whether shorter immobilization periods can provide equivalent outcomes, particularly in carefully selected patients with stable fractures, adequate bone quality, and low comorbidity.

Nondisplaced and minimally displaced distal radius fractures are typically classified as cohorts with a low risk of secondary displacement due to their inherent stability. Research suggests that fractures are stable and can be effectively managed with conservative treatment in the absence of dorsal comminution, with radial shortening <2 mm, lateral displacement <2 mm, and a dorsal tilt angle not exceeding 10°.[19] The initial degree of displacement is a critical factor influencing the risk of early displacement.[20]

Roth et al.[2] reported no displacement, surgical intervention, or malunion in any of the 82 nondisplaced distal radius fractures. Leone et al.[21] highlighted that elderly patients exhibit a greater risk of instability, indicating the need for enhanced monitoring in this demographic.

In the present study, no loss of reduction was observed in nondisplaced fractures; however, displacement was identified in five patients with minimally displaced fractures. Notably, four of these cases involved patients over 60 years of age, suggesting that advanced age may significantly influence fracture stability. Although nondisplaced distal radius fractures are generally considered stable, a redisplacement rate as high as 30% has been reported in minimally displaced fractures, particularly in the presence of dorsal comminution and advanced age.[22] The exclusion of fractures with dorsal comminution in the present study may explain the lower displacement rates observed. The findings indicate that the risk of displacement persists in minimally displaced fractures, emphasizing the need to consider patient characteristics, such as age, during stability assessments and underscoring the importance of a thorough follow-up protocol. Moreover, it is essential to acknowledge that satisfactory clinical outcomes can still be achieved in older patients, even in the presence of displacement.[23]

Research indicates that pain complaints are comparable between patients receiving splint treatment and those undergoing cast treatment, with similar rates of redisplacement in both groups.[5] Studies on displaced and reduced distal radius fractures report significant displacement rates for both techniques; however, they emphasize that splinting and casting demonstrate comparable effectiveness in limiting further displacement.[3,4] A clear consensus on the optimal method of immobilization for stable fractures is lacking; however, some studies suggest that cast immobilization may be unnecessary for preventing redisplacement and may primarily serve to manage pain.[19] Some studies have suggested that more flexible immobilization techniques, such as elastic bandaging, provide comparable stability and may potentially enhance functional outcomes.[10] Future studies evaluating the use of splints and shortened immobilization periods for nondisplaced or minimally displaced distal radius fractures may help optimize treatment protocols and contribute to improved patient comfort and compliance.

Research suggests that junior physicians and less experienced medical personnel frequently exhibit insufficient knowledge of fracture diagnosis, reduction criteria, and immobilization techniques when managing distal radius fractures in emergency departments.[24,25] The application of a volar splint, characterized by its rapid and uncomplicated implementation by skilled plaster technicians, offers a distinct advantage in the high-pressure environment of busy emergency departments; however, it may also entail certain disadvantages, including the risk of loosening. In contrast, circular cast application generally requires the involvement of orthopedic and traumatology residents or specialists, as well as a meticulous and seasoned approach, to prevent complications such as edema, vascular compromise, and nerve compression resulting from overly tight application. This study demonstrated that volar splint immobilization is as effective as circular casting in the management of stable distal radius fractures, yielding comparable clinical and radiological outcomes. Therefore, emergency medicine practitioners may consider volar splinting a viable alternative to circular casting in routine clinical practice.

Several limitations should be acknowledged in this study. The retrospective design inherently limits methodological rigor compared with prospective studies. A six-month follow-up is generally considered sufficient for evaluating functional outcomes; however, patients lost to follow-up after the immobilization period due to perceived improvement may have influenced the radiographic outcomes. The emergence of various complications during an extended follow-up period cannot be excluded. Given that radiographic changes in older patients do not consistently correlate with functional outcomes, conducting analyses in more homogeneous age groups may be advantageous. Additionally, analyzing the relationship between bone mineral density and positional loss, and incorporating these data into future studies, may yield valuable insights.

Another limitation is demographic variability. Although age, sex, and osteoporosis status were similar between the groups, this may have limited the ability to detect clinically meaningful differences. These demographic factors are well known to influence fracture stability and functional recovery, particularly in elderly or osteoporotic patients, and should be carefully considered in future studies. Finally, the lack of standardization of immobilization protocols between the two centers should be acknowledged. Orthopedic residents or specialists applied circular casts in a tertiary care hospital,

whereas trained cast technicians administered volar splints in a secondary care setting. This discrepancy in practitioner profiles may have introduced variability in the technical application of immobilization. However, it also reflects real-world clinical conditions, in which treatment strategies differ based on institutional resources and available expertise. Therefore, although this methodological variability should be considered when interpreting the results, it highlights the practical feasibility of volar splinting in high-volume, resource-constrained clinical settings.

CONCLUSION

This study demonstrates that circular casting and volar splint application yield comparable clinical and functional results in the management of stable, nondisplaced, or minimally displaced distal radius fractures. Both methods represent safe and effective treatment options. In the emergency department context, the ease of application and patient comfort associated with volar splinting support its use as a suitable alternative in appropriately selected patient populations

Ethics Committee Approval: This study was approved by the Ankara Etlik City Hospital Ethics Committee Ethics Committee (Date: 27.09.2023, Decision No: AEŞH-EK1-2023-499).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Yetişkinlerde nondeplase veya minimal deplase distal radius kırıklarının yönetimi: Sirküler alçı ile plaster splint uygulaması arasındaki immobilizasyon karşılaştırması

AMAÇ: Distal radius kırıkları, erişkinlerde en sık görülen kırıklar arasında yer almakta olup, büyük bir kısmı stabil, kaymamış veya minimal kaymış özellik göstermektedir. Bu çalışma, stabil distal radius kırıklarının konservatif tedavisinde kullanılan kısa kol dairesel alçı ve volar splint uygulamalarının klinik ve radyolojik etkinliğini karşılaştırmayı; ayrıca, bu iki yöntemin komplikasyon oranları, hasta konforu ve uygulanabilirliği üzerindeki etkilerini değerlendirmeyi amaçlamaktadır.

GEREÇ VE YÖNTEM: Ocak 2020 ile Ocak 2024 tarihleri arasında, iki farklı hastanenin acil servislerinde tanı alan stabil, kaymamış veya minimal kaymış distal radius kırığı olan hastaların kayıtları retrospektif olarak incelendi. Kırıkların stabilitesi Lindstrom kriterlerine göre değerlendirildi. Çalışmaya dahil edilen 170 hastadan 88'ine kısa kol dairesel alçı, 82'sine ise volar splint uygulandı. Her iki grup da dört hafta boyunca immobilize edildi ve hastalar altı ay süreyle takip edildi. Radyolojik ölçümler (radial yükseklik, radial inklinasyon, palmar tilt ve eklem yüzeyi basamağı) düzenli aralıklarla değerlendirildi. Klinik ve fonksiyonel sonuçlar, Quick Disabilities of the Arm, Shoulder, and Hand (qDASH) ve Patient-Rated Wrist Evaluation (PRWE) ölçekleri ile belirlendi. Komplikasyon oranları ve hasta memnuniyeti de karşılaştırıldı.

BULGULAR: Toplamda 170 hasta (ortalama yaş: 46.9±11.4 yıl) çalışmaya dahil edildi. Radyolojik parametreler açısından alçı ve splint grupları arasında başlangıç ve altı aylık takiplerde anlamlı bir fark tespit edilmedi ($p>0.05$). Klinik ve fonksiyonel değerlendirmelerde qDASH ve PRWE skorları her iki grupta benzerdi ($p>0.05$). Komplikasyon oranları açısından gruplar arasında anlamlı bir fark bulunmadı (alçı grubu %5.7, splint grubu %4.8; $p>0.05$). Splint grubu, uygulama kolaylığı ve hasta konforu açısından avantaj sağladı.

SONUÇ: Stabil distal radius kırıklarının konservatif tedavisinde kısa kol dairesel alçı ve volar splint uygulamaları benzer klinik ve fonksiyonel sonuçlar sunmaktadır. Bununla birlikte, volar splint uygulaması, acil servislerde uygulama kolaylığı ve hasta memnuniyeti açısından etkili bir alternatif olarak değerlendirilebilir.

Anahtar sözcükler: Distal radius kırığı; kısa kol alçı; konservatif tedavi; stabil kırıklar; volar splint.

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ORIGINAL ARTICLE

Comparison of vitamin D, parathyroid hormone (PTH), and bone metabolism markers in hip fracture patients by fracture type and control group

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ABSTRACT

BACKGROUND: Vitamin D, calcium, and bone metabolism markers play a critical role in skeletal health; however, their relationship with different hip fracture types remains uncertain. This study aimed to investigate serum levels of 25(OH) vitamin D, calcium, parathyroid hormone (PTH), alkaline phosphatase (ALP), phosphorus, total protein, and albumin in elderly patients with femoral neck fractures (FNF) and intertrochanteric femur fractures (ITFF), compared to a control group.

METHODS: This retrospective study included 375 patients aged 65 years and older, comprising 117 patients with ITFF, 97 with FNF, and 161 control cases (coxarthrosis/gonarthrosis). Serum biochemical parameters were analyzed using standard laboratory methods. Fractures were classified according to the AO/OTA (Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association) system by two independent observers, and interobserver agreement was assessed using Cohen's kappa coefficient (κ=0.89). Group comparisons were performed using one-way analysis of variance (ANOVA) followed by post hoc Bonferroni tests. A p value <0.05 was considered statistically significant.

RESULTS: Vitamin D levels were significantly lower in both the ITFF and FNF groups compared to controls ($p<0.01$), while no significant difference was observed between the ITFF and FNF groups ($p>0.05$). Similarly, calcium, total protein, and albumin levels were lower in fracture groups than in controls ($p<0.01$). In contrast, PTH levels were significantly higher in patients with fractures ($p=0.001$).

CONCLUSION: Deficiencies in vitamin D and calcium were associated with an increased risk of hip fractures but did not appear to influence fracture pattern. These findings suggest that systemic biochemical parameters should be emphasized in comprehensive fracture risk assessment, underscoring the importance of preoperative evaluation and postoperative correction of metabolic deficiencies in patients with hip fractures.

Keywords: Bone metabolism markers; calcium; femoral neck fracture; hip fracture; intertrochanteric fracture; vitamin D.

INTRODUCTION

Hip fractures are becoming increasingly common due to extended life expectancy in the global population. Vitamin D deficiency is a well-recognized risk factor for hip fracture and has been shown to predict functional recovery and survival following hip fracture surgery. Intertrochanteric and femoral neck fractures are associated with substantial morbidity, mortality, and economic burden. The rising prevalence of osteoporosis further escalates the risk of these fractures.[1-3]

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Vitamin D is a fat-soluble steroid hormone that plays a pivotal role in calcium homeostasis and bone mineralization. Its deficiency has been linked to numerous systemic conditions, including osteoporosis and increased fracture risk. Elderly individuals are particularly susceptible because of reduced sun exposure and dietary insufficiencies. Although the role of vitamin D and calcium deficiencies in skeletal health is well established, their specific influence on different fracture types remains insufficiently explored.

Furthermore, studies examining the relationship between hip fracture classification and specific biochemical parameters, such as alkaline phosphatase (ALP), phosphorus, total protein, and albumin, are scarce.

The aim of our study was to investigate the association between hip fracture type and vitamin D levels, along with other biochemical parameters related to bone metabolism. By elucidating these relationships, this study seeks to provide insights that may contribute to preventive strategies for populations at increased risk.

MATERIALS AND METHODS

This retrospective study analyzed data from patients treated at a single tertiary care center over a five-year period, following approval from the institutional ethics board (ID: 2014//0180). The study was conducted in accordance with the principles of the Declaration of Helsinki. A total of 1,219 patients were identified through hospital registry screening, including 967 patients diagnosed with either femoral neck fracture or intertrochanteric femoral fracture, and 252 patients diagnosed with osteoarthritis (coxarthrosis or gonarthrosis). Demographic and clinical data were recorded at the time of diagnosis and included hip radiographs, comorbidities, regular medication use (osteoporosis treatment, calcium, and vitamin D supplementation), history of prior fractures, treatment modalities, laboratory test results (alkaline phosphatase, total protein, albumin, calcium, phosphorus, parathyroid hormone [PTH], and 25-hydroxyvitamin D [25-OH vitamin D]), and the city of residence during the year preceding the fracture.

The inclusion criteria encompassed individuals aged 65 years and older diagnosed with either an intertrochanteric femur fracture or a femoral neck fracture resulting from low-energy trauma, as well as patients with osteoarthritis who served as the control group.

Exclusion criteria included prior osteoporosis treatment or hormone therapy, high-energy trauma, malignancy, secondary osteoporosis, renal or gastrointestinal disorders, parathyroid or thyroid dysfunction, steroid use, and residence outside the study region for more than one year before enrollment. Ultimately, 375 cases were analyzed, including 117 patients with intertrochanteric fractures, 97 with femoral neck fractures, and 161 with osteoarthritis (coxarthrosis/gonarthrosis).

Demographic characteristics, fracture history, radiological findings, comorbidities, and biochemical parameters (ALP, total protein, albumin, calcium, phosphorus, PTH, and 25-OH vitamin D) measured within the first week after fracture were obtained from hospital records. Although vitamin D levels are known to exhibit seasonal variation, all biochemical analyses were performed using the same chemiluminescence immunoassay method (Abbott Architect System®), ensuring standardization across samples. Seasonal variability was further minimized by collecting samples throughout all seasons. There is no globally defined threshold for optimal vitamin D levels, as these vary according to latitude, sun exposure, and race. In our study, threshold criteria for 25-OH vitamin D levels were determined based on the Diagnosis and Treatment Guidelines for Metabolic Bone Diseases published by the Turkish Society of Endocrinology and Metabolism. Accordingly, levels <10 ng/mL were classified as severe deficiency, 10-20 ng/mL as deficiency, 21-29 ng/mL as insufficiency, ≥30 ng/mL as sufficient, and >150 ng/mL as toxic.[4]

Fractures were classified according to the AO/OTA (Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association) system by two independent orthopedic surgeons who were blinded to the biochemical results.[5] Any discrepancies were resolved by consensus under the supervision of the senior author.

Statistical Analysis

Statistical analyses were performed using NCSS (Number Cruncher Statistical System) 2007 and PASS (Power Analysis and Sample Size) 2008 software (Utah, USA). Inter-observer reliability was assessed using Cohen's kappa coefficient. Post hoc power analyses were conducted to evaluate the statistical power of the study and to reduce the risk of type II error. Descriptive statistics, including mean, standard deviation, median, frequency, and ratio, were used to summarize the data. For intergroup comparisons of normally distributed variables, one-way analysis of variance (ANOVA) was applied, followed by the Tukey Honestly Significant Difference (HSD) test to identify the source of significant differences. Non-normally distributed variables were analyzed using the Kruskal-Wallis test for overall group comparisons, followed by the Mann-Whitney U test to identify differences between pairs of groups. Relationships between variables were assessed using Spearman's correlation analysis. Results were evaluated at a 95% confidence interval, and statistical significance was set at $p<0.05$.

RESULTS

A total of 375 patients were included in the study, with ages ranging from 65 to 93 years (mean, 78.34±6.42 years). Of these, 292 patients (77.9%) were female and 83 (22.1%) were male. The intertrochanteric femur fracture (ITFF) group included 117 patients, the femoral neck fracture (FNF) group included 97 patients, and the control group (patients with coxarthrosis or gonarthrosis) included 161 patients.

Post hoc power analysis demonstrated power values ranging

Table 1. Age and sex distribution of the study groups

	ITFF (n=117)	Femoral Neck Fracture (n=97)	Control (n=161)	P
Age				
Mean±SD (range)	79.59±6.16 (65-93)	78.31±7.26 (65-90)	77.12±5.84 (65-92)	[a]0.056
Sex				
Female, n (%)	91 (77.8)	75 (77.3)	126 (78.4)	[b]0.988
Male, n (%)	26 (22.2)	22 (22.7)	35 (21.7)	

ITFF: Intertrochanteric femur fracture; [a]One-way analysis of variance (ANOVA) test; [b]Chi-square test.

from 0.984 to 1.000 for the primary qualitative outcomes, indicating a minimal risk of type II error and confirming that the sample size was sufficient. Inter-observer reliability for fracture classification was excellent (κ=0.89). No statistically significant differences were observed among the groups with respect to age (p=0.056) or sex distribution (p=0.988) (Table 1).

According to the AO/OTA classification, 38 patients (32.9%) in the intertrochanteric femur fracture group were classified as A1, 59 patients (50.4%) as A2, and 20 patients (17.1%) as A3. In the femoral neck fracture group, six patients (6.3%) were classified as B1, 51 patients (53.7%) as B2, and 38 patients (40%) as B3.

25-OH vitamin D levels were significantly lower in both the ITFF and FNF groups compared to the control group (p<0.01). However, no significant difference was observed between the ITFF and FNF groups (p>0.05). Mean vitamin D levels were 12.28±8.61 ng/mL in the ITFF group and 16.1±13.12 ng/mL in the FNF group. Vitamin D deficiency was prevalent across all groups (Table 2, Fig. 1).

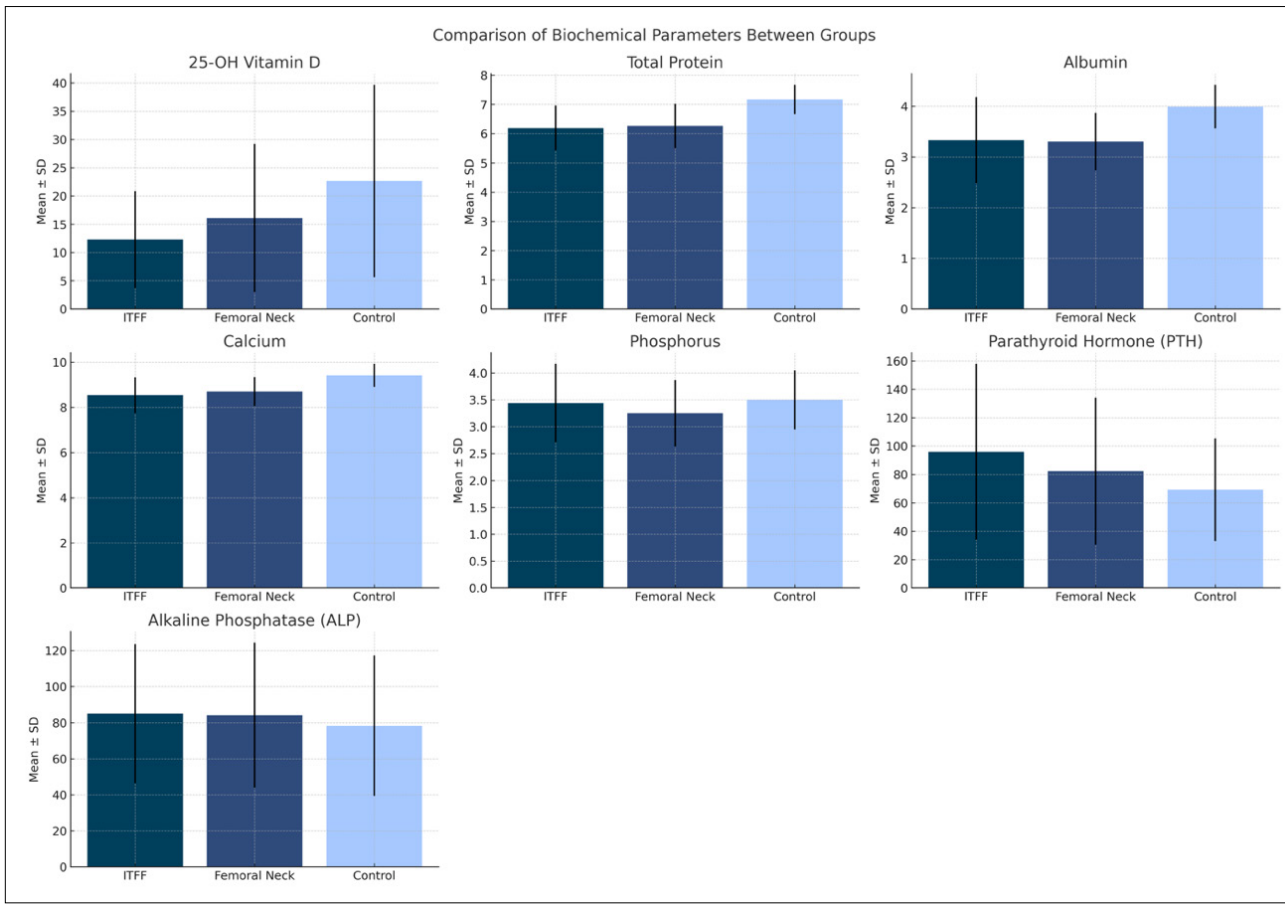

Figure 1. Group-wise mean (±standard deviation) levels of 25(OH) vitamin D, total protein, albumin, calcium, phosphorus, parathyroid hormone (PTH), and alkaline phosphatase (ALP) in the intertrochanteric femur fracture (ITFF), femoral neck fracture (FNF), and control groups.

Table 2. Comparison of 25-OH vitamin D, total protein, albumin, calcium, phosphorus, parathyroid hormone (PTH), and alkaline phosphatase (ALP) levels among fracture groups and controls

	[1]ITFF	[2]Femoral Neck Fracture	[3]Control	[a]p	[b]Post Hoc
25-OH Vitamin D					
Mean±SD	12.28±8.61	16.10±13.12	22.65±17.00	**0.001****	**P^{1-2} 0.059**
Min-Max (median)	3-51.2 (10.50)	1.90-68 (12.10)	5.20-133 (19.80)		**P^{1-3} 0.001****
Severe deficiency, n (%)	53 (45.3)	41 (42.3)	20 (12.4)		**P^{2-3} 0.001****
Deficiency, n (%)	49 (41.9)	33 (34.0)	69 (42.9)		
Insufficiency, n (%)	10 (8.5)	11 (11.3)	45 (28.0)		
Sufficiency, n (%)	5 (4.3)	12 (12.4)	25 (15.5)		
Toxic level, n (%)	0	0	0		
Total Protein					
Mean±SD	6.19±0.77	6.26±0.76	7.17±0.50	**0.001****	**P^{1-2} 1.000**
Min-Max (median)	3.96-9.70 (6.20)	4.47-8.97 (6.20)	5.00-8.50 (7.15)		**P^{1-3} 0.001****
Abnormal, n (%)	71 (60.7)	58 (59.8)	8 (5.0)		**P^{2-3} 0.001****
Normal, n (%)	46 (39.3)	39 (40.2)	153 (95.0)		
Albumin					
Mean±SD	3.33±0.85	3.30±0.57	3.99±0.43	**0.001****	**P^{1-2} 0.952**
Min-Max (median)	1.90-9.00 (3.30)	1.90-4.70 (3.40)	2.40-5.00 (4.00)		**P^{1-3} 0.001****
Abnormal, n (%)	78 (66.7)	60 (61.9)	17 (10.6)		**P^{2-3} 0.001****
Normal, n (%)	39 (33.3)	39 (38.1)	144 (89.4)		
Calcium					
Mean±SD	8.54±0.80	8.70±0.65	9.42±0.51	0.001**	P^{1-2} 0.169
Min-Max (median)	4.10-11.90 (8.50)	6.66-10.40 (8.70)	7.50-10.70 (9.50)		P^{1-3} 0.001**
Abnormal, n (%)	64 (54.7)	42 (43.3)	9 (5.6)		P^{2-3} 0.001**
Normal, n (%)	53 (45.3)	55 (56.7)	152 (94.4)		
Phosphorus					
Mean±SD	3.44±0.73	3.25±0.62	3.50±0.55	0.006**	**P^{1-2} 0.074**
Min-Max (median)	1.10-5.50 (3.40)	1.80-4.50 (3.28)	2.00-5.30 (3.50)		**P^{1-3} 0.764**
Abnormal, n (%)	11 (9.4)	6 (6.4)	4 (2.5)		**P^{2-3} 0.008****
Normal, n (%)	106 (90.6)	91 (93.8)	157 (97.5)		
PTH					
Mean±SD	95.97±61.95	82.26±51.87	69.23±36.16	**0.004****	**P^{1-2} 0.142**
Min-Max (median)	13.30-250.0 (77.10)	21.80-263.0 (65)	16.00-250.0 (65.1)		**P^{1-3} 0.001****
Abnormal, n (%)	52 (44.4)	30 (30.9)	30 (18.6)		**P^{2-3} 0.113**
Normal, n (%)	65 (55.6)	67 (69.1)	131 (81.4)		
ALP					
Mean±SD	84.98±38.57	84.12±40.19	78.31±38.98	0.127	**P^{1-2} 0.394**
Min-Max (median)	36.00-290.00 (79.00)	37.00-306.00 (75.00)	27.00-480.00 (75)		**P^{1-3} 0.065**
Abnormal, n (%)	11 (9.4)	8 (8.2)	7 (4.3)		**P^{2-3} 0.360**
Normal, n (%)	106 (90.6)	89 (91.8)	154 (95.7)		

**Statistically significant; [a]ANOVA; [b]Post hoc pairwise comparisons.

Total protein and albumin levels were significantly lower in both fracture groups compared to the control group (p=0.001), while no difference was observed between the ITFF and FNF groups. Serum calcium levels were also lower in fracture patients (mean, 8.1±0.5 mg/dL; p<0.01). PTH levels were significantly higher in both fracture groups compared

to controls (p=0.001), with abnormal PTH rates of 44.4%, 30.9%, and 18.6% in the ITFF, FNF, and control groups, respectively. As expected, ALP and phosphorus levels did not differ significantly among the groups (Table 2).

DISCUSSION

The primary findings of this study indicate that lower serum calcium and 25(OH) vitamin D levels are associated with an increased risk of hip fractures but do not influence fracture type. These results are consistent with previous reports identifying vitamin D and calcium deficiency as major risk factors for hip fractures.[6-11] The low 25(OH) vitamin D levels observed across all groups, including the control group, are in agreement with prior studies and may reflect insufficient sunlight exposure, reduced outdoor activity, and diminished dermal vitamin D synthesis in elderly individuals.[12] Approximately 85% of vitamin D is synthesized through ultraviolet exposure, with the remainder obtained from dietary sources.[2]

Vitamin D deficiency contributes to secondary hyperparathyroidism, increased bone turnover, and skeletal fragility. Although no difference in 25(OH) vitamin D levels was observed between intertrochanteric femur fracture and femoral neck fracture groups, both fracture groups exhibited significantly lower levels than the control group. Similar to previous studies, our findings indicate that vitamin D deficiency is associated with fracture occurrence rather than fracture subtype. In contrast, several small-sample studies have proposed a relationship between vitamin D levels and fracture severity.[13,14] Differences between FNF and ITFF may be attributable to variations in trabecular bone composition and metabolic activity, as the intertrochanteric region contains a higher proportion of metabolically active trabecular bone.[15,16] Nevertheless, fracture configuration appears to be primarily determined by mechanical and anatomical factors rather than biochemical variables.

Geographical variation in fracture patterns has been previously reported, with trochanteric fractures occurring more frequently in Southern Europe and femoral neck fractures predominating in Northern Europe.[17-19] Our findings are consistent with data from Japan (FNF/ITFF ratio of 1:1.3) and other Mediterranean populations, which demonstrate a higher incidence of intertrochanteric fractures.[20]

Protein and albumin levels were significantly lower in patients with hip fractures compared to controls, consistent with previous studies.[20,21] Whether these findings represent pre-existing risk factors or reflect a post-fracture catabolic response remains unclear. Nevertheless, several studies have identified low protein and albumin levels as independent predictors of fracture risk.[22] Similarly, calcium levels were reduced in both fracture groups, likely secondary to vitamin D deficiency.[21] Randomized controlled trials have demonstrated that adequate dietary calcium and protein intake can reduce the risk of hip fractures.[23]

Parathyroid hormone levels were significantly elevated in the fracture groups, particularly among patients with ITFF, in line with earlier reports.[20,24,25] This elevation most likely represents a compensatory response to vitamin D deficiency rather than a direct effect of the fracture itself. Phosphorus levels were slightly lower in the FNF group but not in the ITFF group, similar to previous findings indicating minimal differences among fracture types.[17] Although elevated alkaline phosphatase levels have been proposed as a potential risk factor for fractures, no significant association was observed in our study.[26]

Several limitations of this study should be acknowledged. The retrospective, single-center design may limit the generalizability of the results, and potential confounding factors, such as lifestyle habits and nutritional intake, could not be fully controlled. In addition, serum vitamin D levels were measured at a single time point, without accounting for seasonal variation that may influence vitamin D status. The lack of longitudinal follow-up data precluded assessment of postoperative changes or the long-term effects of vitamin D and calcium optimization on bone healing and functional recovery. Future prospective, multicenter studies incorporating serial biochemical measurements are needed to validate these findings and to further elucidate the causal relationships between metabolic parameters and fracture risk.

From a clinical perspective, these findings underscore that optimal management of hip fractures should extend beyond surgical fixation to include the identification and correction of underlying metabolic abnormalities. Comprehensive preoperative evaluation and timely optimization of vitamin D and calcium levels may enhance bone quality, promote fracture healing, and reduce postoperative complications. Therefore, routine assessment and management of these biochemical parameters should be incorporated into standard protocols for hip fracture care to ensure a more holistic and effective treatment approach.

CONCLUSION

This study demonstrated a significant deterioration in biochemical markers among individuals with hip fractures. Vitamin D deficiency was prevalent across all groups, with particularly severe deficiency observed in patients with intertrochanteric and femoral neck fractures. The absence of significant differences in biochemical parameters among AO subtypes indicates that, while these markers contribute to overall fracture risk, they do not appear to influence fracture pattern.

Ethics Committee Approval: This study was approved by the İstanbul Medeniyet University Göztepe Training and Research Hospital Clinical Research Ethics Committee (Date: 16.12.2014, Decision No: 2014/0180).

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O.Ş.P.; Supervision: B.K., K.Ö.; Resource: B.K.; Materials: O.Ş.P., K.Ö.; Data collection and/or processing: B.K., S.E.; Analysis and/or interpretation: B.K., M.S.S.; Literature review: B.K.; Writing: B.K.; Critical review: B.K., M.S.S., K.Ö., O.Ş.P.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Kalça kırıklı hastalarda kırık tipine ve kontrol grubuna göre D vitamini, PTH ve kemik metabolizması belirteçlerinin karşılaştırılması

AMAÇ: D vitamini, kalsiyum ve kemik metabolizması belirteçleri iskelet sağlığında kritik bir rol oynamaktadır; ancak bu parametrelerin farklı kalça kırığı tipleriyle ilişkisi net değildir. Bu çalışmada, femur boyun kırığı (FBK) ve intertrokanterik femur kırığı (İTFK) olan yaşlı hastalarda serum 25(OH) D vitamini, kalsiyum, paratiroid hormon (PTH), alkalen fosfataz (ALP), fosfor, total protein ve albümin düzeylerinin kontrol grubu ile karşılaştırılması amaçlanmıştır.

GEREÇ VE YÖNTEM: Bu retrospektif çalışmaya 65 yaş ve üzerindeki toplam 375 hasta dahil edilmiştir; bunların 117'si intertrokanterik femur kırığı (İTFK), 97'si femur boyun kırığı (FBK) ve 161'i kontrol grubunu (koksartroz/gonartroz) oluşturmaktadır. Serum biyokimyasal parametreleri standart laboratuvar yöntemleri ile analiz edilmiştir. Kırıklar, iki bağımsız gözlemci tarafından AO/OTA sınıflamasına göre değerlendirilmiş ve gözlemciler arası uyum değerlendirilmiştir. Gözlemciler arası uyum Cohen's kappa katsayısı ile analiz edildi (κ=0.89). Gruplar arasındaki karşılaştırmalarda tek yönlü ANOVA ve post hoc Bonferroni testleri kullanılmıştır. İstatistiksel anlamlılık düzeyi $p<0.05$ olarak kabul edilmiştir.

BULGULAR: D vitamini düzeyleri hem İTFK hem de FBK gruplarında kontrol grubuna göre anlamlı olarak düşük bulunmuştur ($p<0.01$), ancak İTFK ve FBK grupları arasında anlamlı bir fark saptanmamıştır ($p>0.05$). Benzer şekilde, kalsiyum, total protein, ve albümin düzeyleri kırık gruplarında kontrollerden daha düşük bulunurken ($p<0.01$), PTH düzeyleri kırık hastalarında anlamlı derecede yüksek saptanmıştır ($p=0.001$).

SONUÇ: D vitamini ve kalsiyum eksikliklerinin kalça kırığı riskini artırdığı, ancak kırık paternini belirlemediği görülmüştür. Bu bulgular, kalça kırığı hastalarında metabolik eksikliklerin ameliyat öncesi değerlendirilmesi ve ameliyat sonrası düzeltilmesinin önemini vurgulayarak, sistemik biyokimyasal parametrelerin kapsamlı kırık riski değerlendirmesinde vurgulanması gerektiğini düşündürmektedir.

Anahtar sözcükler: D vitamini; femur boyun kırığı; intertrokanterik kırık; kalsiyum; kalça kırığı; kemik metabolizması belirteçleri.

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ORIGINAL ARTICLE

Surgical strategies for coronoid fixation in terrible triad elbow injuries: A comparative analysis of Tight-Rope and screw fixation

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ABSTRACT

BACKGROUND: The terrible triad of the elbow describes a complex injury pattern characterized by elbow subluxation or dislocation, rupture of the lateral ulnar collateral ligament (LUCL), and concomitant fractures of the radial head and coronoid process. This study aimed to evaluate and compare the clinical outcomes of patients with terrible triad injuries treated surgically at our institution, in whom coronoid fractures were managed using either screw fixation or the Tight-Rope technique.

METHODS: This retrospective cohort study included patients who underwent surgical treatment for terrible triad injuries between January 2017 and December 2023. Patients with Regan–Morrey type 2 or 3 coronoid fractures treated using the Tight-Rope technique were assigned to the Tight-Rope group, whereas those treated with screw fixation comprised the Screw group. Demographic characteristics, range of motion (ROM), visual analog scale (VAS) scores, and QuickDASH (Quick Disabilities of the Arm, Shoulder and Hand) scores at 3, 6, and 12 months postoperatively were analyzed. Patients with type 1 fractures, medial collateral ligament (MCL) injuries, follow-up <12 months, or a history of systemic infection were excluded.

RESULTS: Twenty-nine patients were included (11 in the Tight-Rope group and 18 in the Screw group). No significant differences were observed between the groups in terms of ROM or VAS and QuickDASH scores at 3, 6, and 12 months. After excluding cases requiring LUCL reconstruction and analyzing only patients who underwent LUCL repair (8 Tight-Rope, 13 Screw), the only statistically significant difference was a lower 12-month QuickDASH score in the Screw group. Complications included superficial cellulitis (1 Tight-Rope, 2 Screw) and heterotopic ossification (2 Tight-Rope, 3 Screw), all of which were managed conservatively. Post hoc power analysis based on 12-month QuickDASH scores, VAS scores, and elbow ROM (effect size d=0.77, α=0.05) demonstrated power of 77%, 71%, and 74%, respectively.

CONCLUSION: Functional outcomes were largely comparable between Tight-Rope and screw fixation techniques. These findings align with emerging evidence questioning the routine necessity of coronoid fixation and underscore the importance of individualized surgical decision-making.

Keywords: Lateral ulnar collateral ligament (LUCL); screw fixation; terrible triad; coronoid fracture; tight-rope.

INTRODUCTION

The terrible triad of the elbow describes a complex injury pattern characterized by elbow subluxation or dislocation, rupture of the lateral ulnar collateral ligament (LUCL), and concomitant fractures of the radial head and coronoid process.[1-3] Owing to the difficulty of restoring joint stability, treatment is typically surgical, with the goals of enabling early mobilization and achieving satisfactory postoperative range of motion.[4-6] Operative strategies commonly include LUCL repair or tendon-based reconstruction, in addition to fixation of the radial head and coronoid using various techniques.[6, 7]

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The coronoid process serves as a primary stabilizer of the elbow by resisting posterior displacement of the ulna.[8,9] Despite its recognized importance, no consensus has been established regarding the necessity of coronoid fixation or the optimal surgical technique, and this issue remains controversial.[10,11] In terrible triad injuries, there is broad agreement on the importance of LUCL repair or reconstruction and radial head replacement or fixation; however, the management of Regan-Morrey type 1 and type 2 coronoid fractures continues to be debated.[12] Although many surgeons advocate fixation of these fractures, recent cadaveric studies suggest that when the lateral ligament complex and radial head are adequately reconstructed, sufficient elbow stability may be achieved without coronoid fixation.[13]

Coronoid fixation is technically demanding and associated with a steep learning curve. A variety of techniques have been described, including posterior pull-out sutures, lag screw fixation, precontoured locking plates, suture lasso fixation, the Tight-Rope technique, and suture anchor fixation.[12,14-17] However, it remains unclear which method provides superior outcomes, underscoring the need for comparative studies in this area.[13,18,19]

This study aimed to evaluate and compare the clinical outcomes of patients with terrible triad injuries treated surgically at our institution, in whom coronoid fractures were managed using either screw fixation or the Tight-Rope technique.

MATERIALS AND METHODS

Study Design and Ethical Approval

This study was designed as a retrospective cohort study conducted at a single tertiary referral center. The medical records of patients who underwent surgical treatment for terrible triad injuries of the elbow between January 2017 and December 2023 were reviewed. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Local Scientific Ethics Committee on May 14, 2025 (Approval No: E-25-505).

Study Population

Inclusion Criteria

Patients were eligible for inclusion if they met all of the following criteria:

- Diagnosis of a terrible triad injury requiring surgical intervention
- Presence of a Regan–Morrey type 2 or type 3 coronoid fracture
- Surgical fixation of the coronoid process using either:
  - the Tight-Rope (suture-button) technique, or
  - screw fixation
- Minimum postoperative follow-up of 12 months.

Exclusion Criteria

Patients were excluded if any of the following criteria were present:

- Age <18 years or >65 years
- Regan–Morrey type 1 coronoid fractures
- Concomitant medial collateral ligament (MCL) injury
- History of systemic infection
- Inadequate follow-up (<12 months).

Methodological Clarification

Patients with MCL injuries were intentionally excluded to eliminate the confounding effect of medial-sided instability. Therefore, any medial or anteromedial surgical approach used in this study was performed solely to enhance visualization and fixation of the coronoid when adequate exposure could not be achieved through a lateral approach, and not for MCL repair or reconstruction.

Surgical Technique

All surgical procedures were performed under general anesthesia with the patient in the supine position.

Surgical Exposure

A lateral approach was employed as the standard initial incision in all cases. When adequate visualization of the coronoid fragment was compromised, due to obstruction by the radial head or fracture morphology, a supplementary anteromedial or medial approach was added. Intraoperatively, valgus stress testing was routinely conducted; patients demonstrating medial joint opening suggestive of MCL insufficiency were excluded from the study.

Coronoid Fixation Techniques

Tight-Rope Technique

Following exposure of the coronoid fragment, a 2.5-mm Kirschner wire was used to create a retrograde tunnel from the posterior aspect of the olecranon to the coronoid process. The suture-button construct was subsequently passed antegrade through the tunnel, and fixation was secured posteriorly using a single Endobutton while maintaining anatomical reduction of the fragment (Figure 1).

Screw Fixation

Screw fixation was performed using either retrograde or antegrade screws, depending on fracture morphology and surgical accessibility. The goal of fixation was to achieve stable buttressing of the coronoid fragment (Figure 2).

Associated Procedures

Radial head fractures were managed with screw or plate fixation based on fracture characteristics. The lateral ulnar collateral ligament was repaired when tissue quality permitted tension-free reattachment. In cases where primary repair was not feasible, LUCL reconstruction was performed using a palmaris longus autograft.

Figure 1. A 27-year-old male from the Tight-Rope group. **(a-b)** Preoperative AP and lateral X-rays; **(c-d)** sagittal CT images; **(e-f)** postoperative radiographs with Tight-Rope fixation visible (red ellipses). All steps were performed through a single lateral incision.

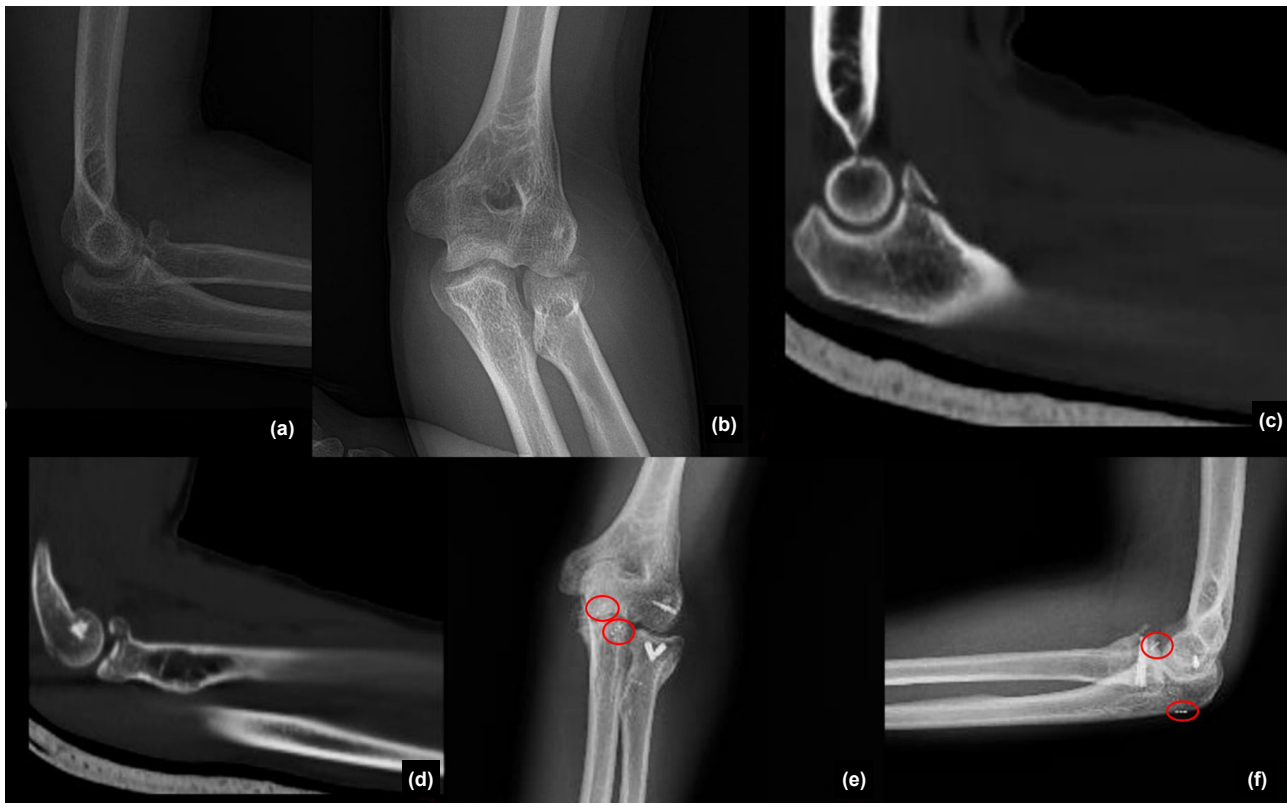

Figure 2. A 38-year-old male from the screw fixation group. **(a-b)** Preoperative AP and lateral X-rays; **(c-d)** sagittal CT images showing coronoid and radial head fractures; **(e-f)** postoperative AP and lateral radiographs. Due to inadequate visualization through a single lateral incision, an additional anteromedial approach was required.

Postoperative Rehabilitation Protocol

A standardized, structured postoperative rehabilitation protocol was implemented for all patients, regardless of whether LUCL repair or reconstruction was performed. Although LUCL repair involves tendon-to-tendon healing and reconstruction requires tendon-to-bone integration, a uniform rehabilitation strategy was adopted. This approach was based on established biomechanical and biological principles indicating that early controlled mobilization, combined with strict avoidance of varus stress, provides sufficient protection for both healing processes while minimizing postoperative stiffness and functional limitations.

Rehabilitation Phases

Phase 1: Immobilization (Weeks 0–3)

- Application of a long-arm splint with the elbow in flexion
- Protection of ligamentous and osseous repairs
- Strict avoidance of varus stress

Phase 2: Early Controlled Mobilization (Weeks 3–6)

- Initiation of isometric flexion–extension exercises
- Supination–pronation exercises performed with the elbow at 90° of flexion
- Continued avoidance of varus loading

Phase 3: Functional Strengthening (Weeks 6–12)

- Progressive strengthening exercises
- Gradual increase in functional use and weight-bearing activities
- Heavy lifting permitted after 3 months.

This rehabilitation strategy is consistent with previously published protocols that emphasize early mobilization under controlled conditions following complex elbow instability surgery and LUCL reconstruction or repair. Such approaches have been shown to reduce postoperative stiffness without compromising stability.[20-22]

Outcome Measures

Patients were evaluated at 3, 6, and 12 months postoperatively. The following outcome measures were assessed:

- Elbow range of motion (ROM)
- Visual Analog Scale (VAS) score for pain
- Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) score.

Statistical Analysis

Statistical analyses were performed using SPSS version 30.0, provided by SPSS Inc. in Chicago, USA. Continuous variables were analyzed using the independent-samples t-test, whereas categorical variables were compared using the chi-square test. A p-value <0.05 was considered statistically significant.

Power Analysis

A post hoc power analysis was conducted using G*Power version 3.1, based on 12-month QuickDASH scores, VAS scores, and elbow ROM outcomes. Assuming an effect size of d=0.77 and an alpha level of 0.05, the calculated statistical power was 77% for QuickDASH, 71% for VAS, and 74% for ROM, given the sample sizes of 11 patients in the Tight-Rope group and 18 patients in the Screw group.

RESULTS

Twenty-nine patients were included in the analysis: 11 in the Tight-Rope group and 18 in the Screw group. Demographic and clinical characteristics are summarized in Table 1.

Functional Outcomes

No statistically significant differences were observed between the groups with respect to QuickDASH scores, VAS scores,

Table 1. Baseline demographic and group-specific characteristics

Characteristic Group	Tight-Rope n=11 (37.9%)	Screw n=18 (62.1%)	Total n=29 (100%)
Age (Mean)	34.55	34.06	34.24
Gender			
Female	3 (27.3%)	5 (27.8%)	8 (27.6%)
Male	8 (72.7%)	13 (72.2%)	21 (72.4%)
Side			
Right	7 (63.6%)	12 (66.7%)	19 (65.5%)
Left	4 (36.4%)	6 (33.3%)	10 (34.5%)
LUCL Treatment			
Repair	8 (72.7%)	13 (72.2%)	21 (72.4%)
Reconstruction	3 (27.3%)	5 (27.8%)	8 (27.6%)

Table 2. Group-specific range of motion (ROM), QuickDASH, and Visual Analog Scale (VAS) scores

	Tight-Rope n=11	Screw n=18	p value	SED	95% CI Upper	95% CI Lower
Range of Motion (°)	131.45	129.00	0.196	1.850	-1.341	6.250
QuickDASH (3rd Month)	25.00	24.56	0.657	0.989	-1.586	2.474
QuickDASH (6th Month)	15.82	16.72	0.168	0.639	-2.215	0.407
QuickDASH (1st Year)	8.91	7.72	0.098	0.693	-0.235	2.609
VAS (3rd Month)	24.00	25.50	0.063	0.774	-3.089	0.089
VAS (6th Month)	17.18	16.61	0.466	0.772	-1.014	2.155
VAS (1st Year)	10.09	9.33	0.354	0.803	-0.890	2.542

Table 3. Group-specific range of motion (ROM), QuickDASH, and Visual Analog Scale (VAS) scores in patients undergoing lateral ulnar collateral ligament (LUCL) repair only (excluding reconstruction with palmaris longus tendon autograft)

	Tight-Rope n=8	Screw n=13	p value	SED	95% CI Upper	95% CI Lower
Range of Motion (°)	132.00	128.92	0.151	2.054	-1.222	7.376
QuickDASH (3rd Month)	24.75	24.00	0.533	1.182	-1.724	3.224
QuickDASH (6th Month)	15.38	16.92	0.053	0.749	-3.116	0.020
QuickDASH (1st Year)	9.25	7.31	0.023	0.787	0.295	3.589
VAS (3rd Month)	24.50	25.46	0.248	0.807	-2.650	0.727
VAS (6th Month)	17.25	16.31	0.314	0.912	-0.967	2.851
VAS (1st Year)	9.88	9.23	0.507	0.951	-1.347	2.636

or ROM measurements at 3, 6, and 12 months postoperatively (Table 2).

After excluding patients who underwent LUCL reconstruction and analyzing only those treated with LUCL repair (8 in the Tight-Rope group and 13 in the Screw group), the results remained comparable between groups, except for a lower 12-month QuickDASH score in the Screw group (Table 3).

Surgical Exposure

Five patients (17.2%) required supplementary non-lateral exposure to achieve coronoid visualization:

- Tight-Rope group: 2 patients (1 medial, 1 anteromedial approach)
- Screw group: 3 patients (1 medial, 2 anteromedial approaches).

Complications

No nerve injuries or fixation failures were observed. Superficial cellulitis developed in one patient in the Tight-Rope group and two patients in the Screw group; all cases resolved with oral antibiotic therapy.

Heterotopic Ossification

Heterotopic ossification (HO) occurred in two patients in the Tight-Rope group and three patients in the Screw group. All cases were managed conservatively according to standard HO protocols, and no patient required surgical excision.

Union

Radiographic union of both the coronoid and radial head fractures was achieved in all patients at final follow-up.

DISCUSSION

This study compared two different coronoid fixation techniques—screw fixation and the Tight-Rope technique—in patients with terrible triad injuries who underwent restoration of both the radial head and the lateral ulnar collateral ligament. Our results demonstrated largely comparable outcomes between the two fixation approaches in terms of elbow range of motion, pain scores, and functional outcomes throughout the 12-month follow-up period. The only statistically significant difference observed was a lower 12-month QuickDASH score in the screw fixation group among patients who underwent LUCL repair. However, the magnitude of this difference was modest and of uncertain clinical relevance.

The interpretation of these findings should be considered within the broader context of the evolving literature on coronoid management. Recent studies have suggested that the necessity of routine coronoid fixation—particularly in Regan–Morrey type 1 and type 2 fractures—may vary and depend more on overall elbow stability than on the fixation technique itself.[13,23-25] Importantly, our study did not evaluate non-fixation strategies and, therefore, should not be interpreted as supporting or opposing the omission of coronoid fixation. Rather, our findings indicate that when coronoid fixation is performed within a stable construct, the choice of technique (screw versus Tight-Rope) may have limited influence on short-term functional outcomes.

Several contemporary studies have investigated the relationship between fixation method and clinical recovery. Shengdi et al. (2023) conducted a prospective randomized controlled trial (RCT) comparing screw fixation, external hinged fixation, and plaster immobilization for coronoid fractures in terrible triad injuries.[26] They reported minimal differences in functional outcomes at final follow-up, although external fixation was associated with improved early pain control.[26] Similarly, Ahn et al. (2024) found no significant differences in outcomes between fixation and non-fixation groups at approximately two years in stable terrible triad reconstructions, further supporting the notion that the role of coronoid fixation may depend more on the integrity of global stabilizers than the specific fixation device used.[13] While these studies primarily address whether coronoid fixation is necessary, our study instead focuses on comparing two fixation techniques in cases where fixation was considered clinically indicated.

Technical considerations influence the choice of fixation method. Screw fixation is widely used and provides rigid stabilization, particularly in fractures with adequate bone stock. In their biomechanical review, Ahn et al. highlighted the superior buttressing effect and early stability achieved with mini-plate and screw constructs compared with suture-based constructs in coronoid fractures.[13] Although plate fixation was not performed in our series, these findings may partially explain the slightly better QuickDASH outcomes observed in the screw group, especially among patients with larger fragments.

Conversely, minimally invasive or anterior buttress-oriented approaches may offer specific advantages in selected patients. Chang et al. (2024) reported excellent midterm outcomes using a coronoid-first anterior approach, emphasizing the importance of exposure and visualization when managing coronoid process fractures.[24] Lin et al. (2024) further described fluoroscopy-guided, minimally invasive anteromedial techniques designed to reduce soft tissue disruption and facilitate earlier mobilization.[27] In our cohort, although the lateral approach was used as the standard technique, the need for supplemental medial or anteromedial exposure in several cases underscores the importance of flexible and individualized surgical strategies.

The Tight-Rope (suture-button) technique remains less extensively studied in the setting of elbow instability but has demonstrated promising results in analogous joints, such as the ankle syndesmosis, where suture-button constructs have shown outcomes comparable to screw fixation.[27,28] The biological and biomechanical principles underlying these constructs may support their application in selected coronoid fractures. Our findings suggest that the Tight-Rope technique, when appropriately applied, yields outcomes comparable to screw fixation without increased complication rates or risk of failure.

Several important insights emerge from this study:

1. When coronoid fixation is performed, both screw and Tight-Rope techniques appear to provide comparable short-term clinical and radiographic outcomes.

2. The fixation method alone may not be the primary determinant of postoperative function, provided that adequate restoration of the radial head and LUCL is achieved.

3. Approach flexibility remains essential, as anatomical variation and fracture patterns frequently necessitate tailored exposure, including supplemental medial or anteromedial incisions.

4. These findings contribute to the ongoing discussion regarding coronoid fracture management, while remaining distinct from studies evaluating fixation versus non-fixation strategies.

This study has several limitations. Its retrospective design and relatively small sample size reduce the power to detect subtle between-group differences, as reflected in the post hoc power analysis. Follow-up was limited to 12 months, and long-term outcomes may differ, particularly with respect to post-traumatic arthritis or late instability. Additionally, intraoperative photographs were unavailable, limiting visual documentation of the surgical techniques. Stratification by fracture size or morphology was not performed, which may influence fixation stability or technique selection. Future multicenter, prospective randomized studies with larger cohorts and longer follow-up are required to clarify the optimal coronoid fixation strategy and to determine whether fixation can be safely omitted in selected cases.

CONCLUSION

In this study, we compared two coronoid fixation methods—screw fixation and the Tight-Rope technique—in terrible triad injuries managed with restoration of the radial head and the lateral ulnar collateral ligament. Our findings showed that both techniques resulted in similar clinical and functional outcomes at 12 months. A modest difference favoring screw fixation was observed in the QuickDASH scores among patients who underwent LUCL repair; however, the clinical relevance of this difference appears limited, as no significant advantages were observed in pain scores, range of motion, radiographic healing, or complication rates.

Importantly, this study does not address fixation versus non-fixation strategies. Therefore, our results should not be interpreted as supporting or refuting routine coronoid fixation. Rather, the data indicate that when coronoid fixation is performed, the choice between screw fixation and a suture-button construct yields largely comparable outcomes. Both methods may therefore represent viable options when selected according to fracture morphology, exposure requirements, and surgeon preference.

These findings align with the current literature indicating that postoperative stability in terrible triad injuries is primarily determined by restoration of the radial head and ligamentous structures. Within this stable reconstructive framework, the specific coronoid fixation technique may play a secondary role in early functional recovery.

Future prospective, adequately powered comparative studies—including cohorts managed without coronoid fixation—are necessary to further clarify fixation indications and define the optimal surgical strategy for coronoid fractures in terrible triad injuries.

Ethics Committee Approval: This study was approved by the Ankara Training and Research Hospital Ethics Committee (Date: 14.05.2025, Decision No: E-25-505).

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Dirsek terrible triad yaralanmalarında koronoid fiksasyonuna yönelik cerrahi stratejiler: Tight-rope ve vida fiksasyonunun karşılaştırmalı analizi

AMAÇ: Dirseğin "terrible triad" yaralanması; dirsek subluksasyonu veya dislokasyonu, lateral ulnar kollateral ligament (LUCL) yırtığı ve eşlik eden radius başı ile koronoid kırıklarını içeren kompleks bir yaralanma paternini ifade eder. Bu çalışma, kliniğimizde cerrahi olarak tedavi edilen terrible triad yaralanmalı hastalarda, koronoid kırıklarının vida fiksasyonu veya tight-rope tekniği ile tedavi edildiği hastaların klinik sonuçlarını değerlendirmeyi ve karşılaştırmayı amaçlamaktadır.

GEREÇ VE YÖNTEM: Bu geriye dönük kohort çalışmasına, Ocak 2017 ile Aralık 2023 tarihleri arasında "terrible triad" yaralanması nedeniyle cerrahi tedavi uygulanan hastalar dâhil edilmiştir. Regan–Morrey tip 2 veya 3 koronoid kırığı bulunan ve Tight-Rope tekniğiyle tedavi edilen hastalar Tight-Rope grubuna, vida fiksasyonu ile tedavi edilenler ise Vida grubuna ayrılmıştır. Demografik özellikler ile birlikte 3., 6. ve 12. aylarda ölçülen hareket açıklığı (ROM), görsel analog skala (VAS) ve QuickDASH skorları analiz edilmiştir. Tip I kırığı olanlar, medial kollateral bağ (MCL) yaralanması bulunanlar, 12 aydan kısa takip süresi olanlar ve sistemik enfeksiyon öyküsü bulunan hastalar çalışma dışı bırakılmıştır.

BULGULAR: Yirmi dokuz hasta çalışmaya dâhil edildi (11 Tight-Rope, 18 Vida). Üç, altı ve on iki aylık değerlendirmelerde iki grup arasında QuickDASH, ROM ve VAS skorları açısından anlamlı bir fark saptanmadı. LUCL rekonstrüksiyonları dışlanıp yalnızca LUCL tamiri yapılan hastalar incelendiğinde (8 Tight-Rope, 13 Vida), istatistiksel olarak anlamlı tek bulgu, vida grubunda 12. ay QuickDASH skorunun daha düşük olmasıydı. Komplikasyonlar arasında yüzeyel selülit (1 Tight-Rope, 2 Vida) ve heterotopik ossifikasyon (2 Tight-Rope, 3 Vida) yer aldı; tümü konservatif olarak tedavi edildi. Post-hoc güç analizi, 12. ay QuickDASH, VAS ve dirsek ROM değerlerine göre (etki büyüklüğü d=0.77 ve α=0.05), sırasıyla %77, %71 ve %74 güç gösterdiği görülmüştür.

SONUÇ: Bu çalışmanın bulguları, her iki tekniğin genel fonksiyonel sonuçlarının benzer olduğunu göstermektedir. Elde edilen sonuçlar, koronoid fiksasyonunun rutin olarak uygulanmasının gerekliliğini sorgulayan güncel literatürle uyumludur ve hasta bazlı, patolojiye özgü cerrahi karar verme süreçlerinin önemini vurgulamaktadır.

Anahtar sözcükler: Koronoid kırığı; LUCL; terrible triad; tight-rope; vida fiksasyonu.

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ORIGINAL ARTICLE

Plate versus screw fixation and long-term ankle osteoarthritis in posterior malleolar fractures: A Bartoníček-based cohort study

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ABSTRACT

BACKGROUND: Posterior malleolar fractures play a critical role in ankle fracture stability and joint congruity. While plate and screw fixation are widely used, existing literature has primarily focused on short-term functional outcomes and reduction quality. The long-term impact of the posterior malleolar fixation technique on post-traumatic ankle osteoarthritis, particularly in relation to fracture morphology, remains insufficiently explored.

METHODS: This retrospective cohort study included 91 adult patients who underwent surgical fixation of posterior malleolar fractures between 2015 and 2021, with a minimum radiological follow-up of 36 months. Patients were treated with either posterior buttress plate fixation (n=42) or posteroanterior screw fixation (n=49). Ankle osteoarthritis was assessed using the Van Dijk classification. Fracture morphology was classified according to the Bartoníček system. Functional outcomes were evaluated using the American Orthopaedic Foot and Ankle Society (AOFAS) score, the Olerud–Molander Ankle Score (OMAS), and ankle range of motion (Prasad classification). Multivariable regression analyses were performed to assess the independent association between fixation method and outcomes.

RESULTS: After adjustment for age, body mass index, follow-up duration, fracture morphology, and open fracture status, screw fixation was statistically associated with a higher degree of ankle osteoarthritis compared with plate fixation (OR 11.22, 95% CI 2.17–58.04; p=0.004). However, the wide confidence intervals indicate considerable statistical uncertainty around the magnitude of this effect, likely reflecting the limited number of outcome events. Sensitivity analysis using a dichotomized osteoarthritis outcome yielded consistent results. Subgroup analyses demonstrated that the association between screw fixation and higher osteoarthritis risk was particularly pronounced in complex fracture patterns (Bartoníček types 3–4). Patients treated with plate fixation achieved significantly higher AOFAS and OMAS scores and demonstrated superior ankle range of motion at long-term follow-up. Increasing Van Dijk osteoarthritis grades were strongly correlated with worse functional outcomes.

CONCLUSION: Posterior buttress plate fixation was associated with a significantly lower risk of long-term post-traumatic ankle osteoarthritis and superior functional outcomes compared with screw fixation. These findings were especially evident in complex posterior malleolar fracture patterns, highlighting the importance of fracture morphology and fixation strategy in long-term joint preservation.

Keywords: Ankle osteoarthritis; Bartoníček classification; posterior malleolar fracture; plate fixation, screw fixation; Van Dijk classification.

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INTRODUCTION

Posterior malleolar fractures constitute a critical component of ankle fracture patterns and are most commonly encountered in trimalleolar injuries. Because the posterior malleolus forms part of the tibial plafond, involvement of this fragment directly affects ankle joint congruity and load transmission, potentially predisposing patients to long-term post-traumatic ankle osteoarthritis when inadequately treated.[1-4]

Historically, surgical decision-making for posterior malleolar fractures was largely based on fragment size, with fixation traditionally recommended when the fragment exceeded 25–30% of the articular surface.[5] However, accumulating evidence indicates that fragment size alone is insufficient to guide treatment. Contemporary concepts increasingly emphasize fracture morphology, articular congruity, and the stabilizing role of the posterior malleolus in syndesmotic integrity, leading to more individualized fixation strategies.[6-8]

Currently, two principal fixation techniques are widely used: screw fixation, commonly performed following indirect reduction, and posterior buttress plate fixation, which permits direct visualization, anatomical reduction, and biomechanically favorable resistance to posterior shear forces.[9,10] Biomechanical and clinical studies suggest that posterior plating provides superior stability and improved control of articular step-off, particularly in complex fracture patterns.[11-13] Nevertheless, screw fixation remains frequently employed due to its technical simplicity and limited soft-tissue dissection.[14]

Despite growing interest in posterior malleolar fixation techniques, the literature reports conflicting clinical results. While some studies demonstrate improved functional outcomes and radiographic alignment with posterior plating, others report comparable short-term functional scores between plating and screw fixation.[7,14,15] Importantly, most prior investigations have focused on early or mid-term outcomes—such as reduction quality and syndesmotic stability—leaving the long-term impact of fixation technique on post-traumatic ankle osteoarthritis insufficiently explored. Post-traumatic ankle osteoarthritis represents one of the most clinically relevant late complications following ankle fractures and is strongly associated with residual articular incongruity and altered joint biomechanics.[16-18]

The Bartoníček classification, which categorizes posterior malleolar fractures according to fracture pattern and fragment morphology, has been proposed as a comprehensive framework to guide surgical decision-making.[7,19] However, data evaluating whether the long-term effects of fixation technique vary across Bartoníček fracture patterns—particularly with respect to radiographically assessed ankle osteoarthritis—remain limited.

Therefore, the purpose of this study was to evaluate the long-term radiographic and functional outcomes of posterior malleolar fractures treated with plate versus screw fixation, with a primary focus on the development of post-traumatic ankle osteoarthritis assessed using the Van Dijk classification. A secondary aim was to determine whether the association between fixation method and osteoarthritis differed according to Bartoníček fracture patterns, as well as to assess functional outcomes and ankle range of motion.

MATERIALS AND METHODS

Study Design and Ethical Approval

This study was designed as a single-center retrospective cohort study evaluating clinical and radiological outcomes following surgical treatment of posterior malleolar fractures. The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Institutional Ethics Committee in 2021 (approval number: 2021/224). Due to the retrospective nature of the study and the use of routinely collected clinical data, the requirement for informed consent was waived by the ethics committee.

Patient Selection

Patients who were diagnosed with posterior malleolar fractures and treated at our institution between January 2015 and December 2021 were retrospectively reviewed. During this period, 149 patients were identified with a diagnosis of posterior malleolar fracture. Of these, 91 patients met the predefined surgical inclusion criteria and were included in the final analysis. The remaining patients were excluded due to nonoperative management, failure to meet surgical criteria, insufficient follow-up duration, or incomplete radiographic data.

Posterior malleolar fractures in this cohort were not limited to isolated posterior malleolar injuries. The majority of cases represented posterior malleolar involvement as part of bimalleolar or trimalleolar ankle fractures. Patients with isolated posterior malleolar fractures, bimalleolar fractures including the posterior malleolus, and trimalleolar fractures were all eligible for inclusion. The presence of associated medial or lateral malleolar fractures was not considered an exclusion criterion, as the primary objective of the study was to evaluate the impact of posterior malleolar fixation technique on long-term ankle osteoarthritis, regardless of associated malleolar injuries.

Patients aged 18 years or older who sustained a posterior malleolar fracture treated surgically, had a minimum radiological follow-up of 36 months, and had complete clinical records and postoperative radiographs available were included in the study. Patients with pre-existing ankle osteoarthritis or a history of previous ankle surgery, pathological fractures, inadequate radiographic follow-up, or incomplete clinical or functional outcome data were excluded.

Surgical indication for posterior malleolar fixation was based on fracture morphology, involvement of the posterior tibial plafond, associated malleolar fractures, and radiographic evidence of ankle or syndesmotic instability, rather than fragment size alone.

Figure 1. Preoperative and postoperative imaging of a posterior malleolar fracture treated with posteroanterior screw fixation. **(a)** Preoperative lateral ankle radiograph demonstrating a posterior malleolar fracture. **(b)** Preoperative sagittal ankle computed tomography image showing involvement of the posterior tibial plafond. **(c)** Preoperative axial ankle computed tomography image illustrating the fracture morphology. **(d)** Postoperative 3-month lateral ankle radiograph demonstrating maintained reduction following posteroanterior screw fixation. **(e)** Postoperative 3-month anteroposterior ankle radiograph demonstrating maintained alignment.

Figure 2. Preoperative and postoperative imaging of a posterior malleolar fracture treated with posterior buttress plate fixation. **(a)** Preoperative lateral ankle radiograph demonstrating a posterior malleolar fracture. **(b)** Preoperative sagittal ankle computed tomography image showing involvement of the posterior tibial plafond. **(c)** Preoperative axial ankle computed tomography image illustrating the fracture morphology. **(d)** Postoperative 3-month lateral ankle radiograph demonstrating maintained reduction following posterior plate fixation. **(e)** Postoperative 3-month anteroposterior ankle radiograph demonstrating maintained alignment.

Surgical Technique

All patients underwent surgical fixation of the posterior malleolar fragment using one of two fixation methods based on surgeon preference and fracture characteristics. In both fixation groups, a posterolateral approach was utilized to allow direct visualization and anatomical reduction of the posterior malleolar fragment. Posteromedial approaches were not used in this cohort.

In the screw fixation group, fixation was achieved using posteroanterior screws inserted from posterior to anterior following direct reduction of the fragment. (Figure 1)

In the plate fixation group, the posterior fragment was stabilized using a posterior buttress plate to provide stable fixation and posterior support. (Figure 2)

All procedures were performed by experienced orthopedic trauma surgeons using standardized operative techniques.

Importantly, posterior malleolar fracture morphology as classified by the Bartoníček system was comparable between fixation groups, and fracture pattern was included as an ad-

justing variable in all multivariable regression analyses to minimize potential selection bias related to fixation choice.

Postoperative Management and Rehabilitation

Postoperative rehabilitation protocols were identical for both fixation groups. Patients were initially immobilized and maintained non–weight-bearing status, followed by progressive range-of-motion exercises and gradual weight-bearing according to radiographic and clinical healing. No differences in rehabilitation protocols were applied between the plate and screw fixation groups.

Radiological and Clinical Evaluation

Radiological evaluation was performed using standard anteroposterior and lateral ankle radiographs. Ankle osteoarthritis was assessed using the Van Dijk classification based on the latest available follow-up radiographs, with a minimum follow-up of 36 months and final evaluations extending up to December 2024. Radiographic evaluations were performed by a fellowship-trained orthopedic trauma surgeon who was independent from the treating surgical team and was not involved in the original operative decision-making process. Although complete blinding to the fixation method could not be guaranteed due to the visibility of implants on standard radiographs, the assessor was unaware of patients' clinical outcomes and group allocation at the time of grading. All assessments were conducted in a standardized and de-identified manner to minimize potential bias.

Fracture patterns were classified according to the Bartoníček classification, and ankle range of motion was assessed using the Prasad classification at final follow-up.

Clinical outcomes were evaluated using the American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot score and the Olerud–Molander Ankle Score (OMAS), both recorded at the final follow-up visit.

Table 1. Baseline demographic and fracture characteristics according to fixation method

Variable	Plate fixation (n=42)	Screw fixation (n=49)	p value
Age, years	38 (32–43)	38 (31–42)	0.820
Body mass index, kg/m²	24 (22–26)	26 (23–27)	0.094
Length of hospital stay, days	3 (2–3.75)	2 (2–3)	0.071
Follow-up duration, months	42 (36–45.5)	42 (39–48)	0.656
Female sex, n (%)	16 (38.1%)	17 (34.7%)	0.906
Left side, n (%)	18 (42.9%)	19 (38.8%)	0.856
Mechanism of injury, n (%)			0.993
Simple fall	20 (47.6%)	23 (46.9%)	
Pedestrian traffic accident (non-occupant)	7 (16.7%)	8 (16.3%)	
Motor vehicle collision (vehicle occupant)	4 (9.5%)	6 (12.2%)	
Motorcycle or bicycle accident	7 (16.7%)	7 (14.3%)	
Sports-related injury	4 (9.5%)	5 (10.2%)	
Risk factors, n (%)			0.520
None	19 (45.2%)	26 (53.1%)	
Smoking	16 (38.1%)	15 (30.6%)	
Diabetes	4 (9.5%)	2 (4.1%)	
Open fracture	3 (7.1%)	6 (12.2%)	
Bartoníček classification, n (%)			0.879
Type 1	3 (7.1%)	5 (10.2%)	
Type 2	19 (45.2%)	21 (42.9%)	
Type 3	13 (31.0%)	17 (34.7%)	
Type 4	7 (16.7%)	6 (12.2%)	
Gustilo–Anderson classification, n (%)			0.830
Grade 0 (closed)	35 (83.3%)	39 (79.6%)	
Grade 1	5 (11.9%)	8 (16.3%)	
Grade 2	2 (4.8%)	2 (4.1%)	

Values are presented as median (interquartile range) or number (percentage), as appropriate. Continuous variables were compared using the Mann–Whitney U test. Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate.

Table 2. Distribution of ankle osteoarthritis severity according to the Van Dijk classification

Van Dijk grade	Plate fixation (n=42)	Screw fixation (n=49)
Grade 0	40 (95.2%)	35 (71.4%)
Grade 1	2 (4.8%)	12 (24.5%)
Grade 2	0 (0%)	2 (4.1%)
Overall distribution, p value		0.004

Values are presented as a number (percentage). The p-value refers to the overall comparison of Van Dijk osteoarthritis grade distribution between fixation methods.

Outcome Measures

The primary outcome measure was the severity of posttraumatic ankle osteoarthritis, assessed using the Van Dijk classification.

Secondary outcome measures included: AOFAS ankle-hindfoot score, OMAS score, ankle range of motion according to the Prasad classification.

Statistical Analysis

Statistical analyses were performed using standard statistical software. Continuous variables were tested for normality and are presented as median and interquartile range (IQR). Comparisons between fixation groups were conducted using the Mann–Whitney U test for continuous variables and the chi-square or Fisher's exact test for categorical variables, as appropriate.

The association between fixation method and ankle osteoarthritis severity was evaluated using ordinal logistic regression analysis, adjusting for potential confounders including age, body mass index, follow-up duration, Bartoníček fracture classification, and presence of open fractures. The proportional odds assumption for ordinal logistic regression models was assessed and was not violated. A sensitivity analysis was additionally performed using binary logistic regression by dichotomizing the Van Dijk classification as grade 0 versus ≥1.

Secondary outcomes were analyzed using multivariable linear regression models for AOFAS and OMAS scores, and ordinal logistic regression for ankle range of motion. Correlations between osteoarthritis severity and functional scores were assessed using Spearman correlation analysis.

A two-sided p-value of <0.05 was considered statistically significant. For subgroup analyses, posterior malleolar fractures were stratified into simple (Bartoníček types 1–2) and complex (types 3–4) patterns based on fracture morphology.

RESULTS

Patient Characteristics

A total of 91 patients with posterior malleolar fractures were included in the study, of whom 42 underwent plate fixation and 49 underwent screw fixation of the posterior fragment. Baseline demographic characteristics and fracture-related variables were comparable between the two groups (Table 1). There were no statistically significant differences with respect to age, sex distribution, body mass index, length of hospital stay, follow-up duration, injury mechanism, risk factors, Bartoníček fracture classification, or Gustilo–Anderson grade (all p>0.05).

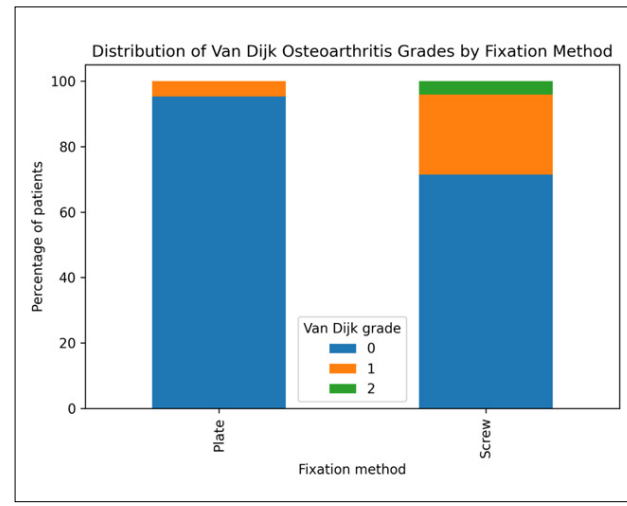

Figure 3. Stacked bar chart illustrating the percentage distribution of Van Dijk ankle osteoarthritis grades according to fixation method. Screw fixation was associated with a higher proportion of advanced osteoarthritis grades compared with posterior plate fixation.

Primary Outcome: Ankle Osteoarthritis (Van Dijk Classification)

Unadjusted Analysis

The distribution of ankle osteoarthritis severity according to the Van Dijk classification differed significantly between fixation methods as shown in Table 2. In the plate fixation group, 40 patients (95.2%) had no radiographic osteoarthritis (Van Dijk grade 0), while 2 patients (4.8%) had grade 1 osteoarthritis and none had grade 2. In contrast, in the screw fixation group, 35 patients (71.4%) had grade 0 osteoarthritis, 12 patients (24.5%) had grade 1, and 2 patients (4.1%) had grade 2 osteoarthritis. (Figure 3) This difference was statistically significant (p=0.004).

Adjusted Analysis

An ordinal logistic regression model was constructed to evaluate the independent association between fixation method and ankle osteoarthritis severity while adjusting for potential confounders, including age, body mass index, follow-up duration, Bartoníček classification, and presence of an open fracture.

After adjustment, screw fixation was independently associated with a higher degree of ankle osteoarthritis compared

Table 3. Multivariable ordinal logistic regression analysis for Van Dijk ankle osteoarthritis

Variable	Odds ratio (OR)	95% CI	p value
Screw fixation (vs plate fixation)	11.22	2.17–58.04	0.004

The model was adjusted for age, body mass index, follow-up duration, Bartoníček fracture classification, and open fracture status. The proportional odds assumption was assessed and was not violated.

Table 4. Subgroup analysis of ankle osteoarthritis according to Bartoníček classification

Bartoníček group	Fixation method	Van Dijk grade 0	Van Dijk grade 1	Van Dijk grade 2
Simple (types 1-2)	Plate (n=22)	21 (95.5%)	1 (4.5%)	0 (0%)
	Screw (n=26)	20 (76.9%)	5 (19.2%)	1 (3.8%)
Complex (types 3-4)	Plate (n=20)	19 (95.0%)	1 (5.0%)	0 (0%)
	Screw (n=23)	15 (65.2%)	7 (30.4%)	1 (4.3%)

Distribution of post-traumatic ankle osteoarthritis severity according to the Van Dijk classification, stratified by posterior malleolar fracture morphology using the Bartoníček classification. Within both fracture subgroups, screw fixation was associated with a higher frequency of advanced osteoarthritis grades, with a more pronounced difference observed in complex fracture patterns (Bartoníček types 3-4).

with plate fixation (odds ratio [OR] 11.22, 95% confidence interval [CI] 2.17–58.04; p=0.004), suggesting an association rather than a proven causal effect (Table 3). The wide confidence intervals surrounding this estimate indicate substantial statistical uncertainty regarding the exact magnitude of the association, likely reflecting the limited sample size and number of outcome events.

A sensitivity analysis using a binary outcome (Van Dijk grade 0 vs ≥1) yielded consistent results, confirming a significantly increased risk of radiographic osteoarthritis in the screw fixation group (OR 11.66, 95% CI 2.21–61.45; p=0.004).

Subgroup Analysis According to Bartoníček Classification

An interaction term between fixation method and Bartoníček classification was included in the regression model; however, no statistically significant interaction was observed (p=0.66).

Subgroup analyses were subsequently performed by stratifying fractures into simple patterns (Bartoníček types 1–2; n=48) and complex patterns (types 3–4; n=43). (Table 4) In patients with simple fracture patterns, screw fixation demonstrated a trend toward higher osteoarthritis risk compared with plate fixation, although this did not reach statistical significance (adjusted OR 10.0; p=0.078). In contrast, among patients with complex fracture patterns, screw fixation was associated with a significantly higher risk of ankle osteoarthritis compared with plate fixation (adjusted OR 18.5; p=0.021). These subgroup findings should be interpreted with caution, as the number of patients within each subgroup was limited and the analyses were not powered to detect definitive interaction effects.

Secondary Outcomes

Functional Outcomes

Patients treated with plate fixation demonstrated significantly higher functional scores at final follow-up. Median AOFAS scores were 90 (IQR 82–91) in the plate group and 80 (IQR 80–86) in the screw group (p<0.001). Similarly, median OMAS scores were 95 (IQR 80–95) in the plate group compared with 80 (IQR 75–85) in the screw group (p<0.001).

In multivariable linear regression analyses adjusting for age, body mass index, follow-up duration, Bartoníček classification, and open fracture status, screw fixation remained independently associated with lower functional scores. Screw fixation was associated with a 4.15-point decrease in AOFAS score (95% CI −6.44 to−1.86; p<0.001) and a 7.44-point decrease in OMAS score (95% CI−10.93 to −3.95; p<0.001).

Range of Motion

Ankle range of motion assessed using the Prasad classification was significantly better in the plate fixation group (median 1 [IQR 1–1]) compared with the screw fixation group (median 1 [IQR 1–2]; p=0.004). In an adjusted ordinal logistic regression model, screw fixation was associated with a significantly higher likelihood of worse range-of-motion categories (OR 5.92, 95% CI 1.80–19.47; p=0.003).

Relationship Between Osteoarthritis and Functional Outcomes

Spearman correlation analyses demonstrated a significant negative correlation between ankle osteoarthritis severity and functional outcomes. Higher Van Dijk grades were associated with lower AOFAS scores (ρ=−0.507, p<0.001) and lower OMAS scores (ρ=−0.590, p<0.001).

DISCUSSION

The most important finding of the present study is that posterior malleolar screw fixation was independently associated with a significantly higher degree of long-term post-traumatic ankle osteoarthritis compared with posterior plate fixation. This association remained robust after adjustment for relevant confounders and was confirmed by sensitivity analyses. In addition, posterior plate fixation was associated with superior functional outcomes and ankle range of motion at long-term follow-up. These findings should be interpreted in the context of the study's retrospective design and the non-randomized selection of fixation method based on surgeon preference and fracture characteristics.

Historically, the treatment of posterior malleolar fractures was primarily guided by fragment size, with fixation recommended when the fragment exceeded 25–30% of the tibial plafond.[5] However, subsequent studies have demonstrated that fragment size alone fails to capture fracture complexity and does not reliably predict clinical or radiographic outcomes.[6,8,20] As a result, contemporary treatment strategies increasingly emphasize fracture morphology, quality of reduction, and the biomechanical role of the posterior malleolus in ankle and syndesmotic stability.[6,7,21] In contrast to most previous comparative studies that have primarily emphasized short- or mid-term functional outcomes and reduction quality, the present study focuses on long-term radiographic ankle osteoarthritis as the primary outcome, highlighting joint preservation rather than early postoperative success.

Posterior buttress plate fixation has been shown to provide superior biomechanical stability compared with anteroposterior screw fixation by counteracting posterior shear forces and improving control of articular step-off.[11–13,22] Clinical studies have similarly suggested that posterior plating allows more accurate reduction and improved syndesmotic stability, particularly in complex fracture configurations.[9,10,23] Nevertheless, screw fixation remains widely used due to its technical simplicity, shorter operative time, and reduced soft-tissue exposure.[14]

Despite these advantages, most previous clinical investigations comparing plate and screw fixation have primarily focused on short-term or mid-term outcomes, including radiographic reduction quality, syndesmotic alignment, and early functional scores.[14,15,20] Long-term degenerative consequences, particularly post-traumatic ankle osteoarthritis, have received considerably less attention.[24,25]

Post-traumatic ankle osteoarthritis represents one of the most clinically significant late complications following ankle fractures and is strongly associated with residual articular incongruity, altered joint biomechanics, and subtle malreduction that may not be clinically evident in the early postoperative period.[16-18,26] The present study expands on previous work by demonstrating that the posterior malleolar fixation technique itself may influence the long-term risk of radiographic ankle osteoarthritis.

In our cohort, screw fixation was associated with an approximately 11-fold increased odds of higher Van Dijk osteoarthritis grades compared with plate fixation after multivariable adjustment. This finding suggests that indirect reduction and screw fixation may be less effective in maintaining long-term joint congruity, particularly under repetitive physiological loading.[17,18,25,27] Even minimal residual step-off or instability has been shown to accelerate cartilage degeneration and contribute to the development of ankle osteoarthritis over time.[16,24] The relatively wide confidence intervals observed in these analyses likely reflect the limited sample size and number of outcome events and indicate some degree of imprecision in the estimated effect sizes.

An important finding of this study is the influence of fracture morphology on the relationship between fixation technique and osteoarthritis. Although no statistically significant interaction was observed between fixation method and Bartoníček classification, subgroup analyses demonstrated that the association between screw fixation and higher osteoarthritis risk was particularly pronounced in complex fracture patterns (Bartoníček types 3–4). These fracture types often involve larger posterior fragments, posteromedial extension, or articular impaction, which may be inadequately addressed by indirect screw fixation alone.[19,28-31] Posterior plate fixation, by allowing direct visualization and anatomical reduction, may therefore offer a biomechanical advantage in these complex patterns. Although subgroup analyses suggested a more pronounced association between fixation method and osteoarthritis risk in complex fracture patterns, these analyses should be considered exploratory and hypothesis-generating due to limited sample sizes and the absence of a statistically significant interaction effect.

Functional outcomes mirrored the radiographic findings. Patients treated with posterior plate fixation achieved significantly higher AOFAS and OMAS scores and demonstrated superior ankle range of motion at long-term follow-up. Furthermore, increasing Van Dijk osteoarthritis grades were strongly correlated with worse functional outcomes, consistent with previous reports linking radiographic ankle degeneration to impaired function and quality of life.[16-18,32-36]

From a clinical perspective, these findings suggest that the posterior malleolar fixation technique may be considered when aiming to optimize long-term joint congruity and preserve ankle function, particularly in complex fracture patterns. In particular, fracture morphology as defined by the Bartoníček classification may help identify patients who are at increased risk of degenerative changes.

This study has several limitations. First, its retrospective design introduces the potential for selection bias, as the choice of fixation method was based on surgeon preference and perceived fracture characteristics rather than randomization. Surgeons may have been more inclined to select posterior

plate fixation for more complex fracture patterns. Although posterior malleolar fracture morphology was systematically classified using the Bartoníček system and included as an adjusting variable in all multivariable analyses, adjustment for this classification alone may not fully eliminate residual confounding related to unmeasured aspects of fracture complexity, soft-tissue injury, cartilage damage, or surgeon decision-making factors. Therefore, the observed association between fixation method and ankle osteoarthritis should be interpreted as associative rather than definitively causal. Prospective or randomized studies would be required to establish a true causal relationship between fixation technique and long-term degenerative outcomes. The relatively wide confidence intervals observed in the regression analyses further indicate some degree of imprecision in the estimated effect sizes, likely reflecting the limited sample size and number of outcome events.

Another important limitation is the heterogeneity of fracture patterns included in the cohort. The study population was not restricted to isolated posterior malleolar fractures; instead, it comprised a mixture of isolated posterior malleolar injuries as well as bimalleolar and trimalleolar ankle fractures with posterior malleolar involvement. Although this approach reflects real-world clinical practice and enhances external validity, associated malleolar fractures and overall injury severity may independently influence the development of post-traumatic ankle osteoarthritis. Consequently, outcomes cannot be attributed exclusively to the posterior malleolar fixation technique in absolute terms. Future studies focusing solely on isolated posterior malleolar fractures could provide a more homogeneous population and allow more precise evaluation of the isolated effect of fixation method.

In addition, subgroup analyses were limited by sample size, which may have reduced the statistical power to detect interaction effects and resulted in wide confidence intervals for some estimates. Furthermore, ankle osteoarthritis was assessed using standard radiographs rather than advanced imaging modalities.[36,37] Despite these limitations, the use of validated radiographic classification systems and a minimum follow-up duration of 36 months enhances the clinical relevance and robustness of the present findings.

From a practical clinical standpoint, the present findings suggest that the fixation strategy should be individualized according to fracture morphology. In simple posterior malleolar fractures (Bartoníček types 1–2), both fixation techniques may yield acceptable outcomes. However, in complex fracture patterns (types 3–4), posterior buttress plating may provide more reliable restoration of articular congruity and potentially better long-term joint preservation. These considerations may assist surgeons in preoperative decision-making, particularly when balancing surgical invasiveness with the goal of minimizing post-traumatic degeneration.

CONCLUSION

Posterior plate fixation was associated with a lower risk of long-term post-traumatic ankle osteoarthritis and superior functional outcomes compared with screw fixation. These findings represent associative observations derived from a retrospective cohort and should be interpreted cautiously rather than as definitive evidence of causality. This association appeared to be more pronounced in complex posterior malleolar fracture patterns, suggesting that posterior plate fixation may offer an advantage in long-term joint preservation in these injuries, although these findings should be interpreted cautiously, given the retrospective design and limited sample size of subgroup analyses.

Ethics Committee Approval: This study was approved by the Bakırköy Dr. Sadi Konuk Training and Research Hospital Clinical Research Ethics Committee (Date: 19.04.2021, Decision No: 2021-08-09).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Posterior malleol kırıklarında plak ve vida fiksasyonunun uzun dönem ayak bileği osteoartriti açısından karşılaştırılması: Bartoníček tabanlı kohort çalışması

AMAÇ: Posterior malleol kırıkları, ayak bileği kırıklarında stabilite ve eklem uyumunun sağlanmasında kritik bir rol oynar. Plak ve vida tespiti yaygın olarak kullanılmakla birlikte, mevcut literatür ağırlıklı olarak kısa dönem fonksiyonel sonuçlar ve redüksiyon kalitesine odaklanmıştır. Posterior malleol fiksasyon yönteminin uzun dönem posttravmatik ayak bileği osteoartriti üzerine etkisi, özellikle kırık morfolojisi ile ilişkisi açısından yeterince araştırılmamıştır.

GEREÇ VE YÖNTEM: Bu retrospektif kohort çalışmaya, 2015-2021 yılları arasında posterior malleol kırığı nedeniyle cerrahi tedavi uygulanmış ve en az 36 ay radyolojik takibi bulunan 91 erişkin hasta dahil edildi. Hastalar posterior buttress plak fiksasyonu (n=42) veya posteroanterior vida fiksasyonu (n=49) ile tedavi edildi. Ayak bileği osteoartriti Van Dijk sınıflamasına göre değerlendirildi. Kırık morfolojisi Bartoníček sınıflaması kullanılarak belirlendi. Fonksiyonel sonuçlar American Orthopaedic Foot and Ankle Society (AOFAS) skoru, Olerud–Molander Ankle Score (OMAS) ve ayak bileği eklem hareket açıklığı (Prasad sınıflaması) ile değerlendirildi. Fiksasyon yöntemi ile sonuçlar arasındaki bağımsız ilişkiyi değerlendirmek amacıyla çok değişkenli regresyon analizleri yapıldı.

BULGULAR: Yaş, vücut kitle indeksi, takip süresi, kırık morfolojisi ve açık kırık varlığına göre yapılan düzeltmeler sonrası, vida fiksasyonu plak fiksasyonuna kıyasla anlamlı derecede daha yüksek ayak bileği osteoartriti şiddeti ile ilişkili bulundu (OR=11.22; %95 GA 2.17–58.04; p=0.004). Ancak geniş güven aralığı, etkinin kesin büyüklüğü konusunda belirgin istatistiksel belirsizlik olduğunu göstermektedir. Osteoartrit sonucunun ikili olarak değerlendirildiği duyarlılık analizinde de benzer sonuçlar elde edildi. Alt grup analizlerinde, vida fiksasyonu ile artmış osteoartrit riski arasındaki ilişkinin özellikle kompleks kırık paternlerinde (Bartoníček tip 3-4) daha belirgin olduğu görüldü. Plak fiksasyonu uygulanan hastalarda AOFAS ve OMAS skorları anlamlı derecede daha yüksek olup, uzun dönem takipte ayak bileği eklem hareket açıklığı daha iyi bulundu. Artan Van Dijk osteoartrit dereceleri ile fonksiyonel sonuçlar arasında güçlü bir olumsuz ilişki saptandı.

SONUÇ: Posterior buttress plak fiksasyonu, vida fiksasyonuna kıyasla uzun dönem posttravmatik ayak bileği osteoartriti riskinin daha düşük olması ve daha iyi fonksiyonel sonuçlar ile ilişkili bulunmuştur. Bu ilişkinin özellikle kompleks posterior malleol kırık paternlerinde daha belirgin olduğu gözlenmiş olup, uzun dönem eklem korunumu açısından kırık morfolojisi ve fiksasyon stratejisinin önemini vurgulamaktadır.

Anahtar sözcükler: Ayak bileği osteoartriti; Bartoníček sınıflaması; plak fiksasyonu; posterior malleol kırığı; vida fiksasyonu; Van Dijk sınıflaması.

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ORIGINAL ARTICLE

The effects of migraine on driving safety, driving habits, and risk perception

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ABSTRACT

BACKGROUND: This study aimed to investigate the multidimensional effects of migraine on driving by evaluating the driving habits of individuals with migraine and their adherence to safety strategies.

METHODS: This multicenter, hospital-based, cross-sectional study was conducted between May and July 2024. Volunteers aged 18-65 years with a diagnosis of migraine and a history of driving were included. Detailed face-to-face interviews were conducted using a form adapted from the Driving Habit Questionnaire to assess demographic characteristics, driving experience, driving preferences, and driving habits. The quality of life of drivers with migraine was assessed using the Headache Impact Test-6 (HIT-6).

RESULTS: Of the 2,548 patients evaluated in the study, 1,333 had driving experience. The mean age of the drivers was 36.7±9.5 years, and 64.4% were female. Patients with migraine drove approximately 4.8 days per week, and 64.1% had more than 10 years of driving experience. Overall, participants demonstrated good compliance with safety precautions: 92.2% always fastened their seat belts, and 85.2% regularly checked their rearview mirrors before driving. However, 28.8% of patients always preferred to be the driver, and 26.3% reported driving faster than the speed limit and contrary to traffic flow. The mean HIT-6 score was 62.2±7.1. Male sex, smoking, alcohol use, longer driving experience, and lower HIT-6 scores were associated with more frequent driving, higher driving speeds, and a greater tendency to perceive themselves as better drivers.

CONCLUSION: Our findings suggest that migraine influences driving behavior by affecting driving frequency, speed preferences, and subjective driving confidence. These factors should be considered in clinical assessments.

Keywords: Driving preferences; driving quality; driving speed; migraine; rearview mirror; seat belt.

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INTRODUCTION

Migraine is a highly prevalent and complex neurological disorder worldwide that significantly impairs individuals' functioning and quality of life.[1] Its clinical presentation is not limited to headache; rather, it is characterized by a multidimensional disability profile involving neurological, autonomic, and cognitive symptoms occurring during the prodromal, ictal, and postdromal phases.[1-3] Dysfunction in sensory input processing and multisensory integration mechanisms, particularly within the central nervous system, may negatively affect the performance of individuals with migraine in cognitively demanding tasks.[4,5] Motor vehicle operation is a complex cognitive-motor activity that requires the simultaneous integration of attentional control, visuospatial processing, executive functioning, and psychomotor coordination. These processes may be directly or indirectly impaired by migraine-related dysfunctions.[6,7] Therefore, systematic evaluation of driving behavior in individuals with migraine is necessary, both in terms of individual functional impairment and broader societal traffic safety.

Recent epidemiological studies suggest that individuals with migraine frequently avoid driving or express concerns about driving safety. For example, data from the OVERCOME Japan study (Observational Survey of the Epidemiology, Treatment and Care of Migraine) showed that 43.9% of individuals with migraine reported that migraine symptoms negatively affected their driving performance, and 32.7% reported consciously avoiding driving due to migraine in the previous year. Notably, more than 20% of participants reported continuing to drive even during severe migraine attacks.[2] However, findings in the literature regarding the association between migraine and road traffic accidents (RTAs) are inconsistent,[2,8-11] highlighting the need for further investigation from both public health and traffic safety perspectives. Advances in vehicle technology and road infrastructure have shifted the attribution of many traffic accidents from technical causes to human error. In fact, according to 2023 data from the Turkish Statistical Institute (TÜİK), drivers were identified as primarily responsible in 88.9% of traffic accidents.[12] These data suggest that individuals with migraine may exhibit behaviors that could jeopardize driving safety in the context of daily life obligations and that migraine-related disability may not be adequately addressed in current clinical assessments of driving safety. The current literature on the effects of migraine on driving habits and safety is limited, heterogeneous, and largely observational.

This study aimed to assess the driving habits of individuals with migraine, the degree of disability experienced during attack periods, and their adherence to safety strategies. By adopting a multidimensional approach to understanding how migraine affects driving, this research seeks to enhance clinical management and inform public policy initiatives.

MATERIALS AND METHODS

This cross-sectional, multicenter study was conducted in a hospital-based setting between May and July 2024. Fifty-seven neurologists, actively involved in patient follow-up and experienced in the diagnosis and management of migraine, working across 40 different clinics, assessed patients using a structured questionnaire based on the Driving Habit Questionnaire[13] (Appendix 1) after obtaining informed consent.

The first section consisted of 21 questions evaluating patients' demographic and migraine-related characteristics. Pain intensity was assessed using the Visual Numeric Scale (VNS). The second section included 53 questions addressing the types of vehicles used; driving experience (driving frequency,

Table 1. Headache Impact Test-6 (HIT-6)[14]

	Frequency				
Questions	**Never**	**Rarely**	**Sometimes**	**Very often**	**Always**
1. When you have headaches, how often is the pain severe?					
2. How often do headaches limit your ability to perform usual daily activities, including household work, work, school, or social activities?					
3. When you have a headache, how often do you wish you could lie down?					
4. In the past four weeks, how often have you felt too tired to perform work or daily activities because of your headaches?					
5. In the past four weeks, how often have you felt fed up or irritated because of your headaches?					
6. In the past four weeks, how often have headaches limited your ability to concentrate on work or daily activities?					
Points	6 points	8 points	10 points	11 points	13 points

The HIT-6 is a tool used to measure the impact of headaches on an individual's ability to function at work, school, home, and in social situations. Each question requires one selected response. The total HIT-6 score ranges from 36 to 78, with higher scores indicating greater headache-related disability.

years of driving, anxiety about accidents); driving preferences (frequency of being the driver); driving behaviors (rearview mirror use, seat belt use, driving speed); perceived driving quality, etc.

Following these two sections, the third section assessed driving-related disability using the Headache Impact Test-6 (HIT-6) (Table 1),[14] an instrument designed to capture patients' perspectives. Physicians administered the questionnaires during face-to-face interviews lasting approximately 30 minutes.

Patients with migraine who had a history of driving were included in this analysis. Migraine was diagnosed according to the International Classification of Headache Disorders, 3rd edition (ICHD-3) criteria.[1] Data reliability and consistency were ensured through a cross-check process conducted by three neurologists and a biostatistician.

The prevalence of migraine in neurology outpatient clinics has been reported as 24.9%.[15] Based on this prevalence, a sample size analysis was performed using G*Power to ensure adequate statistical power to detect meaningful differences. It was calculated that at least 1,337 patients should be included, assuming a 2% margin of error. Accordingly, 2,548 individuals diagnosed with migraine were screened, and 1,583 who met the eligibility criteria regarding motor vehicle use were included in the study. The study flowchart is presented in Figure 1. This study, conducted under the short title "Mig-Drive," was approved by the Acibadem University Medical Research Ethics Committee (28.03.2024) (Decision No: 2024-5/204). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Exclusion Criteria

• Age <18 years (individuals under 18 are not eligible for a driver's license)

• Age >65 years (to minimize age-related confounding factors)

• Absence of a definite migraine diagnosis according to ICHD-3 criteria confirmed by a neurologist

• Inability to provide informed consent or respond to questions due to impaired consciousness.

Headache Impact Test-6 (HIT-6)

The HIT-6 is a brief, structured self-report scale with established validity and reliability, designed to evaluate the impact of migraine on an individual's daily life–particularly functional impairment and time loss–from the patient's perspective.[16,17] The scale consists of six items reflecting the impact of headaches on quality of life; each item is rated on a five-point Likert-type scale. The total score is directly proportional to headache severity. The Turkish validity and reliability study of the scale was conducted by Dikmen et al.[18]

Statistical Analysis

The normality of continuous variables was assessed using the Shapiro–Wilk test. Parametric methods were applied to normally distributed variables, whereas non-parametric methods were used for variables that did not meet the normality assumption. For comparisons between two independent groups, the Independent Samples t-test or the Mann–Whitney U test was used. For comparisons involving more than two groups,

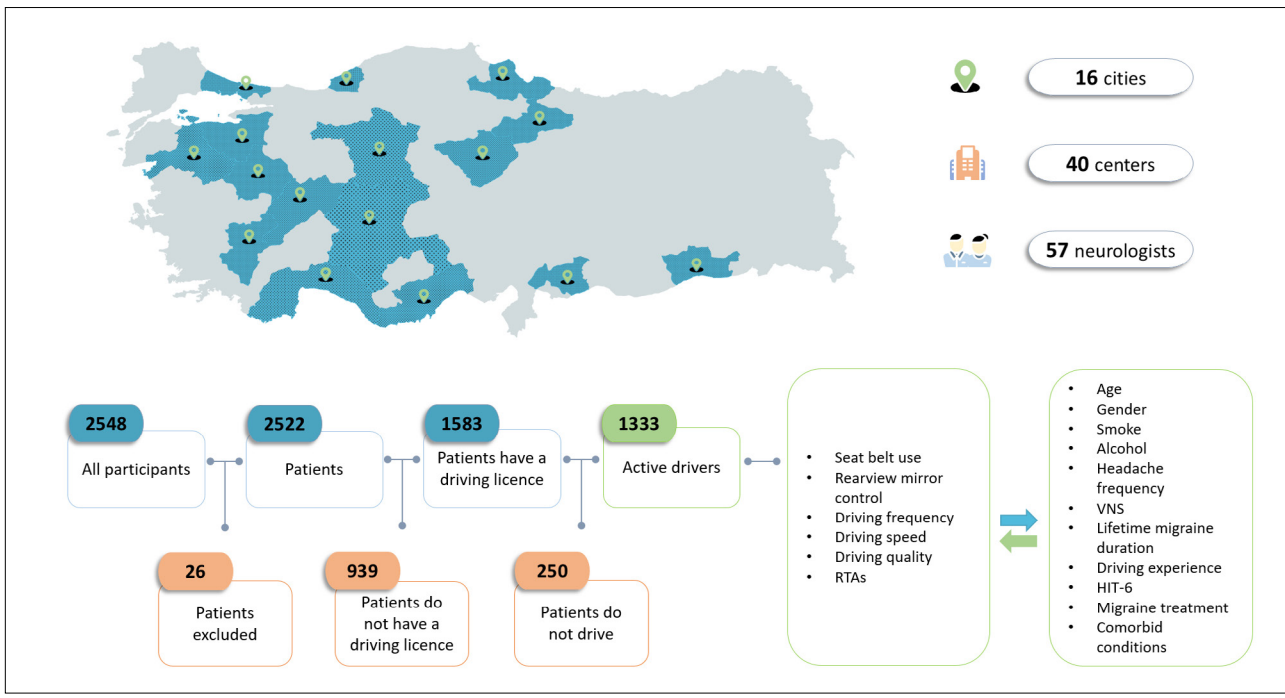

Figure 1. Flowchart of the study, patient distribution, and analyzed parameters. *RTA: Road traffic accidents; VNS: Visual Numeric Scale; HIT-6: Headache Impact Test-6.*

one-way analysis of variance (ANOVA) or the Kruskal–Wallis test was performed. Tukey's post hoc test was applied for multiple comparisons. Linear relationships between continuous variables were evaluated using Pearson's or Spearman's rho correlation coefficients, as appropriate. Categorical variables were analyzed using the χ^2 test or Fisher's exact test. All statistical analyses were conducted using R software (version 4.5.1; R Foundation for Statistical Computing, Vienna, Austria). Statistical significance was set at $p<0.05$.

RESULTS

Of the 2,548 patients evaluated in the study, 1,333 had driving experience (Fig. 1). The mean age of the drivers was 36.7±9.5 years (range: 18-65 years), and 64.4% were female. Among the drivers, 10.6% had less than two years of driving experience, 25.3% had 3-9 years, and 64.1% had more than 10 years of driving experience. Headache characteristics during driving and non-driving periods, as well as other clinical features, are presented in Table 2.

Safety Measures

The study found that 92.2% of drivers always fastened their seat belts while driving (Fig. 2), whereas only 0.3% reported never doing so. Females were more likely than males to fasten their seat belts, with rates of 95.6% and 86.1%, respectively ($p<0.001$). The mean age of those who always fastened their seat belts was higher than that of those who did so only sometimes (37.0±9.4 years vs. 33.0±9.8 years; $p<0.001$). Non-smokers were more likely to fasten their seat belts consistently (94.6% vs. 88.8%), whereas smokers were more likely to fasten them only occasionally (10.7% vs. 5.3%; $p<0.001$). Among individuals with migraine, those who never fastened their seat belts reported a higher mean monthly headache frequency ($p<0.001$). Additionally, individuals who always fastened their seat belts had a mean migraine duration that was 3.64 years longer than those who fastened them only occasionally ($p<0.001$). There was no statistically significant association between lifetime migraine duration and anxiety about having an accident.

Before driving, 85.2% of participants reported always checking their rearview mirrors (Fig. 2), whereas 0.7% reported never doing so. No other factors, significant associations were found between this behavior and other factors, including sex, VNS score, and HIT-6 score.

Driving Preferences

When evaluated according to driving frequency, 28.8% of patients reported always driving, 41.6% often driving, 28% sometimes driving, and 1.7% never preferring to drive. The impact of selected migraine-related clinical characteristics on driving frequency, considered a dependent behavioral variable, is summarized in Table 2. When traveling by car, male patients were more likely to drive than female patients (48.7% vs. 17.8%; $p<0.001$). Driving frequency increased with age up to a certain point but declined significantly in older age groups. A similar pattern was observed with respect to driving experience (Table 2). During driving, VNS scores increased with driving frequency. However, driving frequency decreased as HIT-6 impact severity increased (Table 2). Participants who always preferred to drive had higher rates of smoking (33.7%, $p<0.001$) and alcohol consumption (48.9%, $p=0.001$). As expected, the rate of traffic accidents was higher among drivers who always drove (35.9% vs. 28%), whereas it was lower among those who sometimes drove (20.8% vs. 28.4%; $p=0.013$).

Driving speed relative to the general flow of traffic was ana-

Table 2. Comparison of the frequency of being a driver with age, headache and driving characteristics, and HIT-6 score

	Frequency of a being driver					
	Total	**Never [a]**	**Sometimes [b]**	**Often [c]**	**Always [d]**	**p-value**
	Mean±SD	**Mean±SD**	**Mean±SD**	**Mean±SD**	**Mean±SD**	
Age	36.7±9.5	41.2±11.5[b]	35.1±10.4[ad]	36.5±8.6[d]	38.4±9.3[bc]	<0.001
Lifetime migraine duration (years)	11.5±9.2	13.4±10.7	11.0±9.0	11.4±8.7	12.0±9.9	0.366
Headache frequency (last 3 months)	8.8±7.2	10.4±6.6	8.2±7.3	8.1±6.8	7.9±6.7	0.411
VNS score	7.5±1.5	7.7±1.6	7.5±1.6	7.4±1.4	7.6±1.5	0.418
Driving experience (years)	15.4±10.9	18.7±15.6[b]	11.4±9.8[acd]	14.2±8.8[bd]	17.3±9.6[bc]	<0.001
Driving frequency (times/month)	19.1±10.5	3.4±7.8[cd]	8.2±7.6[acd]	22.5±7.7[abd]	25.6±7.2[abc]	<0.001
Headache frequency while driving (%)	13.0±20.5	12.8±29.9	14.9±25.2	12.4±18.4	11.9±17.4	0.207
VNS score while driving	6.0±2.3	6.1±3.6	5.4±2.5[cd]	6.0±2.0[b]	6.4±2.2[b]	<0.001
HIT-6 score	62.2±7.0	65.9±5.1[d]	63.2±7.1[d]	62.3±6.7[d]	60.8±7.3[abc]	<0.001

SD: Standard deviation; VNS: Visual Numeric Scale; HIT-6: Headache Impact Test-6. Superscript letters indicate subsets of categories whose column proportions or means differ significantly at the $p<0.05$ level. [a]Never; [b]Sometimes; [c]Often; [d]Always.

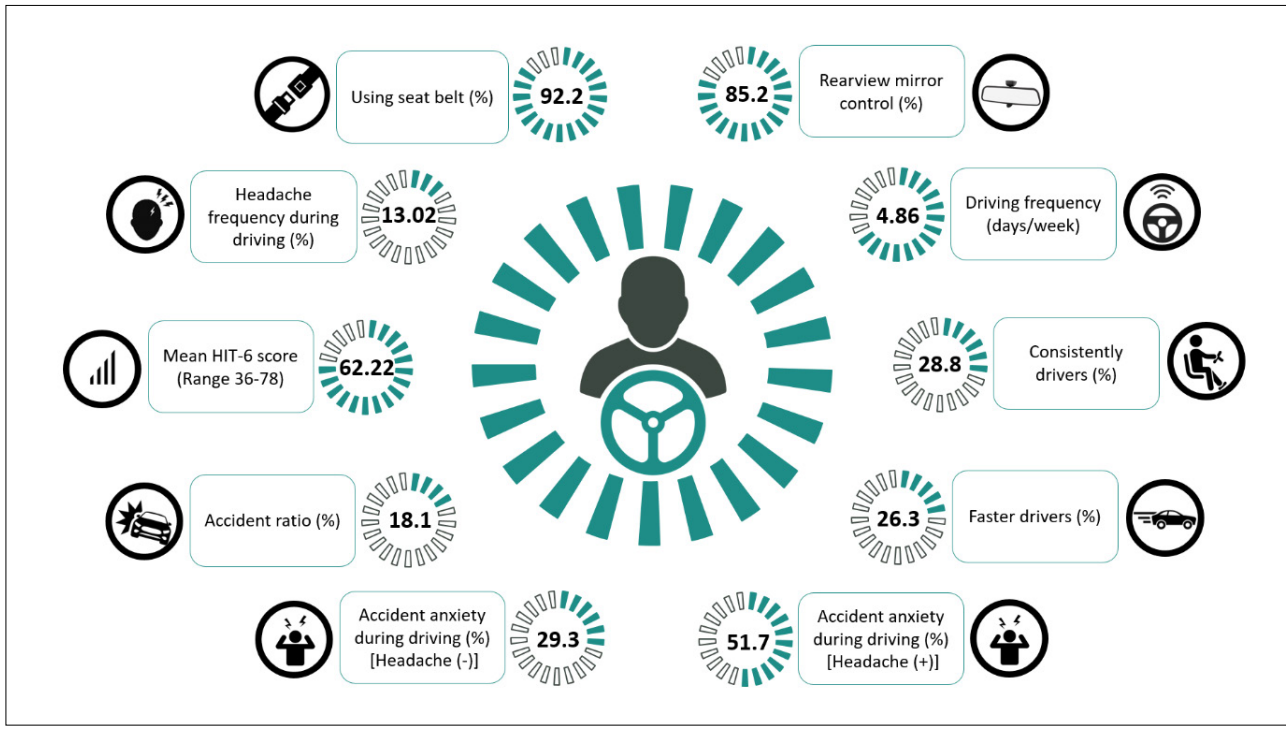

Figure 2. Key findings of the study. *HIT-6: Headache Impact Test-6.*

lyzed across five self-reported categories: much faster, somewhat faster, about the same, somewhat slower, and much slower. Overall, 26.3% of drivers reported traveling faster than the traffic flow, while 16.3% reported driving more slowly. Men were more likely than women to drive faster than the general traffic flow (36.5% vs. 20.6%), whereas a higher proportion of women drove at speeds consistent with traffic flow (65.4% vs. 34.6%) or more slowly than men (21.1% vs. 7.6%); these differences were statistically significant ($p<0.001$). Participants who reported driving much faster than traffic were more likely to smoke (4.2% vs. 1.8% among those driving at or below the traffic speed; $p=0.012$). Similarly, those driving somewhat faster had higher rates of alcohol consumption (33.6% vs. 21.4%); $p<0.001$). In contrast, alcohol use was less prevalent among drivers maintaining speeds similar to the traffic flow (50.7% vs. 58.8%; $p<0.001$). Overall, 29.3% of drivers reported anxiety about having an accident while driving; this proportion increased to 51.7% when driving during a headache episode (Fig. 2). Anxiety about having an accident was less common among those driving at speeds consistent with traffic flow (27.4% vs. 21.9%). In contrast, individuals driving "somewhat slower" (18.2% vs. 11.9%) or "somewhat faster" (27.4% vs. 21.9%) than the traffic flow were more likely to report anxiety ($p=0.001$). Interestingly, no significant differences in anxiety levels were observed among those driving "much faster" or "much slower" than traffic ($p>0.05$). When drivers experienced headaches, those driving "much faster" reported lower levels of anxiety about having an accident (1.9% vs. 3.8%). In contrast, anxiety was higher among those driving "somewhat slower" (17.4% vs. 9.7%) and "much slower" (3.7% vs. 1.4%) compared to those driving in line with the traffic flow ($p<0.001$). Analysis of accident rates showed a lower incidence among drivers traveling at speed "parallel to the traffic flow" (51.1% vs. 58.9%), whereas the rate was higher among those driving "somewhat faster" (29.9% vs. 22.8%; $p=0.032$). Post hoc comparisons indicated a close association between driving speed and driving experience. Drivers traveling somewhat slower than the traffic flow had, on average, 2.3 fewer years of driving experience than those driving at similar speeds ($p=0.028$) and 3.0 fewer years than those driving somewhat faster ($p=0.007$). A negative correlation was observed between the proportion of headaches occurring while driving and driving speed: as headache frequency during driving increased, reported driving speed decreased ($p=0.001$). The mean HIT-6 score among patients driving at much slower speeds (66.2±5.9) was 4.2 points higher than that of those driving at speeds similar to traffic ($p=0.006$) and 4.8 points higher than that of those driving somewhat faster ($p=0.001$). However, no statistically significant association was found between VNS scores and driving speed.

Subjective driving quality was evaluated across five categories: excellent, good, average, fair, and poor. Men were more likely than women to rate their driving as "excellent" (20.7% vs. 7.6%) or "good" (60.8% vs. 51.3%), whereas women were more likely to rate their driving as "average" (35% vs. 17.5%) or "fair" (5.4% vs. 0.8%); these differences were statistically significant ($p<0.001$). Individuals who rated their driving quality as "excellent" were more likely to smoke (16.2% vs. 9.5%;

p=0.006) and consume alcohol (18.8% vs. 10.9%; p=0.010). As HIT-6 impact severity increased, drivers tended to rate their driving quality lower (p=0.001). Those who rated their driving as "excellent" reported lower levels of anxiety about having an accident (8.7% vs. 13.7%), whereas those who rated their driving as "average" reported higher levels of accident-related anxiety (33.5% vs. 26.9%; p=0.007). In the presence of a headache, individuals who rated their driving as "excellent" reported lower anxious about having an accident (8.6% vs. 16.4%), and those who rated their driving as "good" also demonstrated lower anxiety levels (51.3% vs. 57.6%). In contrast, participants who rated their driving as "average" (34% vs. 23.8%) or "fair" (5.3% vs. 1.9%) reported higher levels of accident-related anxiety (p<0.001). Post hoc analysis confirmed the expected association between driving quality and driving experience. Individuals who rated their driving quality as "fair" had, on average, 4.3 fewer years of driving experience than those who rated it as "excellent" (p=0.045). Similarly, those with "average" driving quality had 3.0 fewer years of experience than those with "good" driving quality (p<0.001) and 4.9 fewer years than those with "excellent" driving quality (p<0.001). The mean VNS score among individuals with "average" driving quality was 0.3 points lower than that of those with "good" driving quality (p=0.008) and 0.5 points lower than that of those with "excellent" driving quality (p=0.001). Furthermore, driving quality declined as HIT-6 scores increased (p=0.001). In post hoc analysis, the mean HIT-6 score for individuals with "fair" driving quality (64.9±6.4) was 2.9 points higher than that of those with "good" driving quality (p=0.032) and 3.9 points higher than that of those with "excellent" driving quality (p=0.005).

DISCUSSION

This study comprehensively examined the driving habits, safety behaviors, and migraine-related driving experiences of 1,333 individuals with migraine. Most participants demonstrated appropriate safety behaviors, such as fastening seat belts and checking rearview mirrors; however, these behaviors were influenced by factors including age, sex, and smoking status. Women generally preferred to drive at speeds consistent with or slower than traffic flow, whereas men tended to drive faster. Driving quality was closely associated with both driving experience and HIT-6 scores. While greater migraine-related quality-of-life burden was negatively associated with driving quality and driving frequency, it was positively associated with driving experience.

Safe motor vehicle operation requires a balanced integration of internal and external factors; safe driving depends on sustained attention as well as stable physiological and psychological conditions. In practice, however, a lack of awareness and inaccurate risk perception may lead individuals to underestimate these requirements.[19] Despite its clinical and behavioral relevance, the relationship between driving and migraine has been largely overlooked in the literature. A review examining drivers' perceptions of how specific health conditions affect driving performance identified a notable discrepancy between perceived crash risk and actual driving behavior. In a cross-sectional study conducted in Spain, 63% of drivers reported that headaches or migraine significantly impaired their driving performance.[20] Similarly, an Italian study of patients with episodic migraine found that approximately 15% reported serious driving-related difficulties.[21] In Japan, 43.9% of individuals with migraine indicated that pain and associated symptoms affected their ability to drive at least some of the time.[2]

Given that driving involves complex cognitive, perceptual, and motor processes, recent research has increasingly focused on individual impairments and medical conditions that may contribute to distracted driving.[6] Migraine attacks frequently occur outside the home, and concerns about driving safety during attacks may prompt behavioral adaptations, including seeking treatment, modifying driving preferences, or avoiding driving altogether. In this context, the present study is particularly valuable in its real-world assessment of driving habits among individuals with migraine.

A small study conducted in the United Arab Emirates (UAE) reported that 72.5% of drivers with migraine were male.[8] In contrast, 64.4% of participants in our study were female. Additionally, nearly two-thirds of our sample reported more than 10 years of driving experience. The UAE study also found that 72.5% of drivers with migraine experienced at least one attack per month, and 21.2% reported at least one attack per week. In our study, 70.6% of participants reported experiencing at least one migraine attack while driving during their lifetime. The occurrence of headaches while driving has been rarely addressed in the existing literature; in our cohort, headaches were reported during 13.02% of driving periods.

Migraine and Seat Belt Use

In this study, 92.2% of drivers reported consistently fastening their seat belts while driving. However, certain subgroups were less likely to do so, including males, younger drivers, smokers, and individuals with more frequent headaches. Interestingly, participants with a longer history of migraine were more likely to fasten their seat belts consistently, although this group did not report increased anxiety about having an accident. According to 2024 data from the United States, the overall seat belt use rate was 91.2%, closely aligning with our findings. Approximately 50% of the 23,959 passengers who died in traffic accidents that year were not wearing seat belts.[22] A report from the Turkish National Traffic Safety Program (2001) indicated that only 16% of drivers involved in urban traffic accidents and 35% of those involved in intercity accidents were using seat belts; furthermore, 81% of drivers who died in these accidents were not wearing seat belts.[23] Similarly, 2023 data from TÜİK show that failure to use a helmet or seat belt is the most common passenger-related cause of injury and fatal traffic accidents, with an incidence rate of 27.4%.[24] In a study conducted in the UAE in 2000, only 12.5% of drivers with migraine reported consistent seat belt

use, and only 6.3% had been wearing a seat belt at the time of the accident.[8] These findings suggest that although overall seat belt use has improved over time–likely due to awareness campaigns and in-vehicle warning systems– important gaps remain, particularly regarding behaviors at the time of accidents. Our study identified specific high-risk subgroups less likely to use seat belts, a finding not previously emphasized in the literature. Younger male drivers were particularly prominent in this regard. Previous research indicates that young drivers, especially males, tend to overestimate their driving abilities and underestimate accident risk, thereby increasing their likelihood of engaging in risky behaviors.[25,26] This finding is consistent with known behavioral patterns associated with demographic differences in seat belt use.

Migraine and Frequency of Being the Driver

In our study, although 70.4% of individuals with migraine generally preferred to be the driver, they drove an average of 4.8 days per week and made 19.1 trips per month. These findings are consistent with previous literature. For instance, DiGuiseppi et al.[27] reported that participants aged 65–79 years with migraine drove at least once per week; 71% of the sample were female, and the mean driving frequency was 21.4 days per month. Awaki et al.[2] reported a lower driving frequency, noting that 73.4% of participants with migraine had driven at least once per week in the preceding month. DiGuiseppi et al.[27] also found that, after adjusting for potential confounders, individuals with migraine had significantly less driving exposure than those without migraine, driving approximately one fewer day per month and making about nine fewer trips. Although our study did not include a control group, 29.7% of drivers with migraine reported reduced driving frequency, suggesting that migraine may influence driving behavior. Analysis of demographic variables revealed that male sex, older age, smoking and alcohol use, longer driving experience, and lower HIT-6 scores were associated with a greater tendency to drive more frequently.

Notably, a strong negative association was observed between HIT-6 scores and preference for driving. Similarly, a large-scale survey of 5,485 licensed drivers with migraine reported that greater headache severity and frequency were associated with reduced driving frequency or avoidance of driving altogether.[28] In another study, approximately one-third of participants reported at least one period during the previous 12 months in which they refrained from driving due to migraine or severe headache. The most commonly cited reasons were safety concerns, pain interfering with driving performance, and driving triggering or exacerbating headaches.[2] Sakai et al.[29] similarly reported that 13.3% of participants reduced their driving frequency or avoided driving altogether due to migraine symptoms. Studies demonstrating that individuals with vestibular disorders tend to drive less frequently further support this observation.[30] In our study, however, contrary to the pattern observed with HIT-6 scores, individuals reporting higher headache intensity were more likely to choose to drive. This finding may reflect the fact that some patients continue driving despite pain due to social or occupational obligations, or that their awareness of migraine-related driving risks is limited. Consistent with this, Awaki et al.[2] reported that 20.1% of drivers with migraine continued to drive at least occasionally despite experiencing severe pain.

Migraine and Driving Speed

For more than two decades, excessive speed has been implicated in approximately one-third of motor vehicle-related fatalities.[31] According to 2023 TÜİK data, the most common driver-related cause (37.03%) of fatal and injury traffic accidents is failure to adjust vehicle speed appropriately to road, weather, and traffic conditions, whereas excessive speed was identified as a direct cause of accidents in 0.88% of cases.[24] In our study, 26.3% of individuals with migraine reported driving faster than the general traffic flow. Moreover, accident rates were significantly higher among those who drove faster than traffic. Male sex, smoking, alcohol use, greater driving experience, lower HIT-6 scores, and a lower frequency of headaches while driving were associated with higher driving speeds. These findings indicate that both demographic and clinical factors may influence driving behaviors. Cestac et al.[32] examined young drivers' willingness to exceed 110 km/h on a flat road with a 90 km/h speed limit. Only 43% of female drivers and 26% of male drivers reported that they would never exceed this speed, suggesting that male drivers are more likely to engage in speeding behavior than female drivers. The same study reported that male drivers' intention to speed was associated with higher levels of "thrill-seeking" behavior and greater social pressure to exceed speed limits. Additionally, the tendency to speed increased with greater driving experience.[32] According to TÜİK (2023) data, alcohol use contributed to 0.69% of fatal and injury-related traffic accidents.[24] However, a hospital-based cross-sectional study conducted in the UAE found no significant differences in speeding violations, traffic violations, or alcohol use between individuals with migraine and controls.[8] These findings suggest that migraine may not be directly linked to risky driving behaviors; rather, its effects may be indirect and limited to specific subgroups. In our study, 29.3% of drivers reported anxiety about being involved in a crash while driving. This proportion nearly doubled when a headache was present. These findings indicate that headache episodes may negatively influence perceived driving safety. Similarly, a population-based study conducted in Canada by Edmeads et al.[33] found that 45% of individuals with migraine or tension-type headache reported anxiety about driving during headache attacks. Collectively, these results suggest that pain-related anxiety among drivers with migraine may influence both driving performance and self-confidence.

Migraine and Driving Quality

In our study, male sex, smoking, alcohol use, lower HIT-6 scores, and greater driving experience were associated with more favorable self-assessments of driving quality. This suggests that subjective evaluations of driving ability may not

necessarily reflect objective performance. Supporting this interpretation, a small study (N=28) reported that individuals with chronic pain described their driving quality as "normal" despite their condition.[34] The literature further indicates that young drivers–particularly males–tend to overestimate their driving abilities and underestimate accident risk, thereby engaging more readily in risky behaviors.[25,26] This pattern is consistent with the more favorable self-perception of driving quality reported by male drivers in our study. Additionally, a study by Lesch and Hancock[35] found that female drivers exhibited longer braking reaction times than male drivers when exposed to distractions and were more likely to run red lights. In contrast, older drivers reported preferring reduced exposure to distracting stimuli, acknowledging that such distractions can adversely affect driving performance.[36] These findings suggest that with increasing age, individuals may develop greater driving awareness and self- regulatory strategies to compensate for limited cognitive resources.

Limitations

• The cross-sectional design of the study limits the ability to establish causal relationships.

• The absence of a healthy control group prevented direct comparisons between drivers with and without migraine.

• Driving habits were not evaluated in relation to specific migraine attack phases, making it impossible to assess the acute effects of migraine.

• The use of self-reported data may have introduced recall bias.

• Differences among migraine subtypes (e.g., migraine with aura, vestibular migraine, chronic migraine, etc.) were not examined in detail.

• Neurocognitive testing and objective driving simulations were not performed, limiting direct assessment of actual driving performance.

CONCLUSION

This study is one of the most comprehensive investigations to examine driving behaviors, safety habits, and the multidimensional impact of migraine on driving among individuals with migraine. The findings indicate that migraine significantly influences daily activities, safety behaviors, and individual decision-making processes.

Most individuals with migraine adhered to safety precautions and traffic regulations. Male sex, smoking, alcohol use, lower HIT-6 scores, and longer driving experience were common factors associated with more frequent driving, higher driving speeds, and a greater tendency to perceive oneself as a better driver.

These results underscore the need for healthcare professionals to address not only symptom control but also driving safety and behavioral patterns in the management of migraine, particularly in specific subgroups.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Migrenin sürüş güvenliği, alışkanlıkları ve risk algısı üzerindeki etkileri

AMAÇ: Bu çalışma, migrenli bireylerin sürüş alışkanlıklarını ve hastaların güvenlik stratejilerine uyumunu değerlendirerek migrenin sürüş üzerindeki çok boyutlu etkilerini ortaya koymayı amaçlamaktadır.
GEREÇ VE YÖNTEM: Bu çok merkezli, hastane tabanlı, kesitsel çalışma Mayıs-Temmuz 2024 tarihleri arasında yürütülmüştür. 18-65 yaş aralığında, araç kullanma öyküsü olan migrenli gönüllüler, onamları alındıktan sonra çalışmaya dahil edilmiştir. Hastaların demografik özelliklerini, bireysel sürüş deneyimlerini, sürüş tercihlerini ve alışkanlıklarını değerlendirmek için Sürüş Alışkanlığı Anketi'nden uyarlanan bir form kullanılarak detaylı yüz yüze görüşmeler yapılmıştır. Son olarak, araç kullanmanın hastaların yaşam kalitesi üzerindeki etkisi Baş Ağrısı Etki Testi-6 (HIT-6) kullanılarak değerlendirilmiştir.
BULGULAR: Çalışmamızda değerlendirilen 2548 hastanın 1333'ünün araç kullanma deneyimi vardı; sürücülerin ortalama yaşı 36.7±9.5 yıldı ve %64.4'ü kadındı. Migrenli hastalar yaklaşık olarak haftanın 4.86 günü araç kullanırken; katılımcıların %64.1'inin 10 yıldan fazla sürüş deneyimi vardı. Hastalar genel olarak güvenlik önlemlerine uyuyorlardı: Katılımcıların %92.2'si her zaman emniyet kemerini takıyordu ve %85.2'si araç kullanmadan önce düzenli olarak dikiz aynalarını kontrol ediyordu. Hastaların %28.8'i her zaman sürücü olmak istiyordu ve %26.3'ü trafik akışının aksine hız sınırının üzerinde araç kullanıyordu. Migrenli sürücülerde ortalama HIT-6 puanı, 62.2±7.1 idi. Sık araç kullanma davranışı, daha yüksek sürüş hızları ve kendilerini daha iyi sürücü olarak algılama eğilimiyle ilişkili ortak faktörler erkek cinsiyet, sigara ve alkol kullanımı, daha uzun süreli araç kullanma deneyimi ve düşük HIT-6 skoru idi.
SONUÇ: Bulgularımız, migrenin sürüş sıklığını, hız tercihlerini ve öznel sürüş güvenini etkileyerek sürüş davranışlarını şekillendirdiğini ve bunun klinik değerlendirmelerde dikkate alınması gerektiğini göstermektedir.

Anahtar sözcükler: Dikiz aynası; emniyet kemeri; migren; sürüş hızı; sürüş kalitesi; sürüş tercihleri.

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MİGREN HASTALARINDA SÜRÜŞ ALIŞKANLIKLARININ VE PROBLEMLERİNİN DEĞERLENDİRİLMESİ

Araştırmanın amacı, migren hastalarının sürüş ile ilgili deneyimlerini, tercihlerini, sürüş sırasında yaşadıkları problemleri, baş ağrıları ile başa çıkma metodlarını açığa çıkarmak ve kaza sırasındakimigren atak durumlarına dair bilgi toplamaktır.

Araştırmaya katılmayı kabul ederseniz,sizden anket sorularına dikkatlice yanıt vermeniz istenmektedir. Yaklaşık olarak 15-20 dakika sürmesi beklenen bu ankette sizlere migren baş ağrınızınözellikleri, sürüş deneyimleriniz ve tercihleriniz, sürüş performansınızı etkileyebilecek faktörler, sürüş esnasında baş ağrınız ile başa çıkma metodlarınız, kaza sıklığınız ve kaza anındaki baş ağrısı durumunuz gibi boyutları kapsayan sorular yöneltilecektir. Vereceğiniz yanıtlar sizin baş ağrınızın yaşamınızdakietkisini daha iyi anlamamızı ve sizlere daha etkin çözümler üretmemizi sağlayacaktır.

Araştırmaya katılımınız tamamen gönüllülük temelinde olacaktır. Ankette sizden kimliğinizi ifşa edecek veya çalıştığınız kurum, bölüm, birim gibi belirleyici hiçbir bilgiistenmemektedir. Cevaplarınız tamamıyla gizli tutulacak, sadece araştırmacılar tarafından değerlendirilecektir. Katılımcılardanelde edilecek bilgiler toplu halde değerlendirilecek ve bilimsel yayınlarda kullanılacaktır. Sağladığınız veriler gönüllü katılım formlarında toplanan kimlik bilgileri ile eşleştirilmeyecektir ve sigorta şirketi gibi diğer kurumlara verilmeyecektir.

Çalışma, genel olarak kişisel rahatsızlık verecek sorular içermemektedir. Ancak, katılım sırasında sorulardan ya da herhangi başka bir nedenden ötürü kendinizi rahatsız hissederseniz cevaplamayı yarıda bırakmakta serbestsiniz. Böyle bir durumda çalışmayı uygulayan kişiye, çalışmadan çıkmak istediğinizi söylemeniz yeterli olacaktır.

Çalışmaya ve dolayısıyla migrenlilerin sürüş sırasında yaşadıklarını objektif olarak saptamak ve bu bilinmeyen yükü ortaya koymak adına verdiğiniz destek için teşekkürederiz. Çalışma hakkında daha fazla bilgi almak için Acıbadem Üniversitesi öğretim üyelerinden Prof. Dr. Pınar Yalınay Dikmen (E-posta: pinarya@hotmail.com) ya da Gaziantep Şehir Hastanesi SUAM Nöroloji Anabilim Dalı'ndan Uzm. Dr. Hamit GENÇ (E-posta:hgenc8987@gmail.com) ile iletişim kurabilirsiniz.

- ☐ Çalışma ile ilgili bilgileri okudum, anladım. Çalışmaya katılmaya **onay veriyorum.**
- ☐ Çalışma ile ilgili bilgileri okudum, anladım. Çalışmaya katılmaya **onay vermiyorum.**

Hasta Adı-Soyadı	:	Hekimin Adı-Soyadı	:
İmza	:	İmza	:
Tarih	:	Tarih	:

1.KISIM

Bu kısım araştırmacı hekim tarafından doldurulacaktır.

* Zorunlu soruyu belirtir.

1. E-posta *

_____

2. Çalışma merkezinizin kodunu belirtiniz. *

_____

3. Hasta kodunu belirtiniz. *

_____

4. Yaş *

_____

5. Cinsiyet *

Yalnızca bir şıkkı işaretleyin.

◯ Kadın ◯ Erkek ◯ Diğer:____

6. Meslek *

Yalnızca bir şıkkı işaretleyin.

◯ Şoför ◯ Kaptan ◯ Pilot ◯ Vinç operatörü ◯ Diğer: ____

7. Yaklaşık aylık gelir durumunuz nedir? *

_____

8. Hastanın primer başvuru sebebi baş ağrısı mı? *

Yalnızca bir şıkkı işaretleyin.

◯ Evet ◯ Hayır

9. Tanı *

Uygun olanların tümünü işaretleyin.

☐ Aurasız migren
☐ Auralı migren
☐ Kronik migren
☐ Migren komplikasyonları
☐ Vestibular migren
☐ İlaç kötüye kullanım baş ağrısı
☐ Diğer: _____

10. Auralı migren hastanızın aura tipini belirtiniz. *

Uygun olanların tümünü işaretleyin.

☐ Aura yok
☐ Görsel
☐ Duysal
☐ Konuşma ve/veya lisan
☐ Beyin sapı (Vertiginöz)
☐ Retinal
☐ Motor

11. Migren tanısı aldığınızda kaç yaşındaydınız? *

_____

12. Son 3 aydır, ayda ortalama kaç kez baş ağrısı yaşadınız? (Gün) *

_____

13. Baş ağrılarınızın şiddetine 10 üzerinden kaç puan verirsiniz? *

Yalnızca bir şıkkı işaretleyin.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

14. Baş ağrınıza eşlik eden semptomları belirtiniz? *

Uygun olanların tümünü işaretleyin.

- ☐ Bulantı Kusma
- ☐ Allodini
- ☐ Fotofobi
- ☐ Otonomik bulgular
- ☐ Fonofobi
- ☐ Hareket duyarlılığı
- ☐ Osmofobi
- ☐ Boyun ağrısı
- ☐ Baş dönmesi

15. Baş ağrınızın yönünü belirtiniz? *

Yalnızca bir şıkkı işaretleyin.

- ◯ Hep tek taraflı
- ◯ Bazen tek, bazen iki taraflı
- ◯ Hep iki taraflı
- ◯ Hep tek taraflı fakat yön değiştiren

16. Baş ağrınızın tipini belirtiniz? *

Uygun olanların tümünü işaretleyin.

- ☐ Sıkıştırıcı/baskı
- ☐ Değişken
- ☐ Zonklayıcı/pulsatil
- ☐ Diğer: _____
- ☐ Bıçak saplanır tarzda

17. Migren atağını kontrol altına almak için kullandığınız ilaçları belirtiniz? *

Uygun olanların tümünü işaretleyin.

- ☐ İlaç almıyorum
- ☐ Parasetamol
- ☐ Ağrı kesiciler ve anti-inflamatuar ilaçlar (NSAI)
- ☐ Triptanlar
- ☐ Ergot alkaloidleri
- ☐ Asetilsalilisik asit-Parasetamol-Kafein kombinasyonları
- ☐ Diğer: _____

18. Varsa son 3 aydır aldığınız profilaksi tedavisini/tedavilerini belirtiniz? *

Uygun olanların tümünü işaretleyin.

- ☐ Almıyorum
- ☐ Beta blokörler
- ☐ Trisiklik antidepresanlar
- ☐ SNRI
- ☐ Valproik asit
- ☐ Topiramat
- ☐ Flunarizin
- ☐ GON ve diğer periferal blokajlar
- ☐ Botulinum toksin enjeksiyonu
- ☐ CGRP antagonistleri
- ☐ Diğer: _____

19. Kronik hastalığınız varsa belirtiniz? *

Uygun olanların tümünü işaretleyin.

- ☐ Kronik hastalığım yoktur
- ☐ Hipertansiyon
- ☐ Diyabetes mellitus
- ☐ Tiroid bozukluğu
- ☐ Romatizma
- ☐ Kas hastalığı
- ☐ Ritm bozukluğu
- ☐ Kalp hastalığı
- ☐ İnme
- ☐ Diğer: _____

20. Daha önce bilinen bir psikiyatrik hastalığınız var mı? *

Uygun olanların tümünü işaretleyin.

- ☐ Hayır
- ☐ Depresyon
- ☐ Psikoz
- ☐ Bipolar Bozukluk
- ☐ Anksiyete
- ☐ Diğer:_____

21. Uyku bozukluğunuz varsa belirtiniz. *

Uygun olanların tümünü işaretleyin.

- [ ] Yok
- [ ] Uykuya dalma güçlüğü
- [ ] Sık uyanma
- [ ] Gün içi artmış uykululuk
- [ ] Uyku apnesi
- [ ] Huzursuz bacaklar sendromu
- [ ] Yorgun uyanma
- [ ] Diğer: _____

22. Görme probleminiz varsa belirtiniz. *

Uygun olanların tümünü işaretleyin.

- [ ] Yok
- [ ] Uzağı görememe (miyop)
- [ ] Yakını görememe (hipermetrop)
- [ ] Astigmatizm
- [ ] Göz tansiyonu (Glokom)
- [ ] Şaşılık
- [ ] Çift görme
- [ ] Diğer: _____

23. Aşağıdaki alışkanlıklardan hangisi sizde mevcuttur? *

Uygun olanların tümünü işaretleyin.

- [ ] Sigara
- [ ] Alkol
- [ ] Hiçbiri
- [ ] Diğer: _____

2.KISIM

Bu kısmı hasta dolduracak, hekim tarafından kontrolü sağlanacak.

24. Migren atağı öncesi aşağıdaki semptomlardan hangilerini yaşarsınız? **(Uygun olanların tümünü işaretleyin.)**

- ☐ Sinirlilik
- ☐ Depresif ruh hali veya ruh halindeki değişiklikler
- ☐ Esneme
- ☐ Tükenmişlik
- ☐ Uyuma zorluğu
- ☐ İdrar yapma ihtiyacının artması
- ☐ Yemek isteği
- ☐ Mide bulantısı
- ☐ Işığa veya sese duyarlılık
- ☐ Odaklanmada zorluk
- ☐ Konuşma veya okuma zorluğu
- ☐ Boyun ağrısı veya kas sertliği
- ☐ Hiperaktivite
- ☐ Kabızlık veya ishal
- ☐ Şişkinlik
- ☐ Hiçbiri
- ☐ Diğer: _____

25. Migren atağı sonrası aşağıdaki semptomlardan hangilerini yaşarsınız? * **(Uygun olanların tümünü işaretleyin.)**

- ☐ Yorgun, tükenmiş veya huysuz hissetmek
- ☐ Alışılmadık derecede yenilenmiş veya mutlu hissetmek
- ☐ Kas ağrısı veya zayıflığı
- ☐ Yiyecek isteği veya iştahsızlık
- ☐ Hiçbiri
- ☐ Diğer: _____

26. Yolculuk yaparken, aracı siz kullanmadığınız zaman taşıt tutması yaşıyor musunuz? *

Yalnızca bir şıkkı işaretleyin.

- ◯ Hiç yaşamıyorum
- ◯ Bazen yaşıyorum
- ◯ Sıklıkla yaşıyorum
- ◯ Her zaman yaşıyorum

27. Çocukluk döneminde taşıt tutmanız var mıydı? * **(Yalnızca bir şıkkı işaretleyin.)**

◯ Evet ◯ Hayır

28. Araç kullanıyor musunuz? ***(Yalnızca bir şıkkı işaretleyin.)**

◯ Evet ◯ Hayır ◯ Bıraktım

29. Ehliyetiniz var mı? ***(Yalnızca bir şıkkı işaretleyin.)**

◯ Evet ◯ Hayır

NOT: Hiç araç kullanmıyorsanız, lütfen 54. Sorudan devam ediniz. 54.soruda sadece soldaki "Aracı siz KULLANMIYORKEN" kısmını doldurunuz. Sonrasında devam eden soruları yanıtlayınız.

30. Genelde hangi aracı kullanıyorsunuz? **(Uygun olanların tümünü işaretleyin.)**

- ☐ Otomobil
- ☐ SUV
- ☐ Motorsiklet
- ☐ Bisiklet
- ☐ Martı
- ☐ Minibüs
- ☐ Transit
- ☐ Otobüs
- ☐ Tren
- ☐ Uçak
- ☐ Gemi
- ☐ Tekne
- ☐ Diğer:.....

31. Kaç yaşından beri aktif araç kullanıyorsunuz?

_____

32. Haftada ortalama kaç gün araç kullanıyorsunuz? ***(Yalnızca bir şıkkı işaretleyin.)**

1	2	3	4	5	6	Haftanın her günü araç kullanıyorum
◯	◯	◯	◯	◯	◯	◯

33. Aracı siz kullanırken taşıt tutması yaşıyor musunuz? **(Yalnızca bir şıkkı işaretleyin.)**

- ◯ Hiç yaşamıyorum
- ◯ Bazen yaşıyorum
- ◯ Sıklıkla yaşıyorum
- ◯ Her zaman yaşıyorum

34. Araba sürerken gözlük veya kontak lens takıyor musunuz? *(Yalnızca bir şıkkı işaretleyin.)

Evet Hayır

35. Sürerken emniyet kemeri takar mısınız? Şöyle diyebilir misiniz? *(Yalnızca bir şıkkı işaretleyin.)

Her zaman Bazen Asla

36. Sürüş öncesi aynaları kontrol eder misiniz? *(Yalnızca bir şıkkı işaretleyin.)

Her zaman Bazen Asla

37. Arabayla dışarı çıktığınızda ne sıklıkla siz şoför olursunuz? *(Yalnızca bir şıkkı işaretleyin.)

Her zaman Sıklıkla Bazen Asla

38. Genellilkle, yakın mekanlarda dolaşmayı nasıl tercih edersiniz? *(Yalnızca bir şıkkı işaretleyin.)

Toplu taşıma veya taksi kullanırsınız.
Sizi birisi arabayla gezdirir.
Bizzat kendiniz araba sürersiniz

39. Genel trafik akışına göre genellikle ne kadar hızlı sürüyorsunuz? Şöyle diyebilir misiniz? *
(Yalnızca bir şıkkı işaretleyin.)

Çok daha yavaş
Biraz daha yavaş
Yaklaşık aynı
Biraz daha hızlı
Çok daha hızlı

40. Araba sürüş kalitenizi nasıl değerlendirirsiniz? Şöyle diyebilir misiniz? *(Yalnızca bir şıkkı işaretleyin.)

Kötü Zayıf Ortalama İyi Mükemmel

41. Kendi aracınızla gitmek istemediğiniz bir yere gitmeniz gerektiğinde ne yaparsınız? *
(Yalnızca bir şıkkı işaretleyin.)

Bir arkadaş veya akrabaya araba sürmesi için rica ederim.
Taksi çağırır veya toplu taşımaya/otobüse binerim.
Nasıl hissettiğime bakmaksızın kendim araba sürerim.
Planlarımı iptal eder veya erteleyerek kalırım.
Diğer: _____

42. Araç kullanırken baş ağrısı yaşadınız mı? *(Yalnızca bir şıkkı işaretleyin.)

Evet Hayır

43. Son 1 ayda kaç kez araç kullandınız? * _____

44. Son 1 ayda araç kullanırken kaç kez baş ağrısı yaşadınız? * _____

45. Son 1 ayda, taşıt kullanırken ortaya çıkan baş ağrınız ortalama kaç saat sürdü? * _____

46. Taşıt kullanırken başlayan baş ağrınızın şiddetine 10 üzerinden kaç puan verirsiniz? *
(Yalnızca bir şıkkı işaretleyin.)

1 2 3 4 5 6 7 8 9 10

47. Sürüş esnasında migren atağı yaşadığınızda nasıl başa çıkmaya çalışırsınız? *
(Uygun olanların tümünü işaretleyin.)

- Bir şey yapmadım, aynı şekilde sürüşe devam ettim.
- Ağrı kesici/atak ilacı kullandım.
- Sıvı tükettim.
- Güneş gözlüğü kullandım.
- Araç içi ön cam yerleşimli güneş siperliği kullandım.
- Sürüşe ara verdim ve atağımın geçmesini bekledim.
- Sürüş hızımı düşürdüm.
- Müzik sesini kapattım.
- Aracın camlarını açarak havalanmasını sağladım.
- Araç farlarının daha fazla etkilemesi nedeniyle gece sürüşünden kaçındım.
- Yanımda başka sürücü olması halinde sürüşe onun devam etmesini istedim.
- Trafiğin kalabalık olduğu yerlerde araç kullanmamaya çalıştım.
- Arka koltuktan ön koltuğa geçtim.
- Diğer: _____

48. Sürüş sırasında baş ağrınız varsa endişe/kaygı yaşıyor musunuz veya artıyor mu? *
(Yalnızca bir şıkkı işaretleyin.)

Evet Hayır

49. Geçen yıl içinde migren baş ağrınız nedeniyle araba sürmeyi sınırlamanızı veya sürüşü bırakmanızı öneren biri oldu mu? * **(Yalnızca bir şıkkı işaretleyin.)**

( ) Evet ( ) Hayır

50. Migren nedeniyle araç sürmeyi bıraktınız mı? * **(Yalnızca bir şıkkı işaretleyin.)**

( ) Evet ( ) Hayır ( ) Azalttım

51. Migren nedeniyle araç kullanmayı bıraktıysanız, kaç yaşında bıraktınız? * _____

52. Araç sürmeyi bıraktığınızda kaç yıldır araç kullanıyordunuz? * _____

53. Baş ağrınız yokken ve varken aşağıda belirtilen koşullarda sürüş ile ilgili hangisini söylersiniz?* **(Yalnızca bir şıkkı işaretleyin.)**

Hiç zorluk yaşamıyorum (0 puan)---- Çok zorluk yaşıyorum (5 puan)

Baş ağrınız YOK iken							**Baş ağrınız VAR iken**					
0	**1**	**2**	**3**	**4**	**5**	**Sürüş Koşulu**	**0**	**1**	**2**	**3**	**4**	**5**
						Yağmurlu Hava						
						Karlı Hava						
						Buzlu Hava						
						Sisli Hava						
						Asfalt Yollarda						
						Çamurlu Yollarda						
						Patika Yollarda						
						Yoğun Trafikte						
						Gündüz						
						Gece						
						Şehir İçi						
						Otoyol veya Şehirler Arası						
						İş Saatleri						
						Sola dönüş yaparken						
						Kavşaklarda						
						Trafik lambasının /uyarı levhalarının olmadığı yollarda						
						Paralel park etmek						

54. Yolculuk sırasında aracı siz **kullanmıyorken** ve **kullanıyorken** migren atağına yol açan veya arttıran faktörleri seçiniz ve puanlayınız? *(Yalnızca bir şıkkı işaretleyin.)

0 (Etkilemiyor)---------- 5(Çok etkiliyor)

Aracı siz KULLANMIYORKEN							Aracı siz KULLANIYORKEN					
0	1	2	3	4	5	Durum	0	1	2	3	4	5
						Yoğun Trafik						
						Araç-yakıt kokusu						
						Sigara kokusu						
						Siren sesi						
						Yüksek sesle müzik dinlemek						
						Virajlı yollar						
						Zemini bozuk yollar						
						Sinyal sesleri						
						Dönen kavşaklara yaklaşırken sarı şeritler						
						Sıra sıra ağaçların arasında batan güneş ışınları						
						Dikey çelik kirişler						
						Yere yakın ışık hatları (yol çalışmaları)						
						Yolların ortasında çok dar eğik beyaz flash çizgileri						
						Polis arabalarında yanıp sönen mavi ışıklar						
						Ön cam sileceklerinin sesi ve görüntüsü						
						Kırmızı/Turuncu hız konilerinin yanından geçerken						
						Araç içi aydınlatması						
						Kısa LED aydınlatma (ön far)						
						Uzun LED aydınlatma (ön far)						
						Sinyal lambaları						
						Fren lambaları						
						Karşıdan vuran parlak güneş ışığı						

55. Sürüş esnasında yaşadığınız migren atağı ne gibi sorunlara yol açtı? ***Uygun olanların tümünü işaretleyin.**

- ☐ Yol koşullarına dikkatin azalması
- ☐ Zayıf şerit takibi
- ☐ Hızlı karar vermede bozulma
- ☐ Dikkatin azalması
- ☐ Reflekslerde zayıflama (Hızlı manevra yapma kabiliyetinde azalma/bozulma)
- ☐ Sinirlilik
- ☐ Huzursuzluk
- ☐ Görme bozukluğu
- ☐ Kaza yapma endişesinin/kaygısının artması
- ☐ Diğer: _____

56. Geçen yıl sürücü olarak karıştığınız kaç kaza oldu? Lütfen kendi kusurunuz olsun olmasın, tüm kazaların sayısını söyleyin? *

57. Bu kazaların kaçında kaza anında migren atağı yaşıyordunuz? *

58. Geçen yıl trafik cezası (park cezası hariç) aldınız mı ve bu durumda sizin düşünceniz ne olursa olsun kusurlu bulundunuz mu? **(Yalnızca bir şıkkı işaretleyin.)**

Evet Hayır

3.KISIM

Baş Ağrısı Etki Ölçeği (HIT-6)

59. Baş ağrılarınız olduğunda, ağrınız ne sıklıkla şiddetlidir? * **(Yalnızca bir şıkkı işaretleyin.)**

Asla Nadiren Bazen Sıklıkla Her zaman

60. Baş ağrıları ev işi, çalışma, okul veya sosyal aktiviteleri içeren her zamanki günlük aktivitelerinizi yapabilmenizi ne sıklıkta kısıtlar? * **(Yalnızca bir şıkkı işaretleyin.)**

Asla Nadiren Bazen Sıklıkla Her zaman

61. Baş ağrınız olduğunda, ne sıklıkla yatıp uzanmak istersiniz? * **(Yalnızca bir şıkkı işaretleyin.)**

Asla Nadiren Bazen Sıklıkla Her zaman

62. Geçtiğimiz 4 haftada, ne sıklıkla baş ağrılarınız nedeniyle iş veya günlük etkinliklerinizi yapmak için çok yorgun hissettiniz? * **(Yalnızca bir şıkkı işaretleyin.)**

Asla Nadiren Bazen Sıklıkla Her zaman

63. Geçtiğimiz 4 haftada, ne sıklıkla baş ağrılarınız nedeniyle bıkkın veya gergin hissettiniz?* **(Yalnızca bir şıkkı işaretleyin.)**

Asla Nadiren Bazen Sıklıkla Her zaman

64. Geçtiğimiz 4 haftada, ne sıklıkla baş ağrıları iş veya günlük aktivitelere konsantre olabilmenizi kısıtladı?* **(Yalnızca bir şıkkı işaretleyin.)**

Asla Nadiren Bazen Sıklıkla Her zaman

CASE REPORT

Assessment of causality and impairment following unilateral hypoglossal nerve paralysis: A case report

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ABSTRACT

Isolated hypoglossal nerve injury is an infrequent occurrence in clinical and forensic traumatology practice. Its etiology includes trauma, malignancy, vascular events, autoimmune diseases, and complications of surgical procedures. Clinical manifestations resulting from nerve damage may present early or be delayed. We present the case of a 44-year-old woman who sustained a fracture of the third cervical vertebra following a traffic accident. An anterior approach was employed for instrumentation using an anterior plate spanning two cervical segments. The patient developed dysphagia and swallowing difficulties and subsequently underwent evaluation for disability status. Physical examination revealed significant atrophy and asymmetry of the right half of the tongue body, slight rightward deviation of the tongue apex at rest, and fasciculations. Electromyography performed 22 months after the injury demonstrated chronic axonal injury of the right hypoglossal nerve. Causality assessment favored the traffic accident as the initiating event, with postoperative edema and retraction likely contributing to progression. The condition was classified as permanent, and a 25% functional loss was assigned for tongue paralysis according to national disability criteria. This report highlights the diagnostic, prognostic, and legal complexities of delayed hypoglossal nerve palsy following cervical trauma and underscores the importance of a multidisciplinary approach in determining the etiology and prognosis of isolated hypoglossal nerve paralysis, as well as in establishing medical causality.

Keywords: Forensic traumatology; hypoglossal nerve palsy; anterior cervical surgery; medico-legal causality; disability assessment.

INTRODUCTION

Isolated hypoglossal nerve paralysis is a rare medical condition. It may arise from trauma, neoplasms, cerebrovascular disease, aneurysm, complications related to medical procedures (such as surgery, intubation, or radiotherapy), or may be idiopathic in origin.[1-3] Due to its anatomical location, the hypoglossal nerve is one of the cranial nerves least affected by blunt head trauma. Hypoglossal nerve paralysis may result in dysphagia, facial twitching, and tongue weakness.[4]

Isolated hypoglossal nerve injury has been reported in the literature primarily as case reports, focusing on treatment approaches and prognostic outcomes.[5,6] However, no studies addressing this condition from a forensic medicine perspective have been identified. Medicolegal assessment of hypoglossal nerve injury with delayed symptom onset presents several challenges. In such cases, it is essential to determine causality, assess whether the condition is permanent, and evaluate the severity of clinical impairment (including sensory-organ dysfunction, functional loss, and degree of disability) for both criminal and civil proceedings.

The aim of this case report is to highlight the evaluation of causal relationships and degree of disability based on clinical functionality from a medicolegal perspective.

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CASE REPORT

A 44-year-old female patient presented to the Department of Forensic Medicine seven months after a traffic accident with complaints of dysphagia, tongue weakness, and restricted tongue movement for disability evaluation. The traffic accident resulted in comminuted displaced fractures of the C3 vertebral body and the anterior and posterior walls of the left transverse foramen. Cervical spinal magnetic resonance imaging (MRI) performed on the day of the accident revealed edema-like signal changes in the proximal cervical region, as well as degenerative changes. The patient underwent anterior surgical intervention using a microsurgical technique due to an unstable cervical vertebral fracture and traumatic disc pathology. An anterior plate was placed spanning two segments, including the C3 and C4 vertebral bodies. Discectomy, intervertebral graft placement (cage), and disc prosthesis implantation were performed at the C3–4 level (Fig. 1). No major intraoperative complications were reported. The patient was discharged on the first postoperative day. In the days following discharge, the patient developed swallowing difficulties, followed by weakness on the right side of the tongue, unintentional tongue biting, and chewing difficulties. Upon recommendation by an otolaryngologist, she was referred for swallowing therapy. Atrophy of the right side of the tongue, rightward deviation of the tongue tip, and fasciculations were noted during our team's examination seven months after the injury (Fig. 2). The preliminary diagnosis was considered to be

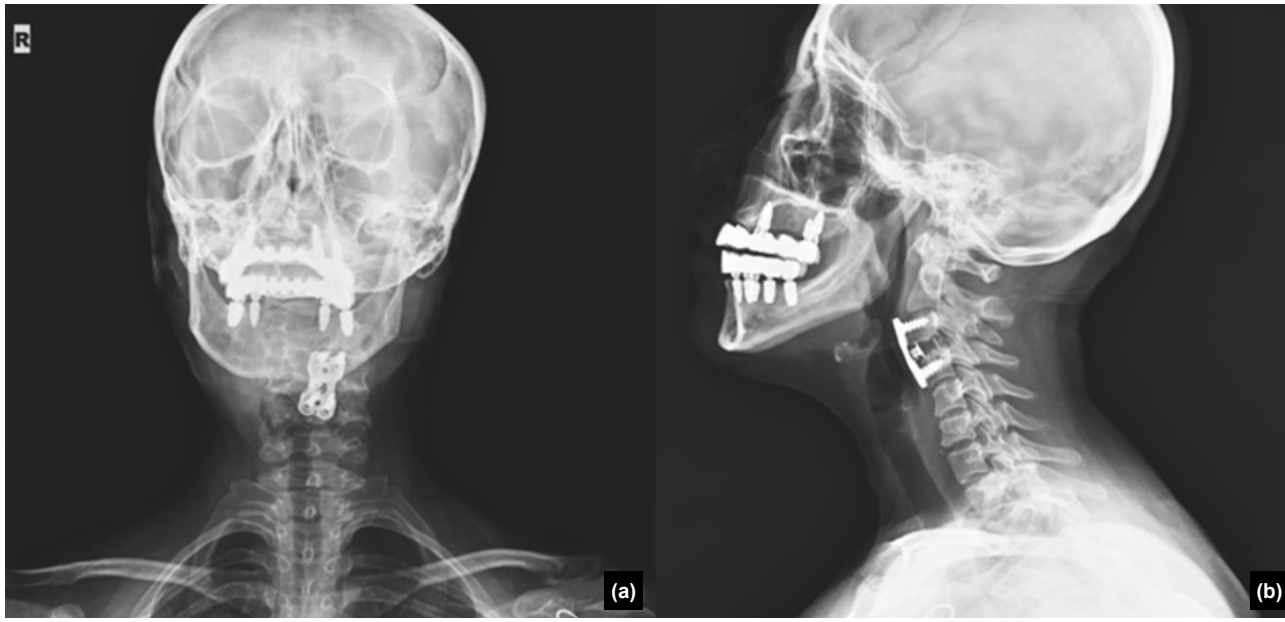

Figure 1. (a) Coronal and **(b)** sagittal cervical spine X-rays demonstrating displaced C3 fractures with postoperative instrumentation.

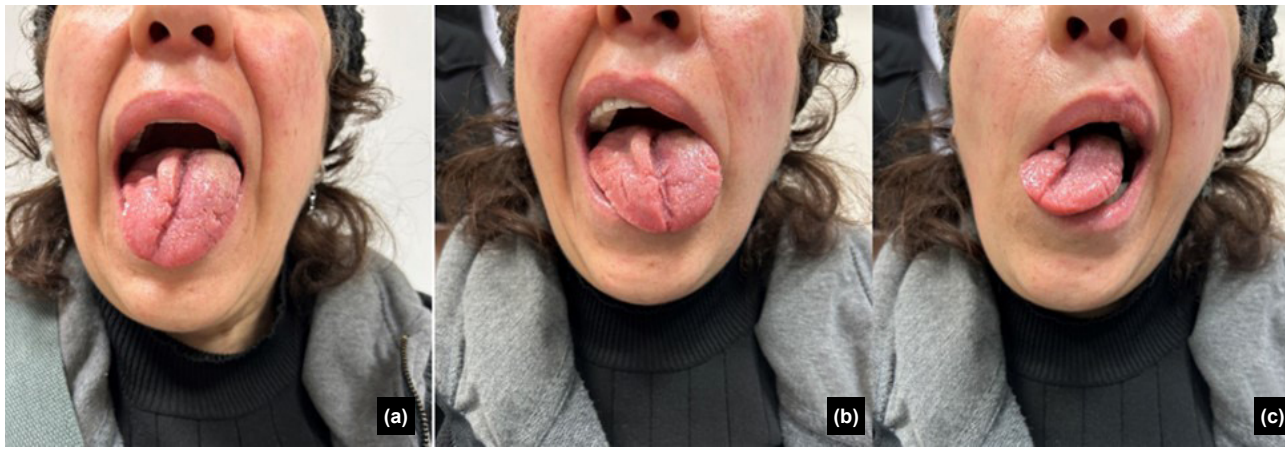

Figure 2. (a) Atrophy of the right half of the tongue and rightward deviation of the tongue apex; **(b-c)** comparison of tongue movement from right to left.

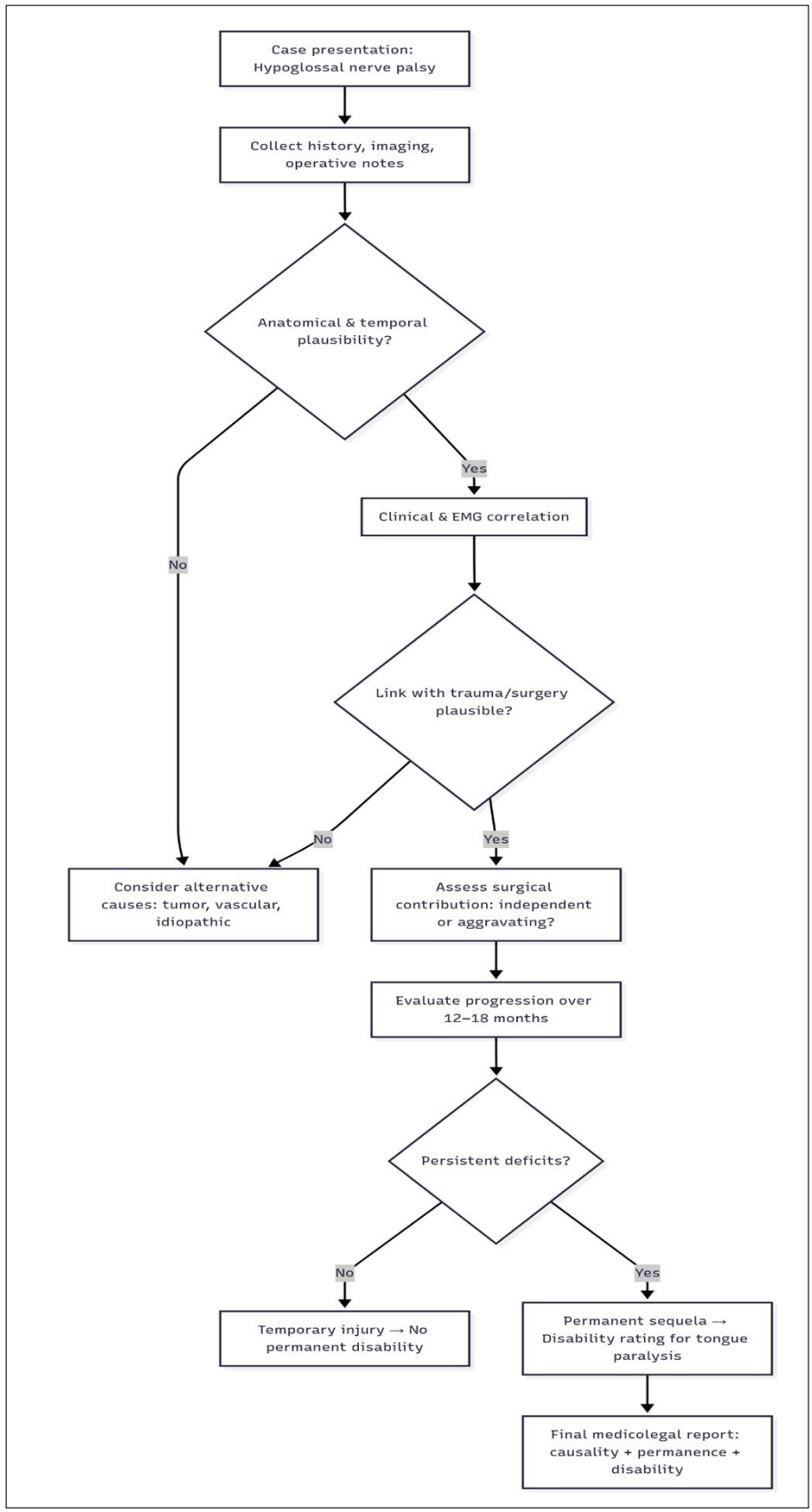

Figure 3. Algorithmic approach to the medicolegal evaluation of cases involving hypoglossal nerve paralysis.

paralysis of the right peripheral hypoglossal nerve secondary to trauma. A neurology consultation and electromyography (EMG) were requested to clarify the diagnosis (central versus peripheral pathology). It was decided that the patient would be re-evaluated after an adequate rehabilitation period and diagnostic confirmation—at least 18 months after the injury—for a final disability assessment.

Following the neurology consultation, needle EMG was performed on the bilateral intrinsic tongue muscles 22 months after the trauma. Denervation potentials and neurogenic motor unit action potentials were observed on the right side, while EMG findings on the left were within normal limits. These results were consistent with active chronic axonal injury of the right hypoglossal nerve. Cranial MRI revealed no evidence of vascular pathology, mass lesion, or diffusion restriction. Physical examination demonstrated significant atrophy and asymmetry of the right half of the tongue body, along with slight rightward deviation of the tongue apex in the neutral position and fasciculations.

The hypoglossal nerve paralysis was considered permanent (sequela) because there was no clinical improvement despite adequate treatment and rehabilitation. A causal relationship was established between the motor vehicle accident and the nerve paralysis. The patient's degree of disability resulting from the nerve paralysis was assessed as 25%, according to the "loss of tongue function due to paralysis" criterion outlined in the Regulation on Disability Assessment for Adults.

Written informed consent was obtained from the patient publication of this case report and associated images.

DISCUSSION

Hypoglossal nerve palsy can be caused by a variety of pathologies (such as malignancy, cerebrovascular events, and autoimmune diseases), as well as trauma and surgery. The most common etiological factors are surgical complications and malignancies.[4,7] Hypoglossal nerve injury has been reported as a surgical complication following anterior cervical spine surgery and carotid endarterectomy.[8,9] Approximately 4% of hypoglossal nerve palsy cases are caused by trauma, with the majority involving occipital condyle fractures affecting the hypoglossal canal.[5] Isolated hypoglossal nerve palsy may occur after penetrating trauma,[10] stretching of the nerve in the cervical region,[11] and minor head trauma.[6] Assessing causality between trauma and nerve injury requires an in-depth understanding of the course of the hypoglossal nerve. The hypoglossal nerve originates from the medulla oblongata. After following a lateral and caudal course within the cranium, it passes through the hypoglossal canal. Upon exiting the cranium, it travels downward in the neck, in close proximity to the internal carotid artery and the internal jugular vein, until it reaches the mandibular angle. Beyond this point, it continues anteriorly to innervate its target tissues.[1,12] Along its course through the cervical region, the nerve is susceptible to injury caused by surgical complications (such as traction) and trauma. In our case, a C3 comminuted vertebral fracture was accompanied by soft tissue edema in the region corresponding to the adjacent nerve pathway. Because the fracture was unstable, anterior cervical instrumentation was performed. Considering the site and mechanism of trauma, it was assumed that nerve stretching due to acceleration-deceleration forces, along with edema, caused neurapraxia. Furthermore, the use of retractors during surgery and postoperative soft tissue swelling may have exacerbated the nerve injury.

The hypoglossal nerve innervates the extrinsic and intrinsic muscles of the tongue (except for the palatoglossus muscle), enabling movements such as tongue protrusion and retraction.[12] It plays a crucial role in swallowing and speech. Dysphagia, dysarthria, odynophagia, tongue weakness, and headache are common symptoms of hypoglossal nerve palsy.[4] Symptoms may appear either abruptly or in a delayed manner following a traumatic event or surgical procedure. Delayed symptom onset may result from nerve compression caused by displaced fracture fragments, callus formation, hematoma, or increased edema at the fracture site.[8] Delayed onset occurs in approximately 38% of cases involving traumatic hypoglossal nerve injuries.[13] Clinical findings may remain undetectable in the early stages of trauma unless axonotmesis or neurotmesis is present. Dysphagia and dysarthria are frequently observed in the postoperative period, particularly after anterior surgical approaches.[14] This can make the diagnosis of hypoglossal nerve palsy difficult in the postoperative setting. One of the most important clinical indicators is noticeable tongue deviation. In our case, the initial neurological examination following the trauma revealed no cranial nerve deficits. However, the patient subsequently reported a gradual progression of dysphagia in the early postoperative period, which was considered consistent with delayed-onset hypoglossal nerve injury. Evaluation suggested that increasing edema in the paraspinal and parapharyngeal regions, secondary to surgery, may have contributed to the onset or worsening of symptoms.

The prognosis of hypoglossal nerve injury largely depends on the underlying cause. In idiopathic cases, nerve function typically returns to normal within a few days.[2] The majority of unilateral isolated hypoglossal nerve injuries recover normal function within the first six months.[15] However, in some traumatic cases and injuries resulting from surgical complications, the subsequent nerve palsy may become permanent.[16,17] In our case, the clinical findings of hypoglossal nerve palsy persisted for approximately 22 months after the accident, with no improvement in symptoms or neurological signs. The absence of nerve palsy findings in the early post-traumatic period, along with the worsening of symptoms in the early postoperative phase, suggests that neurapraxia caused by a stretch injury during the trauma may have progressed to permanent nerve damage due to increased traction and compression from surgery-related edema. In forensic medical practice, if symptoms of nerve injury persist for at least 18

months, the condition is considered permanent (sequela). In accordance with this principle, the resulting disability in this case was considered permanent. The degree of impairment was determined in accordance with the relevant regulation concerning functional loss of the tongue due to paralysis.

In the medicolegal evaluation of the case, the trauma dynamics and associated findings (such as fracture and edema) suggest that traction and acceleration-deceleration forces in the cervical region may have caused injury to the hypoglossal nerve along its anatomical course. Given that clinical signs of nerve injury may not be immediately evident in the early post-traumatic phase, it was hypothesized that either the comminuted fracture of the C3 vertebra or the traumatic forces responsible for the fracture could have induced hypoglossal nerve damage. Postoperatively, edema resulting from the surgical procedure may have facilitated the onset or worsening of clinical symptoms and may have contributed to the progression of the nerve injury to a permanent condition. It was further assessed that both the trauma and the potential surgical complication may have independently contributed to the development of the nerve palsy, complicating the differentiation of their individual effects (alternative causation).[18] Consequently, it was determined that the surgical procedure did not interrupt the chain of causation between the traffic accident and the nerve injury. A causal link was established between the traffic accident and the hypoglossal nerve palsy. Due to the complexity of the case, a neurology consultation was requested. The neurology board concluded that the current clinical condition could not be attributed solely to the surgery and was more plausibly related to the accident. This clinical opinion supported our medicolegal evaluation. The medicolegal assessment algorithm for such cases is presented in Figure 3.

CONCLUSION

Isolated hypoglossal nerve injury is an uncommon condition. For medicolegal assessment, it is essential to understand its prognosis, causes, and clinical manifestations. However, in forensic traumatology, establishing causality is not always straightforward. Each case must be evaluated individually. The mechanism of trauma, associated findings, anatomical localization of the injury, and the patient's clinical presentation should all be carefully considered in every forensic case. Medical interventions that have the potential to influence or interrupt the causal relationship must be thoroughly analyzed, and complex cases should be managed using a multidisciplinary approach.

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Authorship Contributions: Concept: E.N.İ.; Design: E.N.İ., R.A., A.B.O.; Supervision: R.A., A.B.O.; Resource: Z.Ö.İ., B.T.; Materials: Z.Ö.İ., B.T.; Data collection and/or processing: Z.Ö.İ., B.T.; Analysis and/or interpretation: E.N.İ., R.A., A.B.O.; Literature review: E.N.İ., Z.Ö.İ., B.T.; Writing: E.N.İ., Z.Ö.İ., B.T.; Critical review: B.T., R.A., A.B.O.

Conflict of Interest: None declared.

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OLGU SUNUMU - *ÖZ*

Unilateral hipoglossal sinir paralizisinde illiyet bağı ve maluliyet değerlendirmesi: Olgu sunumu

Hipoglossal sinir paralizisi klinikte ve adli travmatolojide nadir görülen bir durumdur. Sinir hasarı etiyolojisinde travma, malignite, otoimmünite ve cerrahi komplikasyonlar gibi çeşitli nedenler bulunmaktadır. Sinir paralizisine bağlı semptom ve klinik bulgular erken dönemde veya gecikmiş olarak gözlenebilir. Bu yazıda trafik kazası sonucu servikal 3.vertebrasında fraktür gelişen 44 yaşındaki kadın bir olgu sunuldu. Anterior cerrahi yaklaşımla servikal vertebrada iki segmentte anterior plak ile enstrümantasyon yapılmıştır. Disfaji ve yutma şikayetleri gelişen hasta maluliyet açısından tarafımızca değerlendirildi. Fizik muayenede, dil sol yarısında atrofi ve asimetrik görünüm tespit edildi. Nötral pozisyonda dil apeksinde sağ deviasyon ve fasikülasyon görüldü. Kaza sonrası 22. ayda gerçekleştirilen elektromiyografide sağ hipoglossal sinirde kronik aksonal hasar tespit edildi. Hastadaki semptom ve bulguların, trafik kazasıyla illiyet bağının olduğu değerlendirildi. Cerrahi işlem ve postoperatif dönemde gelişen ödemin bulguları şiddetlendirdiği düşünüldü. Hastada dil paralizisine bağlı fonksiyonel kaybın kalıcı olduğu ve gelişen dil paralizisinin Erişkinler İçin Engellilik Değerlendirmesi Hakkında Yönetmelik hükümlerine göre hastada %25 engel oranına neden olduğu belirlendi. Bu olgu sunumunda, servikal travma sonrası gelişen gecikmiş izole hipoglossal sinir paralizisinin tanısal, prognostik ve medikolegal değerlendirmesindeki zorlukların tartışılmasıyla birlikte sinir hasarının etiyolojisi, prognozu ve illiyet bağının belirlenmesinde kapsamlı ve multidisipliner yaklaşımın öneminin vurgulanması amaçlandı.
Anahtar sözcükler: Adli travmatoloji, hipoglossal sinir paralizi, anterior servikal cerrahi, medikolegal illiyet bağı, maluliyet değerlendirmesi.

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CASE REPORT

Pelvic and genital trauma in female motorcycle accident patients: A report of two cases and literature review

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ABSTRACT

This study aims to highlight the clinical course of genitourinary injuries associated with pelvic fractures following motorcycle accidents and to raise awareness of these injuries. This case report presents two young female patients who sustained pelvic fractures and genitourinary injuries after motorcycle accidents. The cases are compared in terms of trauma severity, associated injuries, and treatment approaches. The first patient sustained high-energy trauma resulting in severe soft tissue injuries involving the anterior vaginal wall, clitoris, and bladder neck, accompanied by active bleeding. Despite external fixation, the patient died from multi-organ failure. The second patient experienced less severe trauma, presenting with a pelvic fracture and a superficial mons pubis laceration. She was successfully managed conservatively and recovered without complications. These cases highlight the importance of thorough genital examination in female trauma patients, the necessity of a multidisciplinary approach, and the potential for timely surgical intervention to be life-saving. This report contributes to the limited literature on pelvic and genitourinary injuries in women resulting from motorcycle accidents and underscores the need for further clinical research and documentation.

Keywords: Pelvic fracture; motorcycle accident; genital trauma; female trauma patients.

INTRODUCTION

Trauma is a major cause of morbidity and mortality among young adults. According to the World Health Organization, road traffic accidents are among the leading causes of death in individuals aged 15–29 years, with motor vehicle accidents posing a particularly high risk.[1,2] Although head injuries are the primary cause of death in these cases, pelvic injuries also contribute significantly to morbidity.

Approximately 22% of trauma-related injuries resulting from motor vehicle accidents involve the pelvis. In female patients, pelvic injuries may be associated with intra-abdominal organ damage, pelvic hemorrhage, and genital soft tissue injuries.[1] Vulvovaginal trauma occurs in approximately 1% of female motor vehicle accident cases, while urethral injuries are reported in about 0.2%.[3,4] Although relatively rare, urethral trauma often indicates severe and potentially life-threatening injury, requiring prompt diagnosis and management.

Although the initial priority in trauma care is stabilization of life-threatening conditions, timely recognition and management of genitourinary injuries are equally critical. Studies report that nearly one-third of patients with hemodynamically unstable pelvic fractures presenting to Level I trauma centers in the United States die despite aggressive resuscitation.[5] Furthermore, motorcyclists who sustain genitourinary trauma have a significantly higher mortality rate.[6] If left untreated, these injuries may result in long-term complications. Therefore, a thorough and systematic genital examination should be an integral component of the post-trauma evaluation in female patients.

This case report describes two female patients who sustained pelvic fractures and genitourinary injuries following motorcycle accidents. By highlighting the diagnostic and therapeutic

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challenges, this report aims to provide valuable insights for gynecologists and trauma surgeons and to contribute to the limited literature on motorcycle-related pelvic and genitourinary trauma in women.

CASE REPORT

Written informed consent was obtained from the surviving patient for publication of the case details. For the deceased patient, informed consent could not be obtained; however, all data were fully anonymized to ensure patient confidentiality. The case report complies with the principles of the Declaration of Helsinki.

Case 1

A 25-year-old woman was referred to our hospital four hours after a high-energy motorcycle collision. On admission, she was intubated, hypotensive, and required high-dose inotropic support. Her Glasgow Coma Scale (GCS) score was 3, and she was hemodynamically unstable. According to emergency medical personnel, she had been riding a motorcycle at high speed when she collided with a car at an intersection, was thrown onto the road, and lost consciousness. At the scene, she maintained spontaneous respiration and responded to painful stimuli.

Initial cranial computed tomography (CT) performed at the referring center revealed no abnormalities. Thoracic CT demonstrated fully expanded lungs without evidence of hemopneumothorax. Pelvic CT showed a horizontal fracture of the right sacrum. Due to progressive clinical deterioration and the need for multidisciplinary management, the patient was transferred to our tertiary care facility.

In the emergency department, a Focused Assessment with Sonography for Trauma (FAST) examination revealed no intra-abdominal free fluid. Physical examination revealed multiple skin lacerations and ecchymoses, a type I open fracture of the right tibial shaft, and a deep perineal laceration with active venous bleeding. As hemodynamic stabilization could not be achieved, the patient underwent emergency laparotomy and perineal exploration under general anesthesia.

The orthopedic team reduced and stabilized the pelvic fracture using an external fixator. Subsequent multidisciplinary evaluation involved general surgery, urology, and obstetrics and gynecology. Under anesthesia in the lithotomy position, genital examination revealed a normal cervix and intact fornices. A laceration of the anterior vaginal wall was identified, with partial tissue loss involving the clitoral region. The urethra and bladder neck were disrupted, and deep lacerations with active venous bleeding were observed in the paravesical and paravaginal spaces (Fig. 1). A Foley catheter was inserted, draining 200 mL of clear urine. Rectal examination was unremarkable.

While still in the operating room, the patient experienced cardiac arrest and was subsequently transferred to the intensive care unit. Approximately 12 hours after the accident, she died from multiple organ failure.

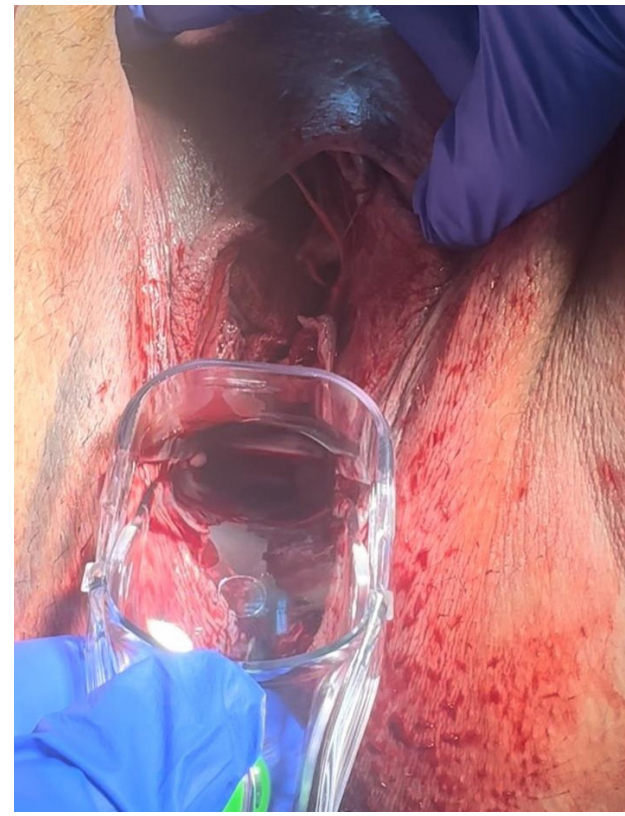

Figure 1. Intraoperative image demonstrating extensive lacerations of the anterior vaginal wall and bladder neck, with active venous bleeding in the paravesical space.

Case 2

A 27-year-old woman was involved in a high-speed motorcycle collision and was ejected from the vehicle. She was brought to the emergency department two hours after the accident. On arrival, she was alert, oriented, and hemodynamically stable, with a GCS score of 15. She had no prior medical conditions or history of surgery. Her primary complaints were pelvic pain and pain in the left leg.

Unlike Case 1, this patient remained hemodynamically stable and sustained more localized injuries. FAST examination excluded intra-abdominal hemorrhage, while CT urography and cystography ruled out urethral and bladder injuries. Imaging studies, including pelvic CT and plain radiographs, revealed a nondisplaced right sacral fracture and a proximal left fibular fracture. The orthopedic team recommended conservative management with bed rest.

The gynecologic trauma team was consulted. Pelvic ultrasonography demonstrated no abnormalities of the uterus, fallopian tubes, or ovaries. On genital examination, there was no significant bruising, edema, or laceration in the perineal region. However, a 2-cm laceration was identified on the mons pubis, confined to the subcutaneous tissue and without

Figure 2. A 2-cm laceration on the mons pubis, confined to the subcutaneous tissue and without active bleeding.

active bleeding on digital examination (Fig. 2). The wound was repaired primarily.

After 48 hours of observation, the patient was discharged. At the three-month follow-up, she reported no genitourinary symptoms, and clinical evaluation confirmed complete healing.

DISCUSSION

This case report describes two female patients who sustained genital injuries in motorcycle accidents, illustrating two distinct clinical courses—one involving fatal multisystem trauma and the other a mild course with complete recovery.

Genital trauma in female motorcycle accident victims is uncommon but presents significant diagnostic and management challenges, particularly in polytrauma settings. Because most published data consist of case reports, the lack of large-scale studies limits the development of standardized treatment protocols. These injuries frequently occur in the setting of high-energy trauma, where hemodynamic stabilization is the primary priority. Although genitourinary injuries are not always immediately life-threatening, severe cases may involve major hemorrhage or nerve damage,[7] requiring individualized management.

From a gynecological perspective, the initial evaluation should focus on identifying pelvic hemorrhage and internal genital injuries, followed by repair of external structures to reduce long-term complications. Genital injuries in motorcycle crashes frequently result from impact with structures such as the fuel tank or handlebars.[8] Because the genital region receives a rich vascular supply from the internal pudendal artery, even superficial trauma can lead to rapid and severe bleeding.[9]

Internal genital injuries require careful assessment due to the risk of massive bleeding and long-term reproductive sequelae. Patients with an Injury Severity Score (ISS) ≥25 have a higher likelihood of requiring hysterectomy (odds ratio [OR]: 3.52), whereas prompt surgical intervention for uterine or adnexal injuries is associated with lower mortality (OR: 0.27 and 0.37, respectively).[10] These findings underscore the prognostic importance of early recognition and timely surgical management in severe pelvic trauma. Although rare, combined vulvovaginal injuries often require surgical repair and occur in fewer than 0.2% of cases in large-scale analyses.[9]

Approximately 14.6% of patients with pelvic fractures sustain bladder or urethral injuries,[11] highlighting the importance of a multidisciplinary approach. Bladder injuries are generally managed surgically with cystostomy, whereas urethral injuries typically require reconstruction and catheterization. Pelvic trauma may also result in sexual dysfunction, which is frequently underrecognized unless specifically assessed.[12] Therefore, routine evaluation of sexual and reproductive function should be incorporated into post-trauma follow-up.

Early intervention, hemodynamic stabilization, and appropriate surgical management are critical to improving survival and outcomes in patients with pelvic fractures. Techniques such as pelvic tamponade, external fixation, angiography, and embolization are effective in controlling bleeding and preventing secondary complications.[13,14] Stabilization of the pelvic ring is essential to prevent recurrent bleeding and organ displacement.

The prognosis of genital trauma resulting from motorcycle accidents depends on injury severity, timing of intervention, and associated complications. Early stabilization and timely surgical management improve both survival and long-term functional outcomes. Patient education and structured follow-up focusing on sexual and reproductive health are also essential components of comprehensive post-trauma care.

CONCLUSION

Although genital trauma associated with pelvic fractures in women following motorcycle accidents is rare, it can lead to serious complications and requires prompt, coordinated care. Further multicenter studies are needed to establish evidence-based protocols and to improve both acute management and long-term outcomes.

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OLGU SUNUMU - *ÖZ*

Motosiklet kazası sonrası kadın hastalarda görülen pelvik ve genital travma: İki olgu sunumu ve literatür incelemesi

Bu çalışmanın amacı, motosiklet kazası sonrası gelişen pelvik kırıklara eşlik eden genitoüriner yaralanmaların klinik seyrini değerlendirmek ve bu travmalar konusunda farkındalık oluşturmaktır. Ayrıca, acil sağlık hizmetlerinde bu tür yaralanmaların tanı ve tedavi sürecine dair dikkat çekilmesi amaçlanmıştır. Bu olgu sunumunda, motosiklet kazası sonrasında pelvik kırık ve genitoüriner yaralanma gelişen iki genç kadın hastanın klinik süreci detaylı şekilde aktarılmıştır. Olgular, travmanın şiddeti, eşlik eden yaralanmalar, uygulanan görüntüleme yöntemleri, cerrahi girişimler ve tedavi yaklaşımları açısından karşılaştırılmıştır. İlk olguda, yüksek enerjili travmaya bağlı olarak anterior vajinal duvar, klitoris ve mesane boynunda ciddi yumuşak doku hasarı ve aktif kanama ile seyreden kompleks bir pelvik kırık mevcuttu. Hastaya acil dış fiksasyon uygulanmış, ancak gelişen çoklu organ yetmezliği nedeniyle hasta kaybedilmiştir. İkinci olguda ise daha yüzeyel karakterde, konservatif yöntemlerle takip edilen mons pubis bölgesinde yüzeyel laserasyon ve pelvik kırık izlenmiş, hasta komplikasyonsuz şekilde tamamen iyileşmiştir. Kadın travma hastalarında ayrıntılı genital muayenenin atlanmaması, multidisipliner yaklaşımın benimsenmesi ve cerrahi müdahalenin zamanında yapılması hayat kurtarıcı olabilir. Bu olgu sunumu, motosiklet kazalarına bağlı olarak kadınlarda gelişen pelvik ve genitoüriner yaralanmalara dair literatürdeki sınırlı bilgi birikimine önemli katkı sağlamaktadır ve benzer olguların yönetimine yönelik farkındalığı artırmayı hedeflemektedir.

Anahtar sözcükler: Genital travma; kadın travma hastaları; motosiklet kazası; pelvik kırık.

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