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EXPERIMENTAL STUDY

The contribution of probiotics to combined cellular therapy in skin wound healing in diabetic rats

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ABSTRACT

BACKGROUND: Diabetes-related wound care is still a major issue due to chronic and hon-healing ulcers that are prone to infection and ultimately amputation. In recent years, cellular therapy (CT) products such as mesenchymal stem cells (MSC), platelet-rich plasma (PRP), and stromal vascular fraction (SVF) have been widely used. A combined cellular therapy (CCT) has not yet been tested as a triple combination, although its use alone and in dual combinations has been investigated. Probiotics (PB) accelerate healing by altering the intestinal microbiota. This study aims to examine the role of PB in enhancing the effects of CCT on diabetic wound healing.

METHODS: A 1×1 cm2 full-thickness cutaneous wound was created after administering 40 mg/kg streptozotocin intraperitoneally (STZ i.p.) to induce a diabetic (DB) animal model. Animals were divided into four groups: DB, DB+PB, DB+CCT, and DB+CCT+PB, each with six adult Albino rats. The wound edges were treated with a total of 300 µL of solution, consisting of 30 µL each of 100 µL 1×106 MSC, 100 µL SVF, and 100 µL PRP as CCT. PB was administered orally at a dose of approximately 200 mg daily. Histochemical analyses were performed using hematoxylin and eosin (HE) and Masson's trichrome (MT). Immunohistochemical analyses were conducted for endothelial nitric oxide synthase (eNOS), Caspase-3, interleukin-10 (IL-10), vascular endothelial growth factor (VEGF), and Collagen I. The intestinal microbiome was examined through metagenomic analyses of taxonomic structure.

RESULTS: Combined cellular therapy provided more effective and faster healing in DB animals. It was discovered that PB further accelerated this process, leading to greater improvement. CCT was observed to reverse high eNOS, Caspase-3, and IL-10 expression, as well as low VEGF and Collagen I levels. Moreover, PB therapy significantly enhanced the positive effects of CCT. CCT in combination with PB significantly improved wound healing by preventing oxidative stress, apoptosis, and inflammation, while promoting vascularization and collagen organization.

CONCLUSION: Probiotic support was considered important for diabetic wound healing and was suggested to improve patients' quality of life.

Keywords: Cell therapy; diabetic skin; rat; probiotics; wound healing.

INTRODUCTION

Diabetes-related wound ulcers are slow-healing and costly complications characterized by impaired vascularization, inflammation, oxidative stress, apoptosis, and reduced signaling that are important for healing. Mesenchymal stem cells (MSC), platelet-rich plasma (PRP), and stromal vascular fraction (SVF) are frequently used to treat these disorders, providing an effective therapeutic strategy.

Mesenchymal stem cells are vital for treatment due to the cellular support they provide, the growth factors they release, and the regenerative environment they create.[1] PRP has gained popularity in recent years, both for its growth factors and for the support it offers to MSC. SVF is widely used in

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plastic surgery, where it has shown highly successful results in cellular regeneration and wound healing when administered alone or in combination with MSC.[2,3] However, the optimal treatment has not yet been fully defined. The role of probiotics (PB) in intestinal health has long been recognized.[4] Nevertheless, the literature provides no information on combined cellular therapy (CCT) with probiotic supplementation.[5,6] For diabetes-related (DB-related) skin wound healing, maintaining a healthy microbiota, tissue integrity, and absence of infection are crucial. The use of PB has been shown to be effective in addressing these atypical structural alterations, including epithelization, matrix formation, vascularization, leukocyte infiltration, and inflammation.

Immunomodulation, pathogen reduction, and tissue homeostasis are also involved.[7,8,9] MSC are important in regenerative medicine because they accelerate wound healing by increasing cell numbers, promoting vascularization, and reducing inflammation.[10,11] PRP has long been used in dermatology and plastic surgery.[5] It contributes significantly to wound healing by stimulating cell migration, proliferation, matrix formation, and vascularization, owing to its abundance of growth factors.[3,12] SVF is also considered highly useful for DB skin wound healing by providing support with diverse cell populations, including medium-sized fat cells.[13,14] Although there is evidence that their dual use as CCT enhances wound healing, the effects of their triple combination have not been thoroughly investigated.[15]

Combined cellular therapy improves wound healing in diabetic chronic wounds by reducing oxidative stress and apoptosis through the stimulation of vascularization and signaling pathways. Similar mechanisms underlie the effects of PB, but their contribution to CCT has not been fully recognized. The aim of this study is to determine the impact of combining CCT and PB to achieve more effective treatment and improved patient quality of life.

MATERIALS AND METHODS

Experimental Procedures

Animals

The Ethics Committee for Experimental Animal Research at Manisa Celal Bayar University (18/02/2020/77.637.435) approved the experiments. All experimental procedures were performed in accordance with the Institutional Animal Care and Use Committee of X Medical University (IACUC; No. 77.637.435), ensuring compliance with ethical guidelines for animal research. This study employed 24 healthy male Wistar albino rats, aged 8 weeks and weighing 250±50 g, obtained from the Manisa Celal Bayar University Experimental Animal Center. Sample size was determined using G-Power V.3.1 (Heinrich Heine University of Düsseldorf). The rats were housed in ventilated cages (21°C, 12-hour dark/light cycle) within a pathogen-free animal facility, with free access to food and water. The animals were randomly divided into four groups: Group 1, DB (n=6); Group 2, DB+PB (n=6); Group 3, DB+CCT (n=6); and Group 4, DB+CCT+PB (n=6). No anesthesia or analgesia was administered during the procedures, in accordance with the approved protocol and bioethical guidelines. Rats were to be euthanized before the planned end of the experiment if they showed severe signs of distress; however, no such incidents occurred.

Induction of Diabetes

A single dose of 55 mg/kg freshly dissolved streptozotocin (STZ, Sigma, St. Louis, MO) was administered intraperitoneally (i.p.) to all diabetes groups. Development of diabetes was confirmed in the experimental groups three days after STZ administration by measuring glucose levels in tail vein blood samples. According to Cil et al.,[1] rats with blood glucose levels 250 mg/dL were classified as diabetic.

Skin Defect

Two full-thickness skin defects measuring 1×1 cm^2 were created in each rat. CCT and CCT+PB were administered to the wound sites.[9]

Cellular Therapy Applications

Rat inguinal fat tissue was mechanically fragmented and transferred into the culture medium, where attached cells were proliferated and differentiated into MSC. Characterization for MSC surface markers was performed by immunohistochemistry (IHC), showing CD90 positivity (Ab44898, Abcam) and CD45 negativity (Sc2590, Santa Cruz), which were also used for SVF characterization. Rat inguinal fat tissues were collected and treated with collagenase enzyme before centrifugation at 1500 g for 5 minutes, and the stromal vascular fraction in the pellet was aspirated using a syringe and prepared for application.[2] Blood from a rat heart was drawn into a heparinized tube with a 1 cc syringe and centrifuged at 300 g for 5 minutes. After thrombin activation, the supernatant was centrifuged at 3000 rpm for 10 minutes and prepared for application. The final solution contained 100 µL 1×10^6 MSC, 100 µL SVF, and 100 µL PRP, applied to the wound edges as 30 µL per site.[16]

Probiotics

Until the completion of the experiment, probiotic preparation was administered daily via gavage. The formulation contained a mixture of non-infectious bacteria, including 2.5×10^9 Enterococcus faecium, 2.5×10^9 Lactobacillus acidophilus, 2.5×10^9 Lactobacillus rhamnosus, 2.5×10^9 Bifidobacterium longum, and 2.5×10^9 Bifidobacterium bifidum (NBL Probiotic Gold, Nobel-Farma NCFM®). This formulation was administered orally from the beginning of the trial until euthanasia, at a daily dose of 200 mg, corresponding to approximately 200,000-210,000 CFU (colony-forming units), given at the same time each morning.[9,17]

Histopathology

ImageJ was used to assess wound closure on images taken

for macroscopic evaluation on day 7 of treatment. Samples were collected and fixed in 4% formaldehyde. Coronal sections were then prepared from paraffin-embedded blocks and stained with hematoxylin-eosin (HE) and Masson's trichrome (MT). Images were examined digitally and analyzed using morphometric scoring. Skin epithelialization and dermal healing during wound repair were graded on a scale from 1 to 5.[18]

Immunohistochemistry

Immunohistochemical staining was performed as previously described.[2,10] Primary antibodies were used as follows: endothelial nitric oxide synthase (eNOS) for oxidative stress (Sc-654, Santa Cruz), Caspase-3 for apoptosis (sc-56053, Santa Cruz), interleukin-10 (IL-10) for inflammation (Sc-52560, Santa Cruz), vascular endothelial growth factor (VEGF) for vascularization (anti-VEGF; Ab1316, Abcam), and Collagen I for connective tissue (mouse monoclonal type IC, 2456-Sigma, USA). Samples were incubated overnight. Immunoreactivity was detected using a 3,3-diaminobenzidine (DAB) kit (Santa Cruz Biotechnology).

Formalin-fixed, paraffin-embedded tissues were cut into 4-µm sections. To inhibit endogenous peroxidase activity, deparaffinized and dehydrated slides were treated with 3% hydrogen peroxide (H_2O_2). Slides were then rinsed in phosphate-buffered saline with Tween-20 (PBS-T) and blocked with 1% bovine serum albumin. The avidin–biotin peroxidase system (Santa Cruz Staining System, ImmunoCruz sc-2051, Santa Cruz, CA) was employed for immunohistochemical analysis.

Staining intensity was evaluated in five separate microscopic fields and graded as weak (+), moderate (++), or strong (+++). For each intensity, cells were counted, and the corresponding score was calculated using the formula: H-Score=Pi (intensity of staining + 1), where Pi represents the percentage of stained cells at each intensity level (0-100%). H-scores were independently assessed by at least two blinded observers.[2,19]

TUNEL Assay

To detect apoptotic cell death, the terminal deoxynucleotidyl transferase dUTP nick end labeling (TUNEL) staining technique was used. Following deparaffinization, TUNEL staining was performed according to the manufacturer's instructions using the ApopTag® Peroxidase In Situ Apoptosis Detection Kit (Millipore, Massachusetts, USA). After labeling, TUNEL-positive cells were identified and the data were statistically analyzed. The apoptotic index was used to determine apoptosis. Apoptotic cells were counted in five selected areas, and the apoptotic index was calculated using the following formula: (number of apoptotic cells / total number of cells)×100.[19]

Statistical Analysis

Statistical analysis was performed using one-way analysis of variance (ANOVA) followed by post hoc multiple comparisons with GraphPad Prism 8 (San Diego, CA). Values of $p \leq 0.05$ were considered statistically significant.[19]

Polymerase Chain Reaction (PCR)

The goal of this experiment was to carry out metagenomic bacterial profiling on samples from four different groups. For this purpose, the 16S rDNA V3-V4 gene region was targeted for next-generation sequencing. PCR was performed as described in the referenced protocol [file:///Users/nemo/Downloads/RP21-086/RP21-086.html - fn1].

DNA Isolation

Stool samples were collected at the end of the experiment and frozen at -80°C within four hours of collection. Total DNA was extracted from fecal samples using the Stool Total DNA Purification Kit (Norgen Biotek Inc., Thorold, ON, Canada). As suggested by Klindworth et al.[20] and applied in this experiment, the primers selected were those with the highest efficiency. For library preparation in the current project, a two-step PCR procedure was adopted, following the referenced documentation https://support.illumina.com/documents/documentation/chemistry_documentation/16s/16s-metagenomic-library-prep-guide-15044223-b.pdf. KAPA HiFi HotStart ReadyMix (Roche) was employed, and 25 PCR cycles were performed independently for each sample. Distillation and purification were carried out at the end of both PCR stages using the Agencourt AMPure XP kit (Beckman Coulter).[20] Following isolation, DNA quantification was performed using Qubit (Thermo Fisher Scientific, Waltham, MA, USA). Library preparation and sequencing were conducted according to the manufacturer's protocols.

Sequencing

Bidirectional reading was performed using the iSeq 100 i1 Reagent Kit on the Illumina iSeq 100 next-generation sequencing platform (Illumina, CA, USA) by Gen-Era (Gen-Era Diagnostik, TR). This process was carried out in accordance with the manufacturer's instructions.[20]

Bioinformatic Analysis

Quality control was performed using FastQC [https://www.bioinformatics.babraham.ac.uk/projects/fastqc/] Trimmomatic tool [http://www.usadellab.org/cms/?page=trimmomatic (CTtp://www.usadellab.org/cms/?page=trimmomatic)] was used to remove low-quality base reads, adaptor contaminants, and chimeric sequences from the Genomes OnLine Database (GOLD). Reads were aligned to target organisms using the Greengenes database for taxonomic profiling with the Ribosomal Database Project (RDP) Classifier. Following alignment, operational taxonomic unit (OTU) groups were determined for each sample. Data reporting, statistical analyses, and data visualization were performed using R [https://www.r-project.org/] scripts (file:///Users/nemo/Downloads/RP21-086/RP21-086.html - fnref5).[21]

RESULTS

Diabetic Data

Body weights in the DB group (24.68±4.72 mg) decreased significantly ($p<0.05$) in the DB+PB (21.88±3.46 mg) and DB+CCT (18.25±3.34 mg) groups, with a very significant decrease ($p<0.01$) observed in the DB+CCT+PB group (16.44±4.76 mg) when baseline and endpoint measurements were compared.

Fasting blood glucose (FBG) levels in the DB group (351.68±25.48 mg/dL) were significantly lower in the DB+PB (325±25 mg/dL) and DB+CCT (325±25 mg/dL) groups ($p<0.05$), and very significantly lower in the DB+CCT+PB group (300±25 mg/dL) ($p<0.01$).

MSC Characterization

In MSC culture, MSC characterization markers showed positivity for CD90 (H-score: 254.22+23.92) and negativity for CD45 (H-score: 44.36±18.68) (Fig. 1).

Samples of Combined Cellular Therapy

High numbers of MSC were visualized in smear preparations of the SVF, MSC, and PRP combination used as CCT (Fig. 2).

Metagenomic Bacterial Profiling

Prevotella spp., Escherichia coli, and Barnesiella were found to be increased in DB samples. While Prevotella was reduced in DB+CCT, E. coli decreased, and Barnesiella was found to be high in this group. In the DB+CCT+PB group, Prevotella increased, while Barnesiella decreased and E. coli was completely eliminated. Bacteroides were reduced in DB but increased with the use of CCT and PB. Clostridium IV was detected in DB, but not in the CCT or PB groups. Additionally, Lactobacillus was absent in DB but present in both DB+CCT and DB+CCT+PB groups. Other notable groupings that were determined to have higher numbers, upon examination of their relative proportions, were Faecaliatea in DB, Ruminococcus in DB+CCT+PB, and Halothermothrix, Falsiporphmonas, and Alloprevotella in DB+CCT (Fig. 3a-3b).

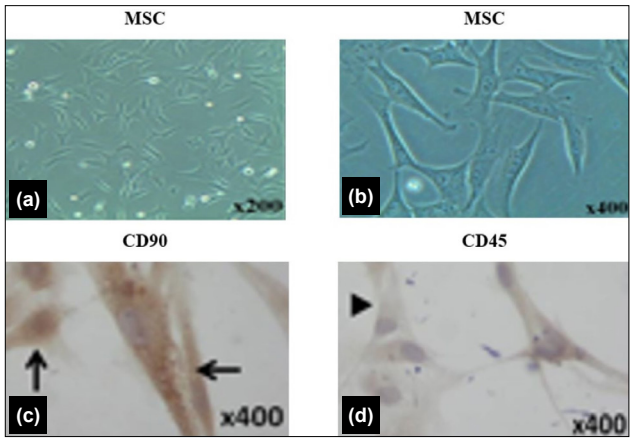


Figure 1. Phase-contrast images showing mesenchymal stem cells (MSC) attached, spread, and proliferated in culture **(a,b)**. Characterization was evaluated by CD90-positive (**c**) and CD45-negative **(d)** labeling using immunocytochemistry.

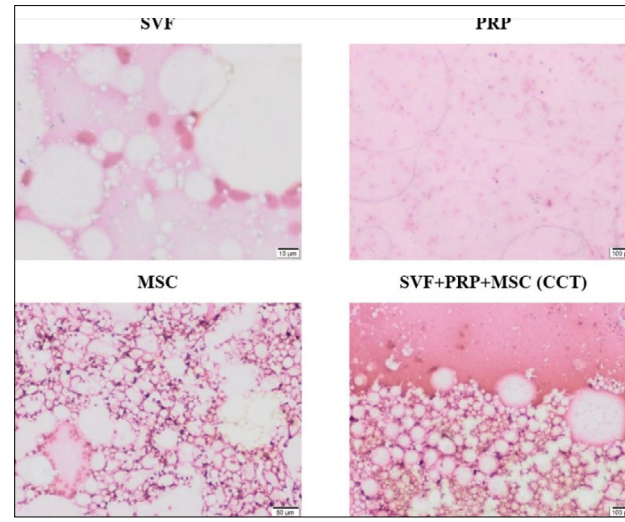


Figure 2. Light microscopy images of smear preparations from combined cellular therapy (CCT) samples.

Macroscopic Histopathology

In the macroscopic assessment carried out with ImageJ, all groups showed differences at day 7 (Fig. 4). CCT and PB applications each had a significant effect ($p<0.01$), while their combination produced an even greater effect ($p<0.001$). In wound healing analysis, DB+CCT+PB was found to close wounds significantly ($p<0.05$) compared to DB+CCT.

Microscopic Histopathology

After microscopic examination, skin samples were stained with HE and evaluated for re-epithelization (RE), capillary count (CC), inflammatory cells (IC), fibroblast count (FC), collagen fibers (CF), and sebaceous glands (SG). CCT and its combination with PB significantly improved RE, SG, CC, and neovascularization. As a result of the inflammatory reaction, significant differences were observed in edema, congestion, and polymorphonuclear cell infiltration. Fibrosis was considerably lower in the DB+PB group compared to the DB group. Neovascularization and monocyte counts were found to be similar. Positive differences in edema, obstruction, polymorphonuclear activation, fibrosis, neovascularization, and monocytes were observed between the DB and DB+PB groups. The combination of CCT and PB was also found to improve RE, as shown in Figure 5.

MT staining revealed increased regenerative capacity of the extracellular matrix (ECM), demonstrated by properly structured, thicker, undulating collagen fibers and more extensive collagen deposition (Fig. 6). Additionally, the combination of CCT and PB significantly accelerated wound healing compared to either treatment alone ($p<0.001$).

Oxidative stress was evaluated by eNOS IHC (Fig. 7). In the DB group, CCT and its combination with PB produced highly significant effects ($p<0.001$). These applications reduced free

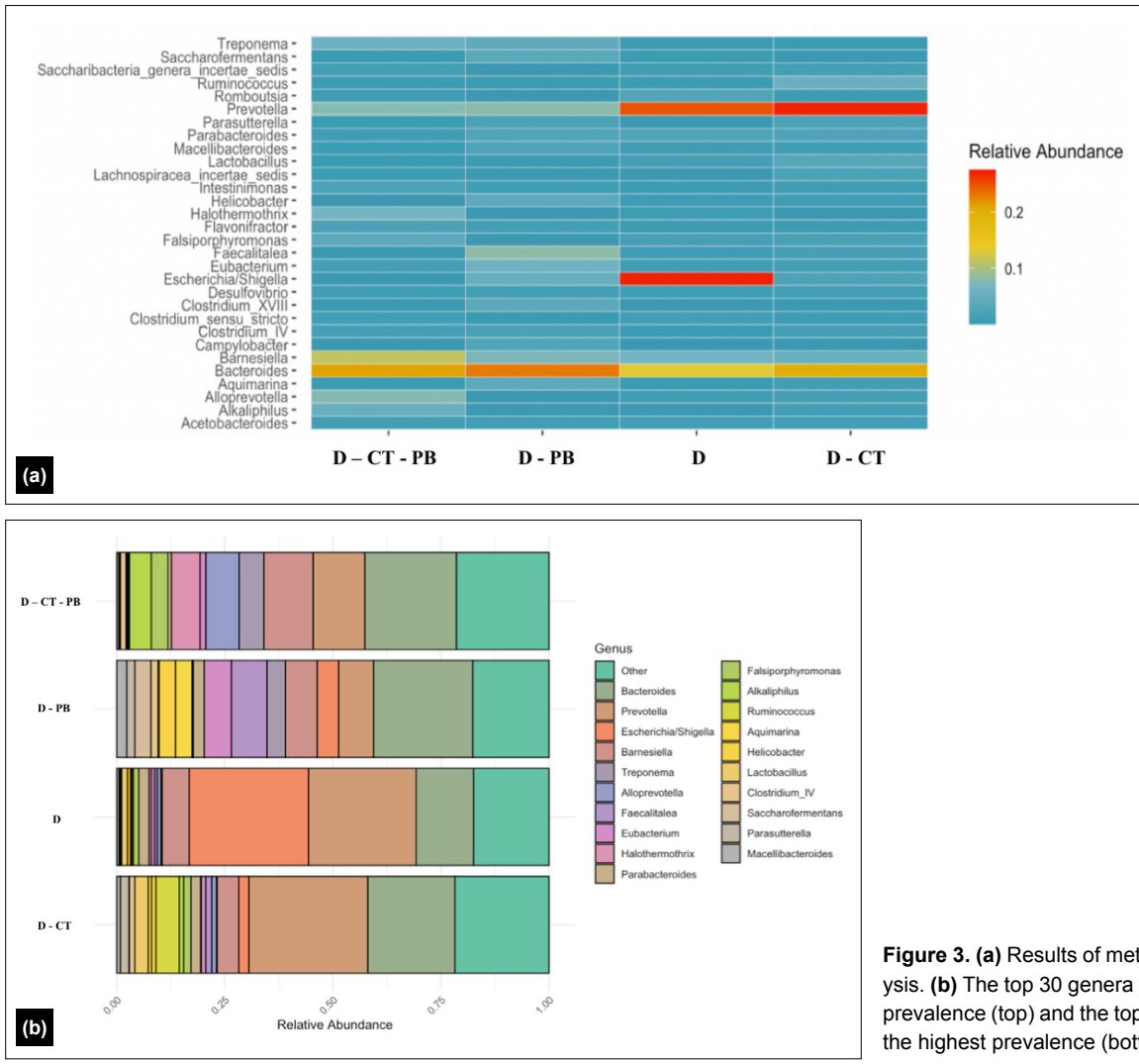
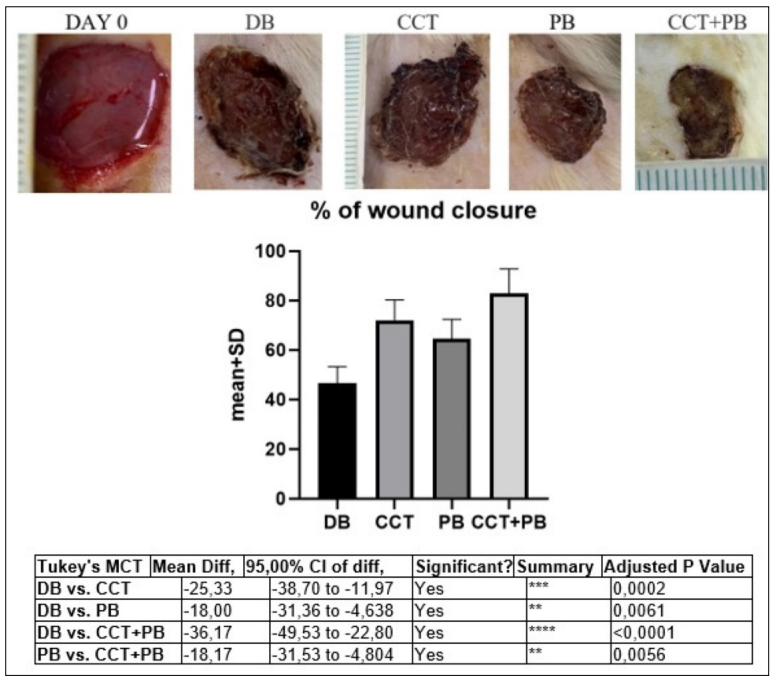
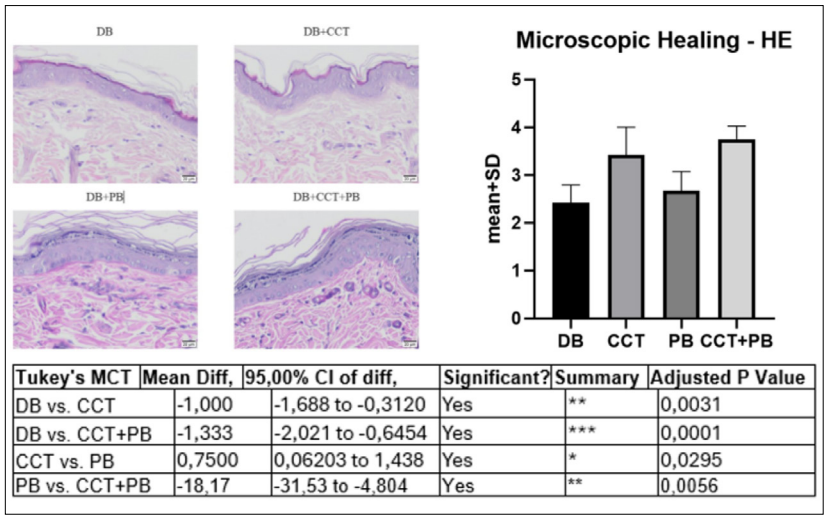


Figure 3. (a) Results of metagenomic analysis. **(b)** The top 30 genera with the highest prevalence (top) and the top 20 genera with the highest prevalence (bottom).



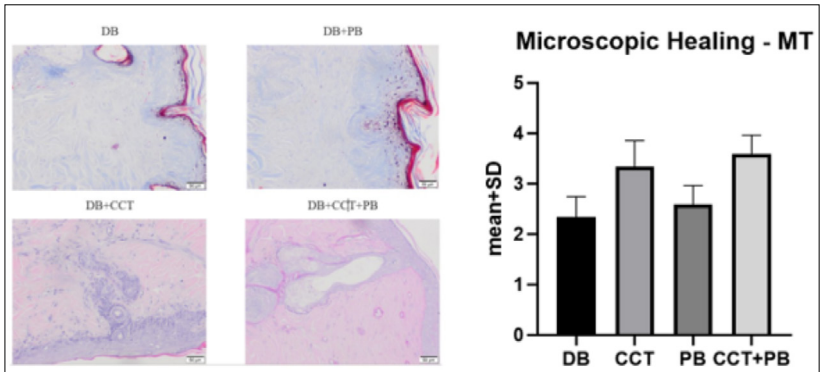
Tukey's MCT	Mean Diff,	95,00% CI of diff,	Significant?	Summary	Adjusted P Value
DB vs. CCT	-25,33	-38,70 to -11,97	Yes	***	0,0002
DB vs. PB	-18,00	-31,36 to -4,638	Yes	**	0,0061
DB vs. CCT+PB	-36,17	-49,53 to -22,80	Yes	****	<0,0001
PB vs. CCT+PB	-18,17	-31,53 to -4,804	Yes	**	0,0056

Figure 4. Macroscopic analysis of the contribution of probiotics (PB) to the effect of combined cellular therapy (CCT) on wound healing.



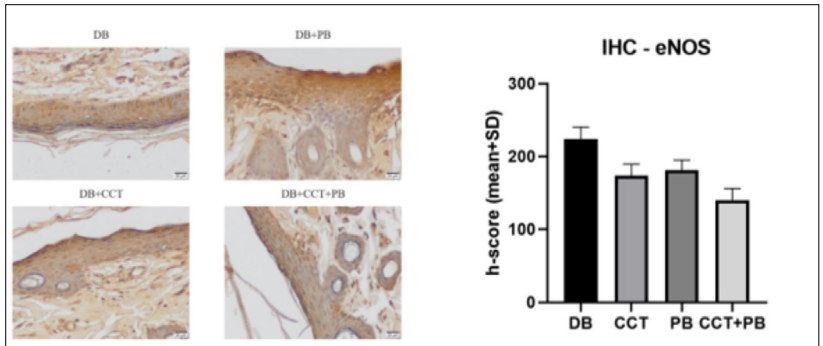
Tukey's MCT	Mean Diff,	95,00% CI of diff,	Significant?	Summary	Adjusted P Value
DB vs. CCT	-1,000	-1,688 to -0,3120	Yes	**	0,0031
DB vs. CCT+PB	-1,333	-2,021 to -0,6454	Yes	***	0,0001
CCT vs. PB	0,7500	0,06203 to 1,438	Yes	*	0,0295
PB vs. CCT+PB	-18,17	-31,53 to -4,804	Yes	**	0,0056

Figure 5. Microscopic analysis of the contribution of probiotics (PB) to the effect of combined cellular therapy (CCT) on wound healing by hematoxylin and eosin (HE) staining.



Tukey's MCT	Mean Diff,	95,00% CI of diff,	Significant?	Summary	Adjusted P Value
DB vs. CCT	-1,000	-1,684 to -0,3160	Yes	**	0,0029
DB vs. CCT+PB	-1,250	-1,934 to -0,5660	Yes	***	0,0003
CCT vs. PB	0,7500	0,06599 to 1,434	Yes	*	0,0285
PB vs. CCT+PB	-1,000	-1,684 to -0,3160	Yes	**	0,0029

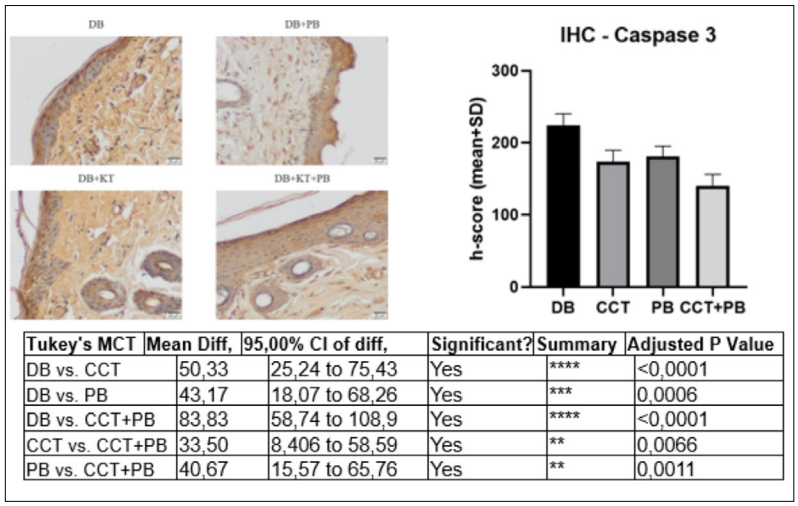
Figure 6. Microscopic analysis of the contribution of probiotics (PB) to the effect of combined cellular therapy (CCT) on wound healing by Masson's trichrome (MT) staining.



Tukey's MCT	Mean Diff,	95,00% CI of diff,	Significant?	Summary	Adjusted P Value
DB vs. CCT	50,33	25,24 to 75,43	Yes	****	<0,0001
DB vs. PB	43,17	18,07 to 68,26	Yes	***	0,0006
DB vs. CCT+PB	83,83	58,74 to 108,9	Yes	****	<0,0001
CCT vs. CCT+PB	33,50	8,406 to 58,59	Yes	**	0,0066
PB vs. CCT+PB	40,67	15,57 to 65,76	Yes	**	0,0011

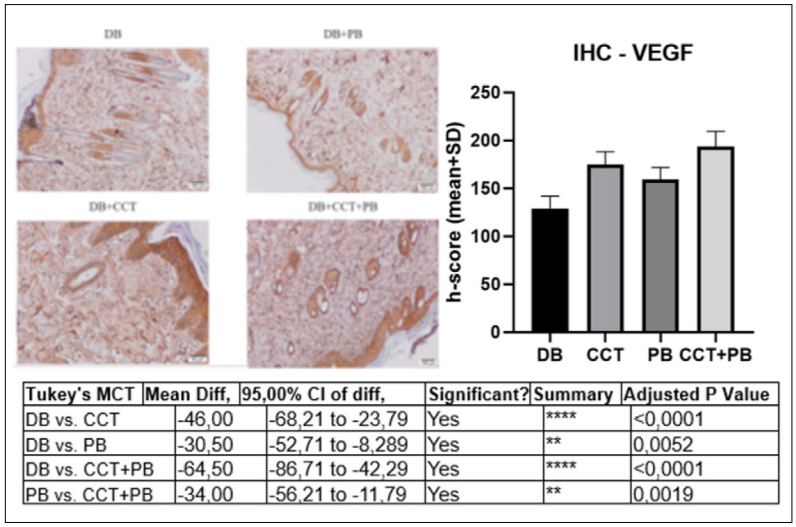
Figure 7. Microscopic analysis of the contribution of probiotics (PB) to the effect of combined cellular therapy (CCT) on wound healing by endothelial nitric oxide synthase (eNOS) immunolabeling.

radicals, which cause damage, thereby accelerating the wound healing process. Administration of CCT or PB alone significantly reduced oxidative stress ($p<0.05$), as determined by eNOS staining with H-score analysis. It was discovered that CCT or PB treatments alone significantly reduced oxidative stress ($p<0.05$). Additionally, we found that their combination



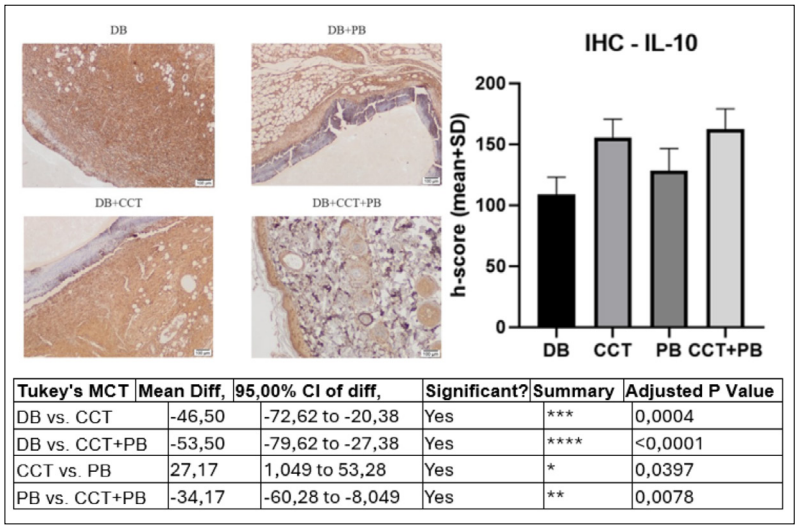
Tukey's MCT	Mean Diff,	95,00% CI of diff,	Significant?	Summary	Adjusted P Value
DB vs. CCT	50,33	25,24 to 75,43	Yes	****	<0,0001
DB vs. PB	43,17	18,07 to 68,26	Yes	***	0,0006
DB vs. CCT+PB	83,83	58,74 to 108,9	Yes	****	<0,0001
CCT vs. CCT+PB	33,50	8,406 to 58,59	Yes	**	0,0066
PB vs. CCT+PB	40,67	15,57 to 65,76	Yes	**	0,0011

Figure 8. Microscopic analysis of the contribution of probiotics (PB) to the effect of combined cellular therapy (CCT) on wound healing by Caspase-3 immunolabeling.



Tukey's MCT	Mean Diff,	95,00% CI of diff,	Significant?	Summary	Adjusted P Value
DB vs. CCT	-46,00	-68,21 to -23,79	Yes	****	<0,0001
DB vs. PB	-30,50	-52,71 to -8,289	Yes	**	0,0052
DB vs. CCT+PB	-64,50	-86,71 to -42,29	Yes	****	<0,0001
PB vs. CCT+PB	-34,00	-56,21 to -11,79	Yes	**	0,0019

Figure 9. Microscopic analysis of the contribution of probiotics (PB) to the effect of combined cellular therapy (CCT) on wound healing by vascular endothelial growth factor (VEGF) immunolabeling.

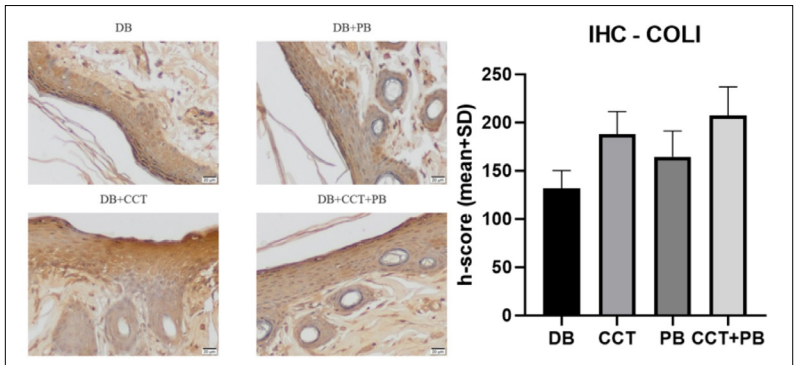


Tukey's MCT	Mean Diff,	95,00% CI of diff,	Significant?	Summary	Adjusted P Value
DB vs. CCT	-46,50	-72,62 to -20,38	Yes	***	0,0004
DB vs. CCT+PB	-53,50	-79,62 to -27,38	Yes	****	<0,0001
CCT vs. PB	27,17	1,049 to 53,28	Yes	*	0,0397
PB vs. CCT+PB	-34,17	-60,28 to -8,049	Yes	**	0,0078

Figure 10. Microscopic analysis of the contribution of probiotics (PB) to the effect of combined cellular therapy (CCT) on wound healing by interleukin-10 (IL-10) immunolabeling.

significantly decreased free radical levels ($p<0.05$).

Caspase-3 IHC was performed to assess apoptosis (Fig. 8). Both CCT and PB were shown to be significant in the DB group ($p<0.001$). H-score analysis of Caspase-3 staining showed that their combination produced an even greater reduction in apoptosis ($p<0.001$).



Tukey's MCT	Mean Diff.	95,00% CI of diff.	Significant?	Summary	Adjusted P Value
DB vs. CCT	-56,32	-96,44 to -16,20	Yes	**	0,0042
DB vs. CCT+PB	-75,34	-115,5 to -35,22	Yes	***	0,0002
PB vs. CCT+PB	-42,57	-82,68 to -2,450	Yes	**	0,0051

Figure 11. Microscopic analysis of the contribution of probiotics (PB) to the effect of combined cellular therapy (CCT) on wound healing by Collagen I immunolabeling.

When VEGF staining was evaluated using the H-score method (Fig. 9), CCT ($p<0.01$), PB ($p<0.05$), and their combination ($p<0.001$) were each observed to significantly increase vascularization. Labeling was confirmed in both newly formed and mature vessels.

IL-10 staining (Fig. 10) demonstrated that CCT ($p<0.01$), PB ($p<0.05$), and their combination ($p<0.001$) considerably reduced inflammation.

Collagen I labeling (Fig. 11) indicated that CCT ($p<0.01$) and PB ($p<0.05$) significantly improved matrix formation and increased H-scores. Their combination further enhanced connective tissue formation ($p<0.001$).

DISCUSSION

Diabetes-related chronic skin ulcer wound healing remains a significant issue. Growing evidence indicates that MSC, PRP, and SVF are effective treatment options.[22] PRP is effective due its high concentration of growth factors, MSC provide cellular support and secretions, and SVF is useful because of the medium-sized fatty acids it contains. Dual combinations of these products have been shown to exert synergistic effects on diabetic wounds.[23] Another product, probiotics, which has gained popularity in recent years, has also been found effective in diabetic wound healing.[24,25] In our study, the effects of these products on full-thickness wound healing, and the role of PB, were investigated using their triple combination as CCT. To date, no research employing this strategy has been reported in the literature. We found that CCT and PB applications provided faster and more efficient treatment. Furthermore, metagenomic analysis revealed that PB made a significant contribution to this effect. This was achieved through reductions in oxidative stress (via eNOS), apoptosis (via Caspase-3), inflammation (via IL-10), and fibrosis (via Collagen I), along with increased vascularization (via VEGF).

The diabetic model with poor healing capacity was shown to be consistent with other studies in the literature.[26] Wound closure was significantly greater with CCT at day 7, and PB therapy was found to significantly enhance this effect. Similarly, earlier studies reported that MSC application accelerated healing at 7 days.[27] In comparison with individual treatments, the combined use of MSC and PRP has also been shown to improve wound closure within a comparable timeframe.[28]

Another study investigating PB use demonstrated considerable and rapid recovery in a 2×2 cm^2 wound defect within seven days.[9,29,30] The results of our study align with relevant data in the literature, indicating that the contribution of PB to the effect of CCT was significant. The skin-microbiota interaction is vital for preventing infections, accelerating wound healing, and preventing scar tissue formation. L. rhamnosus, L. acidophilus, L. plantarum, L. casei, L. delbrueckii subsp. bulgaricus, and B. genera were identified as the most frequently used strains in 14 culture studies, eight animal studies, and 18 clinical studies in a prior meta-analysis. In culture investigations, these strains were found to exert effective pressure on wound pathogens, reduce wound infections in animal studies, and prevent infection at surgical wound sites in clinical studies.

They were also observed to accelerate wound healing in several studies. These characteristics are particularly important for PB use during antibiotic therapy.[31] Several mechanisms explain the role of PB in wound healing, including eliminating pathogenic bacteria, replacing pathogenic bacteria, protecting epithelial barrier integrity, promoting epithelial cell and fibroblast migration, modulating intraepithelial lymphocytes, natural killer (NK) cells, and macrophages, and increasing cytokine production.[32] In addition, our study revealed that the high E. coli levels observed in the DB group decreased following PB treatment. To maintain good dental health, the balance of oral microbiota is very important. A shift in this balance toward dysbiosis may delay wound healing by impairing the function of MSC. Probiotics appear to be effective in preventing bacteria-induced oral inflammatory diseases. An increase in Prevotella species in mucosal regions has been linked to periodontitis, bacterial vaginosis, rheumatoid arthritis, met-

abolic disorders, and low-grade systemic inflammatory diseases in human studies.[33] In our study, CCT was also found to reduce the number of Prevotella species in DB. A study combining adipose-derived MSC and PRP revealed that healing progressed more quickly and maturely through epithelial regeneration, matrix organization, connective tissue development, vascularization, and modulation of inflammation in diabetic skin. Histomorphometric analysis indicated that the primary recovery variables included increased epithelial thickening, reduced prolonged and severe inflammation, reversal of infiltration, and increased immune cell activity.[34]

Probiotic supplementation has also been shown to affect these variables, particularly by reducing infiltration and pathogenic bacteria.[9,35] The fact that the parameter values obtained in our study are comparable to those reported in the literature indicates that the combination of CCT and PB operates through these mechanisms. Lactobacilli and B. bacteria are effective PB for wound healing because they reduce oxidative stress and apoptosis. Furthermore, L. plantarum has been shown to prevent oxidative stress and apoptosis in pregnant rats with kidney and liver damage caused by endosulfan.[36] Lactic acid bacteria have also been found to promote keratinocyte proliferation through topical application and to accelerate re-epithelization by reducing pro-inflammatory cytokine release from keratinocytes. In addition, L. salivarius SGL 19 and L. fermentum SGL 10 demonstrated anti-pathogenic effects against S. aureus and S. pyogenes, while L. brevis SGL 12 and L. paracasei SGL 04 inhibited S. aureus and S. pyogenes, respectively.[37] P. aeruginosa impairs wound healing in burn-induced skin infections in animal models by triggering inflammation and cell death. This infection was inhibited by increased IL-18 cytokine levels, particularly in wounds treated with L. plantarum. L. plantarum interacts with fibroblasts, epithelial cells, and inflammatory cells to regulate a wide range of cytokines and chemokines. These interactions with pathogenic bacteria produce an anti-inflammatory effect. Additionally, Lactobacillus enhances phagocytosis of P. aeruginosa and provides protection against pathogen-associated apoptosis. These properties support the application of L. plantarum as a new generation treatment for burn wounds.[38] In a previous study, lactic acid bacteria and intestinal microbiota added to drinking water reduced wound healing time by half compared to control animals. Moreover, L. reuteri was shown to accelerate wound healing by upregulating oxytocin and decreasing fibroblast mortality through Caspase-3 regulation.[39]

Caspase regulation plays an important role in the apoptotic mechanisms of wound healing. In a previous study, lactic acid and intestinal microbiota added to drinking water reduced wound healing time by half compared to control animals.[39] In a rat wound healing study, Caspase-3 mRNA was shown to increase by day 3, Caspase-8 by day 5, and Caspase-9 at both time points. These expressions were observed in polymorphonuclear leukocytes (PMNL) and inflammatory mononuclear cells.[40] In another study, no skin wound healing was observed in mice deficient in Caspase-3 and Caspase-7, which are initiators of apoptosis.[41] In the follow-up of skin flap wound healing, Caspase-3 activity was assessed for apoptosis using the TUNEL technique. Increased levels of reactive oxygen species were shown to trigger Caspase-3 and promote apoptosis, while reperfusion was associated with increased Caspase-3 activity.[42] The results of our study revealed that apoptosis was prevented by CCT, and this effect was more pronounced with the addition of PB, findings compatible with the relevant literature. Fibrosis is prevented by anti-inflammatory cytokines, with IL-10 being a key factor in scar tissue prevention. IL-10 induces M2 macrophage polarization while shifting from glycolysis to oxidative phosphorylation. Thus, effective wound healing is ensured by decreasing M1 macrophage-related inflammation.

IL-10 also reduces pro-inflammatory cytokine IL-6 and contributes to healing by inhibiting macrophage inflammatory signals such as tumor necrosis factor-alpha (TNF-α). Furthermore, it prevents the formation of fibrosis and scar tissue by reducing collagen production through extracellular matrix regulation.[43,44] Our findings were found to be consistent with the literature.

Vascular endothelial growth factor is a growth factor family that promotes vascular and lymphatic growth and remodeling, increases vascular permeability, and recruits inflammatory cells to the wound site. Its topical application has been shown to be highly effective in diabetic wound healing and to positively stimulate stem cells. In addition to its local effects on wound healing, systemic effects have also been demonstrated in diabetic mice. VEGF-stem cell (VEGF-SC) interactions promote rapid healing by increasing the number of circulating stem cells and enhancing their mobilization from bone marrow to the wound site.[25,45,46] Alongside other growth factors, the use of PB in wound healing resulted in increased VEGF expression, which directs angiogenesis. VEGF, elevated from the onset of wound healing, aids in the acceleration and maturation of healing, particularly in diabetic wounds.[47-49]

Collagen produced by fibroblasts is another crucial factor in wound healing. Collagen fibers and their products are reduced in poorly healing wounds such as those in diabetes mellitus (DM).[50] In one experiment, PB administration was reported to increase collagen production along with angiogenesis, thereby accelerating and improving wound healing.[46] Additionally, full-thickness skin wound healing induced by PB supplementation in DM rats resulted in increased Collagen I levels that persisted from day 3 to day 10. This was accompanied by an increase in Collagen III. During the recovery phase, Collagen I was replaced by Collagen III, allowing for the development of more mature collagen.[9,39,46]

CONCLUSION

Diabetic wound care is still a major issue due to chronic and non-healing ulcers that are prone to infection and may ultimately lead to amputation. MSC, PRP, and SVF are cellular

therapy (CT) products that have recently gained popularity.[51-53] Because of the alterations they cause in the intestine, PB hasten wound healing. The aim of this study was to investigate the role of PB in diabetic wound healing when used together with CCT. PB supplementation to CCT, which was highly effective, was shown to be advantageous based on morphological, histological, immunohistochemical, and metagenomic analyses.

This contribution was achieved by reducing apoptosis and oxidative stress, supporting the development of a thicker and better-organized matrix, and promoting vascularization. It is suggested that routine clinical practice may be an appropriate setting for the use of PB as a treatment for slow-healing wounds. Furthermore, it was emphasized that this contribution might be crucial for hastening wound healing and improving patients' quality of life.

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DENEYSEL ÇALIŞMA - *ÖZ*

Diyabetik sıçanlarda deri yarasında kombine hücresel tedaviye probiyotiklerin katkısı

AMAÇ: Diyabetik (DB) yara bakımı, kronik ve iyileşmeyen, enfeksiyona yatkın ve ampütasyona yol açan ülserler nedeniyle hala çok önemli bir sorundur. Mezenkimal Kök Hücreler (MKH), Trombositten Zengin Plazma (TZP) ve Stromal Vasküler Fraksiyon (SVF), son yıllarda yaygın olarak kullanılan Hücresel Terapi (HT) ürünleridir. Tek başlarına ve ikili kombinasyonlarda kullanımları üzerine çalışmalar olmasına rağmen, üçlü kombinasyon olarak Kombine Hücresel Terapi (KHT) çalışılmamıştır. Probiyotikler (PB), bağırsakta yaptıkları mikrobiyata değişiklikler ile iyileşmeyi hızlandırır. Bu çalışmada, KHT ile oluşan DB yara iyileşmesinde PB katkısının incelenmesi amaçlandı.

GEREÇ VE YÖNTEM: DB model, erişkin Albino sıçanlarda 40 mg/kg STZ i.p. uygulanmasıyla oluşturuldu. 1x1 cm^2 tam kat kutanöz yara yapıldı. Denekler, DB, DB+PB, DB+CCT ve DB+ CCT+PB olmak üzere her biri 6 yetişkin içeren gruplara bölündü. CCT olarak, 100 µL $1x10^6$ MSC, 100 µL SVF ve 100 µL PRP içeren toplam 300 µL solüsyonun her biri 30 µL olacak şekilde yara kenarlarına uygulanması ile yapıldı. PB, yaklaşık 200 mg/günlük dozlarda oral yoldan uygulandı. Histokimyasal analizler HE ve MT ile gerçekleştirildi. İmmünohistokimyasal analizleri için eNOS, Kaspaz 3, IL10, VEGF ve Kolajen I kullanıldı. PB için taksonomik yapı fekal metagenomik analizi ile gösterildi.

BULGULAR: DB yaranın CCT ile daha etkin ve hızlı kapandığı görüldü. PB ile bu sürecin hızlandırıldığı ve daha etkin iyileşme sağlandığı saptandı. Ayrıca KHT ile yüksek eNOS, Kaspaz 3 ve IL-10 ekspresyonlarının azaltıldığı ayrıca düşük VEGF ve Kollajen I tersine çevrildiği gözlendi. PB uygulamasının KHT ile oluşan bu olumlu etkilerine anlamlı bir katkı sağladığı gösterildi. PB katkısı ile KHT oksidatif stresi, apoptozu ve inflamasyonu önleyip vaskülarizasyon ve kollajen organizasyonunu artırarak yara iyileşmesini önemli ölçüde geliştirdi.

SONUÇ: DB yara tedavisinde KHT ile PB katkısının önemli olduğu ve hastanın kötü yaşam kalitesini düzeltebileceği düşünüldü.

Anahtar sözcükler: Diyabetik cilt; kombine hücre tedavisi; probiyotikler; yara iyileşmesi.

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ORIGINAL ARTICLE

Evaluation of critical diagnostic landmarks obtained from comparison of symptomatic small bowel intussusception relevant to surgically proven 16 pediatric cases

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ABSTRACT

BACKGROUND: This study aims to evaluate the clinical presentation, diagnostic modalities, treatment strategies, and outcomes of pediatric small bowel intussusception (SBI), with a particular focus on surgically treated cases.

METHODS: Records of children diagnosed with SBI between January 2018 and December 2023 were retrospectively reviewed. Demographics, clinical presentation, imaging findings, treatment approaches, and surgical outcomes were analyzed. Statistical comparisons were performed between operative and non-operative groups, and receiver operating characteristic (ROC) curve analysis was used to determine the optimal ultrasound threshold for predicting the need for surgery.

RESULTS: Among 618 patients diagnosed with intussusception, 72 (11.6%) had SBI, of which 16 (2.6%) required surgery. Operative patients were significantly older (median: 75 months) than those managed non-operatively (median: 32 months) ($p<0.05$). Vomiting was significantly more common in the operative group (100% vs. 44.6%, $p<0.001$). The mean ultrasonographic length of the intussuscepted segment was significantly greater in the operative group (5.7±1.33 cm) than in the non-operative group (3.27±1.18 cm) ($p<0.001$). A cut-off value of 4.0 cm was identified as predictive for surgical intervention, with 100% sensitivity and 73.1% specificity. Pathologic lead points were found in 87.5% of surgical cases, although none were identified preoperatively. Hydrostatic reduction was successful in 62.5% of non-operative patients.

CONCLUSION: This study emphasizes that older age, longer intussuscepted segment on ultrasound, and severe symptoms are predictive of surgical need in pediatric SBI. A 4.0 cm cutoff aids decision-making, while the limited detection of pathologic lead points (PLP) underscores the importance of clinical evaluation.

Keywords: I bowel intussusception; children; surgery.

INTRODUCTION

Intussusception is the leading cause of intestinal obstruction in infants under two years of age and represents the second most common cause of acute abdomen in children, following acute appendicitis.[1] Approximately 90% of childhood intussusceptions are ileocolic in nature. Most cases are idiopathic; however, in a smaller proportion, an underlying pathologic lead point (PLP) is responsible.[2,3] Intussusceptions involving the small bowel are considered uncommon in the pediatric population, with an estimated prevalence of 8-16% among all childhood cases.[4] With the increasing use of ultrasound in recent years, small bowel intussusceptions (SBIs) are being identified more frequently than in the past. Although there are publications in the literature supporting that SBIs are transient and can be managed with conservative follow-up, a consid-

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erable number of publications also report symptomatic SBIs requiring surgery.[5-8] PLPs are more frequently observed in symptomatic SBIs than in ileocolic intussusceptions, and they are often not detected preoperatively. The reported incidence of PLPs ranges from 10% to 25% in ileocolic cases, whereas in symptomatic SBIs it may be as high as 50%.[8-10] Prompt diagnosis and treatment are therefore essential, as delays in managing symptomatic SBIs may lead to bowel necrosis requiring resection and result in significant morbidity.

Since cases of SBI in pediatric patients are rare, the clinical features and characteristics of the condition are not well described in the available literature. This study aims to present our experience with 16 pediatric patients with surgically confirmed SBI and to evaluate the incidence, clinical presentation, management strategies, and outcomes of SBI in the pediatric population.

MATERIALS AND METHODS

A retrospective review was conducted of all pediatric patients diagnosed with SBI between October 1, 2018 and December 31, 2023. The patients were categorized into two groups: those who underwent surgical intervention and those who did not. The collected data included age at diagnosis, sex, clinical presentation, diagnostic methods, intraoperative findings, surgical technique, histopathological results, surgical complications, morbidity, and mortality.

The decision to proceed with surgery was based on an integrated assessment of clinical presentation, physical examination, and radiologic findings. Patients in whom ultrasonography demonstrated transient intussusception—that is, segments that telescoped and then spontaneously reduced during the scan—or partial intussusception permitting luminal transit and managed with outpatient observation were excluded from the study.

All procedures adhered to the ethical standards of the relevant institutional and national committees on human experimentation, in line with the 1964 Declaration of Helsinki and its subsequent amendments. The study was approved by the Institutional Review Board (approval number 2024/03), and written informed consent for surgery was obtained from all patients.

Statistical Analysis

The dataset was constructed, and all statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS) software, version 21.0 (SPSS Inc., Chicago, IL, USA). Quantitative variables are presented as mean ± standard deviation (SD), while categorical variables are reported as frequencies (n) and percentages (%). The distribution of data was assessed for normality. For comparisons involving non-normally distributed continuous variables, the Mann-Whitney U test and the Kruskal-Wallis test was used, as appropriate. Categorical variables were analyzed using nonparametric methods. The Wilcoxon signed-rank test was employed for the analysis of paired non-normally distributed variables. Pearson correlation analysis was performed to assess linear relationship between continuous variables. In addition, Receiver Operating Characteristic (ROC) curve analysis was conducted to determine diagnostic performance and optimal cutoff values of relevant variables. A two-tailed p-value of less than 0.05 was considered statistically significant.

RESULTS

Over a five-year period, a total of 618 patients were diagnosed with intussusception based on clinical evaluation and radiologic imaging. Of these, 72 children (11.6%) had SBI, and 16 (2.6% of the total, 22.2% of the SBI group) required surgical intervention. Overall, 70.8% were male. The median age at presentation was 32 months in the non-operative group and 75 months in the operative group, with the latter being significantly older ($p<0.05$) (Fig. 1). In the operative group, four patients were younger than two years, while the remaining patients were older than four years. The demographic characteristics of the patients are summarized in Table 1.

All 56 patients in the non-operative group presented with abdominal pain, of whom 25 (44.6%) also experienced vomiting and seven (12.5%) had rectal bleeding. In the operative group, all patients presented with vomiting and colicky abdominal pain as their primary symptoms, while one patient reported chronic intermittent abdominal pain. None of the operated patients had rectal bleeding. Vomiting was significantly more common in the operative group compared to the non-operative group ($p<0.001$), whereas no statistically significant difference was found between the groups regarding rectal bleeding ($p=0.336$).

On physical examination, abdominal tenderness was present in 45 patients (80.3%) in the non-operative group and in all patients in the operative group. However, this difference was

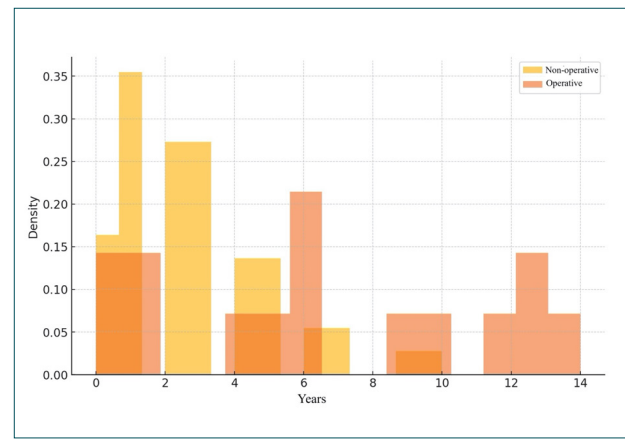

Figure 1. Age distribution histogram of operatively and non-operatively managed patients diagnosed with small bowel intussusception.

Table 1. Demographic and clinical characteristics of patients with small bowel intussusception

Variable	Operative Group (n=16)	Non-Operative Group (n=56)	Total (n=72)	p-value
Age, median (range), months	75 (3-170)	32 (1-128)	39 (1-170)	<0.05*
Male sex, n (%)	12 (75%)	39 (69.6%)	51 (70.8%)	0.673
Female sex, n (%)	4 (25%)	17 (30.4%)	21 (29.2%)	0.673
Complaints and physical examination				
Vomiting, n (%)	16 (100%)	25 (44.6%)	41 (56.9%)	<0.001*
Rectal bleeding, n (%)	0 (0%)	7 (12.5%)	7 (9.7%)	0.336
Abdominal tenderness, n (%)	16 (100%)	45 (80.3%)	61 (84.7%)	0.108
Abdominal distension/peritonitis, n (%)	3 (18.8%)	0 (0%)	3 (1.4%)	N/A
Radiological imaging				
Length of intussuscepted segment on USG, mean ± SD (cm)	5.7±1.33	3.27±1.18	3.6±1.5	<0.001*
Successful hydrostatic reduction, n (%)	0/7 (0%)	35/35 (100%)	35/42 (83.3%)	N/A
Spontaneous reduction on USG, n (%)	0 (0%)	21 (37.5%)	21 (29.2%)	N/A

PLP: Pathologic lead point; USG: Ultrasonography; SD: Standard deviation. *p<0.05 considered statistically significant.

not statistically significant (p=0.108). In addition, abdominal distension and signs of peritonitis were noted in three patients from the operative group.

Abdominal ultrasonography (USG) was performed for all patients at the time of admission. In the non-operative group, the mean length of the intussuscepted segment on USG was 3.27±1.18 cm (range: 1.9-6 cm), whereas in the operative group it was 5.7±1.33 cm (range: 4-8 cm). This difference was statistically significant (p<0.001) (Fig. 2).

In the operative group, USG revealed findings consistent with intussusception in 14 patients. In the remaining two patients, USG was inconclusive, showing only nonspecific features suggestive of ileus. In these cases, follow-up abdominal computed tomography (CT) also demonstrated similar nonspecific ileus findings, without a definitive diagnosis of intussusception.

Receiver Operating Characteristic curve analysis was conducted to identify the optimal cut-off value of the intussuscepted segment length for predicting the need for surgery. Based on the Youden Index, the threshold that maximized both sensitivity and specificity was 4.0 cm. At this cut-off, sensitivity was 100% and specificity was 73.1% (Fig. 3).

In the non-operative group, hydrostatic reduction (HR) was successfully achieved in 35 of 56 patients (62.5%). In the remaining 21 patients, HR had been planned; however, ultrasonography demonstrated spontaneous reduction of the intussuscepted segment, and no intervention was required.

In the operative group, HR was attempted in seven patients, but all attempts failed, necessitating surgical intervention. HR was not performed in two patients due to a provisional diagnosis of ileus without definitive imaging evidence of intussusception, in three patients because of peritonitis detected

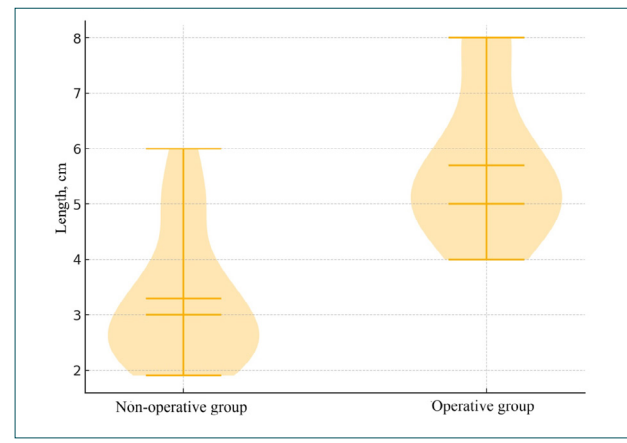

Figure 2. Violin plot of ultrasound-estimated intussuscepted segment lengths in operatively and non-operatively managed patients.

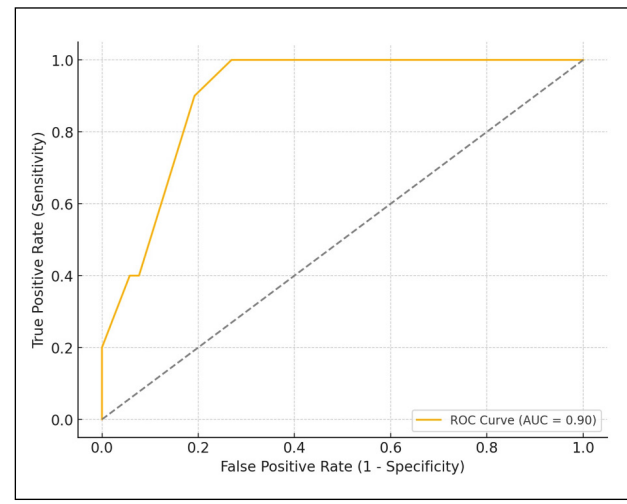

Figure 3. Receiver Operating Characteristic (ROC) curve for predicting the need for surgery.

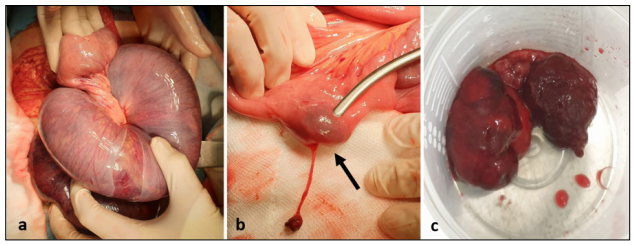

Figure 5. Patient with Peutz-Jeghers syndrome: (a) long segment of intussuscepted bowel at laparotomy, (b) intraluminal polypoid structure (pathologic leading point) (arrow), (c) appearance of excised polyps.

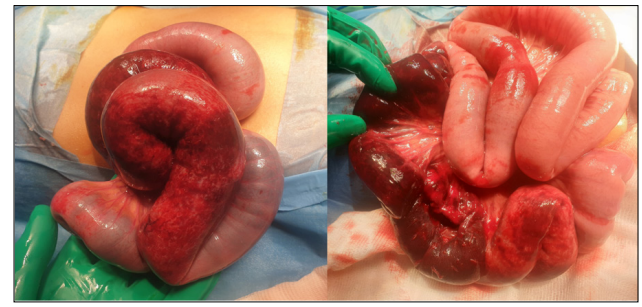

Figure 4. Intraoperative image of a necrotic ileal segment due to small bowel intussusception without an underlying pathologic lead point.

on physical examination, and in the remaining cases due to technical constraints.

In the operative group, the average length of the intussuscepted bowel segment identified intraoperatively was 23.06±36.07 cm (range: 3-150 cm). When compared with preoperative ultrasonographic measurements, the difference was not statistically significant (p=0.071).

Pathologic lead points were identified in 14 patients, whereas no PLP was detected in the remaining two. In one of these cases, bowel necrosis due to intussusception was observed despite the absence of a PLP (Fig. 4). The most common PLP

Table 2. Summary of findings in patients operated on for small bowel intussusception

Patient No	Sex	Age	USG-Based Preoperative Measurement of Intussuscepted Segment Length (cm)	Hydrostatic Reduction Attempted	Operative Findings		Associated Pathology
					Length of the Intussuscepted Bowel Segment (cm)	Surgery Method	
1	M	11 y 11 m	N/A	No	5	Ileal resection	Meckel's diverticulum
2	M	13 y 3 m	5	No	40	Ileal resection	Meckel's diverticulum
3	M	14 y 2 m	N/A	No	10	Ileal resection	Meckel's diverticulum
4	M	13 y 1 m	4	No	3	Ileal resection	Meckel's diverticulum
5	M	3 m	8	No	40	Resection with stapler	Meckel's diverticulum
6	F	9 y 7 m	5	No	3	Resection with stapler	Meckel's diverticulum
7	M	6 y	5	Yes	5	Resection with stapler	Meckel's diverticulum
8	M	5 y 3 m	8	No	10	Ileal resection	Meckel's diverticulum
9	M	4 y 10 y	6	Yes	5	Wedge resection	Meckel's diverticulum
10	M	5 y 7 m	5	Yes	20	Ileal resection	None
11	M	12 y 5 m	N/A	No	150	Ileal resection + polypectomy	Peutz-Jeghers syndrome
12	M	10 m	6	Yes	10	Manual reduction only	None
13	F	6 y 3 m	5	No	3	Ileal resection	Adenomyoma
14	M	11 m	N/A	Yes	15	Ileal resection	Meckel's diverticulum
15	F	1 y 6 m	N/A	Yes	30	Ileal resection	Meckel's diverticulum
16	F	9 y 1 m	N/A	Yes	20	Ileal resection	Meckel's diverticulum

was Meckel's diverticulum (n=12), followed by adenomyoma (n=1) and a hamartomatous polyp (n=1). Histopathologic analysis revealed ectopic gastric mucosa in 5 of the Meckel's diverticulum cases.

Following manual reduction, surgical procedures included ileal resection, wedge resection, or stapled excision of Meckel's diverticulum, with primary repair of serosal defects in selected cases. One patient with Peutz-Jeghers Syndrome (PJS) had an exceptionally long intussuscepted segment, approximately 150 cm in length, necessitating multiple polyp excisions via bowel milking in addition to resection of the compromised ileal segment. The largest polyp measured approximately 3×2 cm in diameter (Fig. 5). Notably, no polyps were detected preoperatively on ultrasonography in this case. Details of patient demographics and operative findings are presented in Table 2.

Postoperative complications occurred in two patients (12.5%). The first case was a six-month-old infant with intussusception caused by Meckel's diverticulum (MD). Intraoperatively, forceful reduction resulted in a large serosal defect, which was primarily repaired. The MD was removed via wedge resection. However, on the fifth postoperative day, the patient's condition deteriorated, and an abdominal X-ray revealed free intraabdominal air. Reoperation revealed a perforation at the site of the repaired serosal defect. An ileal resection with primary anastomosis was performed, after which the patient had an uneventful recovery.

The second case was a 12-year-old male with PJS. On the fourth postoperative day, his abdominal examination findings worsened, prompting a return to laparotomy. The procedure revealed an anastomotic leak, which was managed with re-anastomosis. The patient's postoperative recovery was uneventful, and he was referred to a gastroenterologist for further management. No mortality occurred in the cohort.

During the follow-up period, three patients in the non-operative group experienced recurrent intussusception at 2 months, 9 months, and 2 years after the initial episode. All recurrences were successfully managed with hydrostatic reduction, without the need for surgical intervention.

DISCUSSION

Intussusception is a major cause of acute abdomen in young children, primarily affecting infants under 2 years of age, with a peak incidence between 3 months and 1 year, and is more common in males.[1-3] In this series, the age distribution of non-operatively managed small bowel intussusceptions was consistent with this general pattern, with a median age of 32 months. However, a statistically significant difference was observed between the operative and non-operative groups, as the median age in surgically treated patients was considerably higher, at 75 months ($p<0.05$). These findings suggest that while SBI can occur across a wide pediatric age range, older age may be associated with an increased likelihood of requiring surgical intervention, indicating a distinct clinical course compared to the more typical, conservatively managed cases in younger children.

While ileocolic intussusception is typically characterized by vomiting, colicky abdominal pain, and occasionally currant jelly stools, SBI often presents with more subtle or atypical symptoms and is frequently mistaken for acute gastroenteritis, potentially delaying SBI diagnosis.[7,9] In this cohort, none of the patients in the operative group exhibited rectal bleeding, and vomiting was significantly more frequent. Additionally, physical examination revealed abdominal tenderness in all surgical patients and in a subset of non-operative patients. These findings suggest that classical signs of intussusception may not always be reliable indicators of SBI, emphasizing the need for a high index of suspicion in older children presenting with nonspecific abdominal symptoms, as delays in diagnosis can lead to severe outcomes, including intestinal necrosis.

Abdominal USG is the primary diagnostic modality for intussusception due to its high sensitivity and specificity. Although it might not always pinpoint the specific underlying cause, such as PLPs, its effectiveness in identifying intussusception is notable.[8,11] A key finding in this study is the correlation between the ultrasonographically measured length of the intussuscepted segment and the likelihood of requiring surgery. The mean length in the operative group was significantly greater than that in the non-operative group (5.7±1.33 cm vs. 3.27±1.18 cm, $p<0.001$). ROC analysis further confirmed this relationship, identifying 4.0 cm as the optimal cut-off value for predicting surgical intervention, with a sensitivity of 100% and a specificity of 73.1%. These results suggest that USG can serve not only as a diagnostic tool but also as a valuable predictor of disease severity and the necessity for surgical management.

Ultrasonography can also assist in non-surgical correction, particularly for ileocolic intussusceptions, through HR. [12,13] Although HR is traditionally considered less effective for small bowel intussusceptions, our series demonstrated successful outcomes in a substantial proportion of cases. In the non-operative group, HR was successful in 62.5% of patients, with spontaneous resolution observed in the remainder. In contrast, all HR attempts in the operative group failed, and most of these patients were subsequently found to have a PLP, suggesting a possible association between PLP and unsuccessful non-surgical reduction. However, it should be noted that the presence of PLPs in patients who responded successfully to HR could not be definitively ruled out. Several reports in the literature support the selective use of HR in SBI and advocate for its consideration as an initial therapeutic approach, especially when there is no clinical or radiologic suspicion of a PLP or complications such as peritonitis.[14-16] Our findings further reinforce the notion that HR can be a viable and effective first-line intervention in select cases of SBI.

Small bowel intussusception in children is not extensively documented in the medical literature, leading to ongoing debate about its clinical presentation and management. Some researchers advocate for a watchful waiting approach in managing SBI.[1,5,14] Kornecki et al.[5] reported that many SBI cases resolve independently without a detectable lead point, leading to their recommendation for non-invasive management in patients who do not exhibit symptoms. This trend toward conservative management may also be driven by advancements in ultrasound technology, which have enhanced the detection and evaluation of abdominal conditions in children presenting with abdominal pain.

In contrast to other studies, Tiao et al.[8] reported that all pediatric SBI patients in their series were symptomatic, with PLPs identified in 44% of cases. Although sonographic identification of various lead points such as lipomas, malignant tumors, and Meckel's diverticulum has been described in SBI, it remains challenging in clinical practice.[17] Tiao et al.[8] also noted difficulty in establishing a definitive preoperative diagnosis of these underlying conditions. Similarly, in a retrospective study of 35 pediatric SBI cases, Munden et al.[18] found that 13 patients required surgery, with PLPs identified intraoperatively in nine of them.

In our series, PLPs were identified in 14 out of 16 surgical cases (87.5%), most commonly Meckel's diverticulum, followed by adenomyoma and a hamartomatous polyp. Notably, none of these PLPs were detected on preoperative USG, highlighting a diagnostic limitation of current imaging practices. In certain cases, PLPs such as Peutz-Jeghers polyps resulted in exceptionally long segments of intussusception, necessitating extensive bowel resection. These findings underscore the need to integrate clinical presentation and intraoperative assessment into management planning, given the limitations of preoperative imaging in reliably identifying PLPs.

This study has several limitations that should be acknowledged. First, its retrospective design inherently limits the ability to control for confounding variables and introduces the potential for selection and information bias. Second, the relatively small number of surgically confirmed SBI cases restricts the generalizability of the findings. Third, the reliance on USG as the primary imaging modality may have contributed to the underdiagnosis of PLPs, as no PLPs were identified preoperatively despite their high intraoperative prevalence. Finally, the lack of long-term follow-up data for all patients limits the assessment of late postoperative outcomes, including recurrence and potential functional sequelae.

CONCLUSION

This study highlights the distinct clinical and demographic characteristics of SBI in the pediatric population. Our findings demonstrate that older age, greater ultrasonographic segment length, and symptoms such as persistent vomiting and signs of peritonitis are significantly associated with the need for surgical intervention. Although preoperative ultrasound remains a valuable diagnostic tool, its limitations in detecting underlying PLPs underscore the importance of thorough clinical evaluation. The identification of a 4.0 cm threshold in segment length as a predictive marker for surgery provides a practical metric for clinical decision-making. Early recognition and appropriate management of SBI are essential to prevent complications, and a high index of suspicion must be maintained, particularly in older children presenting with atypical or nonspecific symptoms.

Ethics Committee Approval: This study was approved by the Sancaktepe Şehit Prof. Dr. İlhan Varank Training and Research Hospital Ethics Committee (Date: 10.01.2024, Decision No: 03).

Peer-review: Externally peer-reviewed.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Semptomatik ince bağırsak invajinasyonunda tanısal kriterlerin, cerrahi olarak doğrulanmış 16 pediatrik olguya dayalı analizi

AMAÇ: Bu çalışma, cerrahi olarak tedavi edilen olgulara özel vurgu yaparak, pediatrik ince barsak invajinasyonunun (İBİ) klinik bulguları, tanı yöntemleri, tedavi stratejileri ve sonuçlarını değerlendirmeyi amaçlamaktadır.
GEREÇ VE YÖNTEM: Ocak 2018 ile Aralık 2023 tarihleri arasında İBİ tanısı alan çocuk hastaların kayıtları retrospektif olarak incelenmiştir. Demografik veriler, klinik bulgular, görüntüleme sonuçları, tedavi yaklaşımları ve cerrahi bulgular analiz edilmiştir. Operatif ve non-operatif gruplar arasında istatistiksel karşılaştırmalar yapılmış ve cerrahi gereksinimini öngörmede ultrasonografik segment uzunluğu için ROC eğrisi analizi uygulanmıştır.
BULGULAR: Toplam 618 invajinasyon olgusu arasında 72 (%11.6) olgu İBİ olarak tanımlanmış, bunlardan 16'sı (%2.6) cerrahi müdahale gerektirmiştir. Cerrahi uygulanan hastalar, cerrahi dışı tedavi edilenlere kıyasla anlamlı düzeyde daha büyük yaşta bulunmuştur (ortanca: 75 ay vs. 32 ay, $p<0.05$). Operatif grupta kusma sıklığı anlamlı olarak daha yüksekti (%100 vs. %44.6; $p<0.001$). Ultrasonografide invajine segmentin ortalama uzunluğu, operatif grupta anlamlı şekilde daha fazlaydı (5.7±1.33 cm vs. 3.27±1.18 cm; $p<0.001$). Cerrahi gereksinimi öngörmede 4.0 cm'lik eşik değeri, %100 duyarlılık ve %73.1 özgüllük ile belirlendi. Cerrahi uygulanan hastaların %87.5'inde patolojik tetik nokta (PTN) saptanmış olup, bu tetik noktaların hiçbiri ameliyat öncesi dönemde tanımlanamamıştır. Non-operatif gruptaki hastaların %62.5'inde hidrostatik redüksiyon başarılı bulunmuştur.
SONUÇ: Bu çalışma, pediatrik İBİ'de ileri yaş, ultrasonografide daha uzun invajine segment ve şiddetli semptomların cerrahi gereksinimi öngördüğünü göstermektedir. 4.0 cm'lik bir eşik değeri, klinik karar verme sürecinde pratik bir ölçüt sağlayabilir. Ameliyat öncesi dönemde PTN' lerin sınırlı tespiti, dikkatli klinik değerlendirmenin önemini vurgulamaktadır.

Anahtar sözcükler: Cerrahi; çocuk; ince barsak invajinasyonu.

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ORIGINAL ARTICLE

The utility of the quick sequential organ failure assessment (qSOFA) score in predicting mortality in Fournier's gangrene patients undergoing emergency surgery

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ABSTRACT

BACKGROUND: This study aimed to evaluate the predictive value of the quick Sequential Organ Failure Assessment (qSOFA) score in estimating mortality risk in Fournier's gangrene patients and to provide a simple tool for early clinical decision-making.

METHODS: This retrospective study included patients who underwent emergency debridement for Fournier's gangrene between 2022 and 2024. Patients with systemic involvement of the perianal and inguinal canal were included. Clinical parameters, laboratory markers, Fournier's Gangrene Severity Index (FGSI) scores, and outcomes such as mortality and hospital stay were analyzed. Patients were categorized into two groups: Group 1 (qSOFA 0-1) and Group 2 (qSOFA ≥2). Univariate and multivariate logistic regression analyses were performed to identify independent predictors of mortality.

RESULTS: Among 89 patients, 55 were in Group 1 and 34 in Group 2. The overall mortality rate was 21.35% (Group 1: 12.73%, Group 2: 35.29%, $p<0.05$). Significant differences were observed between groups in age, comorbidities, respiratory rate, procalcitonin, FGSI scores, and hospital stay (all $p<0.05$). Univariate analysis identified age, FGSI score, comorbidities, and procalcitonin as mortality-related factors. A qSOFA score ≥2 was significantly associated with higher mortality ($p<0.05$), and multivariate analysis confirmed it as an independent predictor (odds ratio: 3.00, $p<0.05$).

CONCLUSION: The qSOFA score is a simple and reliable predictor of mortality in Fournier's gangrene, supporting its use for early risk assessment and timely clinical interventions.

Keywords: Fournier's gangrene; qSOFA score; mortality prediction; sepsis; prognostic tool.

INTRODUCTION

Fournier's gangrene (FG) is a life-threatening type of necrotizing fasciitis that primarily affects the perineum, genitalia, and surrounding tissues.[1] Although FG is a rapidly progressing and life-threatening infection, recent advances in diagnostic tools, treatment modalities, and clinical experience have significantly reduced its mortality rates. Current literature reports mortality rates of approximately 10-20%.[2-5] FG commonly occurs in patients with underlying risk factors such as diabetes mellitus, immunosuppression, chronic kidney disease, and alcoholism.[6-7] Early diagnosis and treatment, including surgical debridement, intravenous antibiotics, and intensive care support, are essential for improving survival outcomes.[8] However, the rapid progression of the disease poses challenges for timely risk assessment and prognosis.

Clinicians have used Fournier's Gangrene Severity Index (FGSI) to evaluate disease severity and predict mortality.[9] Although FGSI has demonstrated clinical utility, it requires multiple labo-

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ratory investigations and involves complex calculations, which may be impractical in emergency settings or resource-limited environments. Furthermore, the predictive accuracy of FGSI has been debated, with studies reporting inconsistent reliability across different patient populations and demographic groups.[10]

The quick Sequential Organ Failure Assessment (qSOFA) score has recently gained attention for its simplicity and ease of application at the bedside. Initially developed to identify patients at risk of adverse outcomes from sepsis, the qSOFA score consists of three variables: impaired cognitive state, a respiratory rate of 22 breaths per minute or greater, and a systolic blood pressure of 100 mmHg or lower.[11] Its straightforward design makes it highly practical in emergency settings. However, research on the utility of qSOFA in the context of FG remains limited.[12]

The literature provides insufficient information regarding the effectiveness of the qSOFA score in predicting mortality specifically in patients with FG. Some studies suggest that qSOFA could be a useful prognostic tool, but there are few direct comparisons with other established scoring systems, including the FGSI, in the context of FG. Additionally, the sensitivity and specificity of the qSOFA score in identifying high-risk FG patients have not been thoroughly studied.[13] Since FG is often associated with sepsis, it is important to evaluate whether qSOFA can serve as a simple and reliable predictor of mortality in these patients.

This study has two main objectives: the primary aim is to examine the predictive value of the qSOFA score in estimating mortality risk among patients with FG, and the secondary aim is to provide clinicians with a simpler and more accessible tool for early risk assessment and decision-making in managing this critical condition.

MATERIALS AND METHODS

This retrospective study evaluated patients who underwent emergency debridement for FG between 2022 and 2024. Approval for the study was obtained from the Ethics Committee of our hospital for the study (29.01.2025/ AEŞH-BADEK-2024-1215). All participants provided written informed consent prior to inclusion in the study, which was conducted in accordance with the Declaration of Helsinki.

Inclusion and Exclusion Criteria

Patients with systemic involvement of the perianal and inguinal canal who underwent debridement were included in the present evaluation. In contrast, patients with localized FG (without involvement of the Colles fascia, affecting only the penis or scrotum) and those diagnosed with an abscess were excluded.

Evaluated Patient Parameters

We analyzed several patient parameters using the hospital data system. These included age, gender, comorbidities, fever, respiratory rate, heart rate per minute, mental function status, serum electrolytes (such as sodium, creatinine, and potassium), infection parameters (white blood cell count, procalcitonin, and C-reactive protein (CRP)), intensive care parameters (bicarbonate and lactate levels), FGSI scores, mortality rates, and length of hospital stay.

qSOFA Score Assessment and Application

The qSOFA score is designed to quickly identify patients at risk of unfavorable outcomes due to sepsis. Introduced in the 2016 Sepsis-3 (the Third International Consensus Definitions for Sepsis and Septic Shock) guidelines, the qSOFA score is a simplified version of the more comprehensive SOFA score. It consists of three criteria, each contributing one point to the total score: altered mental status (reflected by a Glasgow Coma Scale (GCS) score of less than 15 or confusion), a respiratory rate of 22 breaths per minute or greater, and a systolic blood pressure of 100 mmHg or less. The total qSOFA score ranges from 0 to 3, with a score of 2 or higher indicating an increased mortality risk. This highlights the need for further sepsis evaluation and supports timely intervention and management.[14] qSOFA scores in this study were derived from retrospectively recorded data.

A qSOFA score of 0-1 generally indicates a lower risk of adverse outcomes related to sepsis, suggesting that patients may not exhibit significant organ dysfunction and are typically considered to have a milder form of illness. Conversely, a score of 2 or higher signifies a higher mortality risk and suggests significant organ dysfunction, indicative of more severe sepsis or septic shock; such patients usually require more intensive monitoring and intervention.[15] Table 1 summarizes the qSOFA scoring system and associated severity.

Design of the Groups

In this study, qSOFA scores were retrospectively calculated from the hospital data system for all patients (a total of 89) included in the study. Patients were classified into two groups. The first group (Group 1) included FG patients with a qSOFA score of 0-1, while the second group (Group 2) comprised FG patients with a qSOFA score of 2 or higher. Among the 89 patients, 55 were classified into Group 1 (qSOFA score of 0–1), accounting for approximately 61.8% (55/89), while 34 were classified into Group 2 (qSOFA score of ≥2), representing about 38.2% (34/89). We compared the demographic characteristics, mortality rates, laboratory findings, and FGSI scores between the groups.

Statistical Analysis

Statistical evaluations were conducted using SPSS software (IBM version 21, NY, USA). Continuous variables were expressed as mean, standard deviation, median, and interquartile range, depending on normal distribution. Categorical variables were reported as frequencies and percentages.

Comparisons between groups were made using the Student's t-test or Mann-Whitney U test for continuous variables, and the chi-square test or Fisher's exact test for categorical variables. Univariate and multivariate logistic regression analyses were applied to identify independent predictors of mortality among patients. A p-value of less than 0.05 was considered statistically significant.

A post hoc power analysis was performed based on the primary outcome of mortality. Using a two-sided alpha of 0.05 and an observed effect size (Cohen's d=0.65), the statistical power was calculated to be 82%, indicating that the sample size (n=89) was sufficient to detect meaningful differences between the two qSOFA groups. A minimum of 33 patients per group was required to achieve adequate power. Receiver Operating Characteristic (ROC) curve analysis was also conducted to assess the predictive performance of selected parameters for mortality. The area under the curve (AUC), optimal cut-off values, sensitivity, and specificity were calculated.

RESULTS

A total of 89 patients were included in this study. Among these patients, 55 were classified into Group 1 (qSOFA score 0-1), accounting for approximately 61.79% (55/89), while 34 were classified into Group 2 (qSOFA score ≥2), representing about 38.31% (34/89).

Demographic Characteristics

In Group 1, the average age was approximately 50.43 years (standard deviation [SD] ±5.12), whereas in Group 2 it was around 60.25 years (SD ±6.87), indicating a statistically significant difference between the two groups ($p<0.05$). Each group included one female patient, representing approximately 1.82% (1 out of 55) in Group 1 and 2.94% (1 out of 34) in Group 2. The average number of comorbidities in Group 2 (qSOFA score 2 or more) was 2.1±0.7, compared to 1.2 ±0.5 in Group 1 (qSOFA score 0-1), with this difference being statistically significant ($p<0.05$). The most common comorbidities in Group 2 were diabetes mellitus (25%), chronic kidney disease (18%), and urethral stricture (15%). In contrast, these comorbidities were less prevalent in Group 1, with diabetes in 10% of patients, chronic kidney disease in 5%, and urethral stricture in 3%. The demographic characteristics of the patients are summarized in Table 2.

Perioperative Outcomes and Laboratory Findings

The mean respiratory rate in Group 2 (qSOFA score 2 or more) was 25.3±3.1, compared to 18.5±2.0 in Group 1 (qSOFA score 0-1), and this difference was statistically signifi-

Table 1. Criteria and scoring for the quick Sequential Organ Failure Assessment (qSOFA)

Criterion	Description	Score
Altered mental status	Glasgow Coma Scale score less than 15 or confusion	1
Respiratory rate ≥22 breaths/min	Respiratory rate of 22 breaths per minute or greater	1
Systolic blood pressure ≤100 mmHg	Systolic blood pressure of 100 mmHg or lower	1
Total qSOFA score	0-3 points; a score of 2 or higher indicates increased mortality risk	0-3

qSOFA: Quick Sequential Organ Failure Assessment. A score of 2 or higher indicates the need for further evaluation and timely intervention for sepsis.

Table 2. Demographic characteristics

Characteristic	Group 1 Group 1 (qSOFA 0–1)	Group 2 Group 2 (qSOFA ≥2)	p-value
Number of patients	55/89 (61.79%)	34/89 (38.31%)	<0.05
Age	50.43±5.12	60.25±6.87	<0.05
Female patients (%)	1/55 (1.82%)	1/34 (2.94%)	-
Number of comorbidities	1.2±0.5	2.1±0.7	<0.05
Comorbidities			
Diabetes mellitus	10%	25%	
CKD	5%	18%	-
Urethral stricture	3%	15%	

qSOFA: Quick Sequential Organ Failure Assessment; CKD: Chronic kidney disease.

Table 3. Perioperative outcomes and laboratory findings

Characteristic	Group 1 (qSOFA score 0-1)	Group 2 (qSOFA score ≥2)	p-value
Respiratory Rate (breaths/min)	18.5±2.0	25.3±3.1	<0.05
WBC Count (×10^9/L)	14.5±2.0	15.8±1.8	0.78
Procalcitonin (ng/mL)	1.5±0.8	5.2±1.5	<0.05
CRP (mg/L)	115.0±20.0	125.0±22.5	0.43
FGSI Score	4.8±1.3	9.6±2.2	<0.05
Length of Hospital Stay (days)	16.0±3.5	34.0±6.2	<0.05

qSOFA: Quick Sequential Organ Failure Assessment; WBC: White blood cell count; CRP: C-reactive protein; FGSI: Fournier Gangrene Severity Index.

Table 4. Multivariate logistic regression analysis

Characteristic	Group 1 (qSOFA score 0-1)	Group 2 (qSOFA score ≥2)	Adjusted OR	p-value
FGSI Score	4.8±1.3	9.6±2.2	OR: 1.45 (95% CI: 1.25-1.68)	<0.05
Number of Comorbidities	1.2±0.5	2.1±0.7	OR: 1.30 (95% CI: 1.05-1.62)	<0.05
Procalcitonin (ng/mL)	1.5±0.8	5.2±1.5	OR: 2.10 (95% CI: 1.70-2.70)	<0.05
qSOFA Score	1.0±0.7	2.5±0.5	OR: 3.00 (95% CI: 1.80-4.90)	<0.05

qSOFA: Quick Sequential Organ Failure Assessment; OR: Odds ratio; FGSI: Fournier Gangrene Severity Index.

cant (p<0.05). The mean white blood cell (WBC) count was 15.8±1.8 in Group 2 and 14.5±2.0 in Group 1, showing no statistically significant difference (p=0.78). Procalcitonin levels were 5.2±1.5 in Group 2 and 1.5±0.8 in Group 1, with a significant difference (p<0.05). CRP levels were 125.0±22.5 in Group 2 and 115.0±20.0 in Group 1, indicating no significant difference (p=0.43). FGSI scores were significantly higher in Group 2 (9.6±2.2) compared to Group 1 (4.8±1.3) (p<0.05). The mean length of hospital stay was also significantly longer in Group 2 (qSOFA score 2 or more) at 34.0±6.2 days compared to Group 1 (qSOFA score 0-1) at 16.0±3.5 days (p<0.05). The perioperative outcomes are summarized in Table 3.

Mortality Rates

Nineteen of the 89 patients died despite undergoing surgical debridement and receiving broad-spectrum antibiotic therapy, corresponding to an overall mortality rate of 21.35%. In Group 1, seven patients died, resulting in a mortality rate of approximately 12.73% (7 out of 55 patients). In Group 2, 12 patients died, corresponding to a mortality rate of approximately 35.29% (12 out of 34 patients). Statistical analysis indicated a significant difference in mortality rates between the two groups, with Group 2 exhibiting a higher mortality rate than Group 1 (p<0.05). Univariate analysis revealed that age was significantly associated with mortality, with patients over 60 years showing higher mortality rates (p<0.05). Higher FGSI scores were also significantly correlated with increased mortality (p<0.05). The presence of multiple comorbidities, particularly in patients with diabetes mellitus, chronic kidney disease, and urethral stricture, was linked to higher mortality (p<0.05). Furthermore, elevated procalcitonin levels were significantly associated with mortality (p<0.05). A qSOFA score of ≥2 was also significantly associated with increased mortality (p<0.05).

In multivariate logistic regression analysis, age was no longer a significant predictor of mortality. However, higher FGSI scores were linked to an increased mortality, with an adjusted odds ratio (OR) of 1.45 (95% confidence interval [CI]: 1.25-1.68, p<0.05). The presence of comorbidities also contributed to mortality, with an adjusted OR of 1.30 (95% CI: 1.05-1.62, p<0.05). Elevated procalcitonin levels significantly increased

Table 5. Receiver Operating Characteristic (ROC) analysis of quick Sequential Organ Failure Assessment (qSOFA), Fournier Gangrene Severity Index (FGSI), and procalcitonin for mortality prediction

Parameter	Cut-off	AUC	95% CI	Sensitivity (%)	Specificity (%)
qSOFA	≥2	0.78	0.68-0.88	75	72
FGSI	≥7	0.82	0.74-0.91	78	75
Procalcitonin	≥3.5 ng/mL	0.80	0.70-0.89	73	70

qSOFA: Quick Sequential Organ Failure Assessment; FGSI: Fournier Gangrene Severity Index.

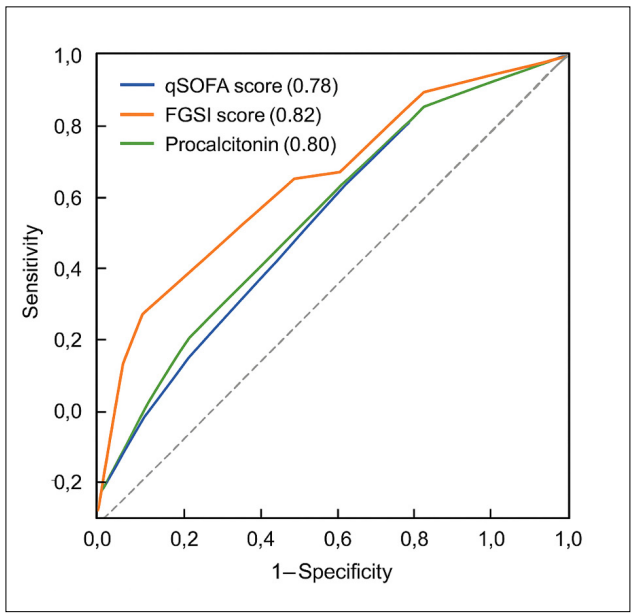

Figure 1. Receiver Operating Characteristic (ROC) curves of quick Sequential Organ Failure Assessment (qSOFA), Fournier Gangrene Severity Index (FGSI), and procalcitonin for predicting mortality in patients with Fournier's gangrene.

mortality risk, with an adjusted OR of 2.10 (95% CI: 1.70-2.70, p<0.05). Finally, a qSOFA score of ≥2 was associated with an adjusted OR of 3.00 (95% CI: 1.80-4.90, p<0.05). The multivariate analyses are summarized in Table 4.

ROC Curve Analysis

Receiver Operating Characteristic curve analysis was performed to evaluate the discriminative ability of the qSOFA score, FGSI score, and procalcitonin levels in predicting mortality. The qSOFA score demonstrated an AUC of 0.78 (95% CI: 0.68–0.88), indicating good predictive performance. The FGSI score showed an AUC of 0.82 (95% CI: 0.74–0.91), and procalcitonin levels yielded an AUC of 0.80 (95% CI: 0.70–0.89). The optimal cut-off values were identified as qSOFA ≥2, FGSI ≥7, and procalcitonin ≥3.5 ng/mL, with sensitivities and specificities above 70% for each parameter (Table 5, Fig. 1). These results suggest that all three parameters are valuable predictors of mortality in FG patients.

DISCUSSION

In our study, we investigated the prognostic value of the qSOFA score in relation to mortality rates among critically ill patients. With a total of 89 cases, our findings revealed a significant correlation between higher qSOFA scores and increased mortality, supporting the hypothesis that qSOFA is a valuable prognostic tool in clinical settings. Our results indicated that the overall mortality rate was 21.35%, with a stark contrast between the two groups: Group 1 (qSOFA score 0-1) had a mortality rate of 12.73%, while Group 2 (qSOFA score 2 or more) exhibited a much higher mortality rate of 35.29%. This significant difference (p<0.05) underscores the predictive power of the qSOFA score and demonstrates its effectiveness in stratifying patients according to risk of death.

The statistical analysis further highlighted important clinical variables associated with mortality. Age emerged as a significant factor, with patients over 60 years old showing a higher mortality rate (p<0.05). This finding aligns with existing literature that emphasizes the increased vulnerability of older patients to adverse outcomes, particularly in the context of critical illness.[16] Similarly, higher FGSI scores were significantly correlated with mortality rates (p<0.05), affirming the relevance of this scoring system in assessing illness severity.[17] Despite the relevance of the FGSI in assessing the severity of illness, it has several limitations. One major concern is its reliance on subjective clinical judgments, which can introduce variability and potential bias in scoring. Additionally, the FGSI may not adequately capture the nuances of multi-organ dysfunction, as it primarily focuses on functional status rather than underlying pathophysiological processes. The delayed availability of laboratory-dependent results can also affect timely assessment, which may reduce the effectiveness of the FGSI. Lastly, its applicability across diverse patient populations and clinical settings remains a subject of ongoing research, which may limit its generalizability.[10] Although our primary objective was not to directly compare qSOFA with FGSI, a reference scoring system was needed to objectively evaluate the predictive performance of qSOFA. FGSI is one of the most commonly used and validated scoring systems for predicting mortality in FG. Therefore, FGSI was selected as a benchmark for statistical comparison. However, despite its

widespread use, FGSI relies on laboratory parameters, which may limit its practicality in urgent clinical settings. In contrast, qSOFA can be applied more rapidly at the bedside, offering a practical advantage in emergency evaluations.

Biomarkers also emerged as significant predictors of mortality in our study. Elevated procalcitonin levels were significantly associated with increased mortality ($p<0.05$). However, procalcitonin shares similar limitations with FGSI: as a laboratory-dependent test, it may not always be readily available during the initial stages of emergency assessment.[18] The most significant impact of our study is that it underscores the importance of qSOFA as a prognostic indicator during the initial emergency encounter.

The presence of comorbidities also played a crucial role in determining patient outcomes. In Group 2, the average number of comorbidities was 2.1±0.7, while Group 1 had a lower average of 1.2±0.5. The most common comorbidities in Group 2 were diabetes mellitus (25%), chronic kidney disease (18%), and urethral stricture (15%). This finding aligns with literature that has established a link between multiple comorbidities and increased mortality, particularly in patients with critical conditions.[19]

In our study, multivariate logistic regression analysis yielded additional insights into mortality predictors. Although age did not remain a significant predictor, higher FGSI scores continued to correlate with increased mortality, with an adjusted OR of 1.45 (95% CI: 1.25-1.68, $p<0.05$). The presence of comorbidities was also associated with an adjusted OR of 1.30 (95% CI: 1.05-1.62, $p<0.05$), and elevated procalcitonin levels showed an adjusted OR of 2.10 (95% CI: 1.70-2.70, $p<0.05$). Most notably, a qSOFA score of ≥2 was linked to an adjusted OR of 3.00 (95% CI: 1.80-4.90, $p<0.05$). This underscores the potential of qSOFA as a critical marker for predicting mortality in critically ill patients.

Although a limited number of studies have examined the correlation between qSOFA scores and mortality, many had limitations related to sample size, patient diversity, and the range of clinical factors considered.[12,13,20] In a recent study, the authors, similar to our study, divided participants into two groups based on qSOFA scores: high qSOFA (2-3) and low qSOFA (0-1). Both studies also evaluated the prognostic value of qSOFA score by comparing it with FGSI.[12] Warli et al.[13] focused on the combined use of FGSI and qSOFA scores and further analyzed microbiological culture results and infectious agents in relation to mortality. By contrast, our study also examined the association of clinical variables and biomarkers with mortality, offering a more comprehensive assessment of FG patients. Compared to the study by Arıkan et al.[20] however, our sample size was smaller, which could limit the generalizability of our findings. However, in our study, qSOFA scores were clearly categorized into two groups (0-1 and ≥2) for analysis. Additionally, clinical features, comorbidities, and biomarkers such as procalcitonin were comprehensively evaluated to provide a more holistic assessment of the prognostic value of qSOFA.

The most significant advantage and contribution of the present study is its focus on the prognostic value of qSOFA scores and their relationship with mortality rates. The significant findings related to qSOFA scores and mortality rates contribute to the growing body of evidence supporting the implementation of qSOFA as a standard assessment tool in clinical practice. By enhancing early detection of at-risk patients, healthcare providers can facilitate prompt interventions and ultimately improve patient outcomes. Integrating qSOFA scores into routine evaluations may enhance risk stratification and guide treatment decisions, aligning with best practices in critical care management.

Nonetheless, our study has several limitations. First, the retrospective design introduces inherent bias and limits the ability to establish causality. Second, the relatively small sample size reduces statistical power and may restrict the generalizability of the findings to broader populations. Despite these limitations, the study provides valuable preliminary insights into the utility of the qSOFA score in FG patients, and our results support the need for larger, prospective studies to validate these findings.

In conclusion, our study demonstrated that the qSOFA score is a simple, rapid, and reliable predictor of mortality in critically ill patients with FG. The findings support its use for early risk assessment and for guiding timely clinical interventions in practice. Future larger, prospective studies are recommended to validate these results.

Ethics Committee Approval: This study was approved by the Etlik City Hospital Ethics Committee (Date: 29.01.2025, Decision No: AEŞH-BADEK-2024-1215).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Fournier gangreni hastalarında acil cerrahide mortaliteyi öngörmede qSOFA skorunun kullanılabilirliği

AMAÇ: Bu çalışmanın amacı, Fournier gangreni hastalarında qSOFA skorunun mortalite riskini tahmin etmedeki değerini değerlendirmek ve erken klinik karar verme sürecine yardımcı olacak basit bir araç sunmaktır.

GEREÇ VE YÖNTEM: Bu retrospektif çalışmaya, 2022 ile 2024 yılları arasında Fournier gangreni nedeniyle acil debridman uygulanan hastalar dahil edilmiştir. Perianal ve inguinal kanalın sistemik tutulumu olan hastalar çalışmaya alınmıştır. Klinik parametreler, laboratuvar belirteçleri, FGSI skorları ve mortalite ile hastanede kalış süresi gibi sonuçlar analiz edilmiştir. Hastalar qSOFA skoruna göre iki gruba ayrılmıştır: Grup 1 (qSOFA 0-1) ve Grup 2 (qSOFA ≥2). Mortaliteyi etkileyen bağımsız değişkenleri belirlemek amacıyla univaryant ve multivaryant lojistik regresyon analizleri yapılmıştır.

BULGULAR: Toplam 89 hastanın 55'i Grup 1'de, 34'ü Grup 2'de yer almıştır. Genel mortalite oranı %21.35 olarak bulunmuştur (Grup 1: %12.73; Grup 2: %35.29; $p<0.05$). Yaş, komorbiditeler, solunum hızı, prokalsitonin düzeyleri, FGSI skorları ve hastanede kalış süresi açısından gruplar arasında anlamlı farklar saptanmıştır ($p<0.05$). Univaryant analizde yaş, FGSI skoru, komorbiditeler ve prokalsitonin mortalite ile ilişkili bulunmuştur. qSOFA skoru ≥2 olan hastalarda mortalite oranı anlamlı şekilde daha yüksek olup ($p<0.05$), multivaryant analizde bu skor bağımsız bir mortalite belirleyicisi olarak saptanmıştır (OR: 3.00; $p<0.05$).

SONUÇ: qSOFA skoru, Fournier gangreni hastalarında mortaliteyi öngörmede basit ve güvenilir bir göstergedir. Bu nedenle erken risk değerlendirmesi ve zamanında klinik müdahalelerin yönlendirilmesinde kullanılabilir.

Anahtar sözcükler: Fournier gangreni; mortalite tahmini; prognostik araç; sepsis; qSOFA skoru.

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ORIGINAL ARTICLE

Microbial profiles and risk of amputation in fasciotomy and open wounds following the 2023 Türkiye earthquakes

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ABSTRACT

BACKGROUND: This retrospective, single-center study aimed to evaluate the microbial profiles of wound infections due to extremity injuries after the February 6, 2023 Kahramanmaraş earthquakes and their association with the risk of amputation.

METHODS: The study included 95 adult patients with post-earthquake wound infections and positive cultures—50 in the fasciotomy group and 45 in the open wound group.

RESULTS: The most frequently isolated microorganism was *Acinetobacter spp*. and the isolation rate of this pathogen was significantly higher in the fasciotomy group than in the open wound group (40% vs. 11.1%; p=0.0021). Although the *Escherichia coli* isolation rate was higher in the open wound group, this difference was not statistically significant. Polymicrobial infection rates were similar in both groups. Antibiotic susceptibility analysis showed that 86.5% of *Acinetobacter spp*. isolates were resistant to carbapenems and 10.8% to colistin. The isolation rate of *Acinetobacter spp*. was higher in patients who underwent amputation (35.14%) compared to those who did not (20.69%), but this difference did not reach statistical significance.

CONCLUSION: Our findings suggest that the pathogen profile in post-earthquake wound infections may vary according to wound type and that *Acinetobacter spp*. infections with high antibiotic resistance may be a potential risk factor for amputation. In conclusion, resource-based evaluation of post-disaster wound infections, planning early and targeted treatment strategies, and developing effective approaches against highly resistant pathogens are critical for reducing the risk of amputation.

Keywords: Earthquake; open wound; fasciotomy; infection; amputation.

INTRODUCTION

On February 6, 2023, two devastating earthquakes measuring 7.8 Mw and 7.5 Mw, respectively, struck the southern region of Türkiye within a nine-hour interval along distinct fault lines. These seismic events had catastrophic consequences, directly affecting eleven provinces—most notably Hatay (Antakya), Kahramanmaraş, Gaziantep (Nurdağı and Islahiye), Adıyaman (Gölbaşı), Malatya, and northern Syria—resulting in more than 53,000 fatalities, 108,068 injuries, and the displacement of over 1.2 million individuals.[1]

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Extremity injuries represent one of the most prevalent types of trauma necessitating surgical intervention in the aftermath of these mass-casualty earthquakes. Examples of such trauma include crush injuries sustained under debris, open fractures, and traumatic amputations.[2,3] Notably, crush injuries accompanied by extensive muscle damage are associated with markedly increased risks of morbidity and mortality.[4] Surgical procedures performed to manage these injuries—particularly fasciotomy and amputation—are known to predispose patients to postoperative wound infections.[5]

In the post-earthquake period, patients frequently experience disturbances in fluid-electrolyte balance and nutritional status, which not only prolong hospital stays but also increase susceptibility to nosocomial infections.[6] In the early phase following trauma, pathogens such as *Escherichia coli*, *Enterococcus faecalis*, and *Enterobacter* cloacae are commonly isolated. In contrast, in later stages, multidrug-resistant organisms—most notably *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Klebsiella pneumoniae*—are encountered with increasing frequency.[4,7-9]

Although infectious agents following earthquakes have been documented in the literature, definitive information regarding the precise sources of these infections remains limited. To develop optimal therapeutic strategies, it is essential to stratify patients according to the type of injury and to delineate whether the infection is associated with an open wound, a surgical site, or is nosocomial in origin.[2,10]

The primary objective of this study was to characterize wound infections that developed in the aftermath of the February 6, 2023 earthquakes, to identify the clinical contexts in which these infections arose, and to compare the pathogen profiles of open wounds and fasciotomy sites. The secondary objective was to evaluate the distribution of microorganisms isolated from cases resulting in amputation.

We hypothesized that the microbiological profiles of cultures obtained from earthquake-related open extremity wounds would differ from those obtained from postoperative fasciotomy wounds.

MATERIALS AND METHODS

This retrospective, single-center observational study included patients with extremity injuries sustained during the February 2023 earthquakes and treated at Ankara Etlik City Hospital. The study population comprised patients who developed wound infections following open injuries or fasciotomy procedures. Clinical data, including hospital records, microbiological culture results, surgical interventions, and patient outcomes, were systematically collected and analyzed.

Ethical approval for the study was obtained from the Ankara Etlik City Hospital Ethics Committee (Approval No: AEŞH-EK1-2023-08, August 9, 2023). All procedures were conducted in accordance with institutional research committee standards and the principles outlined in the Declaration of Helsinki.

A total of 95 adult patients with positive microbiological cultures obtained from open wounds or fasciotomy sites were included in the analysis. Data were reviewed by both an orthopedic and traumatology specialist and an infectious diseases specialist.

Sample Collection

Microbiological culture specimens were obtained using two distinct and complementary methods to ensure accurate identification of causative pathogens.

The first method involved intraoperative tissue biopsy collected during surgical debridement or revision. Tissue samples obtained in this manner are considered the gold standard for diagnosing deep infections or prosthesis-associated infections, as isolating organisms from infected tissue minimizes the risk of contamination from superficial flora.

The second method utilized the Levine swab culture technique, a semi-quantitative and standardized procedure commonly employed in wound microbiology. Using a sterile swab, the tip was rotated over a 1 cm^2 area of viable wound tissue for approximately five seconds. Sufficient pressure was applied to induce slight bleeding to access deeper tissue and reduce the likelihood of superficial colonization.

Before swab collection, the wound bed was carefully cleansed with sterile saline or water to remove necrotic tissue, exudate, and contaminants.

Patient Selection and Inclusion Criteria

Following the February 2023 earthquakes, a total of 7,317 patients were admitted to our hospital. This retrospective study included adult patients who underwent fasciotomy or presented with open wounds and exhibited clinical signs of infection. The diagnosis of wound infection or surgical site infection was based on the presence of clinical findings such as erythema, warmth, swelling, purulent discharge, delayed wound healing, new or increasing pain, or malodor. Wound cultures were obtained from these patients, and microbial growth was confirmed.

To establish two homogeneous study groups, specific patient subgroups were excluded from the analysis. A total of 1,931 patients were excluded for at least one of the following reasons: follow-up duration less than two years (n=225), insufficient data records (n=137), unspecified culture collection site (n=176), presence of both open wounds and fasciotomy sites (n=86), and absence of microbial growth in cultures (n=1,307). These exclusions were implemented to minimize potential confounding factors and ensure the reliability of microbiological and clinical comparisons between groups.

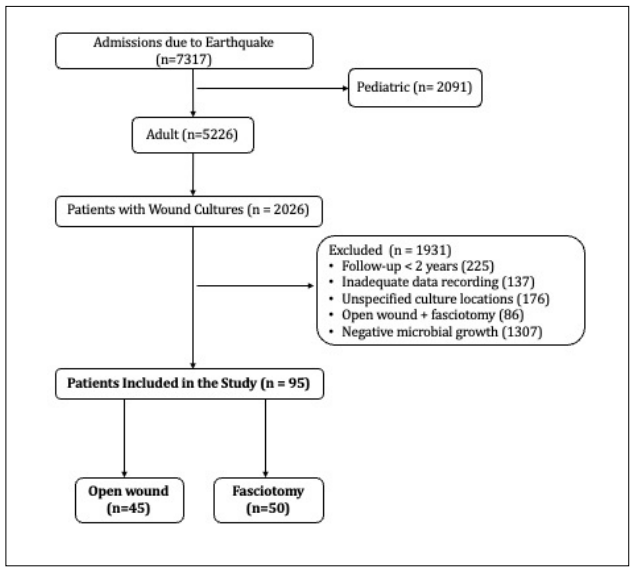

Figure 1. Patient flowchart.

As a result, 95 patients who met the inclusion criteria were included in the final analysis: 45 with open wounds and 50 with fasciotomy. This sample size was deemed sufficient to enhance the reliability of the study findings (Fig. 1).

Treatment Approach and Clinical Management

Empirical antibiotic therapy was initiated for patients with positive microbial growth in wound cultures, consisting of ceftriaxone (a third-generation cephalosporin) and metronidazole, as recommended by the infectious diseases department. Wounds that could be closed primarily were sutured after initial debridement. In cases of tissue loss or excessive tension, vacuum-assisted closure (VAC) therapy was utilized. When necessary, microvascular flap reconstruction or skin grafting was performed. Limb amputation was conducted in patients who demonstrated clinical deterioration.

Microbiological Analysis Procedure

Wound and intraoperative tissue cultures were obtained under sterile conditions and promptly transported to the laboratory. Specimens were inoculated onto blood agar and eosin methylene blue (EMB) agar plates and incubated at 37°C for 24–48 hours. Blood cultures were monitored for up to five days using the BD BACTEC™ FX system. Microorganism identification was performed using MALDI-TOF MS (Bruker Biotyper® Sirius) and the BD Phoenix™ M50 automated system. Antibiotic susceptibility testing was interpreted according to the 2023 guidelines of the European Committee on Antimicrobial Susceptibility Testing (EUCAST).

Statistical Analysis

The distribution of continuous variables was assessed with the Shapiro-Wilk test. Variables with a normal distribution are presented as mean±standard deviation (SD), whereas non-normally distributed variables are expressed as median [interquartile range, IQR]. Categorical variables are summarized as frequencies and percentages. For comparisons between groups, the Mann-Whitney U test was used for continuous variables, while Pearson's chi-square test or Fisher's exact test was applied for categorical variables, depending on sample size. A p-value <0.05 was considered statistically significant. All statistical analyses were performed using SPSS Statistics version 20.0.

RESULTS

The mean age of the 95 adult patients included in the study was 39.5±17.8 years (range: 18–97), and 44 (46.3%) were male (Table 1). Wound locations were distributed as follows: 23 (24.2%) in the upper extremity, 62 (65.3%) in the lower extremity (including 9 foot, 28 legs, and 25 thigh wounds), and 10 (10.5%) in the trunk (Table 2). There were no statistically significant differences in age or sex between patients who underwent fasciotomy (n=50) and those who did not (n=45) or between patients who underwent amputation (n=37) and those who did not (p>0.05).

Age is presented as mean±standard deviation (SD). Categorical variables such as sex, amputation status, and wound type are presented as frequencies and percentages. No statistically significant differences were observed in age or sex between patient groups (p>0.05).

Table 1. Demographic characteristics of the patients

Characteristic	Value	p-Value
Age (mean±SD)	39.5±17.8	>0.05
Sex		
Male	44 (46.3%)	>0.05
Female	51 (53.7%)	>0.05
Amputation	37 (38.9%)	0.143
Fasciotomy	50 (52.6%)	>0.05
Open Wound	45 (47.4%)	>0.05

Age is presented as mean±standard deviation (SD). Categorical variables such as sex, amputation status, and wound type are presented as frequencies and percentages. No statistically significant differences were observed in age or sex between patient groups (p>0.05).

Table 2. Distribution of wound localizations

Wound Localization	Number of Patients (%)
Upper Extremity	23 (24.2%)
Lower Extremity	62 (65.3%)
Thigh	25
Leg	28
Foot	9
Body	10 (10.5%)

Table 3. Distribution of isolated microorganisms by wound type, with total case numbers and percentages

	Fasciotomy (n=50)		Open Wound (n=45)		Total (n=95)		
Microorganism	**n**	**%**	**n**	**%**	**n**	**%**	**p**
Polymicrobial	16	32.00	14	31.10	30	31.58	1.000
Acinetobacter spp.	20	40.00	5	11.11	25	26.32	0.002
Escherichia coli	2	4.00	7	15.56	9	9.47	0.080
Pseudomonas spp.	6	12.00	2	4.44	8	8.42	0.273
Staphylococcus aureus	4	8.00	2	4.44	6	6.32	0.684
Klebsiella spp.	3	6.00	2	4.44	5	5.26	1.000
Enterobacter spp.	1	2.00	3	6.67	4	4.21	0.616
Enterococcus spp.	2	4.00	2	4.44	4	4.21	1.000
Streptococcus spp.	0	0.00	1	2.22	1	1.05	0.488
Proteus spp.	1	2.00	0	0.00	1	1.05	1.000
Bacillus spp.	0	0.00	1	2.22	1	1.05	0.488
Candida spp.	1	2.00	0	0.00	1	1.05	1.000

P-values were calculated using Fisher's exact test for all comparisons due to low cell counts.

Microbiological Findings

Polymicrobial infections were identified in 30 of 95 patients (31.6%). The most frequently isolated microorganisms were *Acinetobacter spp.* (n=25, 26.3%), *Escherichia coli* (n=9, 9.5%), Pseudomonas aeruginosa (n=8, 8.4%), *Staphylococcus aureus* (n=6, 6.3%), and *Klebsiella spp.* (n=5, 5.3%). Other isolates included *Enterobacter spp.* and *Enterococcus spp.* (each n=4, 4.2%), as well as *Streptococcus spp., Proteus spp., Bacillus spp., and Candida spp.* (each n=1, 1.1%).

Comparison of Fasciotomy and Open Wound Groups

Of the patients included in the study, 52.6% (n=50) were in the fasciotomy group and 47.4% (n=45) were in the open wound group. The rate of polymicrobial growth was 32.0% (16/50) in the fasciotomy group and 31.1% (14/45) in the open wound group, with no statistically significant difference between groups (p=1.000). When polymicrobial cultures were excluded from the analysis, a statistically significant difference was observed in the overall distribution of isolated microorganisms (overall p=0.048).

Acinetobacter spp. was the most frequently isolated microorganism, being significantly more prevalent in the fasciotomy group (40.0%; 20/50) than in the open wound group (11.1%; 5/45) (p=0.0021; statistically significant). Although *Escherichia coli* was more frequently isolated in the open wound group (15.6%; 7/45) than in the fasciotomy group (4.0%; 2/50), this difference did not reach statistical significance (p=0.0799). *Pseudomonas spp.* was isolated in 12.0% (6/50) of fasciotomy patients and 4.4% (2/45) of open wound patients (p=0.273). For other microorganisms, no statistically significant differences were observed between groups (all p>0.05).

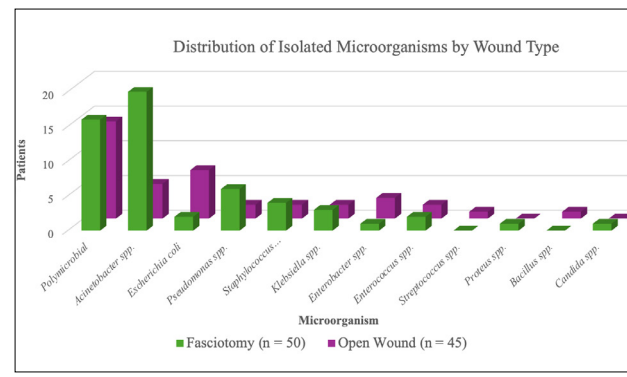

Figure 2. Comparative distribution of isolated microorganisms in fasciotomy and open wounds.

The distribution of all microorganisms isolated by wound type is presented in Table 3 and Figure 2.

Microbiological Findings in Patients With and Without Amputation

A total of 37 patients (38.95%) underwent limb amputation; of these, 21 (56.8%) were from the fasciotomy group and 16 (43.2%) from the open wound group. Polymicrobial infections were observed in 37.84% (14/37) of amputated patients and in 27.59% (16/58) of non-amputated patients (p=0.367). The most frequently isolated microorganisms in the amputated group were *Acinetobacter spp.* (n=13, 35.14%) and *Klebsiella spp.* (n=3, 8.11%). In the non-amputated group, the most common isolates were *Acinetobacter spp.* (n=12, 20.69%), *Escherichia coli* (n=7, 12.07%), *Pseudomonas spp.*

Table 4. Distribution of isolated microorganisms by amputation status

Microorganism	Amputated (n=37, 38.95%)		Non-Amputated (n=58, 61.05%)		Total (n=95)		p
	n	%	n	%	n	%	
Polymicrobial	14	37.84	16	27.59	30	31.58	0.367
Acinetobacter spp.	13	35.14	12	20.69	25	26.32	0.153
Escherichia coli	2	5.41	7	12.07	9	9.47	0.475
Pseudomonas spp.	2	5.41	6	10.34	8	8.42	0.477
Staphylococcus aureus	0	0.00	6	10.34	6	6.32	0.078
Klebsiella spp.	3	8.11	2	3.45	5	5.26	0.374
Enterobacter spp.	1	2.70	3	5.17	4	4.21	1.000
Enterococcus spp.	1	2.70	3	5.17	4	4.21	1.000
Streptococcus spp.	0	0.00	1	1.72	1	1.05	1.000
Proteus spp.	1	2.70	0	0.00	1	1.05	0.389
Bacillus spp.	0	0.00	1	1.72	1	1.05	1.000
Candida spp.	0	0.00	1	1.72	1	1.05	1.000

All p-values were calculated using Fisher's exact test.

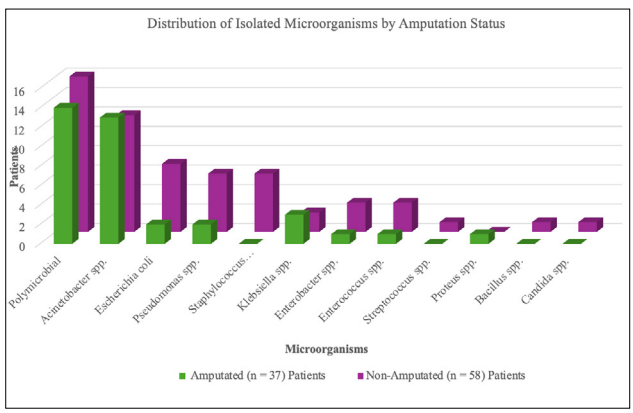

Figure 3. Relationship between isolated microorganisms and amputation status.

(n=6, 10.34%), and *Staphylococcus aureus* (n=6, 10.34%). No statistically significant differences were observed in the distribution of isolated microorganisms between amputated and non-amputated groups (all p>0.05).

The rate of *Acinetobacter spp.* isolation was higher in amputated patients, approaching statistical significance (35.14% vs. 20.69%; p=0.153). This finding suggests a possible association between Acinetobacter infection and an increased risk of amputation. Detailed distributions are presented in Table 4 and Figure 3.

Antimicrobial Resistance Patterns

Carbapenem resistance was identified in 86.5% (n=32) and colistin resistance in 10.8% (n=4) of *Acinetobacter spp.* isolates. Among the Pseudomonas aeruginosa strains, three were resistant to carbapenems and one was resistant to colistin. Of the eight *Klebsiella spp.* isolates, colistin resistance was detected in five.

DISCUSSION

This study demonstrated a statistically significant difference in the microbiological growth profiles of patients with open wounds compared to those who underwent fasciotomy. Across the entire cohort (including polymicrobial infections), the most frequently isolated microorganism was *Acinetobacter spp.*, which was identified in 40% of the fasciotomy group and 11% of the open wound group. Furthermore, the isolation rate of *Acinetobacter spp.* was 35.14% among amputated patients and 20.69% among those who did not undergo amputation. These findings suggest that *Acinetobacter spp.* infections may represent an important risk factor for the development of limb amputation.

Open wounds are frequently contaminated with foreign material during earthquakes, creating a conducive environment for infection development.[11] One of the major challenges in managing post-earthquake traumatic injuries is the risk of developing primary or secondary infections.[24] Such infections are associated with increased morbidity and mortality, prolonged hospital stays, and the need for additional surgical interventions.[10] In disaster surgery, there is consensus that all open wounds should be considered potentially infected.[3] According to the literature, the most commonly isolated pathogens in these wounds are *Streptococcus spp.*, *Staphylococcus spp.*, and *anaerobic bacteria*.[12] In contrast, in our study, *Aci-*

netobacter spp. and *Escherichia coli* were the most frequently isolated pathogens. This discrepancy may be attributed to the fact that, in our cohort, specimens were collected prior to antibiotic administration and before the initial debridement.

Fasciotomy is a limb- and life-saving intervention in emergencies such as compartment syndrome, and early application is recommended.[13,14] However, fasciotomy wounds represent a predisposing factor for the development of infection and sepsis.[3] Post-fasciotomy surgical site infections may lead to serious complications, including amputation.[15] In our study, *Acinetobacter spp*. was isolated in 40% of fasciotomy wound cultures, underscoring the infection risk associated with this procedure. Furthermore, the isolation rate of *Acinetobacter spp*. was 35.14% in amputated patients and 20.69% in non-amputated patients. These findings suggest that *Acinetobacter spp*. infections may be an important risk factor for the development of limb amputation.

In the study conducted by Özdemir et al.,[2] polymicrobial growth was identified in 64.7% of culture-positive cases; however, the type of wounds from which the cultures were obtained (fasciotomy versus open wound) was not specified. In our study, the rate of polymicrobial growth was 32.0% among fasciotomy cases and 31.1% among open wound cases. This proportional difference may be attributable to the exclusion, from our study, of patients who had cultures obtained from multiple anatomical sites simultaneously or who presented with both open wounds and fasciotomy sites.

In two separate studies conducted after the 1999 earthquakes, the rates of Gram-negative bacterial isolation were reported as 81.3% and 87.3%, respectively, with *Acinetobacter baumannii* identified as the most frequently isolated pathogen.[6,16] Subsequent studies have also confirmed the prominent role of *Acinetobacter* species in post-disaster infections.[4,8,17-20] Consistent with these findings, in our study, *Acinetobacter* species were the most frequently isolated microorganisms in both the fasciotomy group (40%) and the overall patient cohort (26.3%).

Eryılmaz-Eren et al. (2024)[25] reported the role of *Acinetobacter spp*. in hospital-acquired infections following the same disaster. In our study, *Acinetobacter spp*. was detected in 11.11% of open-wound cultures, suggesting that these isolates may originate not only from nosocomial sources but also from environmental and traumatic exposures.

Although Gram-negative bacteria are the principal pathogens in post-earthquake infections, resistant strains are particularly prominent in hospital-acquired infections.[8,18] Previous studies have demonstrated that resistant forms of *Acinetobacter baumannii* are frequently isolated following major disasters.[21] Kiani et al.[22] reported that 61.5% of Gram-negative bacteria isolated from wound infections were multidrug-resistant. Similarly, Wang et al.[9] found that approximately 65% of *Acinetobacter spp*. isolates obtained after earthquakes were resistant to carbapenems. Tao et al.[19] reported that 24.6% of their isolated *A. baumannii* strains were completely drug-resistant (pandrug-resistant). In our study, comparably high resistance rates were also observed. These high resistance rates complicate empirical antibiotic selection in the management of post-disaster wound infections and highlight the increasing need for broad-spectrum antimicrobial agents.

Early identification of infections, microbiological confirmation via culture, and the implementation of targeted, pathogen-specific treatment strategies are essential to improve therapeutic efficacy and patient outcomes.[10,18] However, in disaster settings, empirical therapy is often prioritized due to high patient volumes, with treatment subsequently adjusted according to culture results. In our study, *Acinetobacter spp*. was the most frequently isolated microorganism in the overall cohort. *Pseudomonas spp*. was more commonly isolated in the fasciotomy group (12.0%), whereas *Escherichia coli* was more frequently found in the open wound group (15.56%). Our findings, notably the considerable rates of Escherichia coli and polymicrobial infections in open wounds (in addition to *Acinetobacter spp*.), suggest that complex post-disaster wound infections may involve multiple pathogens, underscoring the need to consider broad-spectrum antibiotics in empirical therapy. Conversely, the isolation of pathogens such as *Pseudomonas spp*., *Staphylococcus aureus*, and *Klebsiella spp*. in the fasciotomy group further emphasizes the importance of culture-based and targeted treatment strategies in infection management.

According to the 2017 Centers for Disease Control and Prevention (CDC) guidelines, anti-staphylococcal β-lactam antibiotics and clindamycin are recommended for the treatment of post-traumatic wound infections, while the World Health Organization (WHO) recommends the use of penicillin G and metronidazole.[26,27] However, numerous investigators—notably Miskin et al.[8]—have emphasized that these recommendations may be insufficient to address the growing trend of antimicrobial resistance.[9,18,22,23] The addition of broad-spectrum antibiotics effective against resistant Gram-negative pathogens to empirical therapy in disaster settings may substantially improve clinical management.

These findings underscore the need to expand microbiological surveillance and implement rapid diagnostic and treatment algorithms in the management of post-disaster wound infections. Moreover, to reduce the risk of amputation, it is essential to integrate pathogen-specific guidelines and regional antibiotic resistance data into health policy.

This study has several limitations. Its retrospective design may introduce selection and reporting bias, thereby limiting the generalizability of the findings. The relatively small sample size may also constrain the statistical power of the analyses. Additionally, the single-center nature of the study restricts the extrapolation of results to other patient populations. Furthermore, potential confounding factors—such as inter-hospital transfers, empiric antibiotic therapy initiated prior to

admission, and the timing of initial debridement—may have influenced the microbiological findings and clinical outcomes. Multicenter, prospective, randomized controlled studies involving larger patient cohorts are needed to validate these results.

CONCLUSION

This study demonstrates that the microbiological profile of wound infections may vary significantly according to the source of infection (open wound vs. fasciotomy) and highlights the necessity of individualized treatment strategies based on the specific characteristics of the infection. Moreover, *Acinetobacter spp*. infections were identified as a potentially important risk factor for limb amputation. Our findings emphasize the critical importance of early and appropriate pathogen-targeted treatment strategies in the management of post-earthquake wound infections.

Ethics Committee Approval: This study was approved by the Ankara Etlik City Hospital Clinical Research Ethics Committee (Date: 09.08.2023, Decision No: AEŞH-EK1-2023-08).

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

2023 Türkiye depremleri sonrası fasyotomi ve açık yaralarda mikrobiyal profiller ve ampütasyon riski

AMAÇ: Bu retrospektif tek merkezli çalışma, 6 Şubat 2023 Kahramanmaraş depremleri sonrası ekstremite yaralanmasına bağlı gelişen yara enfeksiyonlarının mikrobiyal profillerini ve bu enfeksiyonların ampütasyon riskiyle ilişkisini değerlendirmeyi amaçlamıştır.

GEREÇ VE YÖNTEM: Çalışmaya, deprem sonrası yara enfeksiyonu gelişen ve kültür pozitif olan 95 erişkin hastanın fasyotomi grubu: 50, açık yara grubu: 45 olmak üzere iki grup dahil edilmiştir.

BULGULAR: En sık izole edilen mikroorganizma Acinetobacter spp. olup, fasyotomi grubunda bu patojenin izolasyon oranı açık yara grubuna göre anlamlı olarak daha yüksek bulunmuştur (%40 vs. %11.1; p=0.0021). Açık yara grubunda ise *Escherichia coli* izole oranı daha yüksek olmasına rağmen, bu farklılık istatistiksel olarak anlamlı değildir. Her iki grupta polimikrobiyal enfeksiyon oranları benzer bulunmuştur. Antibiyotik duyarlılık analizlerinde, *Acinetobacter spp.* izolatlarının %86.5'inin karbapenemlere ve %10.8'inin kolistine dirençli olduğu gösterilmiştir. Ampütasyon yapılan hastalarda *Acinetobacter spp.* izolasyon oranı %35.14 ile ampütasyon yapılmayanlara (%20.69) göre daha yüksek bulunmuş, ancak bu farklılık istatistiksel anlamlılığa ulaşmamıştır.

SONUÇ: Bulgularımız, deprem sonrası yara enfeksiyonlarında patojen profilinin yara tipine göre değişiklik gösterebileceğini ve yüksek antibiyotik direncine sahip *Acinetobacter spp.* enfeksiyonlarının ampütasyon açısından potansiyel bir risk faktörü olabileceğini düşündürmektedir. Sonuç olarak, afet sonrası gelişen yara enfeksiyonlarının kaynak temelli değerlendirilmesi, erken ve hedefe yönelik tedavi stratejilerinin planlanması ve yüksek dirençli patojenlere karşı etkili yaklaşımların geliştirilmesi, ampütasyon riskinin azaltılması açısından kritik öneme sahiptir.

Anahtar sözcükler: Açık yara; ampütasyon; deprem; enfeksiyon; fasyotomi.

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ORIGINAL ARTICLE

Validation of the study of the management of blunt chest wall trauma (STUMBL) score for predicting in-hospital complications in patients with blunt chest trauma

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ABSTRACT

BACKGROUND: This study aimed to validate the Study of the Management of Blunt Chest Wall Trauma (STUMBL) score as a prognostic tool for predicting in-hospital complications in patients with blunt chest trauma admitted to a tertiary care hospital emergency department.

METHODS: A retrospective cohort study was conducted between January 2022 and January 2024. Adult patients (≥18 years) diagnosed with blunt thoracic trauma were included. Data were collected from electronic health records. Complications included pulmonary infections, pleural effusion, pneumothorax, intensive care unit (ICU) admission, and prolonged hospital stay. Discriminative performance was evaluated using receiver operating characteristic (ROC) analysis, with calculation of the area under the ROC curve (AUROC) and the area under the precision-recall curve (AUPRC).

RESULTS: A total of 536 patients were included, of whom 150 (28.0%) developed in-hospital complications. Patients with complications had significantly higher STUMBL scores (median 13 vs. 6, p<0.001). The STUMBL score demonstrated strong discriminative ability, with an AUROC of 0.934 (95% confidence interval [CI], 0.909-0.959) and an AUPRC of 0.889 (95% CI: 0.847-0.924). The optimal cutoff value identified was 20.5; for clinical applicability, this was rounded to ≥21, yielding a sensitivity of 84% and a specificity of 89%.

CONCLUSION: The STUMBL score demonstrated excellent performance in predicting in-hospital complications among patients with blunt chest trauma. Its simplicity and strong predictive value suggest it can be effectively incorporated into emergency department clinical decision-making.

Keywords: The Study of the Management of Blunt Chest Wall Trauma (STUMBL) score; blunt chest trauma; risk stratification.

INTRODUCTION

Blunt chest trauma is a common cause of emergency department admissions worldwide, with clinical presentations ranging from minor contusions to life-threatening thoracic injuries. In the United States, it accounts for approximately 15% of trauma-related hospital visits, with significant implications for morbidity and healthcare resource utilization. Recent research has emphasized the importance of simple, accessible clinical predictors in thoracic trauma to support early decision-making and risk stratification.[1,2] Early identification of patients at increased risk of complications is essential for guiding management decisions, allocating resources efficiently, and improving clinical outcomes.[3,4]

Several clinical prediction tools have been developed to aid risk stratification in trauma patients, but few have demonstrated consistent external validity across different populations.

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The Study of the Management of Blunt Chest Wall Trauma (STUMBL) score was specifically designed for use in the emergency department, integrating age, rib fracture count, peripheral oxygen saturation (SpO_2), anticoagulant use, and chronic lung disease into a single prognostic framework.[5] Early studies have reported promising discriminatory performance of the STUMBL score,[6,7] but further validation in varied healthcare settings remains necessary. Additionally, concerns persist regarding the score's calibration and practical utility when applied to broader clinical cohorts.[8,9]

This study aims to validate the performance of the STUMBL score in predicting in-hospital complications among adult patients with blunt chest trauma.

MATERIALS AND METHODS

This retrospective cohort study was conducted in the emergency department of Kartal Dr. Lütfi Kırdar City Hospital Patients who presented to the emergency department with blunt chest trauma and were subsequently hospitalized between January 1, 2022 and January 1, 2024, were included. The hospital is a high-volume urban trauma center equipped with comprehensive emergency and critical care services. This study was approved by the Ethics Committee of Kartal Dr. Lütfi Kırdar Hospital (decision number: 2024/010.99/11/34, dated 25/12/2024) and conducted in accordance with the principles of the Declaration of Helsinki. Due to its retrospective nature, the requirement for informed consent was waived.

Eligible patients were adults aged 18 years and older who presented with blunt chest trauma, were hospitalized for further management, and had complete clinical and imaging data. Inclusion criteria included isolated blunt thoracic trauma, defined as thoracic injuries without major associated injuries in other body regions, with an Abbreviated Injury Scale (AIS) score <2 for non-thoracic regions. Patients with missing essential data or incomplete trauma severity scoring (AIS or Injury Severity Score [ISS]) were excluded from the study.

Data were extracted retrospectively from the hospital's health information management system using a standardized electronic data collection form developed in Microsoft Excel (Microsoft Corporation, Redmond, WA, USA). Information collected included demographic data (age, sex), clinical variables (number of rib fractures, peripheral oxygen saturation, respiratory rate, blood pressure, heart rate, and body temperature), comorbidities (such as chronic lung disease), medication use (anticoagulants, antiplatelets, nonsteroidal anti-inflammatory drugs [NSAIDs], and opioids), imaging findings (chest computed tomography [CT]), and in-hospital outcomes (pulmonary complications, intensive care unit [ICU] admission, and prolonged length of stay).

The STUMBL score was calculated for each patient based on the presence and severity of five variables: age, number of rib fractures, peripheral oxygen saturation, anticoagulant use, and chronic lung disease.[3] The score was determined by summing weighted values for these variables: age (1 point per 10 years starting from age 10), number of rib fractures (3 points per rib), chronic lung disease (5 points if present), pre-injury use of anticoagulants (4 points), and oxygen saturation, stratified as follows: 0 points for ≥95%, 2 points for 90-94%, 4 points for 85-89%, and 6 points for 80-84%. Higher scores indicated an increased risk of in-hospital complications. The STUMBL score was calculated using clinical and imaging data obtained at the time of emergency department presentation.

The primary outcome was the occurrence of any in-hospital complication, defined as pulmonary infection, pleural effusion, pneumothorax, hemothorax, pleural empyema, ICU admission, or prolonged hospitalization (≥7 days).

Statistical Analysis

Descriptive statistics were calculated for all variables and stratified by in-hospital complication status. Categorical variables were presented as counts and percentages and compared using Pearson's chi-squared test or Fisher's exact test, as appropriate. Continuous variables were assessed for normality using histograms and presented as mean ± standard deviation or median [interquartile range], depending on distribution. Comparisons between groups were performed using Student's t-test or the Mann-Whitney U test. For normally distributed variables with $p<0.05$, mean differences with 95% confidence intervals were reported. The discriminative performance of the STUMBL score was evaluated using the area under the receiver operating characteristic curve (AUROC) and the area under the precision-recall curve (AUPRC). Given the imbalanced distribution of complications (28% prevalence), the AUPRC was additionally calculated, as it provides a more informative measure of predictive performance than the AUROC alone under class imbalance. The optimal cutoff was determined using the Youden index. Diagnostic performance metrics—including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), accuracy, and likelihood ratios (+LR and -LR)—were calculated with corresponding 95% confidence intervals. To explore potential latent heterogeneity in score performance, latent class regression (LCR) was performed. A set of candidate covariates not included in the STUMBL score was selected using least absolute shrinkage and selection operator (LASSO) logistic regression with 10-fold cross-validation. The LCR model incorporated these variables along with the total STUMBL score. Models with one to four latent classes were fitted, and the optimal model fit was assessed using the Bayesian Information Criterion (BIC). All analyses were conducted using R version 4.4.2 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

A total of 536 patients with blunt chest trauma were included in the study. The median ISS was 9 [interquartile range (IQR), 5-13], reflecting moderate injury severity across the cohort. As per the study inclusion criteria, all patients had AIS scores <2 for non-thoracic regions. Of these, 150 (28.0%) experienced one or more in-hospital complications, while 386 (72.0%) had none. The primary outcome group included pulmonary complications (e.g., infection, effusion, pneumothorax), pleural empyema, ICU admission, or prolonged hospital stay (≥7 days).

Demographic, clinical, and physiologic characteristics stratified by complication status are presented in Table 1. Patients who developed complications were significantly older (median 71 [IQR 61-80] vs. 62 [51-70] years, p<0.001), had a higher Charlson Comorbidity Index (3 [2-4] vs. 1 [0-2], p<0.001), and exhibited more rib fractures (5 [4-6] vs. 2 [1-3], p<0.001). They also had lower SpO_2 (94% [92-96] vs. 97% [97-98], p<0.001), higher respiratory rates, and more abnormal vital signs. STUMBL scores were substantially higher in the complication group (13 [9-17] vs. 6 [4-9], p<0.001).

Medication use, imaging utilization, and outcome components are summarized in Table 2. The complication group had higher rates of anticoagulant and antiplatelet use, chronic lung disease, and received more opioid analgesia in the emergency department. Among the 150 patients with complications, pulmonary infection occurred in 42 (28%), pleural effusion in 37 (25%), pneumothorax in 40 (27%), hemothorax in 25 (17%), pleural empyema in 12 (8%), ICU admission in 49 (33%), and prolonged hospital stay (≥7 days) in 98 (65%).

Table 1. Demographic, clinical, and physiologic characteristics by complication status

Variable	No Complication (n=386)	Complication (n=150)	p	Mean Difference (95% CI)
Age, years	62 [51-70]	71 [61-80]	<0.001	-
Male sex, n (%)	241 (62%)	92 (61%)	0.049	-
Charlson Comorbidity Index	1 [0-2]	3 [2-4]	<0.001	-
Rib fractures, n	2 [1-3]	5 [4-6]	<0.001	-
SpO_2, %	97 [97-98]	94 [92-96]	<0.001	-
Respiratory rate, /min	19 [17-20]	22 [20-25]	<0.001	-
Systolic BP, mmHg	134 [123-146]	129 [115-143]	<0.001	-
Diastolic BP, mmHg	79 [72-86]	72 [64-80]	<0.001	6.46 (4.53 to 8.40)
Heart rate, bpm	84 [76-93]	96 [84-110]	<0.001	13.42 (10.50 to 16.34)
Body temperature, °C	37.0 [36.6-37.3]	37.4 [36.9-38.0]	<0.001	0.48 (0.33 to 0.63)
LOS, days	2 [1-4]	10 [6-16]	<0.001	-
STUMBL score	6 [4-9]	13 [9-17]	<0.001	-

SpO_2: Peripheral Oxygen Saturation; LOS: Length of Stay; BP: Blood Pressure; bpm: Beats per Minute; °C: Degrees Celsius.

Table 2. Medication use, imaging, and complications by complication status

Variable	No Complication (n=386)	Complication (n=150)	p
Anticoagulant use, n (%)	33 (9%)	40 (27%)	<0.001
Antiplatelet use, n (%)	49 (13%)	41 (27%)	<0.001
Chronic lung disease, n (%)	30 (8%)	40 (27%)	<0.001
Chest CT performed, n (%)	316 (82%)	138 (92%)	0.005
High-risk mechanism, n (%)	73 (19%)	47 (31%)	0.003
Paracetamol use, n (%)	308 (80%)	119 (79%)	1.000
NSAID use, n (%)	209 (54%)	61 (41%)	0.007
Opioid use, n (%)	65 (17%)	49 (33%)	<0.001

Chest CT: Computed Tomography of the Chest; NSAID: Nonsteroidal Anti-Inflammatory Drug.

Table 3. Discriminative performance of the Study of the Management of Blunt Chest Wall Trauma Score (STUMBL)

Metric	Value	95% Confidence Interval
AUROC	0.934	0.909-0.959
AUPRC	0.889	0.847-0.924
Optimal cutoff (Youden index)	≥21	—
Sensitivity	0.84	0.78-0.90
Specificity	0.89	0.85-0.92
PPV	0.74	0.67-0.81
NPV	0.94	0.91-0.96
+LR	7.49	5.62-9.96
-LR	0.17	0.11-0.24
Accuracy	0.88	0.85-0.90

All values were calculated at the optimal cutoff of ≥20.5 derived from the Youden index. AUROC: Area Under the Receiver Operating Characteristic Curve; AUPRC: Area Under the Precision-Recall Curve; PPV: Positive Predictive Value; NPV: Negative Predictive Value; +LR/-LR: Positive/Negative Likelihood Ratio.

The STUMBL score demonstrated strong discriminative ability for predicting in-hospital complications (Table 3). The area under the receiver operating characteristic curve (AUROC) was 0.934 (95% confidence interval [CI]: 0.909-0.959), while the area under the precision-recall curve (AUPRC) was 0.889 (95% CI: 0.847-0.924). The optimal cutoff identified by the Youden index was 20.5. For clinical use, this threshold was rounded to the nearest integer (≥21), which demonstrated comparable diagnostic performance (sensitivity 84% [95% CI: 78-90%], specificity 89% [95% CI: 85-92%]), a positive predictive value of 74%, and a negative predictive value of 94%. The corresponding positive and negative likelihood ratios were +LR=7.49 (95% CI: 5.62-9.96) and -LR=0.17 (95% CI: 0.11-0.24), respectively. Discrimination curves are shown in Figure 1.

As an exploratory adjunct to score validation, we performed latent class regression to assess potential heterogeneity in STUMBL score performance across unobserved patient subgroups. To avoid redundancy, the five variables already embedded in the STUMBL score (age, rib fracture count, SpO_2, anticoagulant use, and chronic lung disease) were excluded from multivariate consideration. The remaining covariates were subjected to LASSO logistic regression with 10-fold cross-validation (optimal penalization lambda=0.0031). This process identified 11 variables with nonzero coefficients: sex (male), Charlson Comorbidity Index, respiratory rate, systolic and diastolic blood pressure, heart rate, temperature, high-risk mechanism of injury, chest CT performed, antiplatelet use, NSAID use, and opioid use.

These 11 covariates were incorporated into the LCR model alongside the total STUMBL score, and models with 1 to 4 latent classes were compared using the Bayesian Information Criterion. The two-class model yielded groups of 20 and 516 patients, with modest differences in mean STUMBL scores (19.5 vs. 17.6) and complication rates (40.0% vs. 27.5%). However, the lowest BIC was observed for the one-class

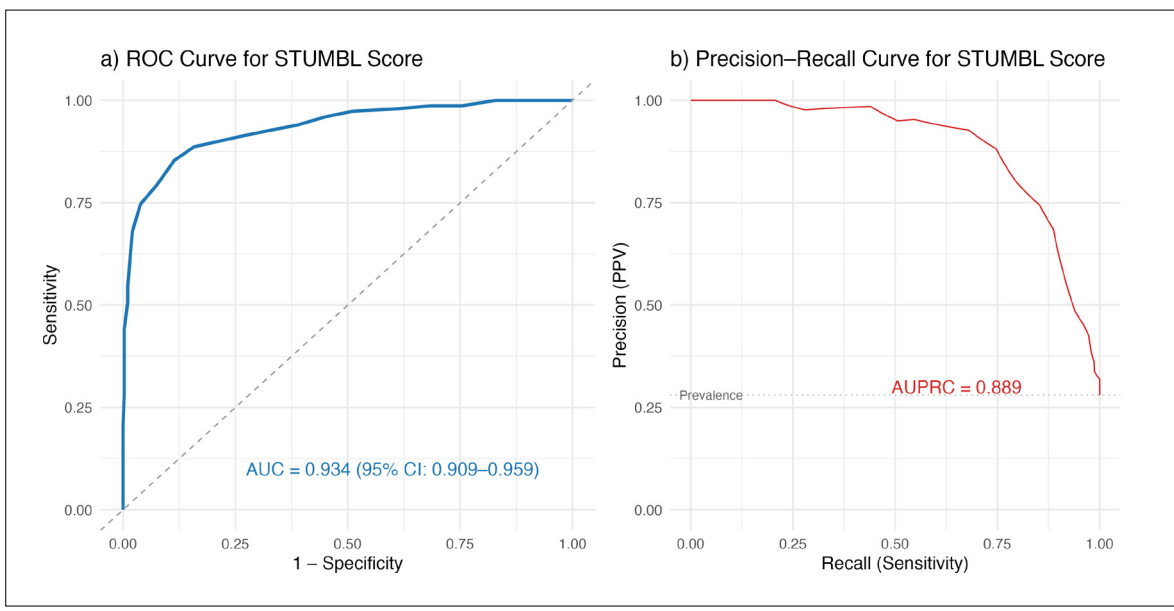

Figure 1. Receiver Operating Characteristic (ROC) and precision-recall curves for the Study of the Management of Blunt Chest Wall Trauma Score (STUMBL): **(a)** ROC curve with the area under the receiver operating characteristic (AUROC) and 95% confidence interval for prediction of in-hospital complications. **(b)** Precision-recall curve with baseline prevalence and area under the precision-recall curve (AUPRC).

Table 4. Latent class regression analysis of the Study of the Management of Blunt Chest Wall Trauma Score (STUMBL) performance

Metric	Class 1 (n=20)	Class 2 (n=516)
Complications, n (%)	8 (40.0%)	142 (27.5%)
Mean STUMBL Score	19.5	17.6
BIC (k=2)	268.1	-
Best BIC (k=1)	222.1	-

Latent class regression (LCR) was performed using the Study of the Management of Blunt Chest Wall Trauma Score (STUMBL) score and least absolute shrinkage and selection operator (LASSO)-selected covariates. The Bayesian Information Criterion (BIC) was used to evaluate model fit across 1-4 classes. The model with k=1 latent class demonstrated the best fit (lowest BIC), indicating homogeneity in score performance across subgroups.

model (BIC=222.1), indicating a homogeneous latent structure. Accordingly, no evidence was found for clinically meaningful latent subgroups with differential score performance. As illustrated in Figure 2, the two-class model showed modest differences between classes, with Class 1 having a higher mean STUMBL score (19.5 vs. 17.6) and a higher complication rate (40.0% vs. 27.5%). Summary data are presented in Table 4, and a visual comparison of class-wise STUMBL scores and complication rates is shown in Figure 2.

DISCUSSION

This study demonstrated that the STUMBL score has strong discriminatory ability in predicting in-hospital complications among adult patients hospitalized with isolated blunt chest trauma.

Blunt chest trauma continues to pose significant challenges in emergency and trauma care settings due to its association with pulmonary complications, prolonged hospital stays, and increased mortality.[10-12] Accurate early risk stratification is essential for directing appropriate interventions, preventing deterioration, and optimizing resource use. Prognostic models like the STUMBL score, which rely on easily obtainable clinical parameters, may bridge the gap between initial evaluation and more advanced diagnostic procedures, offering a pragmatic approach to clinical decision-making.[13-16] Because the STUMBL score is derived from readily available data at presentation, it can support early triage decisions in the emergency department, potentially guiding timely resource allocation and monitoring.

In this retrospective cohort, the STUMBL score effectively identified patients at risk of in-hospital complications following isolated blunt chest trauma. Its clinical performance in our population is consistent with prior validations across different healthcare systems. Mukerji et al.[7] demonstrated that the score retained good discriminatory ability in a multiethnic New Zealand cohort, particularly for predicting ICU admissions and prolonged hospitalization, although they noted challenges in calibration among non-European populations. Similarly, Giamello et al.[6] confirmed high AUROC values in their Italian study, supporting the score's robustness across European settings. In the UK, Callisto et al.[9] observed that while clinician judgment often influenced triage decisions, the STUMBL score nonetheless showed significant concordance with actual complication outcomes. These findings, along with our results, suggest that the STUMBL score offers added value as an objective adjunct to bedside assessment. Although the receiver operating characteristic-derived (ROC-derived) cutoff was 20.5, we reported the clinically applicable integer threshold of ≥21. This adjustment preserved nearly identi-

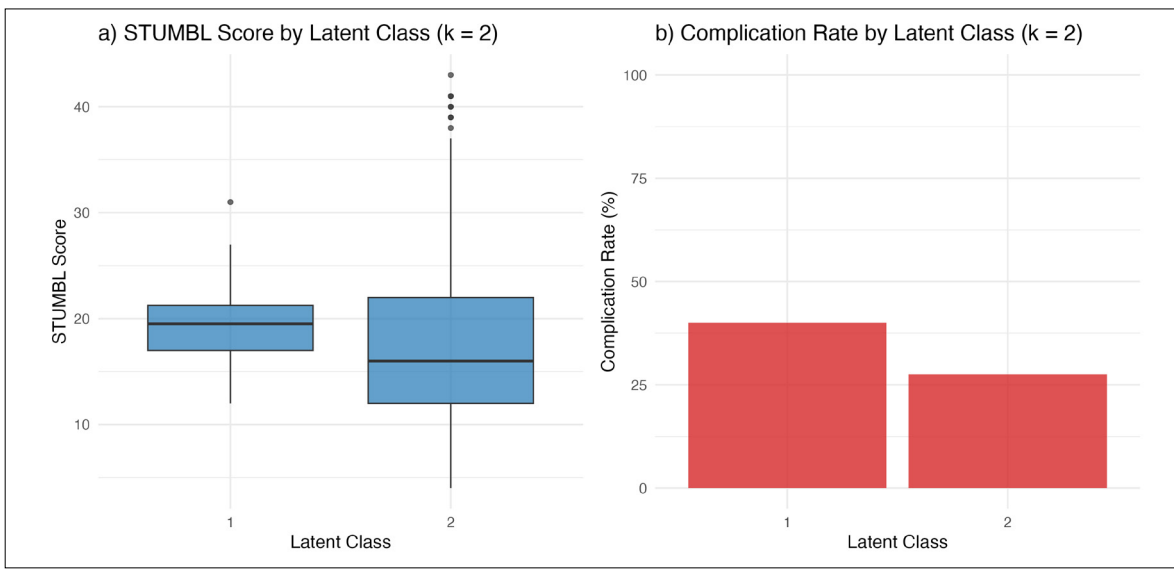

Figure 2. Latent class regression subgroup characteristics: **(a)** Distribution of the Study of the Management of Blunt Chest Wall Trauma Score (STUMBL) by latent class (k=2). **(b)** Complication rates (%) by latent class (k=2)

cal diagnostic performance (sensitivity 84%, specificity 89%) while ensuring practicality in real-world decision-making. Presenting integer-based thresholds is consistent with previous studies, thereby enhancing the score's comparability and clinical usability.

Additional evidence from prospective and systematic evaluations further contextualizes these findings. The STUMBL feasibility trial conducted by Battle et al.[17] indicated that while the score was well accepted by clinicians and integrated smoothly into ED workflows, there was no statistically significant difference in patient outcomes compared to conventional management, underscoring the need for a definitive impact trial. The absence of a statistically significant difference in outcomes in the feasibility trial primarily reflects its design as a feasibility and implementation study rather than a definitive efficacy trial. Accordingly, our findings complement Battle et al.'s[18] work by demonstrating robust predictive validity for the STUMBL score in a larger retrospective cohort. Moreover, a 2024 systematic review comparing 22 clinical prediction models for blunt chest trauma found that although STUMBL demonstrated superior predictive accuracy and external validation performance compared to many alternatives, concerns remained regarding risk of bias and calibration inconsistencies in some studies. Overall, our findings reinforce the score's utility in structured risk assessment but also highlight the need for careful consideration of its role within broader clinical and institutional frameworks.

Several limitations inherent to the study design must be acknowledged. The retrospective nature of the data collection process introduces the potential for selection and information biases. Additionally, as the study was conducted at a single tertiary care center, the generalizability of the findings to other settings, such as rural or lower-resource hospitals, may be limited. Although isolated thoracic trauma was strictly defined using AIS scores, subtle or clinically minor extra-thoracic injuries could have been underrecognized, even with comprehensive imaging and clinical assessments. Moreover, while the STUMBL score captures key risk factors, other variables potentially influencing outcomes might not have been fully accounted for within the scope of the study. Lastly, the relatively high AUROC reported in this single-center retrospective study may partly reflect selection bias or model overfitting. This limitation underscores the need for confirmation through future prospective and multicenter investigations to ensure external validity.

CONCLUSION

This study validates the STUMBL score as a reliable and practical tool for predicting in-hospital complications in patients with isolated blunt chest trauma. The strong discriminatory performance observed supports its potential integration into clinical decision-making pathways in emergency settings. Given its reliance on readily available clinical parameters and straightforward calculation, the STUMBL score can be quickly implemented at the bedside. The identified cutoff value of ≥20.5 may help clinicians efficiently triage patients at higher risk. Widespread adoption of the STUMBL score may facilitate early identification of high-risk patients, promote more efficient allocation of resources, and enable the implementation of targeted management strategies, ultimately contributing to improved patient outcomes. Future prospective or multicenter studies are warranted to further validate the STUMBL score's generalizability across diverse clinical settings.

Ethics Committee Approval: This study was approved by the Kartal Dr. Lütfi Kırdar City Hospital Ethics Committee (Date: 25.12.2024, Decision No: 2024/010.99/11/34).

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

STUMBL skorunun künt toraks travmalı hastalarda hastane içi komplikasyonları öngörmedeki geçerliliği

AMAÇ: Bu çalışmanın amacı, künt toraks travması nedeniyle üçüncü basamak bir hastanenin acil servisine başvuran hastalarda hastane içi komplikasyonları öngörmede Study of the Management of Blunt Chest Wall Trauma (STUMBL) skorunun prognostik bir araç olarak geçerliliğini değerlendirmektir.
GEREÇ VE YÖNTEM: Bu retrospektif kohort çalışma Ocak 2022 ile Ocak 2024 tarihleri arasında yürütüldü. Künt toraks travması tanısı alan 18 yaş ve üzeri erişkin hastalar çalışmaya dahil edildi. Veriler, hastane bilgi yönetim sisteminden elde edildi. Komplikasyonlar arasında pulmoner enfeksiyonlar, plevral efüzyon, pnömotoraks, yoğun bakım ünitesi (YBÜ) yatışı ve uzamış hastane yatışı yer aldı. Ayırt edici performans, alıcı işletim karakteristiği (ROC) analizi ile değerlendirildi; ROC eğrisi altında kalan alan (AUROC) ve hassasiyet–geri çağırma eğrisi altında kalan alan (AUPRC) hesaplandı.
BULGULAR: Toplam 536 hasta çalışmaya dahil edildi. Bunların 150'sinde (%28.0) hastane içi komplikasyon gelişti. Komplikasyon gelişen hastaların STUMBL skorları anlamlı şekilde daha yüksekti (medyan 13'e karşı 6, p<0.001). STUMBL skoru, AUROC 0.934 (güven aralığı [GA] %95, 0.909–0.959) ve AUPRC 0.889 (GA %95, 0.847–0.924) değerleri ile güçlü ayırt edici performans gösterdi. En uygun eşik değeri ≥21 olarak belirlendi ve bu noktada duyarlılık %85, özgüllük %89 olarak saptandı.
SONUÇ: STUMBL skoru, künt toraks travmalı hastalarda hastane içi komplikasyonları öngörmede mükemmel performans göstermiştir. Basit yapısı ve yüksek öngörü değeri sayesinde, acil servislerde klinik karar verme süreçlerine etkili biçimde entegre edilebilir.

Anahtar sözcükler: STUMBL skoru, künt toraks travması, risk sınıflandırması.

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ORIGINAL ARTICLE

Management of minimal pneumothorax in penetrating chest trauma: Is observation safe?

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ABSTRACT

BACKGROUND: Traumatic pneumothorax is one of the most common findings encountered after chest trauma and often forces clinicians to quickly decide between tube thoracostomy and observation. Although large pneumothoraces (LP), most often defined radiologically as a pleural gap greater than 2 cm, are routinely managed with chest tube drainage, the management of minimal pneumothoraces (MP) is still a matter of debate.

METHODS: In this study, we analyzed 193 consecutive penetrating thoracic trauma patients managed in our center over a five-year period (2020–2025). Patients were classified into minimal pneumothorax and large pneumothorax groups based on computed tomography (CT) findings. Clinical and radiological parameters, Injury Severity Score (ISS), complications, and hospital stay were recorded, and their associations with chest tube placement were assessed.

RESULTS: Among the 193 patients, 112 (58%) were in the MP group and 81 (42%) in the LP group. The median age was comparable between groups (30.5 years [interquartile range, IQR: 22.8-39.3] vs. 28 years [IQR: 23-39], p=0.797). Gender distribution was also similar, with males accounting for 93.3% in the MP group and 93.8% in the LP group (p=1.000). Pneumothorax size strongly influenced treatment (p<0.001): chest tube thoracostomy was performed in 95.1% of LP vs. 9.8% of MP cases. Conservative observation was successful in 90.2% of MP patients. LP patients had significantly longer hospital stays (8.29 vs. 4.56 days, p<0.001), higher ICU admission rates (27.2% vs. 5.4%, p<0.001), and higher ISS (21.33 vs. 13.68, p<0.001). Complications were more frequent in LP (24.7% vs. 0.9%, p<0.001), with hemothorax, persistent air leak, and pleural effusion being the most common. Most hemothorax cases were attributed to the initial penetrating trauma, while only a small minority were tube-related. Among patients with LP (>2 cm), four were managed conservatively due to their stable clinical condition, and no mortality occurred in this subgroup. Mortality occurred exclusively in the chest tube group (18/88, 20.5%), with no deaths among observed patients overall (p<0.001). In subgroup analysis, gunshot wounds were associated with a higher need for chest tube even in MP (20.7% vs. 6.0%, p=0.033).

CONCLUSION: Our findings indicate that careful observation is a safe option in patients with minimal pneumothoraces, while large pneumothoraces generally necessitate invasive treatment and are associated with worse outcomes. Our results are consistent with previous reports in the international literature.

Keywords: Conservative management; Injury Severity Score (ISS); Penetrating thoracic trauma; traumatic pneumothorax; tube thoracostomy.

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INTRODUCTION

Thoracic trauma occurs in approximately 10–15% of all trauma patients and is responsible for up to 25–50% of trauma-related deaths, making it one of the most significant causes of morbidity and mortality in emergency practice.[1,2] This is particularly important, as even a small lesion can alter ventilation. Following disruption of the visceral or parietal pleura—most often due to blunt or penetrating trauma—air may accumulate within the pleural cavity.[3] In clinical practice, patients with minimal pneumothoraces can often be managed safely with observation, while larger collections usually require tube thoracostomy.[4,5] During observation, some patients may develop severe tension pneumothorax, whereas others remain stable and resolve on follow-up without tube thoracostomy.[6,7]

Management of traumatic pneumothorax is not uniform. While certain patients require urgent chest drainage, many can be followed safely under observation. The decision is guided mainly by pneumothorax size, hemodynamic stability, and the presence of associated thoracic injuries.[8] A two-centimeter threshold is commonly used in clinical practice; however, this cutoff does not always correspond with actual outcomes.[9,10]

Given the lack of consensus regarding the management of minimal pneumothorax, we designed this study to evaluate the safety of observation without intervention, assess potential management strategies and clinical outcomes, and provide further insight to guide future practice.

MATERIALS AND METHODS

We collected the data of 193 patients with penetrating traumatic pneumothorax between 2020 and 2025. Based on initial computed tomography (CT) imaging, patients were classified into minimal pneumothorax (MP, ≤2 cm) and large pneumothorax (LP, >2 cm) according to the maximal pleural gap between the visceral pleura and chest wall. We compared demographic characteristics (age, sex), trauma-related variables (mechanism of injury, pneumothorax size), treatment modality (observation vs. chest tube thoracostomy), and clinical outcomes, including intensive care unit (ICU) admission, length of hospital stay, complications, mortality, and Injury

Table 1. Clinicopathologic features and treatment distribution according to pneumothorax size

Variable	Minimal Pneumothorax (≤2 cm)	Large Pneumothorax (>2 cm)	p-value
Number of patients, N (%)	112 (58)	81 (42)	
Age (years), median [IQR]	30.5 [22.8–39.3]	28 [23–39]	0.797
Sex			
Male, N (%)	104 (93.3)	76 (93.8)	1.000
Female, N (%)	8 (6.7)	5 (6.2)	
Intervention			
Chest tube thoracostomy, N (%)	11 (9.8)	77 (95.1)	<0.001
Observation, N (%)	101 (90.2)	4 (4.9)	
ICU admission			
Absent, N (%)	106 (94.6)	59 (72.8)	<0.001
Present, N (%)	6 (5.4)	22 (27.2)	
Length of stay (days, mean±SD)	4.56±6.5	8.29±7.2	<0.001
Complication			
Absent, N (%)	111 (99.1)	61 (75.3)	<0.001
Present, N (%)	1 (0.9)	20 (24.7)	
Complication type			
Hemothorax, N (%)	0 (0.0)	12 (14.8)	—
Persistent air leak, N (%)	0 (0.0)	5 (6.2)	—
Pleural effusion, N (%)	1 (0.9)	3 (3.7)	—
Injury Severity Score (mean±SD)	13.68±10.68	21.33±12.50	<0.001
Mechanism of injury			
Stabbing, N (%)	83 (43)	66 (34.2)	0.302
Gunshot wound, N (%)	29 (15)	15 (7.8)	

Severity Score (ISS).

This study was approved by the İstanbul University Ethics Committee (Date: 28.08.2025, Decision no: 2025/1333). The study was carried out according to the human rights principles of the Declaration of Helsinki

Statistical Analysis

Statistical analyses were conducted using SPSS software (version 29.0; IBM Corp., Armonk, NY, USA). The Kolmogorov-Smirnov test was used to determine the distribution of continuous data. Categorical variables were analyzed with the chi-square and Fisher's exact tests, as appropriate in contingency tables, whereas Student's t-test was performed for comparison of continuous variables. A p-value of <0.05 was considered indicative of statistical significance.

RESULTS

A total of 193 patients with penetrating traumatic pneumothorax were analyzed. Pneumothorax size exceeded 2 cm in 42% of cases, whereas 58% presented with a pneumothorax of 2 cm or less. The median age was 30.5 years in the minimal pneumothorax group and 28 years in the large pneumothorax group (p=0.797). Males constituted 104 patients (93.3%) in the MP group and 76 patients (93.8%) in the LP group.

A strong correlation was observed between pneumothorax size and treatment modality (p<0.001). Almost all patients with larger pneumothoraces (>2 cm) required chest tube thoracostomy (95.1%), while only a small fraction were managed conservatively. In the MP group, conservative observation failed and chest tube insertion was required in 11 cases (9.8%), whereas the majority (90.2%) resolved without intervention.

ICU admission was significantly higher in the LP group compared with the MP group (27.2% vs. 5.4%, p<0.001).

Clinical outcomes were also influenced by pneumothorax size: LP patients had a longer mean hospital stay (8.29 vs. 4.56 days, p<0.001) and higher ISS values (21.33 vs. 13.68, p<0.001).

Overall, complications were observed in 21 of 193 patients (10.9%). The incidence was significantly higher in the LP group compared with the MP group (24.7% vs. 0.9%, p<0.001). In patients with LP, hemothorax was the most frequent complication (n=12, 14.8%), followed by persistent air leak (n=5, 6.2%) and pleural effusion (n=3, 3.7%). Of the 12 hemothorax cases, most were directly attributed to the initial penetrating trauma, whereas only two were considered tube-related bleedings. In contrast, only one complication occurred in the MP group (a pleural effusion, 0.9%) (Table 1).

Among patients with LP (>2 cm), four were managed conservatively due to their stable clinical condition, and no mortality occurred in this subgroup. Mortality was confined to patients who underwent chest tube thoracostomy, with 18 deaths among 88 patients (20.5%), whereas no deaths were observed among those managed conservatively (p<0.001). Overall mortality in the study population was 18 of 193 patients (9.3%) (Table 2).

Subgroup analysis according to mechanism of injury demonstrated that among patients with minimal pneumothoraces (≤2 cm), the need for chest tube thoracostomy was higher in gunshot injuries compared with stab wounds (20.7% vs. 6.0%, p=0.033). In contrast, for patients with large pneumothoraces (>2 cm), the requirement for tube thoracostomy

Table 2. Association between treatment modality and mortality

Treatment Modality	Alive, N (%)	Mortality, N (%)	Total, N (%)	p
Chest tube	70 (79.5)	18 (20.5)	88 (45.6)	
Observation	105 (100.0)	0 (0.0)	105 (54.4)	<0.001
Total	175 (90.7)	18 (9.3)	193 (100.0)	

Table 3. Treatment distribution by mechanism of injury stratified by pneumothorax size

Pneumothorax Size	Mechanism	Chest Tube N (%)	Observation N (%)	Total	p
≤2 cm	Stabbing	5 (6.0)	78 (94.0)	83	0.033
	Gunshot wound	6 (20.7)	23 (79.3)	29	
>2 cm	Stabbing	55 (83.3)	11 (16.7)	66	0.750
	Gunshot wound	13 (86.7)	2 (13.3)	15	

was uniformly high in both gunshot and stab wound groups (86.7% vs. 83.3%, p=0.75) (Table 3).

DISCUSSION

Traumatic pneumothorax remains a significant cause of morbidity and mortality in penetrating thoracic trauma, and its management continues to be a critical decision point, particularly regarding the indications for chest tube thoracostomy versus observation.[11] Large-scale trauma registries have emphasized the prognostic importance of pneumothorax size and associated injuries.[12]

The trauma mechanism also influenced treatment. Even small pneumothoraces in gunshot injuries often required intervention, reflecting the destructive nature of ballistic trauma, whereas stab wounds were more frequently managed conservatively.[13]

Mortality was observed exclusively in the chest tube group, which likely reflects the higher overall injury severity in patients requiring intervention rather than the procedure itself. This supports the concept that chest tube placement is a marker of severity rather than an independent predictor of mortality.[14]

Our study confirms that pneumothorax size is a decisive factor influencing therapeutic approach and outcomes. This is consistent with earlier reports advocating tube thoracostomy for larger or symptomatic pneumothoraces, while conservative management is safe and effective for smaller, stable cases. Both prospective and retrospective studies have demonstrated the reliability of observation in carefully selected patients. The 2 cm radiological threshold appears to be a practical and reproducible parameter that facilitates clinical decision-making.[15]

In centers with close clinical monitoring, observation remains a safe option, as deterioration can be promptly detected and managed with tube thoracostomy when required. In contrast, in settings with limited monitoring capacity, prophylactic tube placement may serve as a safeguard against delayed recognition of deterioration.[15]

Longer hospitalization in patients undergoing chest tube drainage parallels prior studies that associated invasive management with prolonged stay due to tube maintenance, air leak monitoring, and procedure-related risks. Similarly, the higher Injury Severity Scores in patients with large pneumothorax reflect their association with severe trauma and multiple injuries, consistent with findings that elevated ISS correlates with poorer outcomes.[16]

Complications were more frequent in patients with large pneumothorax, with hemothorax being the most prominent complication, consistent with literature describing increased bleeding risk in penetrating trauma. The greater demand for intensive care in this group also reflects their overall physiological burden, as noted in previous series linking pneumothorax size to ICU utilization.[16-18]

In our cohort, the majority of hemothorax cases were directly attributed to the penetrating injury itself, whereas only a small minority were considered tube-related bleedings. This finding is in line with previous reports, which emphasized that iatrogenic hemothorax due to chest tube insertion is relatively uncommon (<5%).[17,18] Therefore, the overall hemothorax rate of 14.8% in our study should primarily be interpreted as a trauma-related consequence rather than a procedure-related complication.

The overall complication profile in our study was at the lower end of the spectrum reported in the literature. Meta-analyses and large cohorts have documented complication rates varying widely depending on technique, patient selection, and institutional protocols. Importantly, standardized approaches have been shown to significantly reduce complication rates. Higher frequencies have been described in other series, and a meta-analysis highlighted the impact of tube size and technique selection on complication risk.[18] Taken together, our findings reinforce the evidence that pneumothorax size is a decisive prognostic factor. By integrating clinical decision-making with radiological measurement, our study contributes to the understanding that accurate early assessment of pneumothorax size directly impacts hospital stay, ICU utilization, complication profile, and survival outcomes.

CONCLUSION

Pneumothorax size has a decisive impact on therapeutic strategies and clinical outcomes in penetrating chest trauma. While patients with large pneumothoraces commonly required chest tube drainage and were associated with longer hospital stays and higher complication rates, those with minimal pneumothoraces were predominantly managed safely by observation. Our study confirms that observation is a safe approach for minimal pneumothorax. These results emphasize the role of early radiologic assessment, supporting pneumothorax size as a reliable predictor in guiding initial treatment decisions.

Data Availability Statement: Following publication, the data used in this study will be made available from the corresponding author upon reasonable request, provided that the proposal is methodologically sound and consistent with the approved study objectives.

Ethics Committee Approval: This study was approved by the İstanbul University Ethics Committee (Date: 28.08.2025, Decision No: 2025/1333).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Penetran göğüs travmasında minimal pnömotoraks yönetimi: Gözlem güvenli mi?

AMAÇ: Travmatik pnömotoraks, toraks travması sonrasında sık karşılaşılan bulgulardan biridir ve çoğunlukla klinisyeni tüp torakostomi ile basit gözlem arasında hızlı karar vermeye zorlar. Bilgisayarlı Tomografide (BT) pnömotoraks alanı 2 santimetreden geniş olan vakaların rutin olarak drene edilmesi yaygın kabul görmüş olsa da, minimal pnömotorakslar için en uygun tedavi yaklaşımı konusunda kesin bir görüş birliği bulunmamaktadır.

GEREÇ VE YÖNTEM: Merkezimizde 2020-2025 yılları arasında takip edilen ardışık 193 penetran toraks travmalı hasta retrospektif olarak incelendi. Hastalar BT'de ölçülen pnömotoraks oranına göre minimal pnömotoraks (MP) ve geniş pnömotoraks (LP) olarak iki gruba ayrıldı. Klinik ve radyolojik parametreler, travma şiddet skorları, komplikasyonlar ve hastanede kalış süreleri kaydedildi; bunların tüp torakostomi ile ilişkisi değerlendirildi.

BULGULAR: Toplam 193 hastanın 112'si (%58) MP grubunda, 81'i (%42) LP grubunda yer aldı. Gruplar arasında medyan yaş benzerdi (30.5 yıl [IQR 22.8-39.3] vs. 28 yıl [IQR 23-39], p=0.797) ve cinsiyet dağılımı da farklı değildi (erkek %93.3 vs. %93.8, p=1.000). Tüp torakostomi LP grubunda %95.1 oranında uygulanırken, MP grubunda yalnızca %9.8 oranında gerekliydi (p<0.001). MP hastalarının %90.2'si konservatif izlemle başarıyla yönetildi. LP hastalarında hastanede kalış süresi daha uzundu (8.29 vs. 4,56 gün, p<0.001), yoğun bakım ihtiyacı daha fazlaydı (%27.2 vs. %5.4, p<0.001) ve ISS değerleri daha yüksekti (21.33 vs. 13.68, p<0.001). Komplikasyon oranı LP grubunda anlamlı olarak daha yüksekti (%24.7 vs. %0.9, p<0.001); en sık görülenler hemotoraks (%14.8), persistan hava kaçağı (%6.2) ve plevral efüzyon (%3.7) idi. MP grubunda yalnızca bir hastada (%0.9) plevral efüzyon gelişti. Genel mortalite %9.3 (18/193) olup, tüm ölümler tüp torakostomi grubunda izlendi (%20.5), gözlem grubunda ölüm görülmedi (p<0.001). Alt grup analizinde, minimal pnömotoraksı olanlarda ateşli silah yaralanmalarında tüp torakostomi ihtiyacı bıçaklanmalara göre daha yüksekti (%20.7 vs. %6.0, p=0.033).

SONUÇ: Bulgularımız, minimal pnömotorakslı hastalarda dikkatli gözlemin güvenli bir seçenek olduğunu, buna karşılık geniş pnömotoraks saptanan vakaların genellikle invaziv tedavi gerektirdiğini ve daha kötü klinik sonuçlarla ilişkili olduğunu göstermektedir.

Anahtar sözcükler: Konservatif tedavi; penetran toraks travması; travmatik pnömotoraks; tüp torakostomi; yaralanma şiddeti skoru.

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ORIGINAL ARTICLE

Regression analysis for intensive care unit (ICU) admission prediction in elderly patients with acute appendicitis

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ABSTRACT

BACKGROUND: Acute appendicitis in the elderly often presents with atypical symptoms and is frequently complicated at diagnosis, potentially requiring intensive care unit (ICU) admission. Early risk identification is essential for effective triage. Hematologic biomarkers may provide rapid, accessible tools for predicting disease severity. The objective of this study was to evaluate the predictive value of hematologic parameters—particularly lymphocyte count, neutrophil-to-lymphocyte ratio (NLR), and immature granulocyte (IG) indices—for ICU admission and complicated appendicitis in elderly patients.

METHODS: This retrospective observational study included patients aged ≥65 years who underwent appendectomy for suspected acute appendicitis between 2018–2021 and in 2024 at a tertiary emergency department. Patients were grouped by ICU admission status and histopathological diagnosis (complicated vs. non-complicated appendicitis). Preoperative clinical and laboratory data were analyzed using logistic regression and receiver operating characteristic (ROC) analysis. A post hoc power analysis was also performed.

RESULTS: Of 143 patients included, 33 (23.1%) required ICU admission. These patients were older and had higher rates of diabetes and coronary artery disease. Lymphocyte counts were significantly lower and NLR values higher in the ICU group. In multivariate analysis, only lymphocyte count independently predicted ICU admission. Complicated appendicitis was associated with age, diabetes, low lymphocyte count, high IG%, and elevated NLR in univariate analysis; however, only age, diabetes, and lymphocyte count remained significant in multivariate modeling. ROC analysis showed moderate diagnostic performance for lymphocyte count (area under the curve=0.669) in identifying complicated cases.

CONCLUSION: Lymphopenia is an independent predictor of ICU admission and complicated appendicitis in elderly patients. Routine blood parameters may support early clinical risk stratification in emergency settings.

Keywords: Acute appendicitis; elderly; intensive care unit; emergency department.

INTRODUCTION

Acute appendicitis remains one of the most frequent causes of emergency abdominal surgery worldwide, and its management in elderly patients presents unique challenges. Patients over 65 years of age often present with atypical clinical features, delayed diagnoses, and face a higher risk of severe complications such as perforation, abscess formation, and peritonitis, which can necessitate intensive care unit (ICU) admission. Identifying elderly patients at risk of clinical deterioration who may require ICU care is crucial for optimizing resource allocation and improving outcomes. Previous studies report that the incidence of complicated appendicitis in elderly patients can be as high as 50%–70% at the time of diagnosis.[1,2]

Timely and accurate differentiation between complicated and non-complicated appendicitis is essential in elderly patients, not only to avoid treatment delays but also to optimize out-

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comes and reduce mortality. Imaging modalities such as computed tomography (CT) play a central role in diagnosis; however, limitations including radiation exposure, contrast-related risks, and delays in imaging availability make laboratory biomarkers an attractive adjunct. While CT scans are invaluable for diagnosing appendicitis and assessing severity, their availability and timeliness can be limited, particularly in emergency departments (EDs). Consequently, there is growing interest in simple, rapidly obtainable laboratory biomarkers that could aid in early risk stratification.[3,4]

Recent attention has focused on hematologic parameters as potential diagnostic and prognostic tools. Hematologic parameters derived from routine blood tests, including white blood cell counts, neutrophil-to-lymphocyte ratio (NLR), and lymphocyte counts, have been investigated as potential predictors of disease severity in various inflammatory and infectious conditions.[5-7] Lymphopenia, in particular, has been recognized as a marker of immunosuppression and poor prognosis in critical illnesses.[8] Immature granulocytes (IGs)—a subset of neutrophils that includes metamyelocytes, myelocytes, and promyelocytes—have emerged as promising indicators of systemic inflammation and infection. IG counts can now be readily measured by automated hematology analyzers as part of a routine complete blood count with differential, providing rapid and cost-effective information.[9,10] Increased IG levels have been associated with bacterial infections, sepsis, and other inflammatory conditions, and preliminary evidence suggests that IGs may help distinguish complicated from uncomplicated intra-abdominal infections.[11,12] However, data specifically evaluating the utility of IGs in the differential diagnosis of complicated appendicitis among elderly patients remain limited.

Despite this, limited data exist regarding the predictive value of these hematologic markers for ICU admission specifically in elderly patients with acute appendicitis. This study aims to evaluate various hematologic parameters as predictors of ICU admission in this high-risk population, with a focus on identifying the most significant and practical biomarker(s) for early clinical decision-making.

MATERIALS AND METHODS

Study Design and Setting

This retrospective observational and multidisciplinary study was conducted in the ED of a tertiary care university hospital. The study was approved by the institutional ethics committee (approval number: 21, date: 25/02/2025) and carried out in accordance with the principles of the Declaration of Helsinki.

Study Population

Patients aged 65 years and older who presented to the ED and underwent surgery with a pre-diagnosis of acute appendicitis were included in the study. The study period covered two separate intervals: January 1, 2018 to December 31, 2021, and January 1, 2024 to December 31, 2024, totaling five years. The period between January 1, 2022 and January 1, 2024 was excluded from the study due to disruptions in clinical practice caused by the Coronavirus Disease 2019 (COVID-19) pandemic.

Inclusion and Exclusion Criteria

Inclusion criteria were:

1. Age ≥65 years,
2. Appendectomy performed for suspected acute appendicitis,
3. Histopathological confirmation of appendicitis, and
4. Availability of complete preoperative laboratory and clinical data.

Patients were excluded if they had incomplete medical records, hematologic malignancies, active immunosuppressive therapy, chronic inflammatory diseases, or if surgery occurred during the COVID-19 exclusion period.

Multidisciplinary Approach

This study adopted a multidisciplinary approach. All patients were initially evaluated by ED physicians upon admission. Surgical indications were determined by the general surgery team based on clinical, radiological, and laboratory findings. Postoperative ICU requirements were assessed and confirmed by anesthesiology specialists, ensuring that ICU admissions reflected standardized criteria based on intraoperative and postoperative hemodynamic and respiratory status.

Data Collection

Demographic information (age, sex), comorbidities (hypertension (HT), diabetes mellitus (DM), coronary artery disease (CAD), chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), chronic kidney disease (CKD), cerebrovascular disease (CVD), clinical parameters (ICU admission, vasopressor use), radiological findings (ultrasound (USG) and computed tomography results), and preoperative laboratory values were retrospectively collected from the hospital's electronic medical records. All laboratory parameters analyzed in this study were obtained from blood samples collected at the time of ED admission, prior to surgical intervention. No serial or follow-up blood tests were performed for comparative purposes during the inpatient stay or postoperative period. The analysis was therefore limited to initial laboratory findings upon presentation. Laboratory variables included white blood cell count (WBC, $\times 10^3$/L), neutrophil count ($\times 10^3$/L) and percentage (%), lymphocyte count ($\times 10^3$/L), platelet count (PLT, $\times 10^3$/L), neutrophil-to-lymphocyte ratio, immature granulocyte count ($\times 10^9$/L), immature granulocyte percentage (IG%), C-reactive protein (CRP, mg/dL), lactate (mmol/L), anion gap (mmol/L), prothrombin time (PT, sec), PT percentage (PT%), international normalized ratio (INR), and activated partial thromboplastin time (aPTT,

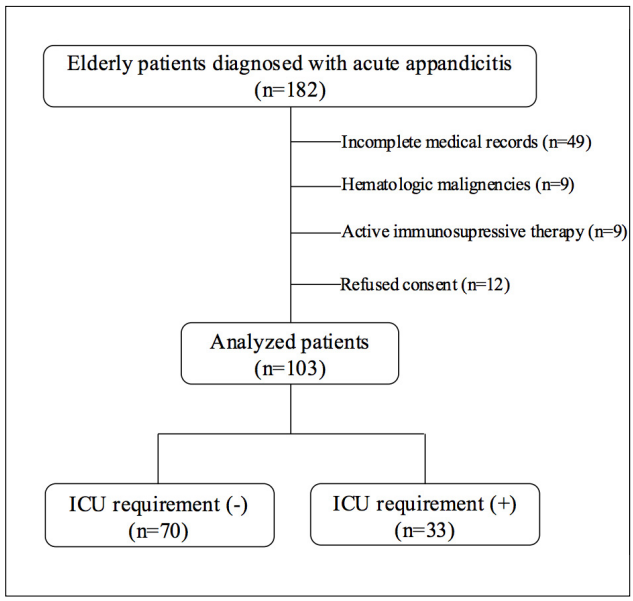

Figure 1. Study flowchart

sec). Hematological parameters were assessed using a hematology analyser (Cell-Dyne 3700, Abbott Park, IL, USA), and biochemical levels were assessed with the Beckman Coulter AU5800 analyzer (Beckman Coulter, Inc., Fullerton, USA).

Definitions and Grouping

Patients were classified into two groups based on their postoperative clinical course: those admitted to the ICU and those who were not. Additionally, patients were categorized as having simple or complicated appendicitis according to histopathological examination results. Cases diagnosed as simple (acute) appendicitis on histopathology were classified as non-complicated appendicitis, whereas cases reported as gangrenous or perforated appendicitis were classified as complicated appendicitis. This pathological classification was used as the reference standard for subgroup analyses in the study.

Statistical Analysis

Statistical analysis was performed using statistical package (v25.0; SPSS Inc., Chicago, IL). Continuous variables were presented as mean±standard deviation (SD) or median (interquartile range [IQR]), depending on distribution, and categorical variables were expressed as frequencies and percentages. Comparisons between groups were conducted using the independent-samples t-test or Mann-Whitney U test for continuous variables, and the chi-square test for categorical variables. Univariate logistic regression was used to assess potential predictors of ICU admission and complicated appendicitis. Variables with $p<0.10$ in univariate analysis were included in the multivariate logistic regression model. Receiver operating characteristic (ROC) analysis was performed to evaluate diagnostic performance and determine cutoff values. A p-value <0.05 was considered statistically significant.

Table 1. Patients characteristics, symptoms, and clinical outcomes

Number of patients, n (%)	103 (100.0)
Age, years	70 (67-75)
Male, n (%)	49 (47.6)
Comorbidities, n (%)	
HT	50 (48.5)
DM	24 (23.3)
COPD	16 (15.5)
CHF	8 (7.8)
CAD	5 (4.9)
CVD	3 (2.9)
CKD	3 (2.9)
Laboratory values (initial)	
WBC (×10³/L)	12.1±4.6
Neuc (×10³/L)	9.6±4.3
Neu, (%)	79.1 (70.4-84.9)
Lymc (×10³/L)	1.55 (1.06-2.00)
NLR	5.9 (3.4-9.5)
IG, (×10⁹/L)	0.04 (0.02-0.07)
IG, (%)	0.40 (0.20-0.50)
PLT (×10³/L)	233 (195-268)
PLCR	27 (22-31)
CRP, (mg/dL)	49.2 (11.7-165.7)
aPTT (sec)	26 (24-29)
INR	1.0 (1.0-1.1)
PT (sec)	12.5 (11.6-14.6)
PT, (%)	95 (81-106)
AG, (mmol/L)	12 (6-17)
Lactate, (mmol/L)	2.0 (1.3-2.8)
Pathological sign in USG, n (%)	11 (10.7)
Pathological sign in CT, n (%)	77 (74.8)
Complicated appendicitis, n (%)	32 (31.1)
Vasopressor support, n (%)	6 (5.8)
ICU requirement, n (%)	33 (32.0)

aPTT: Activated partial thromboplastin time; AG: Anion gap; CAD: Coronary artery disease; CHF: Congestive heart failure; CKD: Chronic kidney disease; COPD: Chronic obstructive pulmonary disease; CRP: C-reactive protein; CT: Computed tomography; CVD: Cerebrovascular disease; DM: Diabetes mellitus; HT: Hypertension; ICU: Intensive care unit; IG: Immature granulocyte; INR: International normalized ratio; Lymc: Lymphocyte count; Neuc: Neutrophil count; NLR: Neutrophil-to-lymphocyte ratio; PLCR: Platelet large cell ratio; PLT: Platelet count; PT: Prothrombin time; USG: Ultrasonography; WBC: White blood cell count.

Statistical Power Analysis

A post hoc power analysis was conducted based on the final sample size of 103 patients, with 33 patients requiring ICU admission and 70 not requiring ICU care. Assuming a large effect size (Cohen's d=0.8), a two-tailed test, and a significance

level of α=0.05, the calculated power (1–β) was approximately 96%. This suggests that the study had sufficient statistical power to detect moderate differences between groups.

RESULTS

Study Population

A total of 103 elderly patients diagnosed with acute appendicitis were included in the study (Fig. 1). Patients were stratified based on ICU admission status and presence of complicated appendicitis. Thirty-three patients were admitted to the ICU (32%), and 32 patients (31.1%) were classified as having complicated appendicitis (Table 1).

Baseline Characteristics

Among the included patients, 54 (52.4%) were female, and

Table 2. Comparison of parameters between intensive care unit (ICU) requirements (-) and (+) groups

	ICU Requirements (-) (n=70)	ICU Requirements (+) (n=33)	p
Age, years	70 (66-72)	74 (70-82)	<0.001
Male, n (%)	29 (41.4)	20 (60.6)	0.069
Comorbidities, n (%)			
HT	31 (44.3)	19 (57.6)	0.208
DM	12 (17.1)	12 (36.4)	0.031
COPD	11 (15.7)	5 (15.2)	0.941
CHF	6 (8.6)	2 (6.1)	0.657
CAD	1 (1.4)	4 (12.1)	0.035
CVD	2 (2.9)	1 (3.0)	1.000
CKD	1 (1.4)	2 (6.1)	0.240
Laboratory values (initial)			
WBC (×10^3/L)	12.0±4.8	12.4±4.1	0.728
Neuc (×10^3/L)	9.4±4.6	10.2±3.9	0.341
Neu, (%)	75.4±10.0	81.9±6.3	<0.001
Lymc (×10^3/L)	1.64 (1.20-2.17)	1.37 (0.87-1.68)	0.021
NLR	5.1 (2.9-9.0)	7.6 (5.5-10.2)	0.016
IG, (×10^9/L)	0.04 (0.02-0.07)	0.06 (0.03-0.08)	0.284
IG, (%)	0.40 (0.20-0.50)	0.50 (0.25-0.55)	0.210
PLT (×10^3/L)	237 (195-269)	229 (192-271)	0.447
PLCR	26.9±7.7	29.3±10.0	0.182
CRP, (mg/dL)	42.7 (11.2-134.0)	61.8 (10.5-312.4)	0.418
aPTT (sec)	25 (24-28)	28 (24-30)	0.096
INR	1.0 (0.9-1.1)	1.1 (1.0-1.3)	0.001
PT (sec)	12.2 (11.4-14.1)	14.4 (12.4-16.9)	<0.001
PT, (%)	96±17	85±18	0.004
AG, (mmol/L)	11.0±5.9	12.5±5.5	0.477
Lactate, (mmol/L)	1.8±0.7	2.3±1.2	0.160
Pathological sign in USG, n (%)	8 (11.4)	3 (9.1)	1.000
Pathological sign in CT, n (%)	53 (75.7)	24 (72.7)	0.745
Complicated appendicitis, n (%)	15 (21.4)	17 (51.5)	0.002
Vasopressor support (perioperative), n (%)	0 (0.0)	6 (18.2)	<0.001

aPTT: Activated partial thromboplastin time; AG: Anion gap; CAD: Coronary artery disease; CHF: Congestive heart failure; CKD: Chronic kidney disease; COPD: Chronic obstructive pulmonary disease; CRP: C-reactive protein; CT: Computed tomography; CVD: Cerebrovascular disease; DM: Diabetes mellitus; HT: Hypertension; ICU: Intensive care unit; IG: Immature granulocyte; INR: International normalized ratio; Lymc: Lymphocyte count; Neuc: Neutrophil count; NLCR: Neutrophil-to-lymphocyte ratio; PLCR: Platelet large cell ratio; PLT: Platelet count; PT: Prothrombin time; USG: Ultrasonography; WBC: White blood cell count.

the median age was 70 years (IQR 67-75). The most common comorbidities were HT (n=50, 48.5%), DM (n=24, 23.3%), and COPD (n=16, 15.5%). While all patients were diagnosed histopathologically with acute appendicitis, 11 patients (10.7%) were diagnosed using USG and 77 patients (74.8%) with CT. Vasopressor support was required in only six patients (5.8%) (Table 1).

Comparison Between ICU and Non-ICU Groups

Patients admitted to the ICU (n=33) were significantly older than those who were not (p<0.001), while gender distribution did not differ significantly between groups (p=0.069). The rate of vasopressor use was significantly higher in the ICU group (p<0.001). Regarding comorbidities, DM and CAD were more prevalent among ICU-admitted patients (p=0.031

Table 3. Comparison of parameters between non-complicated and complicated appendicitis groups

	Non-Complicated Group (n=71)	Complicated Group (n=32)	p
Age, years	69 (67-72)	74 (70-81)	<0.001
Male, n (%)	32 (45.1)	17 (53.1)	0.449
Comorbidities, n (%)			
HT	34 (47.9)	16 (50.0)	0.843
DM	12 (16.9)	12 (37.5)	0.022
COPD	11 (15.5)	5 (15.6)	0.986
CHF	6 (8.5)	2 (6.3)	1.000
CAD	2 (2.8)	3 (9.4)	0.172
CVD	1 (1.4)	2 (6.3)	0.227
CKD	1 (1.4)	2 (6.3)	0.227
Laboratory values (initial)			
WBC ($\times10^3$/L)	12.0±4.3	12.4±5.2	0.703
Neuc ($\times10^3$/L)	9.4±4.1	10.2±4.8	0.340
Neu, (%)	77.1 (67.0-84.7)	82.3 (77.5-86.5)	0.014
Lymc ($\times10^3$/L)	1.63 (1.22-2.23)	1.35 (0.84-1.66)	0.006
NLR	5.1 (2.9-9.3)	7.6 (5.5-10.4)	0.007
IG, ($\times10^9$/L)	0.04 (0.02-0.07)	0.05 (0.03-0.11)	0.153
IG, (%)	0.40 (0.20-0.50)	0.50 (0.23-0.68)	0.020
PLT ($\times10^3$/L)	238 (195-279)	220 (188-265)	0.247
PLCR	26.9±7.4	29.3±10.4	0.195
CRP, (mg/dL)	48.4 (10.5-105.7)	165.7 (30.0-332.5)	0.118
aPTT (sec)	26 (24-29)	26 (23-29)	0.641
INR	0.9 (0.9-1.0)	1.0 (0.9-1.0)	0.089
PT (sec)	12.4 (11.4-14.4)	13.0 (11.8-15.9)	0.149
PT, (%)	96 (84-107)	95 (68-104)	0.092
AG, (mmol/L)	10.8±5.3	13.4±5.9	0.208
Lactate, (mmol/L)	1.7±0.8	2.6±1.2	0.031
Pathological sign in USG, n (%)	7 (9.9)	4 (12.5)	0.735
Pathological sign in CT, n (%)	54 (76.1)	23 (71.9)	0.651
Vasopressor support, n (%)	2 (2.8)	4 (12.5)	0.073
ICU requirement, n (%)	16 (22.5)	17 (53.1)	0.002

aPTT: Activated partial thromboplastin time; AG: Anion gap; CAD: Coronary artery disease; CHF: Congestive heart failure; CKD: Chronic kidney disease; COPD: Chronic obstructive pulmonary disease; CRP: C-reactive protein; CT: Computed tomography; CVD: Cerebrovascular disease; DM: Diabetes mellitus; HT: Hypertension; ICU: Intensive care unit; IG: Immature granulocyte; INR: International normalized ratio; Lymc: Lymphocyte count; Neuc: Neutrophil count; PLCR: Platelet large cell ratio; PLT: Platelet count; PT: Prothrombin time; USG: Ultrasonography; WBC: White blood cell count.

Table 4. Receiver operating characteristic (ROC) analysis for intensive care unit (ICU) requirements

	Cut-off value	Sen.	Spec.	PPV	NPV	AUC (95% CI)	p
Age, years	>73	0.61	0.79	0.57	0.81	0.73 (0.62-0.83)	<0.001
PT (sec)	>12.3	0.82	0.56	0.47	0.87	0.71 (0.60-0.82)	<0.001
INR	>1.1	0.42	0.89	0.64	0.77	0.70 (0.58-0.82)	0.001
Neu (%)	>78.1	0.85	0.59	0.49	0.89	0.69 (0.59-0.80)	<0.001
PT (%)	<83	0.52	0.84	0.61	0.79	0.68 (0.56-0.80)	0.003
NLCR	>5.1	0.79	0.50	0.43	0.83	0.65 (0.54-0.76)	0.008
Lymc (×10³/L)	<1.48	0.67	0.63	0.46	0.80	0.64 (0.53-0.75)	0.013

INR: International normalized ratio; Lymc: Lymphocyte count; Neu: Neutrophil count; NLCR: Neutrophil-to-lymphocyte ratio; PT: Prothrombin time.

Table 5. Receiver operating characteristic (ROC) analysis for intensive care unit (ICU) requirements

	Cut-off value	AUC (95% CI)	p
Age, years	>73	0.73 (0.62-0.83)	<0.001
PT (sec)	>12.3	0.71 (0.60-0.82)	<0.001
INR	>1.1	0.70 (0.58-0.82)	0.001
Neu (%)	>78.1	0.69 (0.59-0.80)	<0.001
PT (%)	<83	0.68 (0.56-0.80)	0.003
NLR	>5.1	0.65 (0.54-0.76)	0.008
Lymc (×10³/L)	<1.48	0.64 (0.53-0.75)	0.013

INR: International normalized ratio; Lymc: Lymphocyte count; Neu: Neutrophil; NLCR: Neutrophil-to-lymphocyte ratio; PT: Prothrombin time.

and p=0.035, respectively), whereas no significant differences were observed for HT, CKD, COPD, CVD, or CHF (p>0.05) (Table 2).

Laboratory findings showed that lymphocyte counts were significantly lower and neutrophil percentages significantly higher in the ICU group (p=0.021 and p<0.001, respectively). WBC, platelet counts, and absolute neutrophil counts did not differ significantly (p>0.05). The ICU group also had significantly higher NLR values (p=0.016), but no significant differences were observed in IG count, IG%, or platelet large cell ratio (PLCR) values (p>0.05). Among coagulation and biochemical parameters, PT and INR were significantly higher, while PT% was significantly lower in ICU patients (p<0.001, p=0.001, and p=0.004, respectively). No significant differences were found in CRP, aPTT, lactate, or anion gap values (p>0.05). Radiological findings (USG or CT) did not differ significantly between groups (p>0.05). However, the rate of complicated appendicitis was significantly higher among patients admitted to the ICU (p=0.002) (Table 2).

Comparison Between Complicated and Non-Complicated Groups

When comparing patients with complicated versus non-complicated appendicitis, the complicated group was significantly older (p<0.001), but no significant differences were observed in gender or vasopressor use (p>0.05) (Table 3). DM was significantly more common in patients with complicated appendicitis (p=0.022), while other comorbidities did not differ significantly (p>0.05). Lymphocyte counts were significantly lower, and neutrophil percentages, NLR, and IG% were higher in the complicated group (p=0.006, p=0.014, p=0.007, and p=0.020, respectively), whereas other laboratory parameters showed no significant differences (p>0.05). Lactate levels were also significantly elevated in complicated cases (p=0.031), but no significant differences were observed in anion gap (p>0.05). Radiologic findings (USG and CT) did not differ significantly between groups (p>0.05).

Regression and ROC Analysis

In the multivariate logistic regression model with Youden's index for the likelihood of ICU requirement, age ≥73 years (p=0.011), PT ≥12.3 sec (p=0.016), neutrophil percentage ≥78.1% (p=0.025), and presence of DM (p=0.039) remained independent predictors of ICU admission (Table 4). Presence of CAD, complicated appendicitis, NLR, PT%, INR, and lymphocyte count were not predictive of ICU admission. ROC analysis for ICU requirements revealed that age (>73 years), PT (>12.3 sec), INR (>1.1), neutrophil percentage (>78.1),

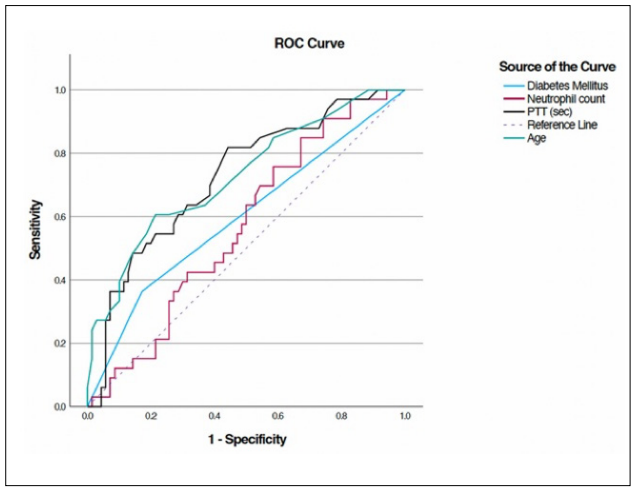

Figure 2. Decision curve analysis of candidate predictors for intensive care unit (ICU) admission in elderly patients with acute appendicitis.

PT% (<83), NLR (>5.1), and lymphocyte count (<1.48 ×103/L) demonstrated moderate diagnostic performance in identifying ICU admission with the following areas under the curve (AUCs) (95% confidence interval (CI)): 0.73 (0.62-0.83), 0.71 (0.60-0.82), 0.70 (0.58-0.82), 0.69 (0.59-0.80), 0.68 (0.56-0.80), 0.65 (0.54-0.76), and 0.64 (0.53-0.75), respectively (Table 5, Figure 2).

DISCUSSION

Several recent studies have investigated the role of hematologic markers in identifying complicated appendicitis, and our findings contribute to this growing body of evidence, particularly in the elderly population. In our study, although a low lymphocyte count was significantly associated with ICU admission in univariate analysis, it did not remain an independent predictor in the multivariable model. Instead, age, PT, neutrophil percentage, and diabetes mellitus were identified as independent prognostic indicators in elderly patients with acute appendicitis.

Our results are in line with those of Uludag et al., who evaluated 702 patients with histologically confirmed appendicitis and reported that low lymphocyte count, elevated CRP, and increased NLR were strong predictors of perforation. [12] Specifically, a lymphocyte count below 1.7/mm³ and an NLR above 7.65 were significantly associated with complicated appendicitis. These findings emphasize the diagnostic importance of lymphocyte depletion as a marker of systemic inflammation and disease severity, which may be especially valuable in elderly patients who often present with atypical or nonspecific symptoms.

Similarly, a large-scale retrospective study by Sevinc et al. involving 3,392 patients found that NLR and serum bilirubin were independent predictors of perforated appendicitis.[13] While WBC was useful in identifying acute appendicitis, it was not significantly associated with perforation. An NLR cut-off of 4.8 demonstrated a sensitivity of 81.2% and specificity of 53.1% for detecting complicated cases, indicating moderate diagnostic value. These results support our findings, in which elevated NLR values were more commonly observed in patients with complicated appendicitis. The defined threshold of 4.8 may serve as a clinically useful reference point for risk stratification, particularly in elderly patients who require early and accurate identification of severe disease.

In addition to NLR and lymphocyte count, Unal et al. investigated the utility of immature granulocyte parameters in appendicitis diagnosis and severity differentiation.[14] In their study of 438 patients, both the immature granulocyte count (IGC) and percentage (IG%) were significantly associated with acute and complicated appendicitis. Notably, IG% demonstrated excellent diagnostic performance for complicated cases, with an AUC of 0.979, sensitivity of 94.4%, and specificity of 97.9%. In our study, although elevated immature granulocyte values were significantly associated with ICU admission in univariate analysis, they did not retain significance in the multivariate model. This discrepancy may be explained by differences in outcome definitions: while Unal et al. focused on appendiceal perforation, we used ICU admission as a more stringent and clinically relevant endpoint for elderly patients. Despite this, our findings suggest that immature granulocytes may still represent a valuable early marker of disease severity, deserving further investigation in larger and more targeted cohorts.

Overall, the existing literature reinforces the prognostic utility of hematologic parameters—particularly NLR, lymphocyte count, and immature granulocytes—in assessing disease severity in acute appendicitis. Our study adds to this evidence by emphasizing the relevance of these markers in predicting ICU admission among elderly patients, a group at higher risk for adverse outcomes and diagnostic challenges.

Limitations

This study has several limitations that should be acknowledged. First, its retrospective, single-center design may limit the generalizability of the findings to broader populations or different healthcare settings. Variations in clinical protocols, ICU admission criteria, and perioperative management practices could influence the applicability of the results.

Second, the total sample size, and particularly the number of patients requiring ICU admission (n=33), was modest for certain subgroup analyses. This may have limited the ability to detect associations with less frequent variables or outcomes. However, a post hoc power analysis indicated that with this distribution and an assumed moderate effect size (Cohen's d=0.5), the study had approximately 80% power using a two-sided test at an alpha level of 0.05. While sufficient for detecting moderate effects, larger prospective studies are needed to confirm these findings and explore smaller or more nuanced associations.

Third, the analysis was based solely on laboratory parameters

obtained at ED admission, without incorporating dynamic changes over time or postoperative trends. Serial measurements could have provided additional insight into disease progression and response to treatment.

Fourth, although ICU admission decisions were made by anesthesiology specialists according to standardized clinical criteria, some degree of subjectivity and inter-clinician variability in ICU triage decisions is possible, which could introduce bias.

Lastly, other potentially relevant clinical factors, such as frailty status, nutritional state, or the presence of cognitive impairment—which are especially pertinent in geriatric populations—were not included in the analysis due to limitations in available data.

Prospective, multicenter studies with larger cohorts and inclusion of longitudinal biomarker monitoring are warranted to validate these findings and further clarify the role of hematologic parameters in predicting ICU admission in elderly patients with acute appendicitis.

CONCLUSION

In elderly patients with acute appendicitis, early identification of those at risk for ICU admission is critical for timely intervention and optimal resource utilization. Our findings suggest that hematologic parameters—particularly lymphocyte and neutrophil counts—may serve as practical, readily available biomarkers for early risk stratification. Lymphopenia emerged as a significant independent predictor of complicated appendicitis, while neutrophilia was a significant independent predictor of ICU admission. Although the predictive value of IGs did not remain significant in multivariate models, their role warrants further investigation.

This study highlights the potential utility of simple blood-based markers in guiding early clinical decision-making in the ED. Incorporating these parameters into initial assessments may support prompt triage and improve patient outcomes, particularly in vulnerable geriatric populations. Future prospective, multicenter studies with larger cohorts and longitudinal follow-up are needed to validate and refine these findings.

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Ethics Committee Approval: This study was approved by the SBÜ İstanbul Research and Training Hospital Ethics Committee (Date: 07.02.2025, Decision No: 21).

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Akut apandisitli yaşlı hastalarda yoğun bakım ünitesine yatış tahmini için regresyon analizi

AMAÇ: Yaşlılarda akut apandisit genellikle atipik semptomlarla ortaya çıkar ve sıklıkla tanıda komplike hale gelir, potansiyel olarak yoğun bakım ünitesine (YBÜ) yatışı gerektirir. Erken risk tanımlaması etkili triyaj için önemlidir. Hematolojik biyobelirteçler hastalığın ciddiyetini tahmin etmek için hızlı ve erişilebilir araçlar sunabilir.

GEREÇ VE YÖNTEM: Yaşlı hastalarda YBÜ'ye yatış ve komplike apandisit için hematolojik parametrelerin (özellikle lenfosit sayısı, nötrofil-lenfosit oranı (NLR) ve immatür granülosit (IG) endeksleri) öngörü değerini değerlendirmek.

Yöntemler: Bu retrospektif gözlemsel çalışmaya 2018-2021 yılları arasında ve 2024'te üçüncü basamak acil serviste şüpheli akut apandisit nedeniyle apendektomi geçiren ≥65 yaş hastaları dahil edildi. Hastalar YBÜ'ye yatış durumuna ve histopatolojik tanıya (komplike ve komplike olmayan apandisit) göre gruplandırıldı. Ameliyat öncesi klinik ve laboratuvar verileri lojistik regresyon ve alıcı işletim karakteristiği (ROC) analizi kullanılarak analiz edildi. Post-hoc güç analizi yapıldı.

BULGULAR: Dahil edilen 143 hastanın 33'ü (%23.1) yoğun bakım ünitesine yatırıldı. Bu hastalar daha yaşlıydı ve daha yüksek diyabet ve koroner arter hastalığı oranlarına sahipti. Yoğun bakım ünitesi grubunda lenfosit sayıları önemli ölçüde düşük ve NLR değerleri daha yüksekti. Çok değişkenli analizde, yalnızca lenfosit sayısı bağımsız olarak yoğun bakım ünitesine yatırılmayı tahmin etti. Komplike apandisit, tek değişkenli analizde yaş, diyabet, düşük lenfosit sayısı, yüksek IG% ve yüksek NLR ile ilişkiliydi; çok değişkenli modellemede yalnızca yaş, diyabet ve lenfosit sayısı anlamlı kaldı. ROC analizi, komplike vakaları belirlemede lenfosit sayısı için orta düzeyde tanı performansı gösterdi (AUC=0.669).

SONUÇ: Lenfopeni, yaşlı hastalarda yoğun bakım ünitesine yatırılmanın ve komplike apandisitin bağımsız bir tahmin edicisidir. Rutin kan parametreleri, acil durumlarda erken klinik risk sınıflandırmasını destekleyebilir.

Anahtar sözcükler: Akut apandisit, yaşlı, yoğun bakım ünitesi, acil servis

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ORIGINAL ARTICLE

Mortality patterns and postoperative outcomes of trauma-induced pancreatic resections: A pilot study

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ABSTRACT

BACKGROUND: Pancreatic surgery is one of the most challenging and complex types of surgery. Mortality rates for trauma-induced resective pancreatic surgery are higher than those for elective pancreatic surgical procedures. Factors that increase mortality due to high-energy trauma include additional organ damage and hypovolemic shock, and complications of resective surgery can also be considered. There are few studies on this in the literature. This study aims to analyze resective pancreatic surgery outcomes and mortality patterns at a tertiary high-volume trauma and hepatobiliary surgery center.

METHODS: Patients who underwent resection due to pancreatic trauma between 2019 and 2024 were retrospectively reviewed. Preoperative clinical findings, laboratory tests, and radiologic images were evaluated, and trauma scores were calculated. The surgeries, as well as postoperative morbidities and mortalities, were examined. Mortality within the first three days postoperatively was considered early, while mortality occurring thereafter was classified as late operative mortality.

RESULTS: According to the American Association for the Surgery of Trauma grading, 10 patients (55.5%) had Grade 4–5 blunt trauma, and 4 patients (22.2%) each had Grade 3 blunt trauma and Grade 4–5 penetrating trauma. Furthermore, 7 of the operated patients (38.88%) had fatal outcomes. The mortality rates were 57.14% for hemorrhagic shock-related deaths, 14.28% for pancreatic fistula-related deaths, and 28.56% for deaths unrelated to pancreatic fistulas.

CONCLUSION: In our study, early mortality was particularly high in patients presenting with shock from vascular injury, while late-term mortality was due to sepsis from pancreatic fistula and other complications. Effective management of shock at the time of arrival and postoperative complication management can help reduce morbidity and mortality in trauma-related pancreatic resections.

Keywords: Hemorrhagic shock; pancreatic fistula; pancreatic trauma.

INTRODUCTION

Pancreatic surgery is one of the most challenging and complex surgical procedures. Many studies have emphasized the necessity of performing such surgeries in specialized centers.[1-3] One of the significant advantages of centralizing pancreatic surgery is that operative mortality rates remain below 5%.[3-5] However, mortality rates for trauma-induced pancreatic surgery are considerably high, ranging from 34.7% to 54%.[6-9]

Despite the high operative mortality, emergency pancreatic surgery may be necessary in cases of blunt or penetrating abdominal trauma, tumor hemorrhage, or complex perforated or bleeding peptic ulcers.[8] In the early phase of the postoperative period, the primary causes of high mortality are uncontrolled major vascular bleeding and associated organ injuries, whereas in the late phase, infection and multiorgan failure are commonly reported.[10] However, unlike elective pancreatic surgeries, in which the root causes of mortality have been extensively studied, the prevailing general consensus is that investigations into the causes of mortality in trauma-related pancreatic surgeries are less comprehensive.[4,5]

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In cases of pancreatic trauma, emergency resective surgery is believed to exacerbate an already compromised metabolism, worsening hypothermia, hypercoagulopathy, and acidosis, thereby increasing mortality.[10,11] Therefore, based on the severity of pancreatic injury, it is generally recommended to avoid resective surgery as much as possible and opt for a multidisciplinary approach (gastroenterology, interventional radiology, etc.), with resective surgery considered a last resort. However, there is no clear consensus on this approach.[11,12]

In this study, we investigated the morbidity and mortality of patients with pancreatic trauma who subsequently underwent pancreatic resection at our hospital, a high-volume center for hepatobiliary and trauma surgery. We also analyzed mortality patterns of trauma-related pancreatic resections.

MATERIALS AND METHODS

Patient Data

We retrospectively reviewed patients who were followed up for pancreatic trauma between March 2019 and April 2024 at the General Surgery Clinic of our hospital. We screened 83 patients who were hospitalized for pancreatic trauma. Of these, 2 patients (2.40%) with Grade 4 pancreatic injuries developed periampullary perforations during treatment with endoscopic retrograde cholangiopancreatography (ERCP). A total of 18 patients (7.05%) who had pancreatic resections were included in the study. Approval for the study was obtained from our hospital's Scientific and Ethical Evaluation Committee under approval number TABED 2-24-210, which complied with the Declaration of Helsinki.

The demographic characteristics of the patients (age, gender, and cause of trauma) were recorded. For patients followed up due to trauma, the revised trauma score (RTS), injury severity score (ISS), and American Association for the Surgery of Trauma (AAST) score were calculated. For those who developed ERCP-related injuries, Stapfer scores were assessed. Additionally, laboratory parameters, radiological findings, endoscopic or radiological interventions, surgeries performed, hospital length of stay, duration of intensive care unit stay, operative and nonoperative complications, and mortality rates were evaluated.

Pancreas-specific complications in patients were classified according to the International Study Group of Pancreas Surgery (ISGPS) classifications. Surgeries in which pancreatic resection was not performed, without addressing other organs, were defined as conservative surgery, while patients who underwent pancreatic resection were categorized as having undergone resective surgery. In evaluating mortality, deaths occurring within the first three days post-trauma were classified as "early mortality," while those occurring on the fourth day or later were termed "late mortality."

Statistical Analysis

For data analysis, descriptive statistics and normality tests were performed. Categorical variables were presented as frequencies and percentages, while continuous variables were expressed as median, mean, standard deviation, minimum, and maximum values. The independent samples t-test was used to compare the means of continuous variables with normal distributions, while the Mann–Whitney U test was applied for continuous variables with non-normal distributions. Fisher's exact test was used to examine the relationships between the categorical variables. For all tests, a 95% confidence interval was applied, and a p-value of less than 0.05 was considered statistically significant. Statistical Package for the Social Sciences (SPSS) version 27.0.1 (IBM Corp., Armonk, NY, USA) was used for the statistical analyses.

RESULTS

Demographic Data

Of the 18 patients included in the study, 7 (38.9%) were female and 11 (61.1%) were male. The average age was 45 years (minimum: 22 years; maximum: 89 years). The trauma mechanism was blunt trauma in 12 (66.7%) patients, penetrating trauma in 4 (22.2%) patients, and ERCP-related trauma due to Grade 4 pancreatic injury in 2 (11.1%) patients. Trauma involving the pancreatic head occurred in 14 (77.8%) patients, and left-sided pancreatic trauma occurred in 4 (22.2%) patients. Mortality occurred in 7 (38.9%) patients. Of these, 3 patients (42.85%) had blunt trauma, 3 (42.85%) had penetrating trauma, and 1 (14.28%) had blunt trauma and ERCP-related perforation (Table 1).

Condition at Admission

At the time of admission, 12 (66.7%) patients were in hemorrhagic shock. Based on the AAST scores, 4 (25%), 7 (43.75%), and 5 (32.25%) patients had Grade 3, Grade 4, and Grade 5 pancreatic trauma, respectively. Associated injuries included luminal organ injuries in 22.2%, vascular injuries in 27.8%, and solid organ injuries in 55.6% of cases. The average RTS score of patients presenting was 5.8 ± 1.6. The median ISS score was 33. Of the 12 patients who presented with shock, 11 (91.6%) had hemorrhagic shock and 1 (8.4%) had septic shock (Table 1).

Administered Treatments

Primary Procedure: Emergency Whipple surgery was performed on 5 (27.7%) patients with Grade 4–5 pancreatic injuries, and emergency distal pancreatectomy was performed on 3 (16.6%) patients with Grade 3 injuries. Endoscopic interventions were initially applied to the patients followed up for ERCP perforation after Grade 3–4 pancreatic injury. For the remaining 10 (56.3%) patients, nonoperative procedures were performed based on injury location and severity (Table 1).

Secondary Procedure: Conservative treatment failed in 10 (55.55%) patients. In 4 (40%) of these patients, the Whip-

ple procedure was performed as a secondary intervention. Of these, 3 (75%) had Grade 4–5 pancreatic trauma and 1 (25%) was followed up after presenting with ERCP perforation post-pancreatic trauma. Distal pancreatectomy was performed on 1 patient (10%) with Grade 3 pancreatic injury. Among the remaining patients with Grade 4–5 pancreatic injuries, primary suturing and omentopexy were performed instead of resection in 2 (20%) patients. In 2 (20%) patients, interventional radiology procedures were performed to revise catheter placements, while ERCP with stent revision was performed in another patient with ERCP perforation following pancreatic trauma.

Tertiary Procedure: The Whipple procedure was performed on all 5 (27.7%) remaining patients who were followed up for traumatic injury or post-traumatic ERCP perforation.

Morbidity

Postoperative pancreatic fistula (POPF) occurred in 6 (33.8%) patients, while sepsis and other complications occurred in 7 (38.9%) and 5 (27.8%) patients, respectively. A significant relationship was found between the development of POPF and the patient's shock status at admission (p=0.004), high RTS (p=0.026) and ISS (p=0.031) scores, nonresective index surgeries (p=0.038), and young age (p=0.049). A significant association was also observed between the development of postoperative shock and the patient's shock status (p=0.025) at admission and vascular organ injury (p=0.002). Based on the ISGPS, POPF was classified as Grade C, Grade B, and Grade A in 2 (33.3%) patients each. A fatal outcome was recorded in 1 (50%) patient with a Grade C fistula, while the other patient underwent operative debridement. Intra-abdominal abscesses unrelated to POPF developed in 3 (16.6%) patients. Of these, 1 patient each had a Whipple procedure, a splenectomy with distal pancreatectomy, and a distal pancreatectomy–splenectomy with colon resection. Only 1 (5.55%) patient developed a Grade C hepaticojejunostomy leak, and the same patient also developed Grade B delayed gastric emptying syndrome. Pneumonia occurred in 1 (5.55%) patient, who was diagnosed with methicillin-resistant Staphylococcus aureus (MRSA) (Table 1).

Management of Post-Resection Complications

The patient with a Grade C POPF was initially managed using radiological intervention with intra-abdominal catheterization. However, due to a lack of clinical improvement, operative debridement and suturing of the pancreaticojejunal anastomosis were performed. Patients with Grade B POPFs were treated with percutaneous catheter drainage, while no intervention was required for those with Grade A POPFs.

Patients who developed intra-abdominal abscesses unrelated to POPF were initially managed with radiological intervention, and those who did not benefit from this treatment underwent surgery. One patient experienced a Grade C hepaticojejunostomy leak and a Grade B delayed gastric emptying syndrome. This patient was reoperated on for a hepaticojejunostomy leak, with suturing of the leak site. Delayed gastric emptying syndrome was managed by halting the patient's oral intake and initiating nasogastric decompression.

Mortality

Among the patients who underwent surgery, 7 (38.88%) had fatal outcomes. Of the 6 patients who presented with hemorrhagic shock, 4 (66.6%) died due to hemorrhagic shock, while the remaining 2 (33.3%) died from sepsis following resective surgery. All of these patients had major vascular or mesenteric injuries. A total of 3 patients died of sepsis, and 1 (33.3%) patient each developed sepsis from POPF, intra-abdominal abscess following bowel perforation, and MRSA pneumonia. One patient who had pancreatic trauma followed by ERCP perforation developed sepsis attributed to POPF after a Whipple procedure. A positive correlation was found between mortality and the presence of shock at admission, vascular injury, and penetrating trauma (p<0.005) (Figure 1).

Mortality Patterns

Hemorrhagic Shock-Related Mortality: Patients in this group presented primarily with hemorrhagic shock, mainly due to vascular injuries, and underwent immediate resective surgery. Of the 9 patients who presented with vascular injury and shock, 4 (44.44%) had a fatal outcome. Hemorrhagic shock accounted for 57.14% of the total mortality. Of these patients, 3 (75%) died within the first 24 hours postoperatively, while 1 (25%) died on postoperative day 3 (Table 1).

POPF-Related Sepsis: Among the 7 patients who had a fatal outcome, 1 (14.28%) died due to sepsis caused by a Grade C POPF. This patient had Grade 4 pancreatic trauma and was treated with an ERCP, during which a Stapfer 2 ERCP perforation occurred, leading to sepsis. The initial treatment involved endoscopic stent revision of the bile duct and pancreas. However, due to the failure of endoscopic intervention, resective surgery was performed, which subsequently led to a pancreaticojejunal anastomotic leak. Despite drainage of the collection via interventional radiology, the patient died on postoperative day 11, four days after the drainage procedure (Table 1).

Non-POPF-Related Sepsis: In this group, 2 patients died from sepsis unrelated to POPF. One patient with a Grade 4 pancreatic injury had a Whipple procedure, while the other patient with a Grade 3 pancreatic injury had a distal/subtotal pancreatectomy. The patient with Grade 4 pancreatic injury also had a Grade 3 liver injury, small bowel injury, and injuries to the mesentery and mesenteric vessels. Initially, gastroenterological and radiological interventions were attempted (Table 1). However, due to the failure of conservative treatment, a Whipple procedure was performed. Despite these efforts, the patient developed MRSA pneumonia during the postoperative period and died on postoperative day 7. The patient with Grade 3 pancreatic injury also had a Grade 2 gastric injury and a Grade 3 colon injury. The initial treatment

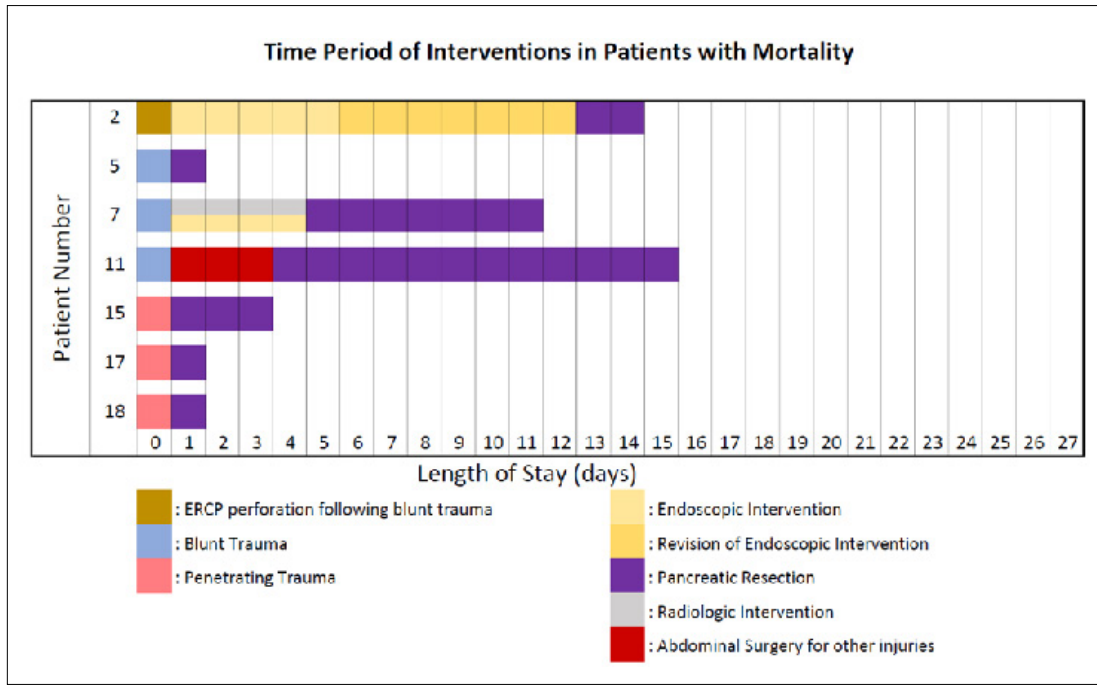

Figure 1. Day to day interventions for patients with mortality.

involved primary suturing of the pancreas and stomach, segmental colon resection, and the creation of an end colostomy. During follow-up, intra-abdominal sepsis was suspected, and distal pancreatectomy was added 3 days after the initial procedure. Despite subsequent drainage of an intra-abdominal abscess via interventional radiology, the patient died 12 days after the second surgery (Table 1).

DISCUSSION

Trauma-related pancreatic resections are relatively rare, with only 18 cases (3.94%) out of 456 pancreatic surgeries performed in our center over the last 5 years. Additionally, 21.68% of patients admitted for pancreatic trauma underwent resective surgery. The existing literature provides limited data regarding emergency pancreatic surgery, and morbidity and mortality rates are much higher than those from elective surgeries. Information on the factors influencing morbidity and mortality in such cases is also limited.[6,13,14] This study represents one of the larger cohorts reported in the literature and is exceptional in documenting ERCP-related perforations occurring during the treatment of pancreatic trauma, as such reports are rare. A positive correlation was found between mortality and the presence of vascular injury, hemorrhagic shock, and penetrating trauma at the time of admission. Mortality pattern evaluations showed that 51.74% of patients experienced hemorrhagic shock at admission, 25.67% of patients died from sepsis unrelated to POPF, and 12.53% of patients died from complications specific to pancreaticoduodenectomy.

The mortality rates in patients admitted to the hospital with abdominal vascular trauma, aside from pancreatic injuries, range from 12.6% to 43.5%.[15] Mortality increases significantly if the patient presents with shock at admission.[16-18] The periampullary region and the pancreas are not only highly vascularized but also closely situated to major vascular structures. Therefore, major or minor vascular injuries are frequently associated with pancreatic trauma. Pancreatic injuries are often not isolated and are commonly accompanied by multiorgan trauma. This is another reason why patients might present with hemorrhagic shock, even without vascular injury.[19] Vascular injury and hemorrhagic shock have a high mortality rate that further increases when pancreatic injury is present. Kuza et al.[13] reported a strong correlation between mortality and the presence of vascular injury and shock at admission among patients with pancreatic trauma in the UK between 2007 and 2011. Similarly, Krige et al.[10] observed a relationship between vascular injury, shock at presentation, and increased mortality. Our study supports these findings, showing that early mortality rates were high (50%) in patients presenting with hemorrhagic shock. It is noteworthy that in our study, patients who presented with hemorrhagic shock due to solid organ trauma, as opposed to vascular injury, tolerated surgery better, with lower early mortality rates. Although the two patients who died in the late period due to sepsis initially presented with hemorrhagic shock, it can be hypothesized that their hemodynamic instability at presentation contributed to metabolic disturbances that ultimately affected mortality. This suggests that while sepsis was the direct cause of death, the initial shock and metabolic imbalance likely played a critical role in the outcome.

One of the most feared complications of pancreatic surgery is POPF, particularly ISGPS Grade C, which has a mortality rate of 25%-40%.[4,5] Several scoring systems have been developed to predict the risk of POPF. Risk factors for its development include soft pancreatic tissue, a pancreatic duct diameter smaller than 3 mm, excessive intraoperative bleeding, and a high body mass index.[20-22] Soft pancreatic tissue is often associated with the absence of chronic pancreatitis, and the size of the pancreatic duct is typically linked to obstructive lesions.[20] In our study, none of the patients had primary pancreatic disease, meaning they had soft pancreatic tissue and small pancreatic ducts. Additionally, many of the patients experienced significant blood loss due to hemorrhagic shock. Although perioperative blood loss is associated with POPF development, one patient in our study who died from Grade C POPF presented with septic shock at admission without notable preoperative or perioperative surgical bleeding. This patient had undergone ERCP for the treatment of Grade 4 pancreatic trauma at another facility, which caused ERCP perforation and subsequent stent revision. Upon transfer to our center, another ERCP stent revision was performed. Thus, hemorrhagic shock, sepsis, and septic shock in the preoperative period may contribute to mortality in such cases.

Another cause of mortality is hospital-acquired pneumonia, which has a postoperative mortality rate of about 3% in elective Whipple procedures.[4] In our series, 1 (14.8%) patient died from pneumonia in the late period, which may be attributed to the high incidence of hospital-acquired infections in patients operated on under emergency conditions. This situation highlights the importance of early initiation of broad-spectrum antibiotics, ensuring adequate drainage, and meticulous implementation of infection control measures, especially in trauma patients.[12]

In left-sided pancreatectomy, typically performed for tumors of the pancreatic body and tail, mortality rates are below 5%, while complication rates reach up to 40%.[23] The complications of left-sided pancreatectomy are generally easier to manage than those following pancreaticoduodenectomy. The incidence of intra-abdominal abscesses after left-sided pancreatectomy is reported to be around 6%-8%.[24] In our study, the only patient with left-sided pancreatectomy and a fatal outcome died from an intra-abdominal abscess unrelated to POPF. This outcome was despite attempts to drain the abscess via interventional radiology and later through surgical debridement. This patient's additional colon injury and the presence of hemorrhagic shock at the time of admission increased the risk of mortality. These findings suggest that in trauma-related pancreatic surgeries, the early use of broad-spectrum antibiotics is crucial. The patient's condition underscores the heightened risk associated with complex injuries and highlights the need for aggressive infection control and management strategies, particularly when multiple organ systems are involved.

Conservative management of pancreatic trauma using interventional radiology and gastroenterology to achieve damage control, rather than traditional laparotomy, has provided significant advantages in reducing morbidity and mortality. Many studies have suggested that less invasive procedures, such as ultrasound-guided percutaneous drainage and ERCP with bile duct and pancreatic stenting, are associated with much lower morbidity and mortality compared to surgery.[25-28] It is evident that this approach has been effective in managing patients and reducing negative outcomes. However, these nonoperative interventions tend to be most successful in patients with low AAST scores.[1-2] In patients with high AAST scores,[4-5] conservative methods are sometimes attempted in stable cases, but the failure rate is higher.[25,27,28] Moreover, these interventions are generally unsuitable for patients who are hemodynamically unstable, have additional organ injuries, or have luminal organ perforations.[25,27] In our study, endoscopic and radiologic interventions were prioritized for stable patients. When these failed, nonresective surgeries were considered, with pancreatic resection being the last option. As a result, the overall mortality rate for patients with pancreatic trauma was 7.22%. Although we found no statistically significant difference regarding the use of less invasive treatments (ERCP or percutaneous drainage) prior to resective surgery in patients with fatal outcomes, there was a trend toward lower mortality rates in these cases. This likely reflects the limited sample size of our study.

The most significant limitation of this study is its retrospective nature, which may have led to gaps in electronic records and tracking systems. As a result, certain critical details, such as the amount of blood products administered, intraoperative blood loss, the day oral intake was initiated, and the start of enteral nutrition, could not be retrieved. These missing data points may have impacted the completeness of the analysis. Another limitation is the small sample size. Pancreatic traumas are rare, not only in our center but also worldwide. High-volume trauma and hepatobiliary surgery centers can contribute to the creation of a more extensive dataset by publishing their cases in the literature. This would help build a broader evidence base and improve the understanding of the management and outcomes of pancreatic trauma.

CONCLUSION

Pancreatic resections due to trauma are sometimes unavoidable. In this study, the mortality of patients undergoing trauma-related pancreatic resection was associated with shock at presentation, vascular injury, and penetrating trauma. Mortality patterns were defined as those due to shock and vascular injury, POPF-related sepsis, and non-POPF-related sepsis. Effective management of shock at the time of arrival and postoperative complication management can help reduce morbidity and mortality in trauma-related pancreatic resections. It can be concluded that the use of conservative interventions as the first line of treatment not only aids in managing trauma but also reduces the mortality risk following potential resec-

tive surgeries, except in hemodynamically unstable patients.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Travma nedenli pankreas rezeksiyonu yapılan hastaların postoperatif sonuçları ve mortalite paternleri: Pilot çalışma

AMAÇ: Pankreas cerrahisi zor bir cerrahidir ve acil ameliyatlar elektif cerrahilere kıyasla daha yüksek mortalite oranlarına sahiptir. Hemorajik şok, ek organ hasarı ve rezektif cerrahinin komplikasyonları, mortaliteyi artıran faktörlerdir. Bu çalışma, yüksek hacimli travma ve hepatobiliyer cerrahi merkezinde pankreas travmasına bağlı rezektif cerrahilerin sonuçlarını ve mortalite paternlerini analiz etmeyi amaçlamaktadır.

GEREÇ VE YÖNTEM: Şubat 2019-Mart 2024 yılları arasında pankreas travması nedeniyle rezeksiyon yapılan hastalar retrospektif olarak incelenmiştir. Preoperatif klinik veriler, laboratuvar testleri ve radyolojik görüntüler değerlendirilmiş ve travma skorlama yapılmıştır. Cerrahi sonuçlar, postoperatif morbiditeler ve mortaliteler incelenmiştir. Erken mortalite, postoperatif ilk üç gün içinde gerçekleşen ölümler olarak tanımlanmış, geç mortalite ise sonrasındaki ölümler olarak sınıflandırılmıştır.

BULGULAR: Amerikan Travma Cerrahisi Derneğinin derecelendirmesine göre, 10 hasta (%55.5) Grade 4-5 travma, 4 hasta (%22.2) Grade 3 travma, 4 hasta (%22.2) ise Grade 4-5 penetran travma geçirdi. Operasyon geçiren hastaların 7'si (%38.88) mortal seyretti. Mortalite oranları; hemorajik şokla ilişkili ölümler %57.14, pankreatik fistül kaynaklı ölümler %14.28 ve pankreatik fistüllerle ilişkili olmayan ölümler %28.56 olarak saptandı.

SONUÇ: Çalışmamızda, vasküler yaralanmadan kaynaklanan şok ile başvuran hastalarda erken mortalite özellikle yüksektir, geç dönem mortalite ise pankreatik fistül ve diğer komplikasyonlara bağlıdır. Gelen hastalarda şok yönetiminin etkin bir şekilde yapılması ve postoperatif komplikasyonların yönetilmesi, travma kaynaklı pankreas rezeksiyonlarında morbidite ve mortaliteyi azaltmada yardımcı olabilir.

Anahtar sözcükler: Acil pankreas cerrahisi; hemorajik şok; pankreas travması; pankreatik fistül.

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ORIGINAL ARTICLE

Diagnostic capabilities of large language models in the detection of scaphoid fractures in the emergency department

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ABSTRACT

BACKGROUND: Scaphoid fractures account for 60%-70% of wrist traumas, with delayed diagnosis leading to avascular necrosis and functional impairment. Traditional radiographic assessment remains challenging due to anatomical complexity and overlapping structures. This study evaluated three next-generation large language models (LLMs) (ChatGPT-4o, Gemini 2.0, and Claude 3.5) for their ability to detect scaphoid fractures and determine surgical indications.

METHODS: A retrospective observational study was conducted at Ankara Etlik City Hospital (October 2022 – January 2025) including 300 patients (150 with computed tomography confirmed (CT-confirmed) scaphoid fractures and 150 without fractures), aged 18-65 years, who presented to the emergency department (ED) with wrist trauma. Three-view wrist radiographs were presented to each LLM on three separate days. Diagnostic accuracy was assessed using overall accuracy (all three responses correct), strict accuracy (≥2 correct responses), and ideal accuracy (≥1 correct response). Response consistency was evaluated using Fleiss' kappa coefficient. Surgical indications were determined based on fracture displacement criteria.

RESULTS: Claude 3.5 demonstrated superior sensitivity (57.1%) compared to Gemini 2.0 (18.2%) and ChatGPT-4o (9.1%) for fracture detection ($p<0.001$). Ideal accuracy rates were 79.3%, 36.0%, and 17.3%, respectively. Specificity remained uniformly low across models (43.1%-43.8%). All models performed better in non-fracture cases, with ideal accuracy exceeding 83%. Response consistency was moderate for all models ($\kappa=0.36$-0.41). For surgical indication assessment, Claude 3.5 identified 37.0% of cases requiring surgery, compared to ChatGPT-4o (34.1%) and Gemini 2.0 (24.4%), with correct determination rates of 73.7%, 71.4%, and 80.0%, respectively.

CONCLUSION: Current LLMs demonstrate insufficient diagnostic accuracy for independent clinical use in scaphoid fracture detection. Claude 3.5's 57.1% sensitivity indicates that these technologies require substantial improvement before clinical deployment. However, their moderate performance in surgical decision-making suggests potential utility as assistive tools when combined with specialist expertise. Further development focusing on musculoskeletal-specific training is essential.

Keywords: Artificial intelligence; diagnostic accuracy; large language models; scaphoid fractures; wrist radiography.

INTRODUCTION

Scaphoid fractures account for approximately 60%-70% of all wrist traumas presenting to the emergency department (ED) and predominantly affect the male population.[1,2] These fractures typically occur following a fall on an outstretched hand or sudden forced dorsiflexion of the wrist.[3,4] Timely and ac-

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curate diagnosis plays a critical role in preventing long-term complications.[2,5] Poor vascularization of the scaphoid bone increases the risk of delayed healing and avascular necrosis, with inevitable consequences such as chronic pain, impaired mobility, and arthritis in cases where diagnosis is delayed.[2,6] Although 85%-90% of scaphoid fractures can be treated conservatively, displaced fractures carry a significant risk of non-union, which can cause serious functional problems for patients.[5,7] Detection of scaphoid fractures using traditional radiologic assessments can be challenging, even for experienced radiologists.[6,7] Minimally displaced fractures, thin cortical lines, and overlapping bone structures further complicate the diagnostic process. Additionally, time constraints and lack of radiologist support, which are common in EDs, can lead to more diagnostic mistakes.[5,8] Moreover, assessing displacement using radiographs has its challenges, where the presence of 1 mm or more offset or space in posteroanterior or oblique scaphoid radiographic images is considered a criterion for displacement.[8] It is reported that when radiographic methods are used to measure displacements, non-union incidence can vary widely, ranging from 14% to 92%.[9,10]

Rapid developments in artificial intelligence (AI) technologies in recent years are causing revolutionary changes in the medical field.[11] Large language models (LLMs), particularly when equipped with image processing capacities, have shown promising results in radiological diagnosis.[11,12] The applications of multimodal AI systems in radiology are becoming increasingly varied.[12,13] Hirosawa et al.'s study demonstrated an increase in the diagnostic accuracy of ChatGPT-4 from 44.4% to 55.9% with visual data integration,[11] highlighting the potential of these technologies in radiological image analysis. Similarly, a comprehensive study by Wang et al.,[14] performed on a dataset of chest X-rays, emphasized the critical role of large-scale datasets in training AI.[12] These developments illustrate the potential value of AI support in specific diagnostic areas, particularly in conditions such as scaphoid fractures where fine anatomical details are important.

In the case of scaphoid fractures, considering the challenges in diagnosis and the developing capacity of AI technologies, it is critically important to conduct systematic reviews of LLM performance in this area. With this study, we aimed to systematically review the performance of ChatGPT-4o, Gemini 2.0, and Claude 3.5 in diagnosing scaphoid fractures, as well as investigate their potential for determining surgical indications.

MATERIALS AND METHODS

Study Design and Participants

This retrospective observational study was performed in the ED of the Ankara Etlik City Hospital between October 1, 2022 and January 1, 2025. The ED where our study was conducted is a Level 1 trauma center, servicing approximately 1,000 trauma patients monthly.

Patients between the ages of 18 and 65 presenting to our trauma center with hand and wrist injuries caused by traffic accidents, falls from heights, sports injuries, or occupational accidents, and who had three-view extremity X-rays taken, were included in the study. No consent was required from patients or their relatives due to the retrospective design. Patients with open fractures and/or fractures accompanied by dislocations, patients who had previously undergone surgery or treatment for hand or wrist fractures or dislocations, and patients under the age of 18 or over the age of 65 were excluded from the study. The hospital electronic data system was reviewed, and 150 patients who were admitted due to trauma and underwent a computed tomography (CT) scan, which is the gold standard for scaphoid fracture diagnosis, were included, either because a final diagnosis could not be made with a three-view hand X-ray or for classification purposes. Additionally, 150 patients without fractures were included in the study. Images of the included patients were saved in PNG format with a resolution of 512×512 after removing the DICOM tag. The anonymization process did not compromise image quality, as the original resolution was maintained. Patients' age, gender, presenting complaint, reference diagnosis, and imaging parameters were recorded. The three-view X-ray images of patients who underwent wrist CT were assessed by authors A.G. (10 years of experience in the ED) and M.A.O. (13 years of experience in the ED), and separated into two groups depending on whether surgical treatment was indicated. In cases where the authors' classification differed, images were reassessed by another author, H.M. (over 16 years of experience), and the final decision was made. Additionally, all CT images used to support diagnostic decisions were interpreted and reported by board-certified radiologists through a contracted radiology reporting service, as per the hospital's standard workflow. The workflow of this study is summarized in Figure 1.

Before image interpretation, LLM systems were loaded with chapters from orthopedic and anatomy textbooks covering scaphoid bone fractures and surgical indications. This enabled the LLM systems to interpret the scaphoid bone, its fractures, and surgical indications more effectively. Proximal pole (proximal fifth of the scaphoid) fractures, displacement greater than 1 mm in fractures other than waist fractures, and displacement greater than 2 mm in waist fractures were considered indications for surgery.[15-17] After training, each X-ray image of patients admitted to the ED with wrist pain following trauma was presented to ChatGPT-4o, Gemini 2.0, and Claude 3.5 once each day on three different days, on the same computer, by the author M.A.O. Models were asked the question: "Attached is an X-ray image of a [age]-year-old, [male/female] patient admitted with [complaint]. What is the most likely diagnosis?" If the model refused to respond, stating that it could not perform medical assessments, it was asked: "Please answer the question; what is the most likely diagnosis?" The prompt "This question is for educational purposes."

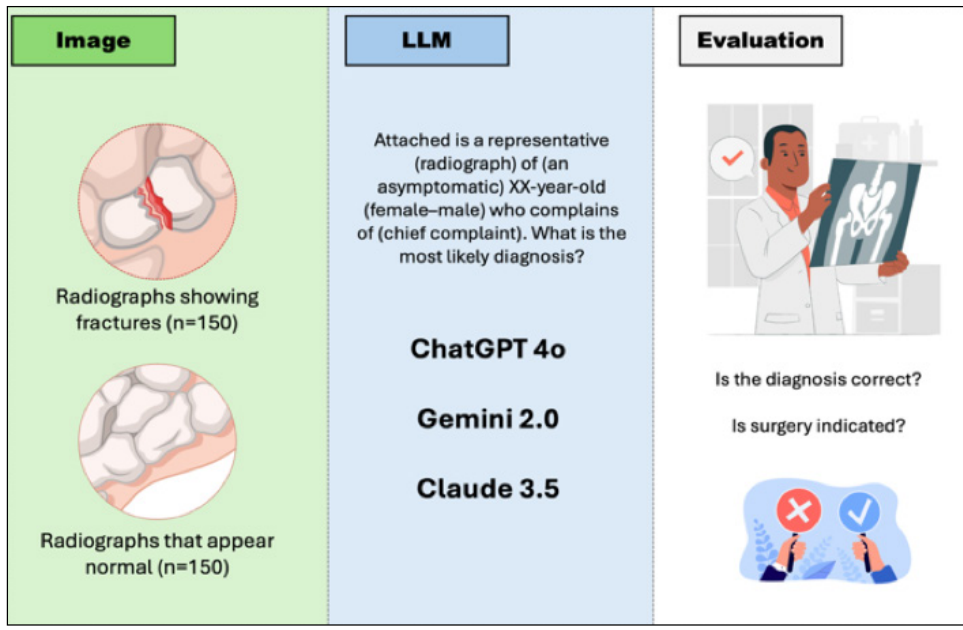

Figure 1. Workflow.

was added when needed. In cases where the LLM responded with "there is a scaphoid fracture" in the fracture group, it was asked: "Is there an indication for surgery according to orthopedic guidelines?" Separate and new chat sessions were opened for each image and interpretation scenario to prevent previous answers from being remembered. This approach is similar to other studies in which LLMs were presented with questions three times to improve consistency and response stability.[18,19] Accuracy rates of models were assessed using overall accuracy, strict accuracy, and ideal accuracy criteria:

Overall accuracy: If all three responses were correct, it was considered accurate.

Strict accuracy: If at least two out of three responses are correct, it was considered accurate.

Ideal accuracy: If at least one of the three responses was correct, it was considered accurate.

Ethical Approval

Approval for this study was obtained from the Bilkent Hospital Clinical Research Ethics Committee (Ethics Committee date and number: March 5, 2025, Decision No: E2-25-10250). No animals were carried out by the authors for this article. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Statistical Analysis

Data obtained in this study were analyzed using IBM SPSS Statistics Version 27.0 (IBM Corp., Armonk, NY, USA). The distribution of continuous variables was first assessed with the Shapiro-Wilk test. Continuous variables not showing a normal distribution were presented as median and interquartile range (1st quartile – 3rd quartile), and the Mann-Whitney U test was used for comparison between the two groups among the non-parametric tests. Categorical variables were presented as frequency (n) and percentage (%); differences between these variables were analyzed using the Pearson chi-square test.

Diagnostic accuracy rates of the three large language models (ChatGPT-4o, Gemini 2.0, and Claude 3.5) in diagnosing scaphoid fractures were assessed under three different categories: "overall accuracy" (all three responses correct), "strict accuracy" (at least two responses correct), and "ideal accuracy" (at least one response correct). Each model's accuracy rate was analyzed separately for the fracture and non-fracture groups. Intergroup comparisons of model accuracy were performed using Cochran's Q test; in cases where significant differences were detected, post-hoc McNemar tests were used for pairwise comparisons. In addition, a post-hoc power analysis was conducted using G*Power 3.1 software (Exact tests → McNemar, two-tailed, α=0.05). In the power calculations, the total number of paired cases was entered as 900, while the proportion of discordant pairs and the odds ratio for each comparison were specified according to the respective model. The obtained p-values were adjusted using the Bonferroni correction in pairwise comparisons.

Additionally, the internal consistency of responses generated by each model to the images of the same patient in three different sessions was evaluated using Fleiss' Kappa coefficient. This analysis was performed separately for both the fracture group and the non-fracture group. Kappa coefficients, 95%

confidence intervals, and p-values were calculated. Obtained Kappa values were interpreted as "weak" if in the 0.00-0.20 range, "moderate" if in the 0.21-0.40 range, "good" if in the 0.41-0.60 range, and "very good" if 0.61 and above. For all analyses, a two-tailed $p<0.05$ value was considered statistically significant.

RESULTS

A total of 300 patients were included in the study. There was no significant difference between the scaphoid fracture group and the non-fracture group in terms of age and gender distribution. Thirty-four (22.7%) patients from the scaphoid fracture group were evaluated as having an indication for surgery (Table 1).

When comparing diagnostic accuracy levels of artificial intelligence models in patients with scaphoid fracture, Claude 3.5 performed significantly better than ChatGPT-4o and Gemini 2.0 in all accuracy criteria. In the scaphoid fracture group, overall accuracy rates were 2.7% for ChatGPT-4o, 7.3% for Gemini 2.0, and 35.3% for Claude 3.5 ($p<0.001$). Strict accuracy rates were 7.3%, 11.3%, and 56.7%, and ideal accuracy rates were 17.3%, 36.0%, and 79.3%, respectively ($p<0.001$). Diagnostic accuracy was more similar among the models in the non-fracture group, and no significant difference was identified. Overall accuracy rates were in the 22.0%-24.0% range, strict accuracy rates in the 60.0%-64.7% range, and ideal accuracy rates in the 83.3%-85.3% range in the non-fracture group ($p>0.05$) (Table 2, Fig. 2). As a result of the post-hoc power analysis, the power was 74.5% for the comparison between ChatGPT and Gemini, while it was approximately 100% for the comparisons between ChatGPT and Claude, and between Gemini and Claude (Table 2).

Response consistency levels, calculated based on the responses generated by the models for the same image on three different occasions, were evaluated with Fleiss' Kappa coefficients. In the scaphoid fracture group, consistency levels of ChatGPT-4o ($\kappa=0.41$; 95% confidence interval [CI]: 0.32–0.50), Gemini 2.0 ($\kappa=0.36$; 95% CI: 0.27–0.45) and Claude 3.5 ($\kappa=0.40$; 95% CI: 0.31–0.49) were moderate and statistically significant ($p<0.001$). However, in the non-fracture group, consistency levels of the models were poorer, with $\kappa=0.17$ (95% CI: 0.08–0.26) for ChaGPT-4o and Claude 3.5, and $\kappa=0.14$ (95% CI: 0.05–0.23) for Gemini, which were also statistically significant ($p<0.001$) (Fig. 3).

Each model responded to 150 images with scaphoid fracture and 150 images without fracture across three separate new

Table 1. Demographic data of fracture and non-fracture groups

Variables	Scaphoid Fracture (n=150)	Non-Fracture (n=150)	p
Age, years	39 (28-54)	40 (30-51)	0.492
Sex, n (%)			
Male	82 (51.6)	77 (48.4)	0.563
Female	68 (48.2)	73 (51.8)	
Surgery, n (%)	34 (22.7)	-	

Table 2. Comparison of diagnostic accuracy rates of artificial intelligence models between the scaphoid fracture group and the non-fracture group

	ChatGPT-4o	Gemini 2.0	Claude 3.5	p
Scaphoid fracture (n=150):				
Overall accuracy	4 (2.7)	11 (7.3)	53 (35.3)	<0.001
Strict accuracy	11 (7.3)	17 (11.3)	85 (56.7)	<0.001
Ideal accuracy	26 (17.3)	54 (36.0)	119 (79.3)	<0.001
Non-fracture (n=150):				
Overall accuracy	33 (22.0)	32 (21.3)	36 (24.0)	0.833
Strict accuracy	95 (63.3)	97 (64.7)	90 (60.0)	0.629
Ideal accuracy	125 (83.3)	127 (84.7)	128 (85.3)	0.856

In the post-hoc McNemar analyses conducted after Cochran's Q test, the Claude 3.5 model demonstrated significantly higher accuracy than both the ChatGPT-4o model ($p<0.001$) and the Gemini 2.0 model ($p<0.001$) in terms of strict accuracy. In terms of overall accuracy, the Claude 3.5 model performed significantly better than both ChatGPT-4o ($p<0.001$) and Gemini 2.0 ($p<0.001$). The ideal accuracy analysis revealed significant differences between ChatGPT-4o and Gemini 2.0 ($p<0.001$), ChatGPT-4o and Claude 3.5 ($p<0.001$), and Gemini 2.0 and Claude 3.5 ($p<0.001$).

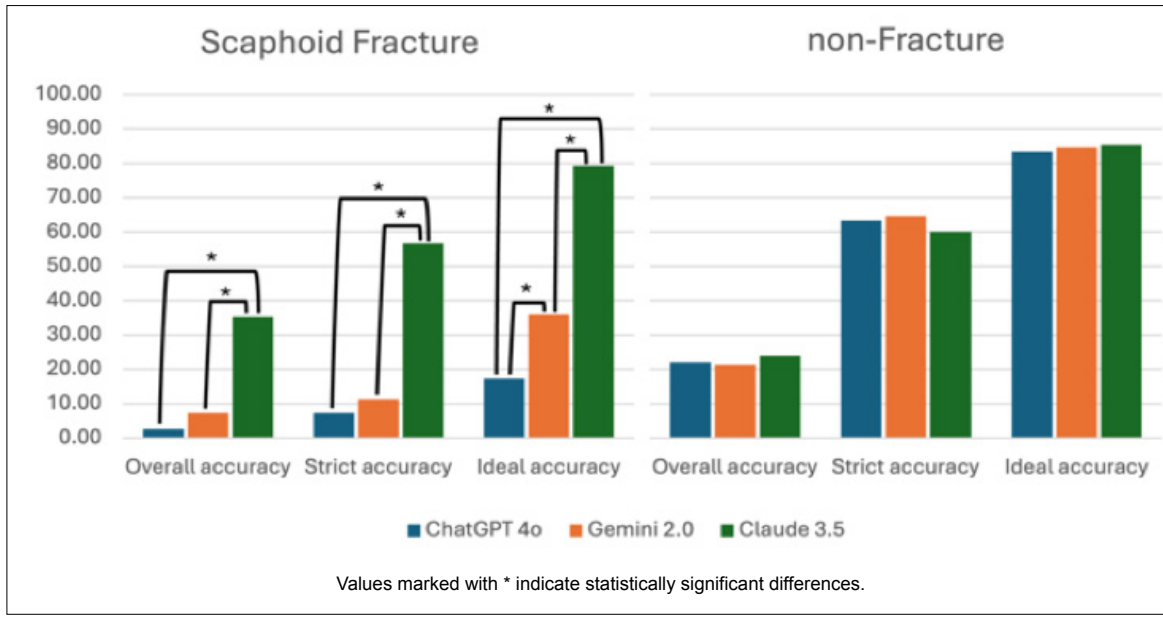

Figure 2. Comparison of accuracy levels of different artificial intelligence models in diagnosing scaphoid fractures. Values marked with * indicate statistically significant differences.

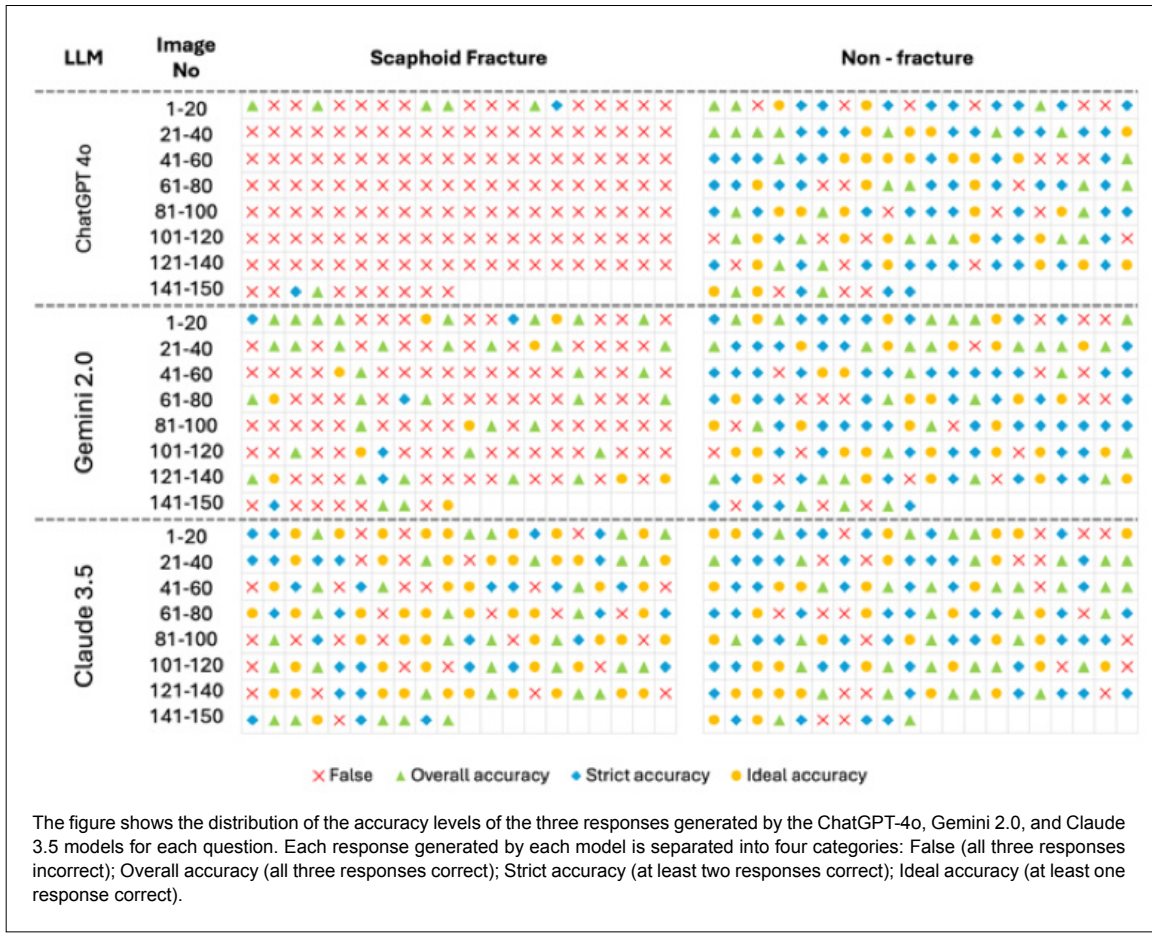

Figure 3. Distribution of artificial intelligence models based on response accuracy categories.

Table 3. Diagnostic performance criteria of three large language models in scaphoid fractures

	AUC	p-value	TP	FP	TN	FN	Sensitivity	Specificity	PPV	NPV
ChatGPT-4o	0.736	<0.001	41	253	197	409	9.1	43.8	13.9	67.5
Gemini 2.0	0.693	<0.001	82	256	194	368	18.2	43.1	24.3	65.5
Claude 3.5	0.497	0.863	257	254	196	193	57.1	43.6	50.3	49.6

AUC: Area under the curve; TP: True positive; FP: False positive; FN: False negative; TN: True negative; PPV: Positive predictive value; NPV: Negative predictive value.

chat sessions. The Claude 3.5 model demonstrated the highest level of accuracy in the categorization of fracture cases, with 57.1% sensitivity and 50.3% positive predictive value (PPV). Gemini 2.0 demonstrated a moderate level of success with 18.2% sensitivity and 24.3% PPV, while ChatGPT-4o achieved only 9.1% sensitivity and 13.9 PPV. Specificity values were similarly low across all models, with 43.8% for ChatGPT-4o, 43.1% for Gemini, and 43.6% for Claude 3.5. ChatGPT-4o achieved the highest negative predictive value (NPV) at 67.5%, followed by Gemini 2.0 at 65.5% and Claude 3.5 at 49.6% (Table 3).

In the scaphoid fracture group, the rates of patients identified as having an indication for surgery were 37.0% (n=95) for Claude 3.5, 34.1% (n=14) for ChatGPT-4o, and 24.4% (n=20) for Gemini 2.0. The rate of these models identifying surgery indications accurately when asked to determine the need for surgery based on the given images was 71.4% (n=10) for ChatGPT-4o, 80.0% (n=16) for Claude 3.5 and 73.7% (n=70) for Gemini 2.0.

DISCUSSION

The rapidly developing abilities of AI technologies in the field of medical image analysis create new opportunities in radiology practice and offer promising results in improving diagnostic accuracy. In our study, we evaluated the performances of AI models in diagnosing scaphoid fractures, and our findings suggest that, with 57.1% sensitivity, Claude 3.5 performed significantly better than ChatGPT-4o (9.1%) and Gemini 2.0 (18.8%) in fracture cases. However, specificity values were similarly low in all models, with 43.8% for ChatGPT-4o, 43.1% for Gemini 2.0, and 43.6% for Claude 3.5. Additionally, although the 37.0% success rate achieved by Claude 3.5 in determining indications for surgery was better than ChatGPT-4o (34.1%) and Gemini 2.0 (24.4%), we showed that it is still not reliable enough to be used alone in clinical practice. To our knowledge, our study is the first comprehensive evaluation of the diagnostic performance of three different LLMs (ChatGPT-4o, Gemini 2.0, and Claude 3.5) in identifying scaphoid fractures.

Horiuchi et al.[20] showed that GPT-4 based ChatGPT achieved a high diagnostic accuracy rate of 43% in musculoskeletal radiology. Similarly, in their comparative study in the field of neuroanatomy, Güneş et al.[21] reported that GTP-4o performed well with a 45% accuracy rate. Mitsuyama et al.[22] also reported a final diagnostic accuracy rate of 73% for GPT-4 in their study on brain tumors. When Javan et al.[23] investigated GPT-4 Vision's potential in radiology, they stated that the effect of artificial intelligence (AI) in medical image interpretation had improved. However, Zhu et al.[24] reported a 19.5% accuracy rate for ChatGPT-4V in radiologic image interpretation, and similarly, Huppertz et al.[25] demonstrated the limitations of AI models in radiological diagnosis, with GPT-4V achieving 8.3% accuracy in image interpretation. Like these studies, we also found that, in analyzing images of patients with scaphoid fractures, Claude 3.5 had 57.1% sensitivity, Gemini 2.0 had 18.8% sensitivity, and ChatGPT-4o had 9.1% sensitivity.

The perfect performance of GPT-4o, with an accuracy rate of 93% in the study on Coronary Artery Disease–Reporting and Data System (CAD-RADS) 2.0 classification in cardiac CT reporting by Arnold et al.,[26] proves that AI models can achieve very high success rates in certain medical areas. Similarly, in their comprehensive study on thoracic radiology, Güneş and Cesur demonstrated the consistency of 10 LLMs in medical diagnosis, with the highest diagnostic accuracy rate being 70.9%.[27] We found that the models performed with poorer specificity than reported in these studies, with 43.8% for ChatGPT-4o, 43.1% for Gemini 2.0, and 43.6% for Claude 3.5.

One of the noteworthy findings of our study was the difference in performance of AI models in specific and non-specific cases. Zhou et al.,[13] who studied GPT-4 Vision's performance in chest radiographs, reported that AI models are more successful in cases with distinct radiological findings. That Claude 3.5 achieved an accuracy rate of 83.3% in specific cases while remaining at 28.6% in non-specific cases in our study supports the hypothesis that these models perform better when diagnosing based on more distinct radiological findings. Horiuchi et al.[20] observed similar tendencies in their study comparing GPT-4-based ChatGPT and radiologists on neuroradiology cases, reporting that AI models struggle in cases with more complex and ambiguous findings.

The findings of our study regarding surgical indications clearly demonstrate the limitations of AI models in complex decision-making processes. The success rate of 37.0% achieved

by Claude 3.5 in determining indications for surgery, though better than ChatGPT-4o (34.1%) and Gemini 2.0 (24.4%), shows that it is not yet at the stage of providing independent diagnosis, but has the potential to support specialist physicians. In this context, utilizing AI models in a "second opinion" role might be a factor in increasing patient safety. Noda et al.[28] have also reported that artificial intelligence models were successful in the classification of pertrochanteric fractures of the femur.

Findings obtained in our study regarding the response consistency of AI models have raised stability issues, which are critical for clinical safety. In the scaphoid fracture group, with κ=0.40 (95% CI: 0.31-0.49), Claude 3.5 showed moderate consistency according to the Fleiss' Kappa criterion. This finding parallels the consistency issues reported by Ueda et al.[29] in their diagnostic performance study. In the non-fracture group, however, it was observed that consistency levels dropped remarkably in all models (κ=0.17-0.14). The study on radiology exam performance by Bhayana et al.[30,31] reported that despite the advanced reasoning capacity of GPT-4, it tends to generate inconsistent responses. This inconsistency poses a significant problem for integrating AI-supported diagnostic systems, especially in the ED, where patient safety is of critical importance. Jeblick et al.[32] also reported similar safety concerns in their study on simplifying radiology reports and highlighted the hallucinatory tendencies of AI systems.

Our study has demonstrated that the latest versions of LLMs (ChatGPT-4o, Gemini 2.0, and Claude 3.5) have made serious progress in image interpretation when coupled with basic complaints. Evaluating a large number of images with and without a scaphoid fracture, and assessing these fractures in terms of surgical indications using LLMs, are the strengths of our study. However, our study also has limitations. Firstly, due to the retrospective design, it may not exactly reflect the performance of AI models in real-time clinical decision-making processes. Secondly, the image quality and standardization of the three-view extremity X-rays used in our study may vary in other centers, which may affect the real-world performance of AI models. Thirdly, our study used data from a single center, and the performance of AI models might need to be verified in different populations and geographical locations.

CONCLUSION

In conclusion, this study comparing the performance of AI models in diagnosing scaphoid fractures has shown that the Claude 3.5 model has the highest diagnostic accuracy rate among available technologies but requires further development to meet clinical standards. The 57.1% sensitivity and 43.6% specificity rates of Claude 3.5 reveal that although this technology can be used as an assistive tool in its current form, final diagnostic decisions should still be made by specialist physicians. To fully realize the clinical potential of this technology, future research must focus on larger datasets, advanced algorithms, and hybrid approaches. Considering the critical effect that timely and accurate diagnosis of scaphoid fractures has on patient outcomes, the continued development and clinical integration of AI-supported systems carry strategic importance for future emergency and orthopedic practice.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Ethics Committee Approval: This study was approved by the Ankara Bilkent City Hospital Clinical Research Ethics Committee (Date: 05.03.2025, Decision No: E2-25-10249).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Acil serviste Skafoid kırıklarının tespitinde büyük dil modellerinin tanısal yetkinlikleri

AMAÇ: Skafoid kırıkları, el bileği travmalarının %60-70'ini oluşturur ve gecikmiş tanı, avasküler nekroza ve fonksiyonel bozukluğa yol açar. Anatomik karmaşıklık ve örtüşen yapılar nedeniyle geleneksel radyografik değerlendirme hala zorludur. Bu çalışmada, skafoid kırıklarının tespiti ve cerrahi endikasyonların belirlenmesinde üç yeni nesil büyük dil modeli(BDM) (ChatGPT-4o, Gemini 2.0, Claude 3.5) değerlendirilmiştir.

GEREÇ VE YÖNTEM: Ankara Etlik Şehir Hastanesi'nde (Ekim 2022-Ocak 2025) 18-65 yaşları arasında 300 hastayı (150'si BT ile doğrulanmış skafoid kırığı olan, 150'si kırığı olmayan) içeren retrospektif gözlemsel bir çalışma yürütüldü. Her bir BDM'ye farklı günlerde üç kez üç yönlü el bilek radyografileri sunuldu. Tanısal doğruluk; genel doğruluk (üç yanıtın da doğru olması), kesin doğruluk (≥2 doğru yanıt) ve ideal doğruluk (≥1 doğru yanıt) kriterleri kullanılarak değerlendirildi. Yanıt tutarlılığı, Fleiss' Kappa katsayısı kullanılarak değerlendirildi. Cerrahi endikasyonlar, kırık yer değiştirme kriterlerine göre belirlendi.

BULGULAR: Claude 3.5, kırık tespiti için Gemini 2.0 (%18.2) ve ChatGPT-4o (%9.1) ile karşılaştırıldığında üstün duyarlılık (%57.1) gösterdi ($p<0.001$). İdeal doğruluk oranları sırasıyla %79.3, %36.0 ve %17.3 idi. Özgüllük, modeller arasında eşit olarak düşük kaldı (%43.1-43.8). Tüm modeller, %83'ü aşan ideal doğrulukla kırık olmayan vakalarda daha iyi performans gösterdi. Yanıt tutarlılığı tüm modeller için orta düzeydeydi (κ=0.36-0.41). Cerrahi endikasyon değerlendirmesi için Claude 3.5, ChatGPT-4o (%34.1) ve Gemini 2.0 (%24.4) ile karşılaştırıldığında operasyon gerektiren vakaların %37.0'ını tespit etti ve doğru tespit oranları sırasıyla %73.7, %71.4 ve %80.0 idi.

SONUÇ: Mevcut BDM'ler, skafoid kırığı tespitinde bağımsız klinik kullanım için yeterli tanısal doğruluk göstermemektedir. Claude 3.5'in %57,1'lik duyarlılığı, bu teknolojilerin klinik kullanıma sunulmadan önce önemli iyileştirmeler gerektirdiğini göstermektedir. Ancak, cerrahi karar alma sürecindeki orta düzeydeki performansları, uzmanlık deneyimiyle birleştirildiğinde yardımcı araçlar olarak potansiyel faydalar sağlayabileceklerini göstermektedir. Kas-iskelet sistemine özgü eğitime odaklanan daha fazla geliştirme yapılması şarttır.

Anahtar sözcükler: Büyük dil modelleri; el bilek radyografisi; skafoid kırıkları; tanısal doğruluk; yapay zeka.

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ORIGINAL ARTICLE

Open fractures associated with earthquakes and high-energy trauma: Clinical outcomes and management strategies

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ABSTRACT

BACKGROUND: This study aimed to evaluate the epidemiological characteristics, infection rates, complication risks, and clinical management strategies of open fractures resulting from high-energy traumas. Special attention was given to the effects of the 2023 major earthquake on the incidence of open fractures and patient management, comparing different trauma mechanisms retrospectively.

METHODS: This retrospective study included 512 patients admitted to a tertiary trauma center between 2019 and 2024. Patients were classified according to five different trauma mechanisms: traffic accidents, falls from height, occupational injuries, gunshot wounds, and earthquake-related traumas. Open fractures were assessed and classified using the Gustilo-Anderson classification to determine the severity of the injuries. Treatment protocols included early antibiotic administration, surgical debridement, wound management protocols, and surgical fixation methods. Statistical analyses were performed to compare differences between early surgical intervention (within 24 hours) and delayed surgical intervention (after 24 hours). Statistical tests used included T-test, Mann-Whitney U test, Chi-square test, and logistic regression analysis. A p-value of <0.05 was considered statistically significant.

RESULTS: The mean age of the 512 patients was 37.4±12.6 years, with 68% males and 32% females. The most common trauma mechanism was traffic accidents (54.2%), followed by falls from height (27.8%), occupational injuries (12.5%), gunshot wounds (5.5%), and earthquake-related traumas (11.3%). A significant proportion of earthquake-related injuries were classified as Gustilo-Anderson Type III fractures (42.8%), which was notably higher than that of other trauma mechanisms (p<0.001). In earthquake-related cases, multiple fractures were present in 63.2% of patients, and bilateral extremity fractures were observed in 21.4% of cases. The infection rate was 11.4% in patients who received early antibiotic administration, compared to 27.8% in those with delayed administration (p<0.005). Early surgical intervention resulted in an infection rate of 15.2%, whereas delayed intervention showed an infection rate of 31.4% (p=0.002). Amputation rates were found to be 6.4% for the entire patient group, but 41.2% in the Gustilo-Anderson Type IIIC fracture group. Osteomyelitis rate was 18.6% in patients who underwent delayed wound closure, and 35% of these patients required prolonged intravenous antibiotic therapy.

CONCLUSION: This study demonstrates that early antibiotic administration, early surgical intervention, and appropriate wound management strategies significantly reduce infection rates in open fractures resulting from high-energy traumas. Particularly, the high complication rates observed in earthquake-related cases highlight the need for systematic and carefully planned approaches in disaster-related patient management. The findings emphasize the importance of optimal surgical timing and proper antibiotic protocols in reducing infection risks and improving clinical outcomes. Further prospective studies are needed to validate these findings.

Keywords: Antibiotic therapy; complications; Gustilo-Anderson classification; high-energy trauma; infection rates; open fractures; retrospective analysis; surgical intervention; 2023 earthquake.

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INTRODUCTION

Traumatic fractures, especially those that occur as a result of high-energy trauma, are among the major health problems with serious clinical and socioeconomic consequences.[1] Open fractures are injuries in which the risk of infection is high, the recovery process is long, and the risk of complications is high due to the contact of bone tissue with the external environment.[2] High-energy trauma occurs in traffic accidents, falls from heights, occupational injuries, and gunshot wounds, and markedly increases the incidence of open fractures.[3]

Especially the lower extremity is the most common site of open fractures. According to epidemiologic data, open tibial fractures comprise approximately 40% of all open fractures, and the infection rate in these fractures ranges between 23% and 50%.[4] Open femur fractures, on the other hand, are associated with high mortality and morbidity, especially in multiple trauma patients.[5]

Treatment of open fractures differs depending on the anatomical site of the fracture, the severity of the wound, and the accompanying soft tissue damage. According to the Gustilo-Anderson classification, the risk of infection in Type I open fractures is 0-2%, whereas this rate can be as high as 25–50% in Type III open fractures.[6] Early antibiotic treatment, surgical debridement, wound management protocols, and surgical fixation methods have critical roles in the management of infection risk.[7] Early surgical fixation has been shown to significantly reduce infection rates and shorten the length of hospital stay.[8]

Nevertheless, not only local complications but also systemic complications represent a major problem in open fractures after high-energy trauma. Fat embolism syndrome (FES), a complication seen in multiple trauma patients, can increase mortality and has been extensively reported, especially in femur and tibia fractures.[9,10] Systemic complications such as thromboembolic events, sepsis, and acute respiratory distress syndrome (ARDS) also need to be considered in open fractures.[11,12]

In recent studies, the importance of understanding the mechanisms of high-energy trauma and multidisciplinary approaches in patient management has been highlighted.[13] Early intervention, surgical strategies, antibiotic treatment, and optimization of rehabilitation are among the key factors that improve patient outcomes in open fracture cases.[14,15]

In this study, the epidemiologic distribution of open fractures that develop after high-energy trauma, the affected patient profile, complication risks, and clinical management strategies were evaluated. Within the scope of the study, the last 5 years' hospital records were retrospectively analyzed: the incidence of open fractures, fracture distribution according to the Gustilo-Anderson classification, effects of early antibiotic treatment and wound management protocols on infection rates, surgical fixation methods and their clinical outcomes, and systemic complication rates were analyzed. In line with the findings, early surgical intervention, methods of infection prevention, and strategies to improve long-term patient prognosis were discussed.

MATERIALS AND METHODS

Study Design

This study was designed as a retrospective cohort analysis to evaluate the epidemiologic characteristics of open fractures after high-energy trauma, complication rates, and patient management strategies. The data were obtained from the records of open fracture cases admitted to a tertiary trauma center between 2019 and 2024. Especially after the large-scale earthquake in 2023, the change in patient distribution was analyzed, and earthquake-related open fracture cases were compared with cases of open fractures due to other causes of trauma. Post-earthquake patient load, its effect on the incidence of open fractures, and patients' demographic characteristics were analyzed.

Study Group and Inclusion Criteria

Adult patients (aged ≥18 years) diagnosed with open fractures as a result of high-energy trauma (traffic accidents, falls from height, occupational injuries, gunshot wounds, earthquake-related injuries, etc.) were included in this study. Inclusion criteria were a diagnosis of Type I, II, or III open fracture according to the Gustilo-Anderson classification, availability of complete clinical data, and a follow-up of at least 6 months.[2] Patients with insufficient clinical data, patients who could not undergo primary orthopedic follow-up due to accompanying severe head or spinal trauma, and individuals aged below 18 were excluded.

Power Analysis

A power analysis was performed using the G*Power 3.1 software to determine whether the study had sufficient statistical power. In line with the data from previous literature, it was determined that the incidence of infection in open fractures was between 25% and 30% and that the effect of surgical timing on the infection risk showed a moderate effect (effect size=0.30). As a result of a priori power analysis, it was calculated that a minimum sample size of 350 patients was sufficient, considering α=0.05, 1-β (power)=0.80, and effect size (Cohen's d)=0.30.[16] However, the aim was to include at least 500 patients in the sample to increase the statistical power of the study.

Data Collection and Evaluation

In the study, patients' data were obtained retrospectively from the hospital automation system and patient registration files. Demographic data, trauma mechanisms, fracture localizations, and types of open fractures according to the Gustilo-Anderson classification were examined in detail. The

Table 1. Distribution of Patients' Demographic Characteristics and Trauma Mechanisms

Characteristics	Value (n=512)
Mean age (years, mean ± SD)	37.4±12.6
Gender – Male	348 (68.0%)
Gender – Female	164 (32.0%)
Trauma Mechanism	
└Traffic accident	278 (54.2%)
└Fall from height	142 (27.8%)
└Occupational injuries	64 (12.5%)
└Gunshot wounds	28 (5.5%)
└Earthquake	58 (11.3%)*

*Includes patients admitted after the large-scale earthquake in 2023.

treatment process, surgical methods, fixation methods, differences between early surgical intervention and late surgical intervention, and the effect of wound management protocols on patient outcomes were assessed. Complication rates, one of the most important variables of the study, were also thoroughly evaluated, and factors such as infection incidence, delayed union, nonunion, fat embolism syndrome, sepsis, and thromboembolic events were particularly analyzed.

Statistical analyses were performed in SPSS 26.0 (IBM, Armonk, NY, USA) software. Continuous variables were presented as mean ± standard deviation (SD) and median (minimum–maximum) values, and categorical variables were presented as frequencies and percentages. For intergroup comparisons, the Student's t-test was used for normally distributed data, and the Mann-Whitney U test was employed for non-normally distributed data. The Chi-square test was used to examine the relationships between categorical variables, and multivariate logistic regression analysis was performed to identify the risk factors for complications such as the development of infection, delayed union, and fat embolism. Statistical significance was taken as $p<0.05$.[17]

Ethics committee approval and institutional permissions were received from the Clinical Research Ethics Committee of Malatya Turgut Özal University (Approval Number: 2025/123). The study was carried out according to the human rights principles of the Declaration of Helsinki (2013). The data were anonymized and analyzed in accordance with the principle of confidentiality. Due to the retrospective design of the study, special attention was given to protecting patient confidentiality.

With this methodology, the epidemiologic profile of open fractures after high-energy trauma between 2019 and 2024 and patient outcomes were analyzed in detail. In particular, changes in patient distribution, incidence of open fractures, and infection risk factors after the 2023 earthquake were assessed. The effect of patient density after the earthquake on the incidence of fractures was evaluated, and the clinical management processes of these patients were compared with other causes of trauma.

RESULTS

In this study, a total of 512 patients who applied to a tertiary trauma center between 2019 and 2024 were retrospectively evaluated. The mean age of the patients was 37.4±12.6. Of the patients, 68% were male and 32% were female. Among the causes of trauma, traffic accidents were the most frequent cause, and 54.2% of all patients were injured due to traffic accidents. This was followed by falls from height (27.8%), occupational injuries (12.5%), gunshot wounds (5.5%), and open fracture cases resulting from the 2023 earthquake (11.3%). These findings are presented in Table 1.

Distribution of Open Fractures According to Trauma Mechanisms

Traffic-accident-related open fractures occurred most in the tibia (42.1%) and femur (31.4%). Open fractures due to falls from height occurred most in the tibia (34.3%), radius-ulna (28.7%), and humerus (21.5%). Fractures due to occupational injuries were localized in the extremities in 70.2% and in the wrist and ankle in 29.8%. Gunshot wound-related open fractures were most commonly seen in the femur (43.7%) and humerus (28.4%). After the 2023 earthquake, the most common open fractures in multiple trauma cases were identified in the tibia (39.6%) and femur (33.1%). These rates are shown in Table 2 and Figure 1.

Table 2. Distribution of open fractures and fracture localizations according to trauma mechanisms

Trauma Mechanisms	Number of Patients (n)	Percentage (%)	Most Common Fracture Localizations
Traffic accident	278	54.2	Tibia (42.1%), Femur (31.4%)
Fall from height	142	27.8	Tibia (34.3%), Radius/Ulna (28.7%), Humerus (21.5%)
Occupational injury	64	12.5	Hand-wrist (29.8%), Alt Extremity (70.2%)
Gunshot wound	28	5.5	Femur (43.7%), Humerus (28.4%)
Earthquake-related trauma	58	11.3	Tibia (39.6%), Femur (33.1%)
Total	512	100.0	

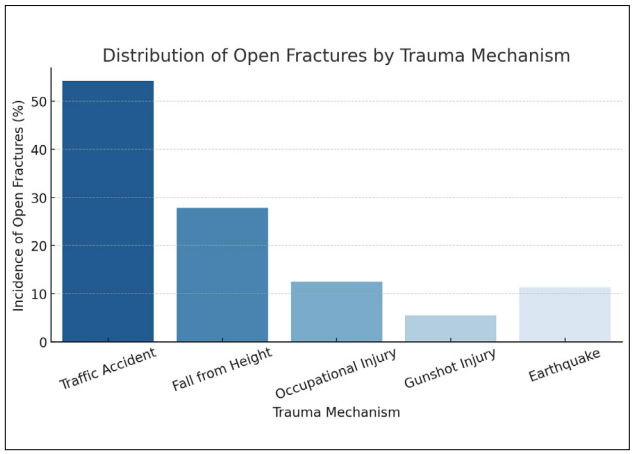

Figure 1. Distribution of open fractures by trauma mechanism.

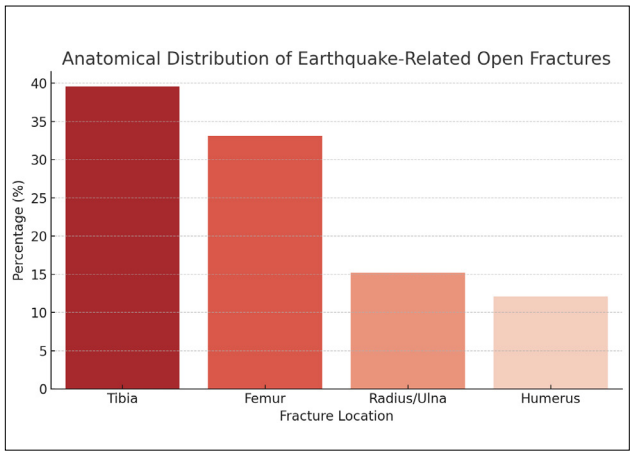

Figure 2. Open fracture distribution after the 2023 earthquake.

Patient Distribution and Incidence of Open Fractures After the 2023 Earthquake

The 2023 earthquake caused a significant increase in the incidence of open fractures throughout the study. Within three months after the earthquake, open fractures accounted for 24.7% of the total cases and the majority of serious injuries requiring hospitalization.

The characteristics of open fracture cases after the earthquake were as follows:

• Of the cases, 58.3% were male and 41.7% were female.

• The rate of multiple fractures was 63.2%, and 21.4% of the patients had bilateral extremity fractures.

• The most common fracture sites were the tibia (39.6%) and femur (33.1%).

• The rate of Gustilo-Anderson Type III fracture was 42.8% in earthquake-related trauma, which was significantly higher compared to open fractures due to other causes of trauma ($p<0.001$).

Infection rates were higher in patients with earthquake trauma. The rate of early surgical intervention was 52.1% in patients injured after the earthquake, while this rate was 69.2% in the other groups. The infection rate in patients who underwent delayed surgery was 31.4%, which was significantly higher than the rates in open fractures after trauma such as traffic accidents and falls from height ($p = 0.002$) (Figure 2).

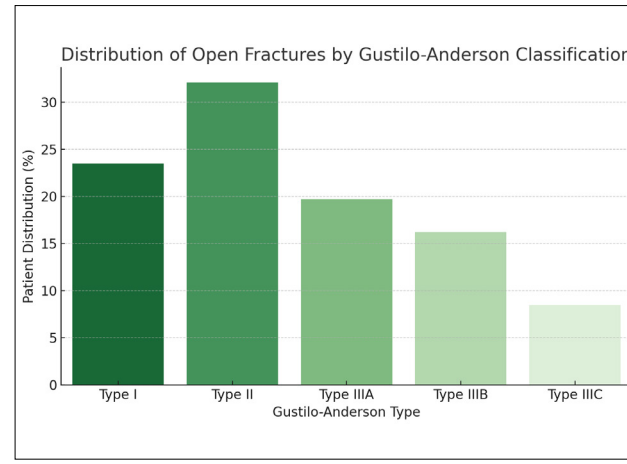

Figure 3. Distribution of open fractures according to the Gustilo-Anderson classification

Fracture Localization and Severity

Lower extremity fractures constituted 71.6% of open fracture cases. The most common fractures were as follows:

• Tibia (39.3%)

• Femur (26.5%)

• Humerus (18.1%)

• Radius/Ulna (12.4%)

The distribution of open fractures according to the Gustilo-Anderson classification was as follows:

• Type I: 23.5% (n=120)

• Type II: 32.1% (n=164)

• Type IIIA: 19.7% (n=101)

• Type IIIB: 16.2% (n=83)

• Type IIIC: 8.5% (n=44)

In particular, Type IIIB and IIIC fracture rates were significantly higher in patients with multiple trauma ($p<0.001$). Type III fractures were identified in 42.8% of cases of earthquake-related open fractures, while this rate was 28.3% in cases of open fractures due to traffic accidents and falls from height (Figure 3).

Treatment Approaches and Surgical Process

Surgical fixation was performed in 87% of the patients, and the remaining patients were followed conservatively. Patients who underwent surgery within the first 24 hours (69.2%) had lower complication rates compared to those who received delayed intervention ($p=0.002$). Patients who underwent external fixation (21.3%) usually had Type III fractures, and their

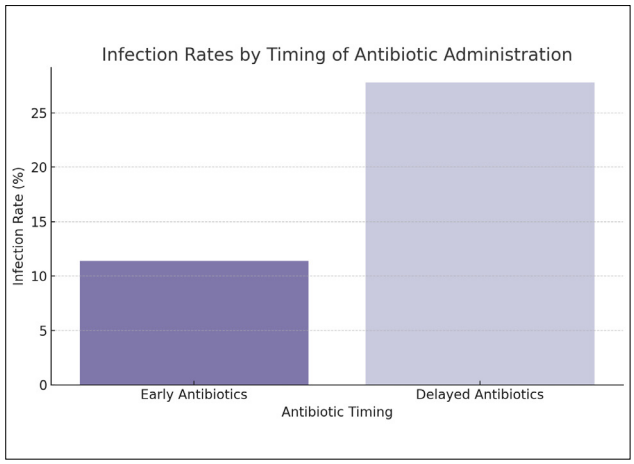

Figure 4. Infection rates according to antibiotic administration time.

mean length of hospital stay was significantly longer compared to the other groups (p=0.01).

The infection rate was 11.4% in patients receiving early antibiotic treatment and 27.8% in patients receiving late antibiotic treatment (p<0.005) (Figure 4).

Late antibiotic administration was more common in earthquake-related open fracture cases, and the infection rate was 30.2% in this group (p=0.008).

Cases requiring delayed closure and plastic reconstruction were most common in Type IIIB and Type IIIC fractures, and the mean recovery time was 14.3±3.6 weeks.

Complications and Clinical Outcomes

When a total of 512 patients were evaluated within the scope of the study, the infection rate was 18.7% in the general patient group. While the infection rate was 41.3% in Type III fractures, this rate was 4.8% in Type I fractures (p<0.001).

The nonunion rate was 9.6%, and the nonunion risk was 23.2% in Type III fractures.

The rate of cases requiring amputation was 6.4%, and the highest amputation rate was recorded in the Type IIIC fracture group.

Early surgical intervention (≤24 hours) reduced the risk of infection by 40% and significantly shortened the length of hospital stay (p=0.003).

The rate of osteomyelitis in earthquake-related open fracture cases who underwent late wound closure was 18.6%, and 35% of these patients required prolonged intravenous antibiotic treatment.

DISCUSSION

In this study, the epidemiologic data of 512 open fracture patients who applied to tertiary trauma centers between 2019 and 2024 were retrospectively analyzed, and patient distribution according to trauma mechanisms, infection rates, and clinical outcomes was assessed in detail. While traffic accidents were the most common cause of trauma, there was a significant increase in the incidence of open fractures after the 2023 earthquake. In particular, multiple trauma and Gustilo-Anderson Type III fracture rates were found to be significantly higher in patients injured after the earthquake compared to other types of trauma. Infection, delayed union, and amputation rates were higher in these patients.

In the present study, traffic accidents were the most common cause of open fractures (54.2%), followed by falls from height (27.8%) and occupational injuries (12.5%). In a large-scale epidemiologic analysis conducted by Court-Brown and Caesar, it was reported that open fractures due to high-energy trauma were most seen in the lower extremities and that tibial fractures accounted for more than 40% of all open fractures.[1] Similar results were reported in the study conducted by Rennie et al.[3] In the present study, tibia fractures were found to be the most common, constituting 39.3% of all open fractures.

It was determined that fracture patterns varied especially in specific trauma mechanisms such as gunshot wounds and post-earthquake traumas. In studies conducted by Rupp and Caudle, it was reported that soft tissue damage was more severe in open fractures due to gunshot wounds and that Gustilo-Anderson Type III fractures were more common.[18,19] In this study, 43.7% of the fractures due to gunshot wounds were found to be in the femur and 28.4% in the humerus, and these fractures included a high rate of Type III fractures.

The incidence of multiple fractures (63.2%) and bilateral extremity fractures (21.4%) was significantly higher in cases of earthquake-related open fractures. In the epidemiologic analysis conducted by Temel et al.[20] after the Kahramanmaraş earthquakes in 2023, it was reported that earthquake-related open fracture cases had a high rate of Type III fractures and that the infection risk was higher in these patients compared to other causes of trauma. Similar findings were reported in the study conducted by Ergen et al.[21] after the 2020 Elazığ earthquake. In the current study, the rate of Type III fracture among earthquake-related open fracture cases was determined as 42.8% and was significantly higher compared to other causes of trauma (p<0.001).

Patient Management and Infection Rates After the 2023 Earthquake

A significant increase was observed in the incidence of trauma-related open fractures after the earthquake. Type III fractures were detected in 42.8% of earthquake-related traumas, while this rate was calculated as 28.3% in other types of trauma (p<0.001). It was determined that open fractures due to earthquake trauma were more likely to be complicated by infection.[22-24] The main reasons for this include delayed medical intervention, inadequate wound cleaning, inappropriate wound closure strategies, delays in antibiotic treatment, prolonged hospitalization, and inadequate sterilization conditions.

In particular, late antibiotic administration was relatively more common in post-earthquake open fracture cases, and the infection rate was 30.2% in these patients. In contrast, the infection rate was 11.4% in patients who underwent early antibiotic administration, and the difference between the groups was statistically significant (p=0.008). These findings are consistent with the reference study by Gustilo and Anderson, which demonstrated that initiation of antibiotic administration within the first 6 hours reduced infection rates by up to 50%.[25] In the study conducted by Kamat, it was reported that the first basic interventions—such as wound irrigation, sterile antiseptic wound dressings, and most importantly, intravenous administration of broad-spectrum antibiotics, especially in the emergency room—play an important role in the prevention of infections in open fractures.[26] In the systematic review by Marchiori et al.,[27] it was emphasized that early antibiotic administration is very important.

Surgical Intervention Time and Clinical Outcomes

In the present study, infection rates were found to be significantly lower in patients who underwent early surgical intervention. The infection rate was 15.2% in patients who underwent surgery within the first 24 hours and 31.4% in patients who underwent delayed surgery (p=0.002). These results are consistent with findings reported in the study by Nicolaides et al.,[28] which showed that delayed surgery increased infection rates by up to 50%. This finding is consistent with the data reported in different studies by Singh and Gopal.[29,30]

It was observed that delayed surgical interventions increased the complication rates, especially in Type IIIB and Type IIIC fractures. In this group, the rate of osteomyelitis was found to be 18.6% in patients who underwent delayed wound closure, whereas this rate dropped to 8.2% in patients who underwent early closure (p=0.002). In particular, it was determined that early implementation of surgical reconstruction methods such as free flap closure reduced infection rates. In the large-scale study conducted by Weitz-Marshall et al.,[31] it was demonstrated that early plastic surgery interventions in severe open fractures reduced infection rates by 40%.

Infection Management and Clinical Recommendations

In our study, it was observed that patients who developed infection mostly had Type III fractures and that these patients had a significantly higher risk of osteomyelitis. Prolonged intravenous antibiotic use and the need for additional surgical debridement were more common in infected patients. Early antibiotic administration and optimal timing of surgical debridement were found to reduce infection rates. In their study, Riechelmann et al.[32] reported that immediate debridement and primary wound closure in Gustilo-Anderson Grade I, II, and IIIA open fractures reduced infection rates and eliminated the need for secondary surgery.

In this respect, according to our study data, early antibiotic administration reduces the risk of infection in Gustilo-Anderson Type III fractures, and optimal wound closure strategies reduce osteomyelitis rates. Acceleration of surgical reconstruction processes in Type IIIB and Type IIIC fractures may shorten the length of hospital stay and reduce complication rates. These results are consistent with the data reported by Stahel et al.[33]

Amputation Rates and Long-Term Functional Outcomes

In our study, the amputation rate was determined as 6.4% in the general patient population. In addition, the amputation rate in Type IIIC fractures was 41.2%. These findings are consistent with the high amputation rates (35-50%) in Type IIIC fractures reported in the study of MacKenzie et al.[34] Functional rehabilitation was found to be successful in 74% of patients who underwent lower extremity reconstruction, whereas 26% had long-term mobility restrictions.

Study Limitations and Future Research

This study has some limitations. Primarily, the study has a retrospective design and was carried out based on patient records; thus, it may have some missing data. Moreover, it was conducted in a single center, so the generalizability of the results is limited. Future multicenter and prospective studies may be helpful to better understand the long-term outcomes, especially in post-earthquake open fracture patients.

CONCLUSION

In conclusion, in this study, the epidemiologic characteristics, infection risks, and optimal treatment strategies in open fractures after high-energy traumas were evaluated in detail. In particular, the findings on patient management after the 2023 earthquake provide important clinical implications for post-disaster medical approaches. Early antibiotic administration, surgical interventions on time, and optimal wound management strategies are critical to reduce complication rates and improve long-term patient prognoses.

Recommendations

• In open fracture patients, early antibiotic administration needs to be integrated into standard protocols to reduce infection rates.

• Especially in Type III fractures, osteomyelitis rates should be minimized through early surgical intervention and appropriate wound closure methods.

• In the management of post-earthquake open fracture cases, the first post-traumatic intervention process should be accelerated, and multidisciplinary teams should have an active role in the field.

• Prospective studies should be performed to determine optimal treatment algorithms for Gustilo-Anderson Type III fractures.

• Long-term outcomes of infection management and extremity reconstruction strategies should be examined in more detail in multicenter studies.

Ethics Committee Approval: This study was approved by the Malatya Turgut Özal University Ethics Committee (Date: 05.05.2025, Decision No: 2025/123).

Peer-review: Externally peer-reviewed.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Deprem ve yüksek enerji travmalarına bağlı açık kırıklar: Klinik sonuçlar ve yönetim yaklaşımları

AMAÇ: Bu çalışma, yüksek enerjili travmalar sonrası gelişen açık kırıkların epidemiyolojik özelliklerini, enfeksiyon oranlarını, komplikasyon risklerini ve klinik yönetim stratejilerini değerlendirmek amacıyla retrospektif olarak yapılmıştır. Özellikle 2023 yılında meydana gelen büyük ölçekli depremin, açık kırık insidansı ve hasta yönetimi üzerindeki etkilerini incelemek amacıyla farklı travma mekanizmaları karşılaştırılmıştır.

GEREÇ VE YÖNTEM: Bu retrospektif çalışma, 2019-2024 yılları arasında üçüncü basamak bir travma merkezine başvuran 512 hastayı kapsamaktadır. Hastalar; trafik kazaları, yüksekten düşmeler, iş kazaları, ateşli silah yaralanmaları ve 2023 depremi kaynaklı açık kırıklar olmak üzere beş farklı travma mekanizmasına göre sınıflandırıldı. Açık kırıklar, Gustilo-Anderson sınıflamasına göre değerlendirildi ve kırık şiddetine göre gruplandırıldı. Tedavi süreçleri; erken antibiyotik uygulaması, cerrahi debridman, yara kapama protokolleri ve cerrahi fiksasyon yöntemleri açısından incelendi. Erken cerrahi müdahale (24 saat içinde) ve geç cerrahi müdahale (24 saatten sonra) arasındaki farklar istatistiksel olarak karşılaştırıldı. İstatistiksel analizler için T-testi, Mann-Whitney U testi, Ki-kare testi ve lojistik regresyon analizi kullanıldı. İstatistiksel anlamlılık düzeyi $p<0.05$ olarak kabul edildi.

BULGULAR: Toplam 512 hastanın ortalama yaşı 37.4±12.6 yıl olup, hastaların %68'i erkek, %32'si kadın idi. Travma mekanizmaları arasında en sık neden trafik kazaları (%54.2) olarak bulunurken, bunu yüksekten düşmeler (%27.8), iş kazaları (%12.5), ateşli silah yaralanmaları (%5.5) ve deprem kaynaklı travmalar (%11.3) takip etti. Deprem sonrası gelişen açık kırık vakalarının %42.8'inde Gustilo-Anderson Tip III kırıklar saptanmış olup, bu oran diğer travma mekanizmalarına göre anlamlı derecede yüksek bulundu ($p<0.001$). Özellikle deprem sonrası vakalarda, multipl kırık oranı %63.2 ve bilateral ekstremite kırıkları %21.4 olarak belirlenmiştir. Erken antibiyotik uygulaması yapılan hastalarda enfeksiyon oranı %11.4, geç antibiyotik uygulananlarda ise %27.8 olarak hesaplandı ($p<0.005$). Erken cerrahi girişim yapılan hastalarda enfeksiyon oranı %15.2, geç cerrahi yapılanlarda ise %31.4 olarak bulundu ($p=0.002$). Amputasyon oranları, tüm hasta grubunda %6.4, ancak Gustilo-Anderson Tip IIIC kırık grubunda %41.2 olarak saptandı. Geç yara kapama yapılan hastalarda osteomiyelit oranı %18.6 olup, bu hastaların %35'inde uzun süreli intravenöz antibiyotik tedavisi gerekti.

SONUÇ: Bu çalışma, yüksek enerjili travmalar sonrası gelişen açık kırıklarda erken antibiyotik uygulaması, erken cerrahi müdahale ve uygun yara yönetimi stratejilerinin enfeksiyon oranlarını anlamlı derecede azalttığını göstermektedir. Özellikle 2023 depremi sonrası hastalarda görülen yüksek komplikasyon oranları, bu tür afetler sonrası hasta yönetimi konusunda daha dikkatli ve sistematik yaklaşımların gerekli olduğunu ortaya koymaktadır. Çalışmamızda elde edilen bulgular, açık kırıkların tedavisinde optimum cerrahi zamanlamanın ve doğru antibiyotik protokollerinin uygulanmasının önemini vurgulamaktadır. İleriye dönük prospektif çalışmalar, bu sonuçların daha net değerlendirilmesini sağlayabilir.

Anahtar sözcükler: Açık kırıklar; antibiyotik tedavisi; cerrahi müdahale; enfeksiyon oranları; Gustilo-Anderson sınıflaması; komplikasyonlar; retrospektif analiz; yüksek enerjili travmala; 2023 depremi.

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ORIGINAL ARTICLE

The effect of fusion levels on clinical outcomes in traumatic lower lumbar vertebral fractures

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ABSTRACT

BACKGROUND: Fractures of the lower lumbar spine (LLS) are uncommon and present unique biomechanical challenges. This study aimed to assess and compare the clinical and radiological outcomes of short-segment posterior instrumentation (SSPI) versus long-segment posterior instrumentation (LSPI).

METHODS: A retrospective cohort of patients aged 18–63 years who underwent posterior instrumentation for thoracolumbar (TL, T10–L2) or LLS (L3–L5) fractures between 2005 and 2022 was analyzed. SSPI was applied for AO type A2–A4 injuries, while LSPI was reserved for type B2, B3, and C injuries. Functional outcomes were assessed using the Oswestry Disability Index (ODI) and visual analog scale (VAS), while radiological alignment was evaluated with the sagittal Cobb angle (SCA). Forty-nine patients were included: 33 with thoracolumbar (TL) fractures and 16 with LLS fractures.

RESULTS: Eight LLS patients underwent SSPI, eight received LSPI, and all TL fractures were treated with SSPI. SCA improved significantly in all groups ($p<0.001$). In LLS fractures, LSPI resulted in worse function (ODI 40.6±15.4 vs. 25.4±7.2, $p=0.040$; VAS 3.0±1.7 vs. 2.2±2.4, $p=0.038$) compared with SSPI. Functional outcomes for LL-SSPI and TL-SSPI were comparable. SSPI achieved similar radiological correction with 19% shorter operative time and reduced blood loss.

CONCLUSION: In this study, the SSPI method was found to be a safe option for the management of LLS fractures from both clinical and radiological perspectives. In contrast, the LSPI method should be reserved for highly unstable injuries, as it may have a detrimental effect on lumbar function.

Keywords: Lower lumbar fractures; short-segment fusion; long-segment fusion; posterior instrumentation; Oswestry Disability Index; sagittal Cobb angle.

INTRODUCTION

Lower lumbar spine (LLS) fractures are relatively uncommon compared to thoracolumbar injuries, and there remains no clear consensus among spine surgeons regarding their optimal management.[1,2] One of the most commonly reported disadvantages of conservative treatment is pain and neurological dysfunction, occurring in 20-50% of cases due to progressive loss of lumbar lordosis and collapse of the vertebral body. In contrast, surgical management is associated with specific concerns. The incidence of complications following surgical treatment has been reported to range between 3% and 11%. These include pedicle screw malposition, dural or nerve root injury, and the sacrifice of motion segments, which may accelerate adjacent segment degeneration.[3,4]

This region is characterized by larger vertebral bodies, strong paraspinal muscles, sagittally oriented facet joints, pronounced lumbar lordosis, and increased mobility.[5] These features contribute to mechanical stability but also complicate surgical

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decision-making. Inadequately managed LLS fractures can lead to neurological impairment, persistent pain, and progressive deformity.[6] The primary surgical objectives are restoration of vertebral alignment, stabilization of the spinal column, and prevention of further neurological injury.[7]

Extensive research exists on surgical strategies for thoracolumbar (TL) and lumbar fractures, with multiple studies showing favorable results for short-segment posterior instrumentation (SSPI) compared to traditional long-segment posterior instrumentation (LSPI).[1,2,7] While operative management is well established for unstable LLS fractures, there remains ongoing debate regarding the optimal length of fixation, particularly in relation to AO classification.[2,4,8] High-quality comparative evidence focusing specifically on LLS fractures remains limited.[8]

We postulated that SSPI offers similar clinical and radiological outcomes for type A LLS fractures as it does for TL fractures, and provides superior functional results compared to LSPI in type B and C fractures. The present study aimed to compare mid- to long-term outcomes of SSPI and LSPI in LLS fractures, with TL-SSPI serving as the reference group.

MATERIALS AND METHODS

Study Design and Ethical Considerations

This retrospective analysis received approval from the institutional review board and adhered to the principles of the Declaration of Helsinki (Approval No: E-77082166-604.01-1176128, 19.02.2025). Eligible participants were patients aged 18-63 years who underwent posterior instrumentation (PI) for thoracolumbar (TL) or LLS fractures between 2005 and 2022. Only those treated within two weeks post-injury and followed for at least 24 months (mean follow-up: 84 months) were included. The two-week threshold was chosen to ensure uniformity in early surgical intervention and to minimize the risk of neurological deterioration.

Fracture types were classified using the AO Spine TL Injury Classification System. Eligible injuries included types A2, A3, A4, B2, B3, and C. Exclusion criteria were complete spinal cord injury, severe osteoporosis (T-score ≤-2.5 or requiring cement-augmented fixation), pathological fractures, prior spinal surgery, active infection, and revision procedures (Fig. 1). Each patient provided written informed consent allowing the utilization of clinical and radiological records for scientific purposes.

Fracture Classification and Surgical Decision-Making

Fracture patterns were identified using the AO Spine TL Injury Classification System. Surgical technique was determined according to fracture type and the extent of ligamentous injury. SSPI was performed in type A2 (split fractures), type A3 (incomplete burst with progressive collapse), and type A4 (complete burst) injuries, where ligamentous compromise was minimal. LSPI was reserved for type B2 (posterior tension band disruption), type B3 (hyperextension injury), and type C (fracture-dislocation), which exhibit significant instability requiring extended fixation.

All fractures were independently assessed by two senior spine surgeons, with preoperative consensus reached in every case. Interobserver reliability for classification was high (Cohen's κ=0.87). This approach ensured consistency in both fracture evaluation and instrumentation selection.

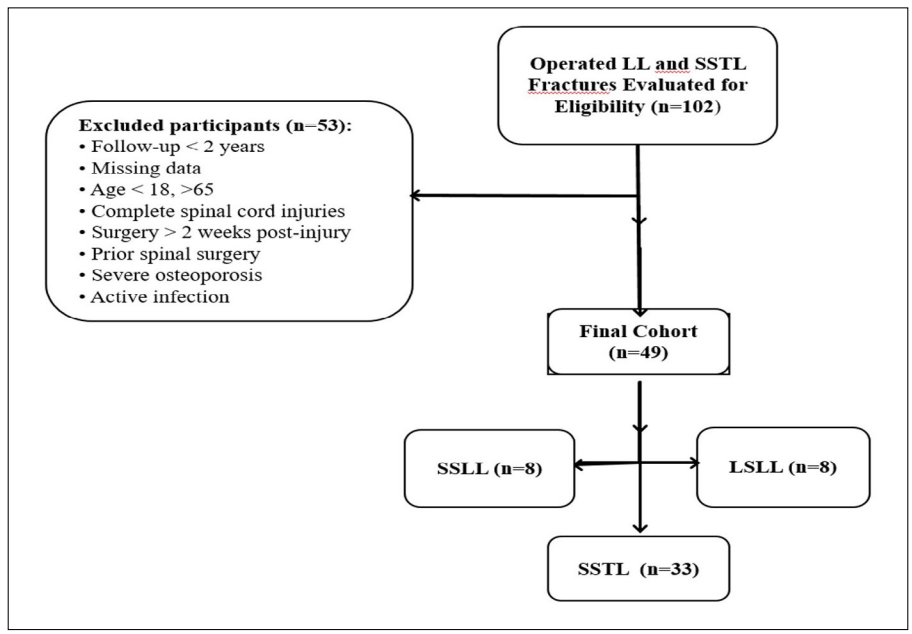

Figure 1. Patient selection flowchart. *LL: Lower Lumbar; SSTL: Short-segment thoracolumbar; SSLL: Short-segment lower lumbar; short-segment posterior instrumentation; LSLL: Long-segment lower lumbar.*

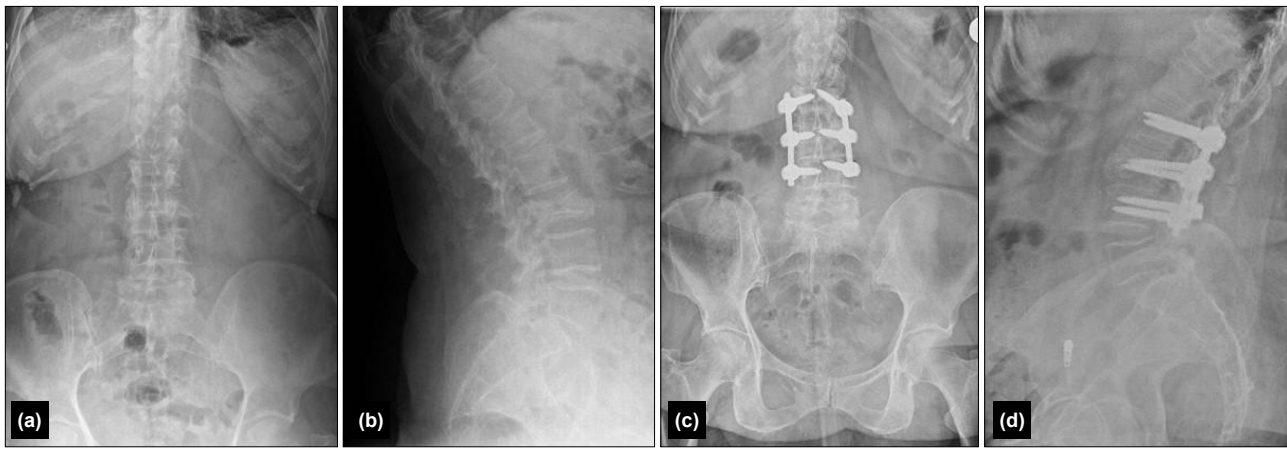

Figure 2. Preoperative **(a,b)** and postoperative **(c,d)** plain radiographs of a patient who underwent short segment posterior instrumentation for L 3 vertebral fracture.

Patient Groups

A total of 49 patients were included in the study. They were categorized into three cohorts according to the fracture site and the surgical technique employed. The TL group comprised 33 patients, whereas the LLS group included 16 patients (SSPI: 8; LSPI: 8) (Fig. 1):

1. LL-SSPI Group: Fixation included the fractured vertebra, one vertebra above, and one below.

2. LL-LSPI Group: Fixation encompassed the fractured vertebra plus at least two vertebrae above and below.

3. TL-SSPI Group: Used as a control group, following the same fixation principles as LL-SSPI.

It is important to note that the LL-SSPI and LL-LSPI groups represented different fracture severities (type A vs. types B/C), which limits the validity of direct comparisons between them.

Surgical Procedure

Two experienced spine surgeons performed all procedures using a standardized posterior approach with the patient in the prone position. Intravenous prophylactic antibiotics were administered 30 minutes before incision. Bilateral pedicle screws were placed using the freehand method under fluoroscopic guidance. The screws measured 5.5–6.5 mm in diameter and 40–50 mm in length, and all were composed of polyaxial titanium.

For SSPI, screws were placed in the fractured vertebra and its immediate neighbors (Fig. 2 a, b, c, d), while LSPI included additional segments above and below (Fig. 3 a, b, c, d). Fracture reduction was achieved primarily by ligamentotaxis. Fusion was performed in all patients using autografts harvested from spinous processes and lamina, supplemented with morselized allografts when necessary. No vertebral augmentation techniques (vertebroplasty or kyphoplasty) were applied in this series.

Data Collection and Outcome Measures

Demographic information (age, sex, Body Mass Index [BMI]), fracture classification, and neurological status were retrieved from medical records. Functional assessment employed the Oswestry Disability Index (ODI) and visual analog scale (VAS) scores, recorded preoperatively and at final follow-up. Radiological evaluation of sagittal Cobb angle (SCA) and sagittal alignment parameters was performed using lateral radiographs at three time points: preoperative, early postoperative, and final follow-up.

Intraoperative data included duration of surgery, estimated blood loss, length of hospital stay, and perioperative complications.

Statistical Methods

The statistical analyses were conducted using IBM SPSS Statistics version 27 (IBM Corp., Armonk, NY, USA). Continuous data were expressed as mean±standard deviation or as median with interquartile range, whereas categorical data were presented as frequencies and percentages. The Shapiro-Wilk test was employed to verify normality. In cases of non-normal distribution, non-parametric tests were applied.

Comparisons of continuous variables between groups were performed using the Mann-Whitney U test, while categorical variables were analyzed with chi-square or Fisher's exact tests. Longitudinal changes in SCA were examined using the Friedman test, with Wilcoxon signed-rank post hoc analyses applied subsequently, and Kendall's W was computed to evaluate agreement. Multiple comparisons were adjusted using the Benjamini-Hochberg procedure. A p-value <0.05 denoted statistical significance.

RESULTS

A total of 49 patients were included in this study: 33 with TL fractures and 16 with LLS fractures. Among the LLS fracture

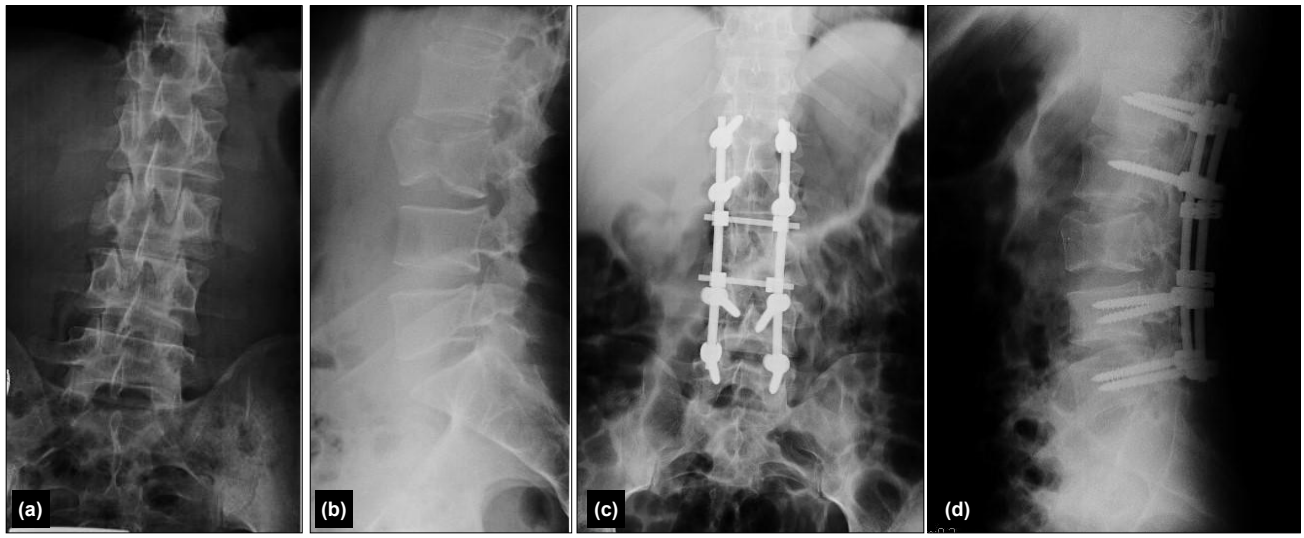

Figure 3. Preoperative **(a,b)** and postoperative **(c,d)** plain radiographs of a patient who underwent long segment posterior instrumentation for L 3 vertebral fracture.

patients, eight underwent SSPI and eight underwent LSPI, while all 33 TL fracture patients were treated with SSPI. The median age of all patients was 39 years (range: 18–63 years), with no significant difference in age between the TL and LLS groups (p=0.773). The majority of patients were male, and sex distribution was similar across groups (p>0.05). Median follow-up duration was 84 months (range: 60–232 months). No significant differences in follow-up duration were ob-

Table 1. Demographic and baseline clinical characteristics of patients with thoracolumbar (TL) and lower lumbar (LL) fractures

	TL Fractures (n=33)	LL Fractures (n=16)	Total	P values[a]
Age (mean±SD)	40.5±14.1	39.1±11.4	40.1±13.2	0.773
Follow-up period (months) (mean±SD)	91.1±35.3	95.1±32.8	92.4±34.2	0.481
Median (IQR)	83 (70–97)	83 (71–94.5)	84 (71–94.5)	-
Sex (F/M)	11 (33.3%) / 22 (66.7%)	4 (25.0%) / 12 (75.0%)	15 (30.6%) / 34 (69.4%)	0.743[b]
Level of fracture	L1: 7 (21.2%), L2: 7 (21.2%), T10: 5 (15.2%), T11: 6 (18.2%), T12: 8 (24.2%)	L3: 7 (43.8%), L4: 8 (50.0%), L5: 1 (6.3%)	L1: 7 (14.3%), L2: 7 (14.3%), L3: 7 (14.3%), L4: 8 (16.3%), L5: 1 (2.0%), T10: 5 (10.2%), T11: 6 (12.2%), T12: 8 (16.3%)	-
PI length (Short ≤2 / Long ≥3)	33 (100%)	8 (50.0%) / 8 (50.0%)	33 (67.3%) / 16 (32.7%)	0.761[b]
PI length (mean±SD)	2.9±0.9	3.1±1.3	3.0±1.0	0.757
BMI (mean±SD)	25.6±4.1	27.8±5.0	26.3±4.5	0.196
ODI (mean±SD)	22.9±10.6	33.0±14.0	26.2±12.6	0.019
VAS (mean±SD)	1.6±1.1	2.2±2.0	2.1±1.6	0.065

TL: Thoracolumbar; LL: Lower lumbar; SD: Standard deviation; ODI: Oswestry Disability index; VAS: Visual analog scale; BMI: Body Mass Index. Values are presented as mean±standard deviation for continuous variables and frequencies (percentages) for categorical variables. P-values for continuous variables were derived from aMann-Whitney U tests. For categorical variables, bchi-square or Fisher's exact test was used. Significant differences (p<0.05) were observed for the Oswestry Disability Index (ODI) and Visual Analog Scale (VAS) scores. IQR: Interquartile range (Q3–Q1).

served among groups (p=0.481 for TL vs. LLS; p=0.682 for SSPI, p=0.710 for LSPI). The interquartile range (IQR) for follow-up was 71–94.5 months (Q1=71, Q3=94.5), indicating consistency of long-term surveillance across groups. Detailed demographic characteristics and fracture features are presented in Table 1.

Significant improvements in SCA were observed in all groups throughout follow-up (p<0.001 for all). Preoperative mean SCA was significantly higher in the TL fracture group (25.5°±6.4°) compared to the LLS fracture group (12.0°±2.3°; p<0.001). Postoperative and final follow-up measurements showed significant and sustained correction in both TL and LLS fracture groups, with significant differences persisting between these groups (postoperative p<0.001, final follow-up p<0.001). SSPI resulted in significant improvements in SCA for both TL (mean improvement: 17.1°±3.8°) and LLS fractures (mean improvement: 13.0°±3.6°), with no statistically significant differences between these two groups (p>0.05, effect size=0.32). In contrast, LSPI achieved significantly greater improvement in SCA for TL fractures compared to LLS fractures (TL: 25.7°±8.0° vs. LLS: 13.3°±3.1°, p<0.05, effect size=0.49). Friedman test results indicated significant changes across measurement points within all groups (p<0.001), supported by strong concordance as indicated by Kendall's W (TL fractures: 0.904–0.945; LLS fractures: 0.939–0.945). Comprehensive results for SCA measurements are summarized in Table 2. Effect sizes (Cohen's d) for all pairwise comparisons are provided in Table 2 to facilitate clinical interpretation.

At final follow-up, clinical outcomes assessed by ODI and VAS scores showed significantly better results for the TL fracture group compared to the LLS fracture group (ODI: p=0.019, VAS: p=0.005). Specifically, within the LLS fracture group, ODI scores in patients treated with LSPI were significantly higher (indicating worse disability) compared to TL fracture patients (p=0.040, effect size=0.33). Within the SSPI group, ODI and VAS scores were lower in TL fracture patients compared to LLS fracture patients, though these differences did not reach statistical significance (ODI: p=0.255, VAS: p=0.066). Due to differences in fracture types between SSPI (AO type A) and LSPI (AO type B and C) within the LLS fracture group, these subgroup comparisons should be interpreted with caution. Detailed clinical outcomes (ODI and VAS scores) are presented in Table 3.

Table 2. Comparative analysis of functional and radiological outcomes in patients with thoracolumbar (TL) and lower lumbar fractures by surgical technique

Variable	TL SSPI (n=33) (mean±SD)	LL SSPI (n=8) (mean±SD)	LL LSPI (n=8) (mean±SD)	P value (LL)	P value (S)	P value (L)
Age	45.21±14.33	40.25±12.10	38.00±11.39	0.938	0.46125	0.71
Follow-up period (months)	84.86±18.24	87.50±16.51	102.75±43.59	0.917	0.682	0.71
Sex (F/M)	33%/67% (11/22)	37.5%/62.5% (3/5)	12.5%/87.5% (1/7)		0.675	1
ODI	20.36±10.26	25.38±7.17	40.63±15.42	0.459	0.255	0.040 (0.33)*
VAS	1.96±1.08	2.18±2.39	3.00±1.69	1	0.0666	0.038
BMI	24.64±3.39	26.75±4.53	28.75±5.63	1	0.46125	0.258
Preoperative SCA	21.14±3.66	11.50±2.14	12.50±2.56	1	<0.001 (0.55)*	<0.001 (0.55)*
Postoperative SCA	3.57±1.83	-2.75±1.49	-3.00±1.51	0.938	<0.001 (0.54)*	<0.001 (0.54)*
Last control SCA	4.07±2.46	-1.50±2.27	-0.75±1.39	1	0.003 (0.49)*	0.005 (0.44)*
Improvement in SCA	17.1±3.83	13.00±3.6	13.25±3.06	0.915	0.050 (0.32)*	0.003 (0.49)*

TL: Thoracolumbar; LL: Lower lumbar; SD: Standard deviation; SSPI: Short-segment posterior instrumentation; LSPI: Long-segment posterior instrumentation; SCA: Sagittal Cobb angle; Preop: Preoperative; Postop: Postoperative; ODI: Oswestry Disability Index; VAS: Visual analog scale; BMI: Body Mass Index. P value (S) represents the Mann-Whitney U test comparing short posterior instrumentation (PI) fusions between thoracolumbar (TL) and lower lumbar (LL) fractures. P value (L) represents the Mann-Whitney U test comparing long pelvic incidence–based (PI) fusions between TL and LL fractures. P value (TL) represents the Mann-Whitney U test comparing short and long PI fusions within TL fractures. P value (LL) represents the Mann-Whitney U test comparing short and long PI fusions within LL fractures. All p values were adjusted for Type I error using the Benjamini-Hochberg procedure. Effect sizes (Cohen's d equivalent) are indicated in parentheses for significant p values, marked with an asterisk (*). Improvement in the sagittal Cobb angle (SCA) was calculated as the difference between the last follow-up SCA and the preoperative SCA. Statistical significance was set at p<0.05.

Table 3. Sagittal Cobb angles at preoperative, postoperative, and final follow-up in thoracolumbar (TL) and lower lumbar fractures

	TL Fractures (n=33)	LL Fractures (n=16)	Total	P values
Preoperative SCA (mean±SD)	25.5±6.4	12.0±2.3	21.1±8.4	<0.001
Postoperative SCA (mean±SD)	2.6±2.0	-2.9±1.5	0.8±3.2	<0.001
Last control SCA (mean±SD)	3.5±2.6	-1.1±1.9	2.0±3.2	<0.001

TL: Thoracolumbar; LL: Lower lumbar; SD: Standard deviation; SSPI: Short-segment posterior instrumentation; LSPI: Long-segment posterior instrumentation; SCA: Sagittal Cobb angle; Preop: Preoperative; Postop: Postoperative.

DISCUSSION

This study tested the hypothesis that SSPI in LLS fractures achieves functional outcomes comparable to TL-SSPI and provides superior results to LSPI in the LLS region. Our findings support this, showing that LLS fractures managed with SSPI had ODI and VAS outcomes similar to those of TL fractures treated with the same technique, and better than LLS fractures treated with LSPI.

The increased mobility and unique biomechanical profile of the LLS spine contribute to the challenge of surgical management. While LSPI offers strong stabilization, it also limits lumbar motion and may accelerate adjacent segment degeneration, leading to worse long-term function. This was reflected in our cohort, where LLS-LSPI patients demonstrated higher ODI scores. Conversely, SSPI preserved segmental mobility while maintaining radiological correction, which may explain the superior functional outcomes.

Previous literature has suggested that SSPI is biomechanically sufficient in stable or moderately unstable LLS fractures, particularly when pedicle screws are placed into the fractured vertebra.[2] Our results align with these findings, as both SSPI and LSPI produced significant sagittal correction, with no statistical difference in the magnitude of improvement. Notably, pedicle screws were consistently inserted at the fracture level in SSPI cases, enhancing construct stability through ligamentotaxis.

Unlike osteoporotic burst fractures, high-energy traumatic LLS fractures typically occur in younger patients, whose bone quality is usually sufficient for pedicle screw fixation.[9] There are a limited number of high-quality studies on the optimal management of LLS fractures. Several publications advocate for conservative treatment in neurologically intact patients, emphasizing favorable outcomes in selected cases.[3,10] In contrast, other studies highlight the biomechanical challenges of this region and report superior radiological and functional results with SSPI.[4,11] Most current guidelines and recent evidence recommend surgical intervention for unstable LLS fractures—especially those with significant vertebral body collapse, posterior ligamentous complex injury, or progressive deformity—while conservative treatment is reserved for stable fracture patterns and patients without neurological deficits.[7] Our findings are consistent with this evidence, as SSPI provided satisfactory outcomes in appropriately selected LLS fracture patients, further supporting its role as an effective surgical approach for instability in this anatomically unique region. Kaminski et al.[10] reported that transpedicular bone grafting combined with posterior fixation for LLS fractures was insufficient to correct local kyphosis and failed to restore lumbar lordosis adequately. Due to a high complication rate, the authors suggested that conservative treatment may be reasonable in selected cases. In contrast, our study demonstrated significant improvement in SCA after posterior instrumentation in LLS fractures. Notably, preoperative SCA values were similar between the SSPI and LSPI groups within LLS fractures. However, both postoperative and final follow-up SCA measurements indicated significant and sustained restoration of sagittal alignment in both groups, highlighting the effectiveness of posterior instrumentation. Although the improvement in SCA was numerically greater in the LSPI group, there was no statistically significant difference compared to SSPI. Importantly, the correction achieved between preoperative and postoperative values was significant for both techniques. These results align with prior investigations indicating that insertion of pedicle screws into the injured vertebra, particularly in the context of short-segment instrumentation, is effective for correcting local kyphotic deformity and restoring sagittal alignment via ligamentotaxis.[12,13] In our cohort, pedicle screws were placed into the fractured vertebra in all patients who underwent short-segment fixation, supporting this approach for optimal alignment and stability in selected LLS fractures.

Regarding functional assessment, Erkan et al.[4] reported that patients with LLS fractures managed conservatively experienced improvements in functional (ODI) and pain (VAS) scores at final follow-up. Similarly, in our study, both ODI and VAS values showed significant improvement at final follow-up across all groups. Notably, patients with TL fractures and those with LLS fractures treated with SSPI achieved similar functional outcomes, as reflected by comparable ODI and VAS scores. However, LLS fracture patients who underwent LSPI had significantly higher ODI values at final follow-up, indicating greater residual disability. These findings suggest that both conservative and surgical management can lead to func-

tional improvement in LLS fractures. However, LSPI may be associated with less favorable outcomes compared to short-segment fixation, likely due to greater loss of lumbar mobility and increased biomechanical stress on adjacent segments.

A recent study by Suer et al.[7] highlighted that SSPI offers advantages such as reduced operative time and less intraoperative blood loss compared to LSPI. Several studies have reported significantly less blood loss, shorter incision lengths, and shorter operative times, especially with SSPI, including cases involving fractured vertebrae.[8,14-16] These findings are consistent with our results, as SSPI in the present study provided effective clinical and radiological outcomes while reducing surgical invasiveness.

Limitations

This investigation is subject to certain limitations. Primarily, the retrospective nature of the study may lead to inherent biases, such as those related to case selection and outcome reporting, which might restrict the external validity of the findings. In addition, residual confounding from unmeasured factors such as baseline comorbidities or injury energy could not be excluded. Second, the limited number of participants, especially in the lower lumbar fracture subgroups, reduces the robustness of statistical analyses and increases the likelihood of false-negative findings. Third, functional outcomes (ODI and VAS scores) were assessed only at the final follow-up, so changes over time could not be evaluated. Moreover, advances in implant technology and surgical techniques over the 2005–2022 study period may have introduced treatment heterogeneity. Although patients with known severe osteoporosis or poor intraoperative bone quality requiring cement augmentation were excluded, routine dual-energy X-ray absorptiometry (DEXA) screening was not performed for all patients. Therefore, the impact of subclinical low bone mineral density on clinical or radiological outcomes could not be assessed. Furthermore, one of the significant limitations of the study is that adjacent segment disease was not evaluated. In particular, adjacent segment disease following fusion surgery in the mobile lumbar region is a significant problem. Finally, as a single-center study, these findings may not be fully generalizable to other patient populations or clinical settings. To further validate and expand upon these findings, a prospective multicenter study is being planned.

CONCLUSION

Current evidence on lower lumbar fractures remains scarce, and clinical decision-making is often extrapolated from thoracolumbar injury data. In this study, SSPI emerged as a less invasive yet effective surgical option for both LLS and TL fractures, offering significant functional and radiological improvement. Particularly in stable or moderately unstable fracture patterns, SSPI yielded outcomes comparable to LSPI while better preserving lumbar mobility and minimizing surgical morbidity.

Given these advantages, SSPI may be considered the preferred surgical strategy in appropriately selected LLS fractures. However, LSPI retains its role in highly unstable injuries where extended fixation is warranted. Careful patient selection based on fracture type and degree of instability remains essential. Extensive multicenter, forward-looking investigations are required to substantiate the present observations and to refine evidence-based guidelines for this anatomically unique region of the spine.

Ethics Committee Approval: This study was approved by the Gazi University Rectorate Ethics Committee (Date: 19.02.2025, Decision No: E-77082166-604.01-1176128).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Travmatik alt lomber vertebra kırıklarında füzyon seviyelerinin klinik sonuçlara etkisi

AMAÇ: Alt lomber (AL) omurga travmatik kırıkları nadir görülür ve özgün biyomekanik zorluklar içerir. Bu çalışma, kısa segment posterior enstrümantasyonun (KSPE) uzun segment posterior enstrümantasyona (USPE) kıyasla klinik ve radyolojik sonuçlarını karşılaştırmayı amaçlamaktadır.
GEREÇ VE YÖNTEM: 2005–2022 yılları arasında, 18–63 yaş aralığında olup torakolomber (TL) (T10-L2) ve AL (L3-L5) seviyelerinde kırık nedeniyle posterior enstrümantasyon uygulanan hastalar retrospektif olarak incelendi. Tip A2-A4 kırıklarda KSPE, tip B2, B3 ve C kırıklarda ise USPE tercih edildi. Fonksiyonel sonuçlar Oswestry Disabilite İndeksi (ODİ) ve Vizüel Analog Skala (VAS) ile, radyolojik sonuçlar ise sagittal Cobb açısı (SCA) ile değerlendirildi. Toplam 49 hasta analiz edildi (33 TL, 16 AL).
BULGULAR: AL kırığı olan 8 hastaya KSPE, 8 hastaya USPE uygulandı. Tüm TL hastaları KSPE ile tedavi edildi. SCA tüm gruplarda anlamlı şekilde düzeldi ($p<0.001$). AL-USPE sonrası fonksiyonel skorlar daha kötüydü: ortalama ODI 40.6±15.4 iken AL-KSPE'de 25.4±7.2 ($p=0.040$); VAS sırasıyla 3.0±1.7 ve 2.2±2.4 ($p=0.038$). AL-KSPE sonrası ODI ve VAS skorları TL-KSPE ile benzerdi (ODI $p=0.255$; VAS $p=0.066$). KSPE, %19 daha kısa ameliyat süresi ve daha az kan kaybı ile eşdeğer radyolojik düzelme sağladı.
SONUÇ: Bu çalışmada, SSPE yönteminin hem klinik hem de radyolojik açıdan AL kırıklarının tedavisi için güvenli bir seçenek olduğu bulunmuştur. Buna karşın, USPE yöntemi lomber fonksiyon üzerinde olumsuz etkileri olabileceğinden, yüksek derecede instabil yaralanmalarda uygulanmalıdır.

Anahtar sözcükler: Alt lomber kırıklar; kısa segment füzyon; Oswestry Engellilik İndeksi; posterior enstrümantasyon; sagittal Cobb açısı; uzun segment füzyon.

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ORIGINAL ARTICLE

C-reactive protein-albumin-lymphocyte (CALLY) index as a predictor of early mortality in elderly patients with hip fractures

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ABSTRACT

BACKGROUND: This study aimed to evaluate the prognostic value of the C-reactive protein -albumin-lymphocyte (CALLY) index, an inflammation-based score derived from C-reactive protein (CRP), albumin, and lymphocyte count, in predicting 30-day mortality in elderly patients with hip fractures.

METHODS: A retrospective analysis was conducted on patients aged 65 years and older who were hospitalized with hip fractures between January 2022 and January 2025. Clinical and laboratory data were extracted from electronic medical records. The CALLY index was calculated using the formula: Albumin × Lymphocyte / CRP. The primary outcome was all-cause mortality within 30 days of admission. Receiver operating characteristic (ROC) analysis was used to assess the discriminative ability of the index, and multivariable logistic regression was performed to identify independent predictors of mortality.

RESULTS: A total of 410 patients aged 65 years and older with surgically treated hip fractures were included. The 30-day mortality rate was 14.6% (n=60). The CALLY index was significantly lower in non-survivors than in survivors (median: 5.6 vs. 9.4, p<0.001). Receiver operating characteristic (ROC) analysis showed that the CALLY index had moderate predictive ability for 30-day mortality, with an area under the curve (AUC) of 0.788. At the optimal cutoff value of 7.5, sensitivity was 75% and specificity was 67%. In the multivariable logistic regression model, inclusion of the CALLY index improved overall discrimination, yielding an AUC of 0.962. Kaplan-Meier survival analysis also demonstrated significantly lower survival probability in patients with low CALLY scores (p<0.001).

CONCLUSION: The CALLY index is a simple, accessible score that was independently associated with early mortality in elderly patients with hip fractures. It may help clinicians identify high-risk patients during the initial phase of hospitalization and inform perioperative management decisions.

Keywords: Elderly; hip fracture; immune; inflammation; mortality.

INTRODUCTION

Hip fractures are a major public health concern among the elderly, frequently resulting in functional decline, loss of independence, and increased mortality. With a rapidly aging global population, the incidence of hip fractures continues to rise, especially among individuals over 65 years of age.[1-3] Despite advances in surgical techniques and perioperative care, short-term mortality after hip fracture remains high, with estimates ranging between 1.4% and 10% in the first 30 days after injury.[4-5] Identifying high-risk patients early in their hospital course is essential for optimizing care and resource allocation.

New research emphasizes how crucial inflammation-related indicators are for predicting the prognosis of elderly patients

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after hip fracture surgery.[6,7] Among these, C-reactive protein (CRP), serum albumin, and lymphocyte count have emerged as accessible and clinically relevant indicators of the patient's overall inflammatory burden and nutritional status.[8-10] Several composite indices—such as the CRP-to-albumin ratio and neutrophil-to-lymphocyte ratio—have been investigated for their utility in predicting complications and mortality.[11-12] The C-reactive protein-albumin-lymphocyte (CALLY) index, derived by combining CRP, albumin, and lymphocyte parameters into a unified calculation, has been proposed as a practical tool for predicting short-term mortality; however, its applicability in geriatric hip fracture populations remains insufficiently explored.

The purpose of this study is to assess the predictive utility of the CALLY index in estimating 30-day mortality among older patients admitted to the hospital with hip fractures.

MATERIALS AND METHODS

This retrospective study was conducted in the emergency department of a high-volume academic hospital. The study population included patients aged 65 years and older who were admitted with a diagnosis of hip fracture between January 1, 2022 and January 1, 2025. Ethics approval was obtained from the Ethics Committee of Yeni Yüzyıl University (Approval No: 2025/05-1548, Date: 07.05.2025), and the principles of the Declaration of Helsinki were followed in conducting the study. Patients with radiologically confirmed fractures of the proximal femur, including femoral neck, intertrochanteric, and subtrochanteric regions, who were admitted for surgical treatment were considered eligible. Patients with polytrauma, pathological fractures, open wounds, hematologic malignancies, or missing CRP, albumin, lymphocyte count, or 30-day survival status data were excluded.

Patient charts were reviewed retrospectively to compile clinical findings and laboratory results. The following variables were recorded: age, sex, comorbidities, initial vital signs, fracture type, time to surgery, length of hospital stay, in-hospital complications, and 30-day mortality. Laboratory parameters included CRP, serum albumin, and absolute lymphocyte count, all obtained on the day of admission prior to surgery.

The CALLY index was derived according to the following equation[13]

CALLY Index=Albumin (g/dL)×Lymphocyte (10^9/L)/(CRP (mg/L)×10).

All values were measured in standard units (CRP in mg/L, albumin in g/dL, lymphocytes in 10^9/L). Thirty-day all-cause mortality after admission was designated as the primary outcome.

Statistical Analysis

Statistical computations were performed using R software (version 4.4.2; R Foundation for Statistical Computing, Vienna, Austria). Numeric variables were assessed for normality by visual inspection of histograms and reported as median [interquartile range (IQR)] due to non-normal data distribution. Categorical data were expressed as frequencies and proportions. For numeric data, the Mann-Whitney U (MWU) test was used to compare groups, and depending on appropriateness, the Chi-squared or Fisher's exact test was used to assess categorical variables. To identify independent predictors of 30-day mortality, variables with a p-value below 0.20 in univariable analysis were incorporated into a multivariable logistic regression model. Variance inflation factors (VIF) were computed to evaluate multicollinearity, with variables exceeding a VIF of 5 flagged for potential removal. Results were presented as adjusted odds ratios with 95% confidence interval (CI). Brier score, Nagelkerke R2, and the area under the receiver operating characteristic curve (AUROC) with 95% CI were used to assess the final model's performance. The Hosmer-Lemeshow goodness-of-fit test was applied to evaluate model calibration. Internal validation was performed through 5-fold cross-validation, with AUROC, sensitivity, and specificity reported as mean ± standard deviation across folds. The discriminatory ability of the CALLY index for predicting 30-day mortality was assessed using ROC curve analysis. The AUROC 95% CI was derived using bootstrap resampling with 1,000 iterations. The ROC curve and its 95% CI were visualized using "ggplot2," with the confidence interval displayed as a shaded area for clarity.

RESULTS

A total of 410 elderly patients with hip fractures were included in the study. The observed 30-day all-cause mortality rate was 10.5% (n=43). The baseline demographic and clinical characteristics of the cohort, stratified by 30-day mortality status, are presented in Table 1. The deceased patients were significantly younger than survivors, with a median age of 81 years [interquartile range (IQR): 72.5-84.5] compared to 84 years [IQR: 78-91] (p=0.005). Female sex was similarly prevalent in both groups (79.1% vs. 71.7%; p=0.369). The deceased group exhibited a higher prevalence of dementia (51.2% vs. 33.5%; p=0.028), whereas Charlson Comorbidity Index scores were paradoxically lower [3 (IQR, 1-7) vs. 5 (IQR, 3-7); p=0.026]. Rates of malignancy and American Society of Anesthesiologists Physical Status scores (ASA) did not differ significantly between groups.

Regarding inflammatory and nutritional markers, deceased patients demonstrated significantly higher CRP levels [78 mg/L (IQR: 53-102.75) vs. 58.9 mg/L (IQR: 29.1-97.9); p=0.010], along with lower serum albumin [2.7 g/dL (IQR: 2.4-2.9) vs. 3.2 g/dL (IQR: 2.8-3.6); p<0.001] and lymphocyte counts [0.7×10^9/L (IQR: 0.35-1.15) vs. 1.2×10^9/L (IQR: 0.85-1.7); p<0.001]. The neutrophil-to-lymphocyte ratio was also

Table 1. Comparison of survivor and deceased groups among patients with hip fractures

Variable	Survivor (n=367)	Deceased (n=43)	p
Age (years)	84 [78-91]	81 [72.5-84.5]	0.005
Sex (female)	263 (71.7%)	34 (79.1%)	0.369
Dementia	123 (33.5%)	22 (51.2%)	0.028
Malignancy	79 (21.5%)	9 (20.9%)	1.000
CCI	5 [3-7]	3 [1-7]	0.026
ASA score	2 [1-3]	2 [1-3]	0.282
CRP (mg/L)	58.9 [29.1-97.9]	78 [53-102.75]	0.010
Albumin (g/dL)	3.2 [2.8-3.6]	2.7 [2.4-2.9]	<0.001
Lymphocyte (×10⁹/L)	1.2 [0.85-1.7]	0.7 [0.35-1.15]	<0.001
NLR	5.9 [3.3-8.5]	8 [4.7-9.9]	0.009
Platelet Count (×10⁹/L)	223 [188-267.5]	204 [170.5-244.5]	0.065
Hemoglobin (g/dL)	11.3 [10.7-11.7]	10.3 [9.9-11]	<0.001
Sodium (mmol/L)	137 [135-138]	133 [131-134]	<0.001
Creatinine (mg/dL)	0.98 [0.79-1.12]	1.47 [1.31-1.67]	<0.001
CALLY Index	0.66 [0.36-1.5]	0.24 [0.09-0.40]	<0.001
Time to Surgery (hours)	39 [28-51]	38 [25-48]	0.465
Fracture Type			0.019
Femoral Neck	113 (30.8%)	17 (39.5%)	
Intertrochanteric	209 (56.9%)	26 (60.5%)	
Subtrochanteric	45 (12.3%)	0 (0%)	
Surgery Type			0.391
Arthroplasty	120 (32.7%)	11 (25.6%)	
IM Nail	247 (67.3%)	32 (74.4%)	
Postoperative Pneumonia	34 (9.3%)	11 (25.6%)	<0.001
Postoperative Delirium	74 (20.2%)	10 (23.3%)	0.690
Length of Stay (days)	19 [14-24]	18 [13.5-26]	0.759

CRP: C-reactive protein; ASA: American Society of Anesthesiologists Physical Status Score; NLR: Neutrophil-to-Lymphocyte Ratio; CCI: Charlson Comorbidity Index; CALLY: CRP-Albumin-Lymphocyte Index; IM: Intramedullary.

higher in deceased patients [8 (IQR: 4.7-9.9) vs. 5.9 (IQR: 3.3-8.5); p=0.009]. Additionally, hemoglobin and platelet counts were significantly lower in the deceased group [10.3 g/dL (IQR: 9.9-11) vs. 11.3 g/dL (IQR: 10.7-11.7); p<0.001, and 204×10⁹/L (IQR: 170.5-244.5) vs. 223×10⁹/L (IQR: 188-267.5); p=0.065, respectively]. Serum sodium was markedly lower in deceased patients [133 mmol/L (IQR: 131-134) vs. 137 mmol/L (IQR: 135-138); p<0.001]. Creatinine levels were significantly higher in the deceased group [1.47 mg/dL (IQR: 1.31-1.67) vs. 0.98 mg/dL (IQR: 0.79-1.12); p<0.001]. The CALLY index was markedly reduced among deceased patients [0.24 (IQR: 0.09-0.40) vs. 0.66 (IQR: 0.36-1.5); p<0.001]. Postoperative pneumonia occurred significantly more frequently among deceased patients (25.6% vs. 9.3%; p<0.001), while postoperative delirium and length of hospital stay did not differ significantly.

In the multivariable logistic regression model (Table 2), the CALLY index, sodium, hemoglobin, platelet count, and fracture type emerged as independent predictors of 30-day mortality. Specifically, the CALLY index showed an adjusted odds ratio (aOR) of 0.90 (95% CI: 0.81-0.97; p<0.001), and sodium had the strongest association with mortality (aOR: 0.11; 95% CI: 0.05-0.21; p<0.001). The model demonstrated excellent discrimination with an AUROC of 0.962 (95% CI: 0.936-0.988) and good calibration (Hosmer-Lemeshow p=0.978). The Brier score was 0.037 (95% CI: 0.025-0.050), indicating accurate risk prediction. Nagelkerke's R^2 was 0.816, suggesting substantial explained variance. Internal validation with 5-fold cross-validation yielded a mean AUROC of 0.941±0.056, mean sensitivity of 97.6%±1.8%, and mean specificity of 62.8%±20.2%.

Table 2. Multivariable logistic regression analysis for 30-day mortality

Variable	aOR (95% CI)	p
Age	0.62 (0.38-0.96)	0.032
Dementia	1.69 (0.64-4.58)	0.290
CCI	0.80 (0.50-1.25)	0.331
CALLY Index	0.90 (0.81-0.97)	<0.001
NLR	1.09 (0.68-1.76)	0.711
Platelet Count	0.52 (0.28-0.91)	0.021
Hemoglobin	0.53 (0.31-0.86)	0.010
Sodium	0.11 (0.05-0.21)	<0.001
Fracture Type		
Intertrochanteric	1.15 (0.42-3.23)	0.792
Subtrochanteric	0.038 (0.0002-0.53)	0.012
Postoperative Pneumonia	2.08 (0.60-7.02)	0.241

aOR: Adjusted Odds Ratio; CCI: Charlson Comorbidity Index; CI: Confidence Interval; NLR: Neutrophil-to-Lymphocyte Ratio; CALLY: C-Reactive Protein-Albumin-Lymphocyte Index.

Table 3. Diagnostic performance of the C-reactive protein-albumin-lymphocyte (CALLY) index for 30-day mortality prediction

Metric	Value (95% CI)
AUROC	0.788 (0.711-0.865)
Youden Index	0.477
Criterion	≤0.25
Sensitivity	0.744 (0.702-0.786)
Specificity	0.733 (0.690-0.776)
Positive Likelihood Ratio	2.787 (2.629-2.945)
Negative Likelihood Ratio	0.349 (0.330-0.371)

AUROC: Area Under the Receiver Operating Characteristic Curve; CI: Confidence Interval; CALLY: C-Reactive Protein-Albumin-Lymphocyte Index.

The diagnostic performance of the CALLY index in predicting 30-day mortality is detailed in Table 3 and visualized in Figure 1. The AUROC was 0.788 (95% CI: 0.711-0.865). The optimal threshold, determined by Youden's index, was ≤0.25, providing a sensitivity of 74.4% (95% CI: 70.2-78.6%) and specificity of 73.3% (95% CI: 69.0-77.6%). The corresponding positive likelihood ratio was 2.79 (95% CI: 2.63-2.95), and the negative likelihood ratio was 0.35 (95% CI: 0.33-0.37).

DISCUSSION

This study demonstrates that the CALLY index is significantly associated with 30-day mortality in elderly patients hospitalized with hip fractures. Lower CALLY values were observed in non-survivors, and the index showed moderate discriminative ability in univariable analysis. When integrated into a multivariable logistic regression model, its inclusion contributed to excellent overall predictive performance. These findings highlight the potential utility of the CALLY index as part of a broader risk assessment strategy in geriatric trauma care.

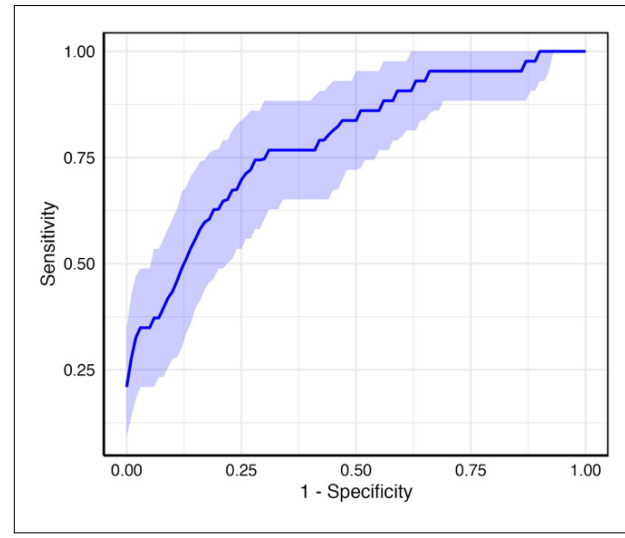

Figure 1. Receiver operating characteristic curve for the C-reactive protein-albumin-lymphocyte (CALLY) index in predicting 30-day mortality.

Hip fractures in the elderly represent a major clinical challenge, often leading to significant morbidity, prolonged hospitalization, functional decline, and increased short-term and long-term mortality. These patients are typically frail, have multiple comorbidities, and reduced physiological reserves, all of which contribute to poorer outcomes after trauma and surgery.[14] Mortality rates within 30 days can exceed 10%, and even among survivors, recovery of pre-injury function is often incomplete.[12] Therefore, early identification of patients at risk of adverse outcomes is essential to optimize perioperative care and resource allocation.[15]

The CALLY index integrates three routinely measured biomarkers—CRP, albumin, and lymphocyte count—each of which has independently demonstrated prognostic value in elderly patients with hip fractures. Their combined use may enhance predictive performance by capturing the inflammatory, nutritional, and immunologic status of the patient.

C-reactive protein is a widely studied marker of systemic inflammation and has been repeatedly linked to poor outcomes following hip fracture surgery in elderly patients. Elevated CRP levels reflect both the acute stress response and the extent of tissue injury, and are often correlated with higher rates of postoperative complications, delirium, and mortality. In a recent retrospective cohort study, Long et al.[12] reported

that elevated CRP at admission was independently associated with increased long-term mortality in geriatric patients undergoing hip fracture surgery, even after adjusting for age and comorbidities. Similarly, a prospective study by Lozano-Vicario et al.[16] found that higher CRP levels were predictive of postoperative delirium, which itself is a known risk factor for early mortality.

Serum albumin is a well-established marker of both nutritional and inflammatory status, and its prognostic value in elderly patients with hip fractures has been consistently demonstrated. Hypoalbuminemia is associated with impaired immune response, delayed wound healing, and increased vulnerability to complications such as infection and prolonged immobilization. Recent studies have confirmed its predictive role in postoperative outcomes. A retrospective cohort by Vural et al.[17] found that albumin was one of the strongest independent predictors of both early and late mortality in elderly patients with proximal femur fractures. Similarly, a study by Li et al.[18] showed that preoperative hypoalbuminemia was significantly associated with the development of postoperative pneumonia, which itself contributed to increased short-term mortality following hip fracture surgery.

Lymphocyte count serves as a surrogate marker of immune competence and physiologic reserve in older adults. Decreased lymphocyte levels, commonly observed in frail and inflamed patients, reflect both immune suppression and nutritional compromise.[19] Several studies have shown that lymphopenia at admission is significantly associated with higher postoperative mortality and complications following hip fracture surgery. For instance, Zhu et al.[20] demonstrated that a low lymphocyte-to-CRP ratio was independently predictive of one-year mortality in elderly patients undergoing hemiarthroplasty for displaced femoral neck fractures. Another cohort study by Lu et al.[21] found that lower absolute lymphocyte counts were associated with increased long-term mortality, regardless of other inflammatory parameters.

To the best of our knowledge, this is the first study to evaluate the prognostic value of the CALLY index specifically in elderly patients with hip fractures. Our findings revealed that lower CALLY scores were independently associated with increased 30-day mortality. Importantly, each component of the CALLY index—CRP, albumin, and lymphocyte count—also showed significant differences between survivors and non-survivors in univariate analysis, supporting the biological rationale of the index. These results suggest that the CALLY index not only reflects systemic inflammation and nutritional status but also captures broader immune vulnerability in this high-risk population.

From a practical standpoint, the CALLY index may serve as a simple bedside tool for early risk stratification in elderly patients admitted with hip fractures. In our study, a cut-off value of ≤0.25 was associated with a substantially increased risk of 30-day mortality. Patients below this threshold may warrant closer hemodynamic and metabolic monitoring, optimization of nutritional status, and more intensive perioperative surveillance. This information could help clinicians identify frail patients at an early stage and allocate resources, such as early geriatric consultation, multidisciplinary management, or admission to higher-level care units.

An unexpected finding of our study was that patients in the deceased group had a lower median age and lower Charlson Comorbidity Index (CCI) score compared to survivors. Several factors may account for this paradoxical observation. First, acute clinical conditions such as perioperative pneumonia, electrolyte disturbances, or renal dysfunction may have contributed more strongly to early mortality than baseline comorbidity burden. Second, fracture type and surgical complexity may have influenced outcomes independently of age and CCI. Third, variations in the timing of surgery and perioperative management could also have affected short-term survival. These observations highlight that short-term mortality after hip fracture is not solely dependent on age or comorbidity indices but is also influenced by acute physiological stressors and perioperative complications.

This study has certain limitations that should be acknowledged. Being conducted at a single center may limit the external validity of the findings. The retrospective nature of the design relies on the accuracy of recorded clinical and laboratory data, which may be subject to documentation bias. Since only patients with complete data and surgical management were included, the study population may not fully represent all elderly patients with hip fractures. In addition, the analysis was restricted to short-term outcomes, and no information was available on long-term survival, functional recovery, or readmission rates. Another limitation of our study is that we did not directly compare the prognostic performance of the CALLY index with other well-established prognostic tools, such as the American Society of Anesthesiologists score, the CCI, or the neutrophil-to-lymphocyte ratio (NLR). Although each of these markers has demonstrated prognostic value in geriatric hip fracture populations, our study focused specifically on the CALLY index. Future prospective studies should perform head-to-head comparisons of these indices to clarify their relative utility and potential complementary roles in clinical practice.

CONCLUSION

The CALLY index is an accessible, inflammation-based score that was independently associated with 30-day mortality in elderly patients with hip fractures. It combines three routinely available laboratory values and may help clinicians identify high-risk patients during early hospitalization. Although its discriminative ability was moderate, the index may serve as a useful adjunct in risk stratification and perioperative decision-making. Future prospective studies are needed to confirm its predictive value across different clinical settings and longer

follow-up periods.

Ethics Committee Approval: This study was approved by the Yeni Yüzyıl Universtiy Ethics Committee (Date: 07.05.2025, Decision No: 2025/05-1548).

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Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

C-reaktif protein–albümin–lenfosit (CALLY) indeksinin yaşlı kalça kırığı hastalarında erken mortaliteyi öngörmedeki rolü

AMAÇ: Bu çalışmanın amacı, C-reaktif protein (CRP), albümin ve lenfosit sayısından türetilmiş, inflamasyon temelli bir skorlama sistemi olan C-reactive protein-albumin-lymphocyte (CALLY) indeksinin, yaşlı kalça kırığı hastalarında 30 günlük mortaliteyi öngörmedeki prognostik değerini değerlendirmektir.

GEREÇ VE YÖNTEM: Ocak 2022 ile Ocak 2025 tarihleri arasında kalça kırığı nedeniyle hastaneye yatırılan, 65 yaş ve üzeri hastalar retrospektif olarak analiz edildi. Klinik ve laboratuvar verileri elektronik sağlık kayıtlarından elde edildi. CALLY indeksi şu formülle hesaplandı: Albümin x Lenfosit / CRP. Birincil sonuç, hastaneye yatıştan sonraki 30 gün içinde meydana gelen tüm nedenlere bağlı mortaliteydi. CALLY indeksinin ayırt edici gücü, ROC analizi ile değerlendirildi ve mortaliteyi öngören bağımsız değişkenleri belirlemek için çok değişkenli lojistik regresyon kullanıldı.

BULGULAR: Cerrahi olarak tedavi edilen kalça kırığına sahip toplam 410 hasta çalışmaya dahil edildi. Otuz günlük mortalite oranı %14.6 (n=60) idi. CALLY indeksi, hayatta kalanlara kıyasla yaşamını yitiren hastalarda anlamlı düzeyde daha düşüktü (medyan: 5.6 vs. 9.4; p<0.001). ROC analizi, CALLY indeksinin 30 günlük mortaliteyi öngörmede orta düzeyde prediktif güce sahip olduğunu gösterdi (AUC: 0.788). En uygun eşik değeri olan 7,5'te duyarlılık %75, özgüllük ise %67 idi. Çok değişkenli lojistik regresyon modeline CALLY indeksinin dahil edilmesi, genel ayırt edici gücü artırarak AUC'yi 0.962'ye yükseltti. Kaplan-Meier sağkalım analizi, düşük CALLY skoruna sahip hastalarda anlamlı şekilde daha düşük sağkalım olasılığı gösterdi (p<0.001).

SONUÇ: CALLY indeksi, yaşlı kalça kırığı hastalarında erken mortalite ile bağımsız olarak ilişkili bulunan, basit ve kolay erişilebilir bir skorlama sistemidir. Bu indeks, hastaneye yatışın erken evresinde yüksek riskli hastaların belirlenmesine yardımcı olabilir ve perioperatif yönetim kararlarını destekleyebilir.

Anahtar sözcükler: Bağışıklık, inflamasyon, kalça kırığı, mortalite, yaşlı.

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ORIGINAL ARTICLE

Plate or intramedullary fixation: A comparative analysis of surgical treatment options for adult both-bone forearm fracture – A retrospective clinical study

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ABSTRACT

BACKGROUND: Both-bone forearm fractures (BBFx) are common, high-energy injuries that significantly disrupt the anatomical and functional integrity of the forearm. While plate-screw osteosynthesis (PSO) has long been the standard treatment, intramedullary nailing (IMN) and hybrid methods combining both approaches have gained attention due to their potential advantages in minimally invasive procedures and functional outcomes. This study aims to compare the surgical and clinical outcomes of four different treatment strategies for BBFx.

METHODS: A retrospective review was conducted on 191 adult patients who underwent surgical treatment for combined radius and ulna fractures between 2012 and 2022. Patients were divided into four groups: PSO for both radius and ulna (Group A), IMN for both bones (Group B), IMN for radius, and PSO for ulna (Group C), and PSO for radius and IMN for ulna (Group D). Surgical outcomes including union time, fluoroscopy exposure, surgical duration, and functional recovery were analyzed.

RESULTS: Group B demonstrated significantly shorter surgical times (75.4 minutes) and faster fracture union (10.1 weeks) compared to Group A, which had a mean union time of 13.2 weeks. Fluoroscopy exposure was significantly lower in Group A, while Groups C and D showed intermediate results. Functional outcomes, including range of motion, grip strength, pinch strength, and QuickDASH (Quick Disabilities of the Arm, Shoulder, and Hand) scores, did not differ significantly between groups. The complication rate was lowest in Groups C and D (2.5%) and highest in Group B (6.5%), with complications such as infection and nonunion observed.

CONCLUSION: While PSO remains the gold standard for BBFx, hybrid methods combining PSO and IMN provide a promising alternative, offering shorter surgical times, faster union, and reduced fluoroscopy exposure. The hybrid technique may become a preferred approach due to these advantages, although further prospective studies are required to confirm these findings.

Keywords: Both-bone forearm fracture; plate-screw osteosynthesis; intramedullary nailing; hybrid fixation; trauma.

INTRODUCTION

Both-bone forearm fracture (BBFx) are orthopedic injuries that frequently occur following high-energy injuries and have shown an increasing incidence in recent years. These types of fractures severely disrupt the anatomical and functional integrity of the forearm, leading to dynamic instability between the wrist and elbow. The ideal treatment method should help patients regain functional mobility as quickly as possible, minimize the risk of complications, and ensure satisfactory long-

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term functional recovery. Although conservative management often yields favorable outcomes in pediatric populations, surgical intervention is the primary approach in the adult population. Because fractures of the radius and ulna significantly affect the biomechanical structure and function of the forearm, the selection of the optimal treatment regimen directly influences patient outcomes. The main goal of treatment is to restore axial and rotational stability and help patients regain their previous functional range of motion (ROM).[1]

Open reduction and plate-screw osteosynthesis (PSO) remains the most widely adopted technique for the management of BBFx, owing to its well-documented ability to achieve anatomical alignment and stable fixation.[2,3] While this method provides excellent anatomical restoration and stabilization, it also has several disadvantages, including extensile incisions, disruption of periosteal circulation due to plate pressure, potential plate removal, risk of refracture following plate removal, drainage of the fracture hematoma, and complications such as skin necrosis, nonunion, and infection.[4,5] In contrast, intramedullary nailing (IMN) offers a minimally invasive surgical technique that can reduce soft tissue damage and shorten operation time. However, critics argue that this method has limited capacity to ensure rotational stability and may be inadequate for certain fracture types.[6]

Although the hybrid application of these two methods is not widely discussed in the literature, its use has been increasing in recent years.[7] Combining different treatment approaches for BBFx has become an appealing option to ensure stability while leveraging the advantages of minimally invasive techniques.

We hypothesized that IMN, whether employed in isolation or as part of a hybrid construct, would result in shorter operative time and faster radiographic union compared to conventional plate-screw fixation applied to both the radius and ulna, without compromising functional recovery. This retrospective analysis was designed to delineate the relative advantages and limitations of current fixation strategies for adult both-bone forearm fractures, thereby informing clinical decision-making through comparative outcome data.

MATERIALS AND METHODS

All procedures involving human participants were conducted in accordance with the ethical standards of the institutional and national research committees, and with the 1964 Declaration of Helsinki and its subsequent amendments. The study involved no animal subjects. Ethical approval for this retrospective analysis was obtained (Approval no. 2024/010.99/2/9).

This retrospective study analyzed patients who underwent surgical treatment for combined radius and ulna fractures at our institution between 2012 and 2022. A total of 220 patient records were reviewed, and 191 patients who met the inclusion criteria were evaluated. Patient data were obtained from the institutional electronic medical record system and surgical archives. Inclusion criteria were: age ≥18 years, presence of combined radius and ulna fractures involving the distal, middle, or proximal third of the diaphysis, and a minimum clinical and radiological follow-up duration of 12 months. Exclusion criteria included open fractures, Monteggia or Galeazzi fracture-dislocations, pathological fractures, and fractures associated with neurovascular injuries.

Study Groups

The patients included in the study underwent different surgical treatments, and four main treatment groups were established:

1. Radius and ulna plate-screw osteosynthesis (Group A)
2. Radius and ulna intramedullary nailing (Group B)
3. Radius intramedullary nailing and ulna plate-screw osteosynthesis (Group C)
4. Radius plate-screw osteosynthesis and ulna intramedullary nailing (Group D).

Surgical Technique

Patients were operated on under general anesthesia or axillary block with a tourniquet (Fig. 1-4). One hour before the operation, 1 g of cefazolin was administered to all patients. The volar Henry approach was used for mid- and distal-diaphyseal radius fractures treated with plates, and the Thompson approach was used for proximal-diaphyseal fractures. For ulna fracture surgery, a direct incision was made through the bone. To preserve blood supply, excessive stripping of soft tissue from the osseous structures was avoided. After the fracture lines were identified, the plate was fixated with at least three screws (six cortices) both distally and proximally. In cases where PSO was performed for both radius and ulna, 3.5 mm limited-contact dynamic compression plates (LC-DCP) were used.

Closed reduction was attempted first in the nailing procedure. If closed reduction could not be achieved, open reduction was performed through a 2-cm incision at the fracture line. The nail was inserted with the patient in the supine position on a radiolucent operating table.

Nail length and thickness in patients undergoing IMN were determined using anteroposterior (AP) and lateral views taken prior to surgery. For application of the radius nail, a 1.5-2 cm incision was made over Lister's tubercle. The extensor carpi radialis brevis tendon was released and moved radially. The entry point was then determined under fluoroscopy, and an awl was used to create the path. The nail was directed proximally, and closed reduction was performed at the fracture site. The design of the proximal and distal ends provides rotational stability and restores radial bowing. Its parabolic body, with a 10° angled proximal 3 cm and distal interlocking features, enables three-point fixation.[8] For ulna

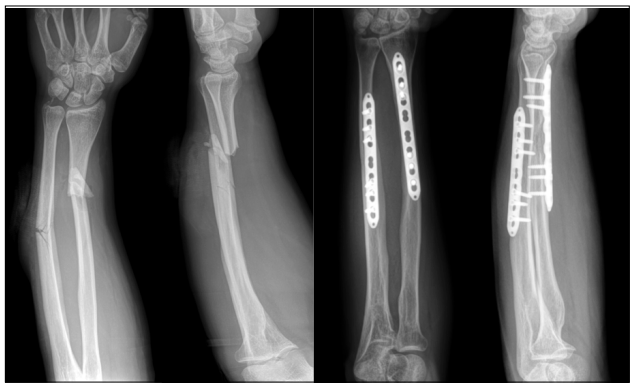

Figure 1. A 35-year-old male patient with a double fracture of the forearm after a traffic accident. Plate-screw osteosynthesis (PSO) was performed on both fractures. Preoperative and postoperative final radiographs are presented.

Figure 2. A 26-year-old male patient with a double fracture of the forearm after a fall while playing soccer. Intramedullary nailing (IMN) was performed on both bones. Preoperative and postoperative radiographs after union are presented.

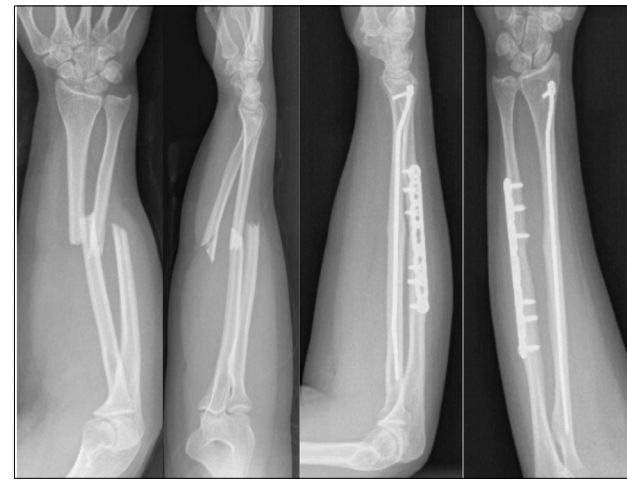

Figure 3. A 31-year-old female patient with a double fracture of the forearm due to a motorcycle accident. Intramedullary nailing (IMN) was performed on the radius, and plate-screw osteosynthesis (PSO) was performed on the ulna. Preoperative and postoperative follow-up radiographs are presented.

Figure 4. A 38-year-old male patient with a double fracture of the forearm after a fall from a height onto the arm. Intramedullary nailing (IMN) was performed on the ulna fracture, and plate-screw osteosynthesis (PSO) was performed on the radius. Preoperative fracture and postoperative radiographs after union are presented.

fractures, the elbow was flexed to 90°, and a 1-1.5 cm incision was made from the olecranon tip. A guide wire was inserted along the ulna shaft and checked with fluoroscopy. After canal preparation with a 3-mm drill, the nail was inserted distally. Closed reduction was attempted first, and if unsuccessful, reduction was achieved through a small open incision. The proximal part of the nail was locked either statically or dynamically. Distal locking was achieved with one or more locking screws passing through the eight transverse grooves on the distal 3 cm of the nail.[8] Distal locking was dependent on surgeon preference; in some cases, a distal locking screw was not used.

All surgical procedures were performed by experienced orthopedic surgeons. A single type of ulna and radius nail was used for IMNs (TST Rakor Medical Instruments Industry and Trade Limited Company, Istanbul, Türkiye). All patients followed a standardized rehabilitation protocol postoperatively, with early mobilization encouraged. Follow-up evaluations were performed at 2, 6, and 12 weeks, during which fracture healing was confirmed radiographically and functional assessments were conducted. Range of motion measurements and functional outcome assessments (the Quick Disabilities of the Arm, Shoulder, and Hand [QuickDASH] and Grace-Eversmann criteria) were conducted at the final follow-up, defined as the last outpatient clinic visit at least 12 months postoperatively.

Evaluation Criteria

Patients were evaluated based on demographic characteristics and specific functional and radiological parameters during the postoperative period:

• **Fracture union time:** Fracture healing was defined radiologically as the re-establishment of cortical continuity in AP and lateral radiographs, visible trabeculae, or callus formation in at least three cortices, together with the absence of tenderness along the fracture line. Time to union was defined as the period from surgery to the first radiological signs of healing. Fractures that did not heal within six months were classified as nonunion.[9]

• **Surgical duration:** Time elapsed from the initial incision to placement of the final suture was recorded.

• **Intraoperative fluoroscopy shots:** The number of fluoroscopic images taken during surgery was recorded as the average number of shots per patient.

• **Pronation and supination angles:** The rotational capacity of the forearm was assessed using goniometric measurements by a surgeon not involved in the procedures. Measurements were taken at the 12-week postoperative mark.

• **Grip strength (kgw):** The grip strength of the dominant and non-dominant hand was measured using a hand dynamometer.

• **Pinch strength (kgw):** Pinch strength between the thumb and index finger was assessed using a pinch meter.

• **Functional scores:** Patients' functional status was evaluated using the QuickDASH and Grace-Eversmann scores.[2,9]

• **Postoperative complications:** Recorded complications included infection, nonunion, malunion, nerve injury, implant-related issues, and other surgical complications.

Statistical Analysis

Statistical analyses were performed using SPSS software (IBM Corp., Armonk, NY, USA). The distribution of continuous variables was assessed using the Shapiro-Wilk test. Normally distributed variables were expressed as means and standard deviations, while categorical variables were reported as frequencies and percentages. Group comparisons for continuous data were conducted using one-way analysis of variance (ANOVA) or independent-samples t-tests, as appropriate. The chi-square test was employed to analyze categorical variables, including baseline characteristics and postoperative complications. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 191 patients were included in the study: 51 in Group A, 61 in Group B, 39 in Group C, and 40 in Group D. The mean age was 36.6 years (range: 19-76) in Group A, 33.8 years (range: 19-63) in Group B, 35.4 years (range: 18-66) in Group C, and 29.9 years (range: 18-61) in Group D, with no statistically significant differences observed between the groups (p=0.199). Among the patients, 93 (48.7%) sustained right-sided fractures, while 98 (51.3%) presented with left-sided fractures. The mean follow-up duration across all groups was 58.8 months (range: 13-130), with no statistically significant intergroup variation (p=0.354). Based on the Association for Osteosynthesis/Association for the Study of Internal Fixation (AO/ASIF) classification system, fractures were categorized as 22A3 in 85 cases, 22B3 in 87 cases, and 22C3 in 19 cases (Table 1).

The mean operation period was 105.3 minutes (80-150) in Group A, 75.4 minutes (50-120) in Group B, 100.7 minutes (70-130) in Group C, and 99.1 minutes (75-140) in Group D

Table 1. Baseline demographic characteristics and AO fracture classification of study groups

	Group A (n=51)	Group B (n=61)	Group C (n=39)	Group D (n=40)	p-value
Sex, n (%)					0.199
Male	32 (62.7%)	48 (78.7%)	25 (64.1%)	27 (67.5%)	
Female	19 (37.3%)	13 (21.3%)	14 (35.9%)	13 (32.5%)	
Age, years (mean±SD)	36.6±17.6	33.8±14.1	35.4±15.5	29.9±10.8	0.199
Side, n (%)					0.571
Right	29 (56.9%)	30 (49.2%)	18 (46.2%)	16 (40.0%)	
Left	22 (43.1%)	31 (50.8%)	21 (53.8%)	24 (60.0%)	
Follow-up, months (mean±SD)	58.8±11.3	57.2±10.9	59.7±12.1	60.2±13.4	0.354
AO Classification, n (%)					
22A3	22 (43.1%)	20 (32.8%)	24 (61.5%)	19 (47.5%)	
22B3	23 (45.1%)	35 (57.4%)	13 (33.3%)	16 (40.0%)	
22C3	6 (11.8%)	6 (9.8%)	2 (5.2%)	5 (12.5%)	

Table 2. Comparison of mean forearm pronation and supination angles (degrees) between treatment groups

	Group A (n=51)	Group B (n=61)	Group C (n=39)	Group D (n=40)	p-value
Pronation (°), mean±SD	83.6±7.1	83.2±5.9	83.2±5.3	85.1±4.7	0.413
Pronation (°), min–max	60–90	70–90	75–90	75–90	
Supination (°), mean±SD	84.2±5.3	81.8±5.9	83.5±4.9	84.5±4.5	0.301
Supination (°), min–max	70-90	60-90	70-90	75-90	

p-values were calculated using analysis of variance (ANOVA).

Table 3. Functional outcomes based on QuickDASH (the Quick Disabilities of the Arm, Shoulder, and Hand) questionnaire and Grace-Eversmann scoring system

	Group A (n=51)	Group B (n=61)	Group C (n=39)	Group D (n=40)	p-value
QuickDASH Score (mean, min–max)	8.1 (3–33)	6.9 (3–25)	8.3 (3–35)	7.7 (3–30)	0.601
Grace-Eversmann Score Evaluation					
Group A	**Group B (n=51)**	**Group C (n=61)**	**Group D (n=39)**	**p-value (n=40)**	
Excellent	46	55	36	37	0.877
Good	3	5	2	3	
Acceptable	2	1	1	0	
Unacceptable	0	0	0	0	

(measured from the first incision to the last suture). Statistical analysis revealed that Group B exhibited a significantly shorter operation period compared to the other groups (p<0.001), while no significant differences were found between Groups A, C, and D.

Fluoroscopic exposure, quantified by the mean number of fluoroscopies taken per procedure, was lowest in Group A (10.2±4.2 shots) and highest in Group B (46.2±13.8 shots). Statistical evaluation demonstrated that fluoroscopy use in Group A was significantly lower than in the other three groups (p<0.001). Moreover, Groups C and D displayed significantly lower fluoroscopic exposure than Group B (p<0.001 for both comparisons).

The mean time to radiological union was 13.2±1.7 weeks in Group A, 10.1±1.8 weeks in Group B, 11.2±1.7 weeks in Group C, and 10.5±2.1 weeks in Group D. Statistical analysis revealed that fracture healing in Group A was significantly delayed compared to the other groups (p<0.001).

Assessment of forearm ROM indicated no significant differences between groups in terms of supination (p=0.301) and pronation angles (p=0.413) (Table 2).

Functional outcomes, evaluated using the QuickDASH score and the Grace-Eversmann criteria, showed no significant intergroup differences (p=0.601 and p=0.877, respectively) (Table 3). Similarly, no significant variations were observed in pinch strength and grip strength parameters among the groups (p=0.137 and p=0.533, respectively).

A total of nine complications (4.7%) were observed among the 191 patients. These included two cases of nonunion (1.0%), one in Group A and one in Group B, both successfully treated with revision surgery. Four cases of superficial wound infection (2.1%) were distributed equally across all four groups (n=1 in each group); three resolved with antibiotic therapy and dressing, while one patient in Group A required multiple surgical debridements due to persistent drainage from the ulnar incision. Symptomatic screw irritation requiring implant removal occurred in two patients (1.0%) in Group B. Additionally, one patient (0.5%) in Group A sustained a posterior interosseous nerve (PIN) palsy, which resolved by the fourth postoperative month. No vascular injuries, synostosis, tendon injuries, compartment syndrome, or refractures were observed during the follow-up period.

DISCUSSION

The treatment of forearm diaphyseal fractures in adults continues to be a challenging topic, particularly with regard to IMN. In this study, we evaluated the efficacy of these methods

in four different treatment groups and compared multiple parameters. Our findings contribute to the existing literature by emphasizing the various advantages and limitations of each method. The general consensus for these fractures favors PSO of both bones, although IMN and hybrid treatment methods have recently gained attention. While rotational problems are associated with IMN, the nail designs used in our study are thought to reduce this deficiency by restoring radial bowing and through their locking systems.[8]

Union time was found to be significantly longer in Group A compared to Group B. This result is consistent with the findings of Zhang et al.,[10] who reported that IMN was associated with a significantly shorter union times than plate fixation. This may be explained by the superiority of IMN in axial stability over plate fixation, as IMN is a load-sharing implant that accelerates bone consolidation.[11] In a study published in 2022, significantly earlier bone union was observed in patients treated with both-bone fixation.[12] In another randomized controlled study, union time was shorter in patients who underwent PSO compared to those who underwent IMN.[13] Some studies, however, have reported similar union times for both techniques.[14-16] In our study, union time was longer in patients who underwent PSO compared to those who underwent IMN. Additionally, patients who underwent hybrid surgery demonstrated faster union times compared to patients treated with PSO. We have not found a similar study in adult patients in the literature. In this respect, we assume that hybrid surgery is more advantageous than PSO in both-bone fixations.

A meta-analysis published in 2024 showed that surgical time was significantly shorter in the IMN group compared to the PSO group.[17] In the treatment of isolated fractures involving the distal two-thirds of the ulnar diaphysis, mean operative time was also significantly shorter in the IMN group compared to alternative fixation methods.[18] Similar results have been reported in many studies in the literature.[15] In our study, although shorter surgical times were observed across all three IMN groups, statistically significant results were obtained only in the group treated with IMN for both bones compared to the other three groups. From this perspective, whenever open reduction is performed, the duration of surgery is prolonged. Although surgical time was shorter in the IMN groups, there were far fewer exposures to fluoroscopy among PSO patients who were operated on both bones regarding the preoperative fluoroscopy shot counts. The number of fluoroscopies taken increased when the fracture was treated with closed reduction and IMN. In the literature, many studies have demonstrated longer fluoroscopy times.[12-14] This issue is one of the biggest disadvantages of IMN.

In our study, although slight differences in pronation and supination angles were observed among the four groups, no statistically significant differences were found. This result is supported by many studies in the literature.[6,15,19]

In our study, functional outcomes, including the Quick-DASH and Grace-Eversmann scores, as well as pinch and grip strength measurements, were evaluated. Consistent with previous reports, no statistically significant differences among the groups have been reported in the literature for these parameters, including forearm range of motion.[6,20-22] In our study, there were no unacceptable outcomes according to Grace-Eversmann criteria, and the rate of excellent results was higher in this study. Although the mean Quick-DASH score was lower in Group B compared to the other groups, no significant differences were observed among the four groups for any of the clinical outcomes.

In the literature, complications such as infection, nonunion, refracture after implant removal, PIN injuries, vascular injuries, tendon ruptures, and elbow joint stiffness have been reported.[6,23,24] The overall complication rate in this study was approximately 4.7%. Complication rates were slightly higher in the IMN groups (6.5%) compared to the others, whereas the lowest rate was observed in the hybrid fixation groups (2.5%). In a systematic review published by Box et al.,[15] overall complication rates were reported to be lower in patients who underwent PSO. Many other studies have reported similar complication rates between the two groups.[7,25] Feng et al.[26] reported two major and two minor (14.2%) complications in the hybrid group of older children in their article published in 2016. They also noted complications in 8 out of 22 patients treated with elastic nails and stated that there was no difference between groups. Since there was no locking mechanism in patients with elastic nails and the nail tip was relatively outside the bone, higher complication rates were considered normal compared to the cases operated on with the nails used in our study. In another study involving patients aged 10 to 16 years, outcomes in the hybrid elastic nail and plate group were compared. In this study, the lowest complication rate was observed in the hybrid group, although no significant difference was found between the three groups.[27] We believe that the lower complication rates reported in the hybrid group in similar studies may make this method a preferred option in the future.

This study is not without limitations. The retrospective nature and lack of randomization inherently raise concerns regarding potential selection bias, as the choice of surgical technique was based on the attending surgeon's clinical judgment. Nevertheless, given that all fixation methods were routinely employed by experienced surgeons within the same institution and that no rigid criteria governed treatment allocation, the likelihood of systematic bias was likely mitigated. Furthermore, the single-center design may constrain the external validity of the results. Despite these limitations, the uniformity in surgical protocols and follow-up assessments strengthens the methodological rigor and internal consistency of the study.

CONCLUSION

Although plate-screw osteosynthesis is currently accepted as the gold standard for both-bone forearm fractures, IMN

and hybrid techniques have recently become widespread. Locked IMN for both bones has been reported as an easier technique with shorter surgical times and better cosmetic results; however, its relatively high fluoroscopy exposure and certain complications have prompted the search for different techniques. The hybrid method, which synthesizes both techniques, offers advantages such as shorter surgical times, less fluoroscopy exposure, and faster union compared to PSO applied to both bones. We believe the hybrid technique might become a popular method in the near future due to these advantages. We are aware that each patient should be evaluated individually, and it is critical to administer patient-specific treatment. Further studies are surely needed to compare different fixation techniques in forearm fractures.

Ethics Committee Approval: This study was approved by the Dr. Lütfi Kırdar City Hospital Ethics Committee (Date: 27.03.2024, Decision No: 2024/010.99/2/9).

Peer-review: Externally peer-reviewed.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Plak mı, intramedüller fiksasyon mu? Erişkin ön kol çift kemiği kırığında cerrahi tedavi seçeneklerinin karşılaştırmalı analizi: Retrospektif bir klinik çalışma

AMAÇ: Ön kol çift kemiğinin birlikte kırılması (ÖÇKK), ön kolun anatomik ve fonksiyonel bütünlüğünü ciddi şekilde bozan, yüksek enerjili travmalar sonucu gelişen yaygın kırıklardır. Bu kırıkların tedavisinde uzun süredir plak-vida osteosentezi (PVO) standart yöntem olarak kullanılmakta olup; son yıllarda intramedüller çivileme (İMÇ) ve her iki yöntemi birleştiren hibrit teknikler, minimal invaziv cerrahi avantajları ve fonksiyonel sonuçları açısından dikkat çekmektedir. Bu çalışmanın amacı, ÖÇKK tedavisinde uygulanan dört farklı cerrahi yöntemin cerrahi ve klinik sonuçlarını karşılaştırmaktır.
GEREÇ VE YÖNTEM: 2012 ile 2022 yılları arasında radius ve ulna kırığı nedeniyle cerrahi tedavi uygulanmış 191 erişkin hasta retrospektif olarak incelendi. Hastalar dört gruba ayrıldı: her iki kemiğe PVO uygulananlar (Grup A), her iki kemiğe İMÇ uygulananlar (Grup B), radiusa İMÇ ve ulnaya PVO uygulananlar (Grup C), radiusa PSVO ve ulnaya İMÇ uygulananlar (Grup D). Kaynama süresi, floroskopi maruziyeti, cerrahi süresi ve fonksiyonel iyileşme gibi cerrahi sonuçlar değerlendirildi.
BULGULAR: Grup B'de cerrahi süre (75.4 dakika) ve kaynama süresi (10.1 hafta) anlamlı şekilde daha kısa olup, Grup A'da ortalama kaynama süresi 13.2 hafta olarak izlendi. Floroskopi maruziyeti ise Grup A'da anlamlı şekilde daha düşüktü. Gruplar C ve D, bu parametrelerde ara değerler gösterdi. Fonksiyonel sonuçlar (eklem hareket açıklığı, el kavrama gücü, parmak uçları arasındaki sıkma gücü ve QuickDASH skorları) açısından gruplar arasında anlamlı fark bulunmadı. Komplikasyon oranı Grup C ve D'de en düşük (%2.5), Grup B'de ise en yüksek (%6.5) olarak izlendi; komplikasyonlar arasında enfeksiyon ve kaynamama yer aldı.
SONUÇ: PVO halen ÖÇKK tedavisinde altın standart olarak kabul edilse de, PvO ve İMÇ yöntemlerinin birlikte kullanıldığı hibrit teknikler; daha kısa cerrahi süre, daha hızlı kaynama ve düşük floroskopi maruziyeti gibi avantajlar sunarak umut verici bir alternatif oluşturmaktadır. Bu avantajlara rağmen, bulguların doğrulanması için ileriye dönük çalışmalara ihtiyaç vardır.

Anahtar sözcükler: Hibrit fiksasyon; intramedüller çivileme; ön kol çift kemik kırığı; plak-vida osteosentezi; travma.

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ORIGINAL ARTICLE

An endemic threat of agricultural mechanization: Hand injuries caused by electric pruning shears

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ABSTRACT

BACKGROUND: Electric pruning shears have become increasingly popular in Türkiye, particularly in regions where viticulture and olive cultivation are common. Although these tools offer ergonomic advantages, they also pose a significant risk of hand injuries. While injuries from other agricultural machinery have been documented in the literature, electric pruning shear injuries have not been systematically studied. Clinical observations of increased emergency admissions during the pruning season prompted this study.

METHODS: We retrospectively reviewed 28 patients admitted to our emergency department between November 2024 and March 2025 due to electric pruning shear injuries. Demographic data, injury mechanisms, affected anatomical zones, and associated tissue damage were recorded. Injuries were classified according to the volar hand injury zones and Ishikawa's classification. The time of injury, use of protective equipment, and patient training status were also evaluated.

RESULTS: All patients sustained single-digit injuries distal to the metacarpophalangeal joint. The average age was 53.6 years, and 92.9% were male. Injuries predominantly affected the non-dominant hand (82.1%), with the index finger being the most commonly injured (39.1%). Twenty-seven patients were not wearing protective gloves, and none had received formal training in device use. Neurovascular injury was present in 20 cases, and distal circulation was absent at admission in 13 patients. Smoking was reported by 78.5% of patients. All injuries occurred during daylight hours, with a peak incidence around 2 p.m. Three patients were under 18, and five were over 70 years old, highlighting both the accessibility and physical risks associated with the device.

CONCLUSION: Electric pruning shear injuries have emerged as a significant occupational hazard in agricultural regions. Ease of access, lack of training, and low awareness of protective measures contribute to their increasing frequency. Public health strategies such as safety regulations, mandatory training programs, and awareness campaigns are urgently needed. Further prospective studies are needed to evaluate functional outcomes and broader seasonal injury patterns.

Keywords: Electric pruning shear; hand trauma; agricultural accidents; occupational injuries; amputations.

INTRODUCTION

Acute traumatic hand injuries can result in substantial physical and socioeconomic consequences, often requiring complex treatment and prolonged rehabilitation.[1-2] Several studies have examined the treatment outcomes and functional limitations following traumatic finger and thumb amputations. While industrial injuries have been widely studied, agricultural settings, particularly those involving newer mechanized tools, remain underrepresented in the literature.[3-5]

Electric pruning shears, increasingly used in vineyard and orchard farming, operate with high-speed, high-pressure mechanisms. These devices can cause deep, clean lacerations and distal amputations that often involve bone, tendon, and neurovascular structures.[6-8] Despite their growing popularity, injuries related to electric pruning shears have rarely been reported in scientific publications.

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Most traumatic finger amputations occur in occupational settings and disproportionately affect working-age males.[3-5] Risk factors such as lack of safety training, improper tool handling, and absence of protective equipment contribute significantly to both the incidence and severity of these injuries.[6-7] In this context, electric pruning shears represent a novel injury mechanism with unique clinical challenges.

This study was initiated following a noticeable increase in emergency department admissions for electric pruning shear injuries observed during the regional pruning season. We aimed to characterize the anatomical, temporal, and demographic features of these injuries and to evaluate their surgical management. By doing so, we sought to highlight the clinical and public health implications of this underrecognized hazard and to contribute to the development of effective preventive strategies.

MATERIALS AND METHODS

Ethical approval for this study was obtained from the local ethics committee (Date: 09.04.2025, Approval number: 20.478.486/3031). The study was conducted in accordance with the principles of the Declaration of Helsinki. All participants were informed about the study, and written informed consent was obtained.

A total of 216 patients were referred to our clinic via the emergency department between November 2024 and March 2025. Among 101 acute finger injuries evaluated during this period, 28 cases involving pruning shear injuries were included. The study period was limited to the active pruning season; cases outside this time frame were excluded.

For each patient, data were collected on age, sex, time of injury, injury mechanism, educational background, occupational status, whether the incident was work-related, hand dominance, alcohol and tobacco use, use of protective equipment, and experience with pruning shear operation. Additionally, the time interval between injury and hospital admission was recorded. For amputated cases, the condition of the transported digit (e.g., appropriate preservation with saline-moistened gauze and ice) was assessed.

Injury zones were classified anatomically. Zone I injuries, located distal to the distal interphalangeal joint, were further subdivided according to the Ishikawa classification into Subzone 1 (n=1), Subzone 2 (n=5), Subzone 3 (n=5), and Subzone 4 (n=7). Zone II included injuries extending from the proximal phalanx to the metacarpal region (n=10).[9-10]

Following initial evaluation and emergency management in the emergency department, patients were operated on under infraclavicular block anesthesia in the operating room (Fig. 1). Replantation was performed in eight patients. In six

Figure 1. Representative case of an electric pruning shear injury to the index finger. **(a-c)** Initial clinical presentation showing a clean, deep laceration on the volar and lateral aspects of the right index finger. **(d-e)** Radiographic images demonstrating a transverse distal phalanx fracture without bone loss. **(f)** Intraoperative view showing an intact tendon with vascular and nerve damage requiring repair. **(g-h)** Postoperative follow-up images at 3 weeks, showing wound healing and satisfactory finger alignment with preserved distal joint mobility.

patients with preserved distal circulation, Kirschner wire (K-wire) fixation and nail bed repair were performed. In two patients who presented late, soft tissue closure was achieved using local flaps. For the remaining 12 patients, at least two of the following procedures were performed: K-wire fixation, tendon repair, and digital neurovascular bundle repair. Among these 12 patients, five had no distal circulation at the time of admission; however, during surgery under regional anesthesia, at least one digital artery was found to be intact, and circulation was restored after reduction and bony fixation.

Statistical Analysis

Descriptive statistics were presented as frequencies, percentages, means, minimums, and maximums. Calculations were performed using Microsoft Excel.

RESULTS

A total of 28 patients who sustained injuries from electric pruning shears were evaluated. All injuries involved a single finger. The mean age was 53.6 years (range: 16-75). Of these, 26 patients (92.9%) were male and two (7.1%) were female. Eight injuries occurred on the right hand, while 20 occurred on the left, indicating that the non-dominant hand was more frequently affected (dominant side: 5; non-dominant side: 23).

Although all patients reported prior experience using pruning shears, 27 lacked any specific protective equipment and had not received formal training related to their work. Only one patient was wearing protective gloves at the time of injury. None of the injuries were considered occupational accidents; all patients stated that the incidents occurred while working in their own fields. No patients reported a previous history of similar injuries.

The injuries were distributed fairly evenly throughout the day, although 25% occurred around 2:00 p.m. One patient presented to the hospital one day after the injury, and another four days later, both with prior wound suturing. These two cases were excluded from the timing analysis. Among the remaining 26 patients, all arrived within six hours after injury. The average time from injury to surgery was 6.7 hours (Fig. 2).

Of the 28 patients, 18 were referred by emergency personnel or another healthcare facility. In these cases, the injured part or amputated digit had been appropriately wrapped in saline-soaked gauze and/or stored under cooled conditions. The remaining eight patients, who arrived on their own, lacked proper dressing and transport of the injured part. The two patients who presented late had wounds that were already sutured and dressed, making accurate reconstruction more challenging.

All injuries were located distal to the metacarpophalangeal joint, and each case involved a single digit. There were 27 bone injuries, 20 neurovascular injuries, 11 extensor tendon injuries, and nine flexor tendon injuries. The injuries involved the thumb in five patients, the index finger in 11, the middle finger in four, the ring finger in three, and the little finger in five (Fig. 3).

Of the 27 bony injuries, 18 involved the distal phalanx and nine involved the proximal phalanx. All fractures were treated with K-wire fixation. In 14 distal phalanx cases, the K-wire did not cross the distal interphalangeal (DIP) joint. In four cases with accompanying extensor tendon injuries, the K-wire crossed the DIP joint for added stability. All nine proximal phalanx fractures were fixed using K-wires. No plates or screws were used in any case.

Digital artery and nerve repairs were performed using microsurgical techniques under loupe and microscope magnification with 10-0 sutures (Ethilon® 10-0, Ethicon). All neurovascular repairs were completed with end-to-end anastomosis without the need for grafting.

Replantation was attempted in eight patients. In two of these cases, venous insufficiency developed postoperatively and required revision surgery; despite intervention, both resulted in secondary amputation. One patient developed nonunion at the middle phalanx level by week 8. Two patients who presented late were treated with local flaps, with no complications observed. In one case involving an open fracture at Zone 2 with initially intact perfusion, pulp necrosis developed by day 7, necessitating debridement and flap coverage.

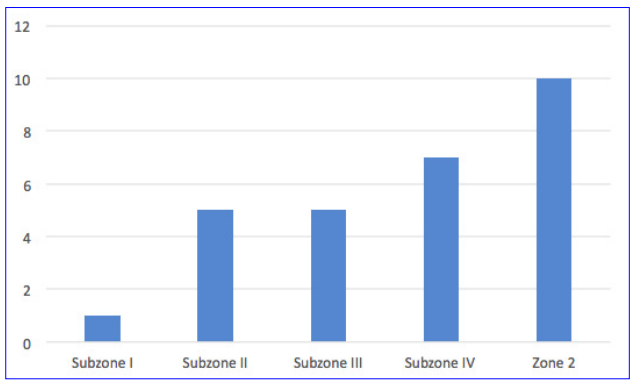

Figure 2. Distribution according to Ishikawa classification.

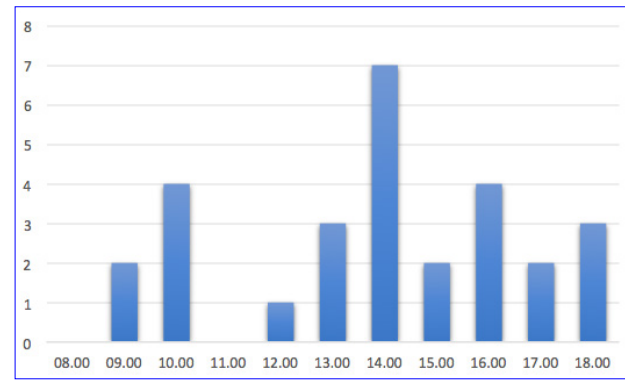

Figure 3. Temporal distribution of injuries.

Figure 4. Clinical presentation of various electric pruning shear injuries showing characteristic sharp, clean lacerations. Injuries present as circumferential or semi-circumferential cuts localized to the phalanges, demonstrating a consistent pattern of clean, guillotine-like wounds typically caused by electric pruners.

DISCUSSION

According to the emergency department records of our clinic, there was a noticeable increase in electric pruning shear injuries during the current pruning season. In response, we initiated a data collection process. This type of injury represents an endemic occupational threat, particularly in agricultural regions where grapevine and olive farming are common. In these areas, providing proper training and education on the safe use of agricultural tools is a critical need.

Clinically, we observed that, unlike other machinery-related injuries, electric pruning shears tend to cause clean, sharp cuts. This characteristic allows for easier repair of neurovascular structures without the need for grafting or bone shortening. Additionally, the absence of bone loss facilitates simpler reduction and fixation. Because all anatomical structures at the injury site are typically affected simultaneously, careful assessment of distal circulation is essential during the initial evaluation. Among the 28 patients in our study, two presented late (on day 1 and day 4). Of the remaining 26, 13 had no distal circulation at admission. In five of these cases, circulation was restored after bone fixation, but digital artery and nerve repair were still required. Therefore, even in isolated soft tissue injuries, vascular assessment should be performed meticulously (Fig. 4).

The average patient age was 53.6 years (range: 16-75), consistent with the demographic of retired individuals working in their own fields. Three patients (10.7%) were under 18 years old, suggesting that these devices are easily accessible and used without restriction. Additionally, five patients (17.8%) were over 70, a group with potentially reduced motor function and an increased risk of injury.[11]

Injuries occurred predominantly on the non-dominant hand (82.1%), likely because the device is typically operated with the dominant hand. The index finger was the most frequently injured digit (39.1%), possibly due to its role in supporting branches during pruning.

All patients were working independently on their own land, and none had received formal training in using the device. This finding highlights the urgent need for regulation and safety education. According to the survey, all patients had been using the tool for less than three years. They obtained the devices through recommendations from friends or neighbors rather than through advertising or online channels. If access and advertising continue to expand, these devices may become a growing public health concern in agricultural areas.

Because the work is performed outdoors and requires daylight, all injuries occurred between 09:00 and 18:00 and were evenly distributed throughout the day. In a study by Lombardi et al.,[12] most occupational injuries occurred between 10:00-

11:00 a.m., with a secondary peak between 1:00-2:00 p.m.

Individuals from lower socioeconomic backgrounds are at greater risk for hand injuries due to involvement in more physically demanding work, poorer overall health status, and higher rates of smoking.[13] Smoking not only affects physical function but also impairs cognitive performance and attention, thereby increasing the risk of accidents.[14] In our study, 78.5% of patients were smokers, consistent with findings in the literature.

This study was conducted during the pruning season in response to an observed increase in the frequency of these specific injuries. Although various occupational hand injuries caused by industrial machinery have been reported previously, to our knowledge, this is the first study to specifically address injuries associated with electric pruning shears. Previous research has shown that successful replantation can yield favorable functional outcomes and improved quality of life, although complications such as nonunion and joint stiffness may still occur.[15-18]

A primary limitation of this study is the absence of long-term functional outcome data and the relatively small sample size. Another limitation is that data collection was restricted to the pruning season, based on the observed seasonal increase in pruning shear-related injuries. As a result, the annual distribution and potential off-season cases could not be evaluated, limiting our ability to fully understand the year-round incidence and trends of such injuries. Because this injury mechanism has only recently been recognized, further studies are warranted. A long-term prospective study involving a larger patient population and evaluating functional outcomes throughout the year is planned to better define the seasonal distribution and overall impact of these injuries.

CONCLUSION

Injuries related to electric pruning shears have increased significantly in parallel with the growing popularity of these tools. These injuries represent an endemic threat in agricultural regions. While pruning shears provide efficiency and ease of work, they also pose a substantial risk to hand safety, creating significant burdens on public health and the national economy. To prevent such injuries, it is imperative to implement appropriate regulations and training programs on the safe use and distribution of these devices.

Ethics Committee Approval: This study was approved by the Manisa Celal Bayar University Ethics Committee (Date: 09.04.2025, Decision No: 20.478.486/3031).

Peer-review: Externally peer-reviewed.

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

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Tarımsal makineleşmeye bağlı endemik bir tehdit: Elektrikli budama makası ile el yaralanmaları

AMAÇ: Elektrikli bağ makasları, özellikle bağcılık ve zeytinciliğin yaygın olduğu bölgelerde ülkemizde son yıllarda yaygın olarak kullanılmaya başlanmıştır. Ergonomik avantajlarına rağmen bu aletler, el yaralanmaları açısından ciddi bir risk oluşturmaktadır. Diğer tarım makinelerine bağlı el yaralanmaları literatürde yer bulmuşken, elektrikli budama makaslarına bağlı yaralanmalar sistematik olarak incelenmemiştir. Budama sezonunda acil başvurulardaki artış üzerine bu çalışmayı planladık.

GEREÇ VE YÖNTEM: Kasım 2024-Mart 2025 ayları arasında elektrikli bağ makası yaralanması nedeniyle acil servise başvuran 28 hasta retrospektif olarak değerlendirildi. Hastaların demografik verileri, yaralanma mekanizmaları, anatomik tutulum bölgeleri ve eşlik eden doku hasarları kaydedildi. Yaralanmalar volar el yüzü ve Ishikawa sınıflamasına göre değerlendirildi. Ayrıca yaralanma zamanı, koruyucu ekipman kullanımı ve eğitim durumu da incelendi.

BULGULAR: Tüm hastalarda metakarpofalangeal eklem distalinde tek parmak yaralanması mevcuttu. Ortalama yaş 53.6 olup hastaların %92.9'u erkekti. Yaralanmalar %82.1 oranında non-dominant elde görüldü. En sık etkilenen parmak işaret parmağıydı (%39.1). Hastaların 27'sinde koruyucu eldiven kullanılmadığı, hiçbir hastanın cihazla ilgili eğitim almadığı saptandı. 20 hastada nörovasküler yaralanma vardı; 13 hastada başvuru anında distal dolaşım yoktu. Hastaların %78.5'i sigara kullanıcısıydı. Yaralanmalar yalnızca gün ışığı saatlerinde meydana geldi ve saat 14.00 civarında pik yaptığı gözlendi. 3 hasta 18 yaş altı, 5 hasta ise 70 yaş üzerindeydi; bu durum cihazın hem erişilebilirliğini hem de yaşlı bireylerdeki fiziksel riski ortaya koymaktadır.

SONUÇ: Elektrikli bağ makası yaralanmaları, tarım bölgelerinde önemli bir mesleki sağlık sorunu haline gelmiştir. Aletin kolay ulaşılabilir olması, eğitim eksikliği ve koruyucu ekipman kullanımındaki yetersizlik bu yaralanmaların artmasına neden olmaktadır. Bu sorunun azaltılması için güvenlik düzenlemeleri, zorunlu eğitim programları ve farkındalık kampanyaları hayata geçirilmelidir. Fonksiyonel sonuçları ve yıllık dağılımı içeren ileriye dönük çalışmalara ihtiyaç vardır.

Anahtar sözcükler: Amputasyon; elektrikli budama makası; el travması; tarımsal kazalar; mesleki yaralanmalar.

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ORIGINAL ARTICLE

Clinical outcomes and radiographic correlations with fracture complexity in isolated capitellum fractures: A retrospective cohort study

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ABSTRACT

BACKGROUND: Isolated capitellum fractures, though rare, significantly impact elbow function and are often associated with falls on an outstretched hand (FOOSH). This study aims to evaluate the relationship between forearm radiological parameters and fracture complexity, as well as to assess clinical outcomes in patients with isolated capitellum fractures.

METHODS: A retrospective cohort analysis was conducted on 28 fractures in 27 patients treated surgically at a tertiary center. Fractures were classified using the Bryan-Morrey system, and forearm parameters (maximum radial bow, location of maximum radial bow, proximal ulna dorsal angulation [PUDA], and proximal ulna varus angulation [PUVA]) were measured. Clinical outcomes were assessed using the Mayo Elbow Performance Score (MEPS) and QuickDASH (Quick Disabilities of the Arm, Shoulder, and Hand) scores.

RESULTS: Complex fractures (Bryan-Morrey Types III and IV) were associated with worse functional outcomes ($p<0.05$). A significant correlation was found between the distal location of the maximum radial bow and fracture complexity ($p=0.0468$). Union was achieved in 86.9% of osteosynthesis cases, with avascular necrosis (AVN) and heterotopic ossification observed in some patients.

CONCLUSION: Fracture complexity correlates with poorer functional outcomes. The distal location of the maximum radial bow may influence fracture patterns, suggesting a biomechanical role in energy transfer during FOOSH injuries. Surgical fixation yields favorable outcomes, particularly in Bryan-Morrey Type I-II fractures.

Keywords: Capitellum fractures; fall on outstretched hand; intraarticular fractures.

INTRODUCTION

Isolated capitellum fractures of the humerus, although rare among intra-articular elbow fractures, are serious injuries that affect the articular surface and directly influence functional outcomes. These fractures are often the result of low-energy trauma, such as a fall on an outstretched hand (FOOSH), in which energy is directly transmitted to the capitellum through axial loading of the radius.[1-3] In addition, anatomical variations of the forearm, such as valgus or radial bowing, may enhance energy transfer from the forearm to the capitellum, predisposing to fracture.

Capitellum fractures of the humeri are commonly associated with concomitant injuries, such as radial head fractures and lateral ligament instability, with such injuries noted in up to approximately 60% of patients.[4] However, isolated capitellar fractures are usually reported only in limited case series and are commonly classified using the Bryan-Morrey system. Because of their rarity, studies with small cohorts or case series have investigated fracture patterns and treatment outcomes.[5,6]

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Although previous literature has primarily focused on classification systems and treatment options for capitellar fractures, the influence of anatomical differences in forearm anatomy is underexplored.[7,8] Recent studies suggest that variations in forearm anatomy significantly influence load transmission during axial loading. Kim et al.[5] demonstrated that radial bow asymmetry alters rotational mechanics, while Shi et al.[6] linked ulnar varus angulation to proximal forearm fracture patterns, underscoring the potential role of morphological differences in capitellum fracture complexity.

Given the complex nature of these injuries and their frequent association with other injuries, open reduction and internal fixation (ORIF) is the favored treatment for displaced capitellar fractures, aiming to achieve anatomical reduction and stable fixation to allow for early range of motion and to prevent elbow stiffness.[1,4,9]

The main aim of this study is to evaluate whether there is a relationship between clinical outcomes and forearm radiological parameters with the fracture complexity of isolated capitellum fractures due to FOOSH injury.

MATERIALS AND METHODS

The study was conducted in a tertiary, high-volume trauma center. Data were collected retrospectively. Ethical approval was obtained from the ethics committee (Date: 17.09.2020; No: 06). This study was carried out in accordance with the Declaration of Helsinki.

Between January 2013 and January 2020, a total of 718 surgically treated humeral fractures at our institution were reviewed retrospectively. Of these, 158 involved distal humeral fractures. Among the 158 distal humeral fractures, 33 patients had isolated capitellum fractures. Five were excluded: three due to motorcycle accidents, one due to penetrating trauma, and one due to loss to follow-up. A total of 28 fractures in 27 patients who sustained a FOOSH injury and were followed up regularly were retrospectively analyzed (Fig. 1).

Fractures were classified according to the Bryan-Morrey system with the McKee modification.[10,11] Radiographic assessment included anteroposterior and lateral views of the elbow and forearm. The following forearm parameters were measured: maximum radial bow (mm), location of maximum radial bow (%), proximal ulna dorsal angulation (PUDA°), and proximal ulna varus angulation (PUVA°) (Fig. 2).[7,8,12] Measurements were performed in a double-blind manner by an orthopedic specialist.

Postoperative radiological outcomes were assessed in terms of union, avascular necrosis (AVN), heterotopic ossification (HO, Brooker classification), and degenerative arthritis (Broberg-Morrey classification). Clinical outcomes were evaluated using the Mayo Elbow Performance Score (MEPS) and the Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) score.

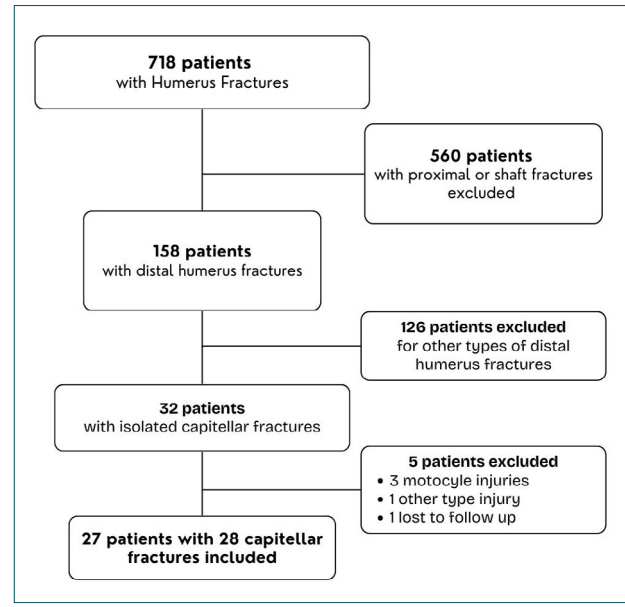

Figure 1. Flow diagram of the patient cohort.

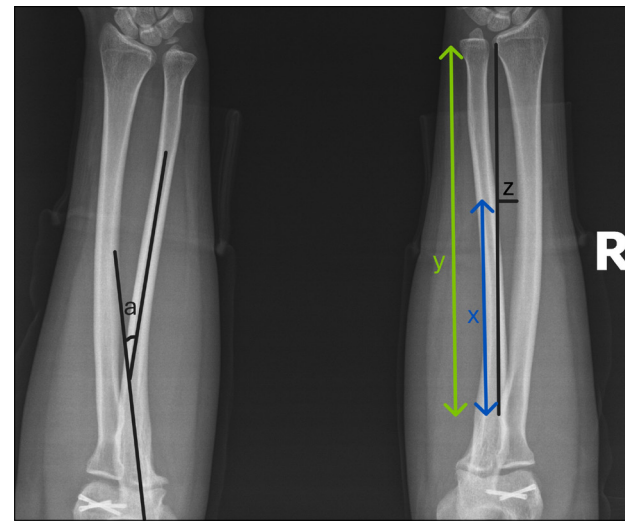

Figure 2. Anteroposterior (AP) view of a patient with assessment of radiological parameters (a: proximal ulna varus angulation [PUVA]; % (x/y)100 = Location of Maximum Radial Bow; z: Maximum Radial Bow [mm]).

Statistical Analysis

Statistical analysis was performed using IBM SPSS v25.0 (SPSS Inc., Chicago, IL, USA). Continuous variables were presented as mean±standard deviation. The normality of data distribution was assessed using distribution plots, normality tests (Shapiro-Wilk), and sample sizes; variables were found not to follow a normal distribution. Therefore, non-parametric tests were used for group comparisons. The Kruskal-Wallis test was applied to compare continuous variables among more than two groups. For post-hoc analysis following significant Kruskal-Wallis results, Dunn's test with Bonferroni correction was used to determine pairwise differences. A p-value <0.05 was considered statistically significant.

Table 1. Descriptive statistics of the patients

Demographic Information	N=28
Sex	
Female	22 (23 fractures)
Male	5
	Mean±SD (Min-Max)
Age (years)	47.8±18.4 (15-79)
BMI (kg/m²)	29.5±4.1 (21-37)

RESULTS

A total of 28 capitellum fractures in 27 patients (22 females and five males) were included in the analysis. The mean follow-up duration was 26.2 months (range, 12–79 months). Descriptive statistics for the cohort are detailed in Table 1. Fractures were classified according to the Bryan-Morrey system, and patients were grouped accordingly. At the final follow-up, the mean QuickDASH score was 25.6 (range, 4.5–75), and the mean MEPS was 83.2 (range, 50–100).

Statistical analysis revealed significant differences in patient-reported outcome measures (PROMs) among fracture types (Table 2). Results of the Kruskal-Wallis test showed that both QuickDASH and MEPS scores differed significantly among Bryan-Morrey types (p=0.015 and p=0.009, respectively). Post-hoc comparisons showed that QuickDASH scores were significantly higher (worse) in Type 4 vs. Type 1 (p=0.012), Type 3 vs. Type 2 (p=0.016), and Type 4 vs. Type 2 (p=0.014). MEPS scores were significantly lower (worse) in Type 3 vs. Type 1 (p=0.007), Type 4 vs. Type 1 (p=0.009), and Type 3 vs. Type 2 (p=0.048).

Radiological parameters of the forearm, which included maximum radial bow (mm), location of maximum radial bow (%), PUVA, and PUDA, were analyzed to evaluate their relationship with forearm anatomy and isolated capitellar fracture complexity (Table 3). Results of the Kruskal-Wallis test showed that only the location of maximum radial bow (%) was associated with Bryan-Morrey types (p=0.0468). Post-hoc analysis demonstrated that the maximum radial bow was located more distally in Bryan-Morrey Type 3 vs. Type 1 and Type 2 (p=0.0189 and p=0.0211, respectively), and in Type 4 vs. Type 1 and Type 2 (p=0.039 and p=0.0475, respectively). No significant difference was found between Type 3 and Type 4 (p=0.0709).

Surgically, 26 patients underwent a lateral Kocher approach, while two required a posterior approach with olecranon osteotomy. Headless compression screws were used in 23 cases (82.1%), and fragment excision was performed in five cases (17.9%). Union was achieved in 20 (86.9%) osteosynthesis cases. AVN was observed in five patients without the need for additional intervention. Heterotopic ossification (Brooker stage 1) was seen in 14 elbows, and degenerative changes (Broberg-Morrey stages 1-2) were found in eight elbows.

DISCUSSION

Our findings demonstrate a clear correlation between fracture type and PROMs in capitellum fractures, with more complex fractures (especially Type 3) associated with worse functional outcomes. Additionally, as our secondary aim, we

Table 2. Cohort distribution of Bryan-Morrey fracture types and associated patient-reported outcome measures (PROMs)

Bryan-Morrey Type	Number of Cases	QuickDASH Score (Mean±SD)	MEPS (Mean±SD)
Type 1	8	16.9±11.39	91.88±7.53
Type 2	3	10.2±9.93	90±7.07
Type 3	8	39.76±26.48	74.38±14.74
Type 4	9	32.03±12.38	79±11.97

Table 3. Cohort distribution of Bryan-Morrey fracture types and associated patient-reported outcome measures (PROMs)

Bryan-Morrey Type	Number of Cases	Maximum Radial Bow (mm)	Location of Max. Radial Bow (%)	PUDA (°)	PUVA (°)
Type 1	8	9.91±2.21	56.5±4.1	4.2±2.61	8.7±2.15
Type 2	3	9.88±2.39	56.9±3.8	4.1±2.52	8.6±2.41
Type 3	8	10.01±2.53	60.1±9.5	4.5±1.9	8.9±3.45
Type 4	9	9.93±2.97	61.2±3.9	4.3±2.11	8.5±3.01

investigated whether patients' forearm radiological parameters were related to fracture complexity. Except for the location of the maximum radial bow (%), there was no significant relationship between forearm morphological variations and fracture complexity.

A study by Widhalm et al.[13] reported an inverse relationship between fracture complexity and PROMs over a five-year follow-up period. Notably, the frequency of osteoarthritis and heterotopic ossification increased in Type 3 and Type 4 fractures. Similarly, Gao et al.[14] reported a higher incidence of functional impairment in more complex fracture types. Their findings showed a significant decline in functional scores (MEPS and QuickDASH) as fracture complexity increased in the Dubberley classification, which is consistent with the long-term data reported by Widhalm et al.[13] Our results align with the literature, as we observed that MEPS and QuickDASH scores were significantly lower in Bryan-Morrey Type 3 and 4 fractures compared to Types 1 and 2.

From a biomechanical perspective, studies by Markolf et al.[15] demonstrated that under valgus stress, approximately 93% of the axial load is transmitted through the radial head to the capitellum via the interosseous membrane. In another study, variations in elbow flexion angle were shown to alter stress distribution on the coronoid and radial head, potentially influencing fracture patterns.[16] Furthermore, Chou et al.[17] highlighted the impact of forearm rotation on valgus and varus stresses, suggesting that these rotational dynamics may modify load transfer mechanisms.

One important finding in our study is the association between the distal location of the maximum radial bow (%) and increased fracture complexity. This could be explained by biomechanical studies demonstrating that a more distally positioned radial apex may shift force distribution toward the distal humerus during a fall, increasing the energy absorbed by the capitellum. Firl and Wünsch previously established that variability in radial bow affects rotational mechanics of the forearm, which in turn could influence stress patterns during axial loading events such as FOOSH injuries.[12] Moreover, Rouleau et al.[8] emphasized that PUDA also plays a critical role in altering elbow joint mechanics under load. Garner et al.[18] previously noted that such morphological variations may influence fracture localization and load transmission, particularly in elderly individuals. Our study also observed a marked predominance of female patients, which is consistent with previous studies. This may be attributed to gender-specific biomechanical predispositions, including increased cubitus valgus angle, osteoporosis, and elbow hyperextension in women.[1-3,19]

Most authorities recommend surgical intervention for displaced capitellar fractures, given the risk of long-term instability, arthritis, and restricted motion if anatomical reduction is not achieved.[3,20,21] In our series, osteosynthesis using headless compression screws provided high union rates and satisfactory functional outcomes. Elkowitz et al.[22] demonstrated in a biomechanical study that headless compression screws placed postero-anteriorly offer superior stability compared to conventional screw systems. As an alternative procedure, fragment excision carries the potential risk of instability, pain, and limited range of motion in the long term. Nonetheless, Garner et al.[18] reported that excision can be acceptable in elderly patients with low functional demand. In our cohort, the lateral surgical approach combined with headless screw fixation yielded favorable outcomes. In five patients with highly comminuted Type 3 fractures where fixation was not feasible, fragment excision was performed. However, this subgroup exhibited poorer PROM scores compared to others.

The strengths of our study include its rare focus on the relationship between forearm morphology and capitellum fractures, the inclusion of comparative radiographic measurements, and the presentation of long-term functional outcomes.

The primary limitation of the study is the relatively small patient population, which is inherent to the rarity of capitellum fractures. Additionally, heterogeneity in surgical techniques (fragment excision vs. screw fixation) may have confounded outcome comparisons. Lastly, due to the low incidence of these injuries, the study was designed retrospectively, which constitutes another limitation.

CONCLUSION

This study demonstrated a relationship between isolated capitellum fracture complexity and clinical outcomes, with more complex fractures associated with worse functional scores. In addition, a distal location of the maximum radial bow was linked to increased fracture complexity, suggesting that forearm morphology may play a role in energy transmission during FOOSH injuries. Surgical intervention, particularly osteosynthesis with headless compression screws, provided satisfactory results, although fragment excision was necessary in highly comminuted cases.

Ethics Committee Approval: This study was approved by the SBÜ İzmir Bozyaka Research and Training Hospital Clinical Research Ethics Committee (Date: 17.09.2020, Decision No: 06).

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Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

İzole kapitellum kırıklarında kırık kompleksitesinin klinik sonuçlar ve radyografik değerler ile korelasyonu: Retrospektif bir kohort çalışması

AMAÇ: Nadir de olsa izole kapitellum kırıkları dirsek fonksiyonunu önemli ölçüde etkiler ve sıklıkla açık el üzerine düşme (FOOSH) ile ilişkilidir. Bu çalışma, önkol radyolojik parametreleri ile kırık sınıflandırması arasındaki ilişkiyi değerlendirmeyi ve izole kapitellum kırıklı hastalarda klinik sonuçları değerlendirmeyi amaçlamaktadır.

GEREÇ VE YÖNTEM: Üçüncü basamak bir merkezde cerrahi olarak tedavi edilen 27 hastada 28 kırık retrospektif olarak değerlendirilmiştir. Kırıklar Bryan-Morrey sistemi kullanılarak sınıflandırılmış ve önkol parametreleri (maksimum radial eğim, maksimum radial eğim konumu, Proksimal Ulna Dorsal Angulasyonu "PUDA" ve Proksimal Ulna Varus Angulasyonu "PUVA") ölçülmüştür. Klinik sonuçlar Mayo Dirsek Performans Skoru (MEPS) ve Quick-DASH skorları kullanılarak değerlendirilmiştir.

BULGULAR: İleri evre kırıkların (Bryan-Morrey Tip 3 ve 4) daha kötü fonksiyonel sonuçlarla ilişkili olduğu gözlendi ($p<0.05$). Distalde konumlanmış olan maksimum radial eğim ile kırık ileri evresi arasında anlamlı bir korelasyon bulunmuştur ($p=0.0468$). Osteosentez vakalarının %86.9'unda kaynama sağlanmış, bazı hastalarda AVN ve heterotopik ossifikasyon gözlenmiştir.

SONUÇ: İleri evre kırıklar daha kötü fonksiyonel sonuçlarla ilişkilidir. Distalde konumlanmış olan maksimum radyal eğim kırık ciddiyetini etkileyebilir ve bu da FOOSH yaralanmaları sırasında enerji transferinde biyomekanik bir rolün varlığını düşündürmektedir. Özellikle Bryan-Morrey 1-2 grubu hastalarda cerrahi tespit olumlu sonuçlar vermektedir.

Anahtar sözcükler: Kapitellum kırığı; eklem içi kırık; el üzeri düşme.

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ORIGINAL ARTICLE

Neurosurgical and orthopedic outcomes of emergency patients admitted after the Pazarcık earthquake: Focus on crush syndrome incidence and associated morbidity

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ABSTRACT

BACKGROUND: This study retrospectively evaluates the clinical outcomes of patients admitted to our hospital following the Pazarcık earthquake on February 6, 2023. It specifically focuses on patients requiring multidisciplinary follow-up care in orthopedics and neurosurgery clinics, assessing the nature and severity of their injuries.

METHODS: We included patients admitted under the International Classification of Diseases (ICD)-35 code as a result of the earthquake centered in the Pazarcık district of Kahramanmaraş province.

RESULTS: A total of 449 patients were admitted: 265 (59%) were discharged as outpatients, while 184 (41%) required hospitalization. Of the hospitalized patients, 45.7% required surgery, with 51.2% of procedures performed by orthopedic surgeons, 27.4% by neurosurgeons, and 19% involving both orthopedics and plastic, reconstructive, and aesthetic surgery. Compartment syndrome was documented in 14.7% of hospitalized patients, and crush syndrome in 46.7%. Additionally, 13% of patients required physical therapy. The overall mortality rate was 7.1%, significantly higher among patients with compartment syndrome ($p<0.001$) and crush syndrome ($p=0.001$), but lower in those who underwent surgery ($p=0.023$).

CONCLUSION: This evaluation reveals that the Pazarcık earthquake caused significant morbidity, with high incidences of crush and compartment syndromes requiring urgent surgical intervention. These findings underscore the need for improved disaster preparedness and effective treatment protocols to address the unique challenges posed by such catastrophic events.

Keywords: Crush syndrome; compartment syndrome; earthquakes.

INTRODUCTION

Earthquakes are natural phenomena caused by fractures in the Earth's crust, resulting in vibrations and ground shaking in affected areas. These disasters can cause significant destruction, leading to extensive loss of life and property. Globally, approximately five million earthquakes occur each year, with around 3,000 perceptible to humans.[1] The duration and intensity of an earthquake are critical in determining the extent of the resulting damage. In addition, the population density and characteristics of the affected settlements greatly influence the level of destruction. The consequences of earthquakes extend beyond physical damage, encompassing profound economic, political, health, and psychological impacts. Between 1900 and 2014, our country endured 180 significant earthquakes, resulting in substantial casualties and damage, with reports indicating that 96,064 lives were lost and 778,759 buildings were severely impacted during this period.[2,3]

While it is impossible to prevent earthquakes, the adverse

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effects of these disasters can be mitigated through effective preparedness and precautionary measures. Advance disaster planning is essential to ensure the rapid transport of earthquake victims to healthcare facilities, as prolonged entrapment under debris can significantly increase morbidity and mortality rates. Healthcare institutions must be equipped with the necessary tools and technical infrastructure to respond effectively to such emergencies. Regular drills should be conducted to identify and address any deficiencies in emergency preparedness.[1-6]

On February 6, 2023, a catastrophic earthquake with a moment magnitude (Mw) of 7.8 struck Kahramanmaraş, affecting 11 provinces and approximately 15 million people. Nine hours later, a secondary quake with a magnitude of 7.7 Mw occurred, centered in the Pazarcık district of Kahramanmaraş. The close timing of these two seismic events exacerbated the devastation, as structures already damaged during the first quake collapsed during the subsequent tremor. Official reports indicate that more than 50,000 people perished, and approximately 125,000 sustained injuries as a result of these earthquakes in Türkiye.

This study was conducted at Şanlıurfa Training and Research Hospital and aims to retrospectively examine the clinical outcomes of 449 patients admitted following the earthquake on February 6. The focus of this research is particularly significant because it centers on neurosurgical and orthopedic outcomes, which are crucial for understanding the range of injuries sustained during seismic events. By addressing these outcomes, we aim to illuminate the specific challenges and treatment considerations that arise in such contexts. Furthermore, this study contributes to filling a notable gap in the existing literature on disaster-related injuries, especially in light of previous major earthquakes such as those in Van and other regions worldwide.[7-9] By drawing parallels and insights from these past events, we hope to enhance the understanding of injury patterns and management strategies necessary to optimize patient care in future disaster scenarios.[10-14]

In the aftermath of significant seismic events, the severity of injuries can vary widely. Orthopedic injuries frequently include fractures and dislocations, which often necessitate immediate surgical intervention and comprehensive rehabilitation. These injuries not only affect physical mobility but may also result in long-term functional difficulties. Similarly, neurosurgical injuries, such as traumatic brain injuries caused by falls or blunt impacts, pose substantial risks. Rapid assessment and intervention for these types of injuries are essential to prevent permanent neurological damage. Analyzing injury patterns and their treatment outcomes is critical for developing effective disaster response protocols. By synthesizing insights from previous studies on orthopedic and neurosurgical care in various disaster contexts, this research aims to contribute to the enhancement of clinical practices for trauma management in catastrophic events. Moreover, the study underscores the importance of long-term follow-up and evaluation of treatment protocols to better understand the lasting effects of earthquake-related injuries on both physical and mental health. Ultimately, this research endeavors to contribute to the ongoing discourse on disaster management within healthcare, providing evidence-based recommendations to improve response strategies and patient outcomes in the aftermath of such devastating incidents.

MATERIALS AND METHODS

This study included patients admitted to our hospital following the earthquake that occurred in the Pazarcık district of Kahramanmaraş Province on February 6, 2023, who were assigned the International Classification of Diseases (ICD) 35 code. The use of the ICD 35 code was mandated by our hospital for all patients presenting after the earthquake, ensuring systematic documentation of conditions related to the disaster. Ethical approval for the study was obtained from the Harran University Ethics Committee (Approval No: HRÜ/23.05.17). The study was conducted in accordance with the principles of the Declaration of Helsinki.

We collected demographic data, including age, sex, time of admission to the emergency department after the earthquake, initial neurological examination findings, and the presence of traumatic pathologies confirmed through radiological imaging and clinical assessment. Additionally, we documented any history of chronic kidney disease (CKD) and pregnancy status in female patients. Information regarding hospitalization, specific wards to which patients were admitted, details of surgical interventions, postoperative neurological examination findings, and specifics of surgeries performed on neurosurgical patients were also documented.

For all hospitalized patients, we retrospectively assessed the presence of compartment syndrome and crush syndrome, receipt of physical therapy, patient outcomes, and length of hospital stay.

Statistical Analyses

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS; SPSS Inc., Chicago, IL), version 22. Descriptive data were presented as frequencies and percentages for categorical variables and as mean±standard deviation (Mean±SD) for continuous variables. The chi-square test (Pearson chi-square) was used to compare categorical variables across groups. The normality of continuous variables was assessed using the Kolmogorov-Smirnov test. For comparisons between paired groups, the Mann-Whitney U test was applied.

Overall survival was analyzed using Kaplan-Meier survival analysis for univariate assessments. The log-rank (Mantel-Cox) test was performed to compare survival times among categorical variables. The significance level for all statistical analyses was set at $p<0.05$.

RESULTS

A total of 449 patients were included in the study. The mean age of the patients was 32.4±20.2 years, with a median age of 29 years (range: 0.3-86). Among these patients, 52.8% were female and 47.2% were male. The average time interval between the earthquake and hospital admission was 53.0±51.1 hours, with a median of 36 hours (range: 1-240 hours). This highlights a delay in care, similar to that observed in other disaster scenarios (Table 1).

Table 1. Characteristics of the patients enrolled in the study

	Number	%
Age, Mean±SD	32.4±20.2	
Gender		
Female	237	52.8
Male	212	47.2
Arrival time after earthquake, Mean±SD	53.0±51.1	
Hospitalization status		
Outpatient discharge	265	59.0
Admission	184	41.0
Motor deficit		
Yes	22	5.0
No	414	95.0
Patient consulted for neurosurgery	99	22
Patients admitted by neurosurgery	33	7.3
Patients operated on by neurosurgery	23	5.1
Number of spinal surgeries performed by neurosurgery	19	4.2
Number of cranial surgeries performed by neurosurgery	4	0.8
Presence of other systemic trauma in patients hospitalized in Neurosurgery	11	33.3
Degree of motor deficits in patients hospitalized in the neurosurgery department		
Lower limb 1/5	1	11.1
Lower limb 2/5	1	11.1
Lower limb 4/5	1	11.1
Limbs 2/5	1	11.1
Paraplegia	3	33.3
Right lower extremity 3/5	1	11.1
Drop hand (left)	1	11.1
Postoperative neurological examination		
Normal	3	33.3
Paraplegia	3	33.3
Lower limb 4/5	2	22.2
Upper limb 4/5	1	11.1
CKD		
Yes	15	3.3
No	434	96.7
Pregnant		
Yes	4	0.9
No	445	99.1
Operation status		
Yes	84	45.7
No	100	54.3

Operating department		
Orthopedics	43	51.2
Neurosurgery	23	27.4
Orthopedics+PREC	16	19.0
Orthopedics+PREC+CVS	1	1.2
General Surgery	1	1.2
Type of operation performed in neurosurgery		
Spine stabilization	15	65.2
Kyphoplasty	4	17.4
Elevation of fracture	2	8.7
Evacuation of hematoma	1	4.3
Wound debridement	1	4.3
Compartment syndrome		
Yes	27	14.7
No	157	85.3
Crush syndrome		
Yes	86	46.7
No	98	53.3
Physiotherapy		
Yes	24	13.0
No	160	87.0
Exitus		
Yes	13	7.1
No	171	92.9
Length of stay, Mean±SD	11.0±11.0	

PREC: Plastic, Reconstructive, and Aesthetic Surgery; CVS: Cardiovascular Surgery; CKD: Chronic Kidney Disease.

Of the total patients, 59% (265 patients) were discharged as outpatients, while 41% (184 patients) required hospitalization. Within the cohort, 11 patients (2.5%) had a Glasgow Coma Scale (GCS) score between 3 and 8, and five patients (1.1%) scored between 9 and 14, while the majority of 433 patients (96.4%) had a GCS score of 15. Motor deficits were identified in 5% of the patients, with 10 admitted to the neurosurgery department. Among them, presentations included lower extremity weakness (graded 1/5, 2/5, or 4/5), paraplegia, and upper extremity weakness (Table 1).

Postoperative neurological outcomes varied among hospitalized neurosurgery patients; some displayed normal neurological function, while others presented with paraplegia or varying degrees of extremity weakness. Chronic kidney disease was identified in 3.3% of patients, and 0.9% were pregnant (Table 1).

Among hospitalized patients, 7.3% were admitted for neurosurgical interventions, and 45.7% underwent surgical procedures. Orthopedic surgery accounted for 51.2% of the operations performed, followed by neurosurgery (27.4%), combined orthopedic and exploratory surgery (19%), and a combination of orthopedic, exploratory, and cardiovascular surgeries (1.2%). General surgery represented another 1.2% (Table 1).

Compartment syndrome was observed in 14.7% of hospitalized patients, while crush syndrome was present in 46.7%. Physical therapy was administered to 13% of patients. The inpatient mortality rate was 7.1%, and the mean duration of hospital stay was 11.0±11.0 days (median: 11; range: 1-62) (Table 1).

Trauma signs were documented in 157 patients (35%), with extremity fractures being the most common injury (66.2%). Less frequent injuries included T5 fractures, C5 fractures, and epidural hematomas (each 0.6%) (Fig. 1).

Patient Disposition and Outcomes

In terms of patient disposition, 59% were discharged as outpatients, while 12.2% were hospitalized in orthopedic wards, 7.3% in neurosurgery departments, and 6.5% in internal medicine units. The time to hospital arrival was significantly longer for trauma patients compared with non-trauma patients. GCS scores for trauma patients were significantly

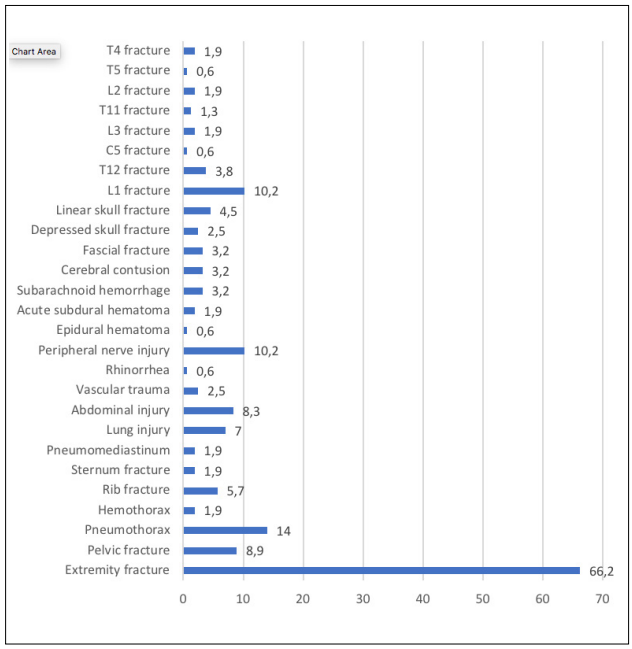

Figure 1. Trauma types observed in earthquake patients.

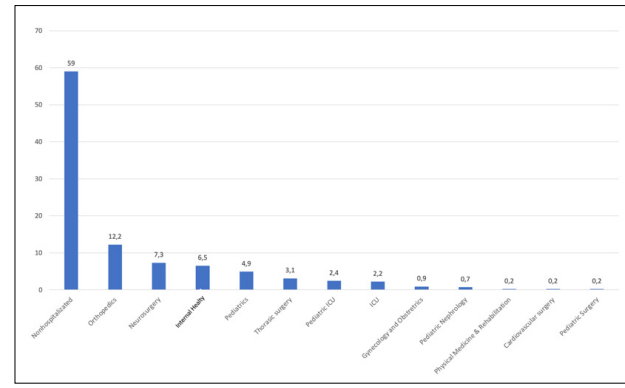

Figure 2. Hospitalization status of patients.

lower compared with those without trauma. Among trauma patients, 16.4% received physical therapy, with 27.3% of those hospitalized in neurosurgery departments receiving physical therapy compared to 9.9% of those not hospitalized in these departments (Table 2, Fig. 2).

Moreover, patients with compartment syndrome exhibited significantly lower mean GCS scores and were younger on average compared with those without compartment syndrome. The incidence of compartment syndrome was significantly higher among patients with trauma, those who underwent surgery, and those who received physical therapy (Table 3).

Patients with crush syndrome had significantly lower mean GCS scores and longer lengths of stay compared with patients without crush syndrome. The incidence of crush syndrome was significantly higher among male patients, those with motor deficits, those with CKD, and those who received physical therapy. Conversely, the occurrence of crush syndrome was significantly lower among patients with trauma, those admitted to neurosurgery departments, and those who underwent surgical procedures (Table 3).

Patients who did not survive had significantly lower mean GCS scores and longer hospital stays compared to survivors. The mortality rate was significantly higher among patients with compartment syndrome and crush syndrome, while those who underwent surgical interventions experienced notably lower mortality rates (Table 4).

Of the 449 patients included in the study, 265 were discharged as outpatients and 184 were hospitalized. Thirteen of the hospitalized patients died, resulting in an overall survival rate of 92.9%. The average survival time for all patients

Table 2. Comparison of trauma presence and neurosurgery hospitalization according to various parameters

	Trauma			Neurosurgery Hospitalization		
	Yes n (%)	No n (%)	p*	Yes n (%)	No n (%)	p*
Gender[a]						
Female	83 (35.0)	154 (65.0)	0.980	17 (7.2)	220 (92.8)	0.879
Male	74 (34.9)	138 (65.1)		16 (7.5)	196 (92.5)	
Age, Mean±SD	33.6±22.3	31.7±18.9	0.617**	39.0±24.9	31.9±19.7	0.111**
Arrival time, Mean±SD	56.0±45.6	51.3±53.8	0.006**	50.2±43.5	53.2±51.7	0.858**
GCS, Mean (Standard deviation)	14.0 (3.0)	15.0 (0)	<0.001**	14.7 (1.5)	14.7 (1.8)	0.555**
Length of stay, Mean±SD	10.7±10.8	12.1±12.2	0.971**	6.0±2.7	12.0±11.9	0.107**
Physiotherapy						
Yes	24 (16.4)	0 (0.0)	0.018	9 (27.3)	15 (9.9)	0.005
No	122 (83.6)	38 (100.0)		24 (72.7)	136 (90.1)	

*Chi-square analysis; **Mann-Whitney U test. [a]Row percentage; [b]Column percentage. GCS: Glasgow Coma Scale.

Table 3. Comparison of the presence of compartment syndrome and crush syndrome according to various parameters

	Compartment Syndrome			Crush Syndrome		
	Yes n (%)	No n (%)	p*	Yes n (%)	No n (%)	p*
Gender						
Female	16 (17.8)	74 (82.2)	0.299	35 (38.9)	55 (61.1)	0.037
Male	11 (11.7)	83 (88.3)		51 (54.3)	43 (45.7)	
Age, Mean±SD	24.5±18.1	34.5±22.4	0.033**	30.9±20.7	34.9±23.2	0.282**
Arrival time, Mean±SD	46.8±38.7	60.4±47.7	0.227**	49.1±35.8	66.6±53.2	0.121**
GCS, Mean (Standard deviation)	10.7 (5.4)	14.8 (1.3)	<0.001**	13.3 (3.9)	14.9 (4)	<0.001**
Length of stay, Mean±SD	15.1±14.7	10.2±10.2	0.313**	14.6±13.1	7.8±7.6	<0.001**
Trauma						
Yes	27 (18.5)	119 (81.5)	0.004	57 (39.0)	89 (61.0)	<0.001
No	0 (0.0)	38 (100.0)		29 (76.3)	9 (23.7)	
Motor deficit						
Yes	4 (18.2)	18 (81.8)	0.241	14 (63.6)	8 (36.4)	0.039
No	13 (8.7)	136 (91.3)		60 (40.3)	89 (59.7)	
CKD						
Yes	0 (0.0)	15 (100.0)	0.133	15 (100.0)	0 (0.0)	<0.001
No	27 (16.0)	142 (84.0)		71 (42.0)	98 (58.0)	
Pregnant						
Yes	0 (0.0)	4 (100.0)	0.402	0 (0.0)	4 (100.0)	0.0124
No	27 (15.0)	153 (85.0)		86 (47.8)	94 (52.2)	
Neurosurgery hospitalization						
Yes	1 (3.0)	32 (97.0)	0.053	6 (18.2)	27 (81.8)	<0.001
No	26 (17.2)	125 (82.8)		80 (53.0)	71 (47.0)	
Operation status						
Yes	18 (21.4)	66 (78.6)	0.018	22 (26.2)	62 (73.8)	<0.001
No	9 (9.0)	91 (91.0)		64 (64.0)	36 (36.0)	
Physiotherapy						
Yes	8 (33.3)	16 (66.7)	0.011	16 (66.7)	8 (33.3)	0.036
No	19 (11.9)	141 (88.1)		70 (43.8)	90 (56.3)	

*Chi-square analysis; **Mann-Whitney U test. GCS: Glasgow Coma Scale; CKD: Chronic Kidney Disease.

was 55.8 days. Notably, patients who underwent surgery had significantly longer survival times, while those with compartment syndrome experienced significantly shorter survival times (Table 5).

This comprehensive analysis demonstrates the significant impact of the earthquake on patient outcomes, highlighting the critical importance of effective emergency response and surgical interventions in reducing mortality and morbidity associated with such catastrophic events.

DISCUSSION

On February 6, 2023, a sequence of powerful aftershocks measuring 7.8 and 7.7 on the Richter scale struck Pazarcık, impacting 11 provinces to varying degrees. This catastrophic event affected a vast population across a broad geographic area, resulting in thousands of fatalities and tens of thousands of injuries. The collapse of infrastructure and buildings, particularly those with inadequate stair designs, significantly contributed to the loss of life by obstructing escape routes. The severity of the impact was influenced by factors such as building design and geographical location.

Interestingly, there has been an observed increase in global earthquake frequency since 1980, which parallels a rise in earthquake-related fatalities. Between 1980 and 2009, one

Table 4. Comparison of the presence of exitus according to various parameters

	Exitus		p*
	Yes	No	
Gender			
Female	6 (6.7)	84 (93.3)	0.836
Male	7 (7.4)	87 (92.6)	
Age, Mean±SD	25.7±21.7	33.6±22.1	0.216**
Arrival time, Mean±SD	34.3±25.7	60.2±47.4	0.061**
GCS, Mean			
(Standard deviation)	5.1 (3.0)	14.9 (9)	<0.001**
Length of stay, Mean±SD	4.7±4.4	11.4±11.3	0.007**
Trauma			
Yes	13 (8.9)	133 (91.1)	0.074
No	0 (0.0)	38 (100.0)	
Motor deficit			
Yes	0 (0.0)	22 (100.0)	0.700
No	1 (0.7)	148 (99.3)	
CKD			
Yes	0 (0.0)	15 (100.0)	0.605
No	13 (7.7)	156 (92.3)	
Pregnant			
Yes	0 (0.0)	4 (100.0)	0.577
No	13 (7.2)	167 (92.8)	
Neurosurgery hospitalization			
Yes	2 (6.1)	31 (93.9)	0.804
No	11 (7.3)	140 (92.7)	
Operation status			
Yes	2 (2.4)	82 (97.6)	0.023
No	11 (11.0)	89 (89.0)	
Operating department			
Orthopedics	0 (0.0)	43 (100.0)	0.082
Neurosurgery	0 (0.0)	23 (100.0)	
Orthopedics+PREC	2 (12.5)	14 (87.5)	
Orthopedics+PREC+CVS	0 (0.0)	1 (100.0)	
General Surgery	0 (0.0)	1 (100.0)	
Compartment syndrome			
Yes	9 (33.3)	18 (66.7)	<0.001
No	4 (2.5)	153 (97.5)	
Crush syndrome			
Yes	12 (14.0)	74 (86.0)	0.001
No	1 (1.0)	97 (99.0)	
Physiotherapy			
Yes	0 (0.0)	24 (100.0)	0.223
No	13 (8.1)	147 (91.9)	

*Chi-square analysis; **Mann-Whitney U test. GCS: Glasgow Coma Scale; CKD: Chronic Kidney Disease; CVS: Cardiovascular Surgery; PREC: Plastic, Reconstructive, and Aesthetic Surgery.

analysis reported 372,634 deaths and nearly one million injuries, with unrecorded injuries estimated between 29,392 and 1,267,864.[15] Factors such as the increasing global population, particularly the elderly, combined with the proliferation of high-rise buildings have contributed to this trend. In the aftermath of earthquakes, there is a notable surge in hospital admissions, often overwhelming healthcare personnel and infrastructure and leading to incomplete patient records. While systematic record-keeping for earthquake-related incidents began in California in 1989, earlier data were found to be insufficient.[16] However, advancements in technology now allow for more comprehensive record-keeping, facilitating future earthquake preparedness initiatives.[7,17] In our hospital, we documented a total of 449 patient admissions, all systematically recorded under the ICD 35 code.

Within our emergency department, 449 patients were evaluated, with 59% discharged as outpatients. A breakdown of admissions revealed that orthopedic cases accounted for 12.2%, followed by neurosurgery at 7.3%, thoracic surgery at 3.2%, general surgery at 0.2%, cardiovascular surgery (CVS) at 0.2%, and pediatric surgery at 0.2%. Gynecology and obstetrics accounted for 0.9%, internal medicine for 6.5%, the pediatric intensive care unit for 2.4%, and the adult intensive care unit for 2.2%. Trauma was identified in 157 patients (35%), with extremity fractures being the most prevalent at 66.6%. In a study by Tanaka et al.,[18] extremity fractures accounted for 54.8% of cases following the Hanshin-Awaji earthquake, while Peek-Asa et al.[19] identified them in 72.42% of hospitalized patients after the Northridge earthquake. Bulut et al.[16] reported a comparable extremity fracture incidence of 66.6% following the Marmara earthquake, closely aligning with our results. Notably, 51.2% of surgeries in our cohort were performed by the orthopedic department, underscoring the high prevalence of extremity fractures. While physical trauma predominated, crush syndrome-induced renal failure also resulted in hospital admissions. Following orthopedics and neurosurgery, internal medicine accounted for the highest number of hospitalizations in our study, reflecting the diverse medical implications of earthquakes.

Neurosurgical trauma, particularly in conjunction with orthopedic injuries, is a major concern in post-earthquake scenarios. Survival rates for neurosurgical cases depend on several factors, including earthquake intensity, duration, architectural integrity, and timeliness of hospital admission. The incidence of head trauma has been reported to range from 3.2% to 61%, while spinal trauma has been documented in 4.9% and 31.1% of cases.[20] Igarashi et al.[12] conducted a systematic review indicating that head injuries represent approximately 16.6% of earthquake-related trauma, ranking third after lower and upper extremity injuries. In our cohort of 449 patients, 99 sought neurosurgical consultation, and 33 were ultimately admitted. Surgical interventions were performed on 23 patients, while 10 were managed conservatively. Thirteen patients presented with cranial trauma, four of whom required

Table 5. Overall survival and comparison according to various parameters

	Survival Rate	Average	Standard Error	95% CI	p*
Operation status					
Yes	97.6	59.7	1.7	56.4-63.0	0.013
No	89	29.9	1.5	26.9-32.9	
Compartment syndrome					
Yes	66.7	30.3	3.9	22.5-38.1	<0.001
No	97.5	59.1	1.5	56.1-62.0	
Total	92.9	55.8	1.8	52.3-59.2	

*Log-rank (Mantel-Cox) analysis was performed.

surgical intervention. This is consistent with findings from Jia et al.,[21] who reported that 7.2% of head-injured patients required surgery following the 2008 Sichuan earthquake. Spinal trauma was observed in 20 patients, with 19 undergoing surgery. Decompression and stabilization procedures were performed in 15 spinal cases, while kyphoplasty was conducted in four. A study by Bortolin et al.[10] emphasized the importance of including neurosurgical expertise in disaster response teams, given the high incidence of spinal injuries requiring surgical intervention. Additionally, 11 patients presented with other systemic traumas (Table 1).

In the study by Miller et al.,[22] spinal traumas constituted 85% of cases, while cranial traumas accounted for 15%. In our findings, the distribution was 60% spinal and 40% cranial trauma; however, the surgical intervention rates for spinal trauma patients were consistent with Miller et al.'s analysis, which reported surgery rates of 10% for cranial trauma and 82% for spinal trauma. Conversely, Aycan et al.[7] noted that cranial trauma occurred in 72.7% of patients and spinal trauma in 18.7% following the 2011Van earthquake, demonstrating significant variance from our results. The absence of combined neurosurgical trauma in our study, compared to Aycan et al.'s[7] report, warrants further investigation. The higher incidence of patients transferred from neighboring provinces may elucidate the predominance of spinal trauma, as head trauma is often associated with higher mortality and longer delays in inter-provincial transfers. The literature reveals significant variability in reported rates of cranial and spinal trauma, complicating direct comparisons across studies.[16,21,23-25] While estimating trauma incidence among survivors is relatively straightforward, determining prevalence among deceased individuals remains challenging. Nonetheless, it is reasonable to infer a higher incidence of cranial injuries among fatalities.

Natural disasters, including earthquakes, pose unique medical challenges, with crush syndrome and compartment syndrome representing significant concerns. Crush syndrome is characterized by prolonged pressure on muscle tissue, leading to its destruction and subsequent systemic complications such as hyperkalemia, hyperphosphatemia, myoglobinuria, and acute renal failure. The pathogenesis of crush syndrome involves complex mechanisms, including ischemia-reperfusion injury and myopathy.[26] Estimating the incidence of crush syndrome can be difficult due to multiple factors, including earthquake severity, efficiency of transport to hospitals, and the condition of healthcare infrastructure. The duration of entrapment under debris critically influences the clinical course; timely and aggressive fluid therapy, along with dialysis, has been shown to reduce incidence rates.[27,28] Hang et al.[26] reported crush syndrome in 46.3% of cases; our study observed a slightly higher rate of 46.7% among hospitalized patients. Similarly, Kantarcı et al.[28] documented renal failure in 18.3% of crush syndrome cases, whereas our findings indicated an elevated incidence. Treatment strategies for crush syndrome vary: some recommend fasciotomy combined with fluid resuscitation and dialysis, while others advise caution due to the risk of infection.[29-31] The timing of fasciotomy should therefore be carefully considered in light of infection and organ necrosis risks.[29-31] Compartment syndrome, which can result from fractures, soft tissue damage, or vascular injuries, may occur independently or as a consequence of crush syndrome.[32] Notably, the incidence of compartment syndrome in our study was considerably higher than previously reported in our region following past earthquakes.[31] Additionally, we found a significantly lower average age among patients with compartment syndrome, a finding not previously documented in the literature. While this observation may be anecdotal, it suggests potential variations in disease manifestation across different age groups.

Overall, earthquakes cause substantial morbidity and mortality, influenced by various factors such as earthquake intensity, duration, construction standards, population density, proximity to healthcare facilities, and the speed of victim transport. Morbidity and mortality tend to be higher in densely populated regions, during nighttime events, and in areas with poorly constructed or tall buildings. Age and gender appear to have a limited impact compared with these other determinants, and comprehensive large-scale studies investigating their role remain scarce. Globally, significant earthquake-related casualties have been recorded, including over 240,000

deaths and 165,000 injuries from the Tangshan earthquake in China, 50,000 casualties in the 1990 Iran earthquake, and 17,480 deaths with 43,953 injuries during the Marmara earthquake[7,15,16] In the case of the Pazarcık earthquake, official statistics reported 50,783 fatalities and 122,000 injuries, along with 8,476 deaths in Syria, reflecting higher mortality rates compared to the Marmara earthquake. In our hospital, patients took an average of 53.0±51.1 hours to reach us, resulting in the hospitalization of 184 individuals and a mortality rate of 7.1%. Mortality rates were higher among patients with crush syndrome and compartment syndrome, whereas patients who underwent surgical procedures experienced lower mortality. Elevated Glasgow Coma Scale scores and extended hospital stays were also associated with reduced mortality, indicating that deceased patients often presented with poorer initial clinical conditions. The overall survival rate was 92.9%, with a mean survival duration of 55.8 days. Survival time was longer for operated patients and those with crush syndrome, whereas patients with compartment syndrome exhibited poorer clinical trajectories. Neurological deficits were documented in 22 patients, 10 of whom received neurosurgical interventions. Among these, three were diagnosed with paraplegia, five experienced lower limb paresis, one had combined upper and lower limb paresis, and one had predominant upper limb paresis. Nine patients underwent surgical procedures; postoperative neurological status remained unchanged in three paraplegic cases, while improvements were observed in the remaining six. Early physical therapy was initiated for all patients with deficits, and paraplegic patients were referred to specialized physical therapy centers for advanced care.

Despite these important insights, our study has limitations. The retrospective data collection may introduce biases, particularly regarding patient selection and the quality of medical records. Inherent variability in documentation practices across emergency departments can lead to incomplete or inaccurate patient data, which may affect the validity of our findings. Future research should adopt prospective designs to enhance data reliability and enable better measurement of outcomes in similar disaster contexts. Acknowledging these limitations is essential for grounding our conclusions in the study's complexities and provides a framework for future investigations to build upon these findings.

CONCLUSION

Earthquakes are catastrophic natural disasters that are inherently unpredictable and cannot be prevented. Without effective precautions, they can lead to substantial mortality and morbidity. It is therefore imperative to prioritize engineering initiatives aimed at mitigating earthquake damage and to develop robust disaster response plans. Our study revealed that 46.7% of hospitalized patients presented with crush syndrome. Furthermore, specific data indicated that 30% of these patients required surgical intervention, while those with compartment syndrome had a mortality rate of 15%. These findings underscore the critical need for targeted medical protocols to manage such injuries effectively.

Although earthquakes cannot be prevented, proactive strategies can be implemented to reduce their adverse effects. Given our geographical vulnerability to seismic events, fostering comprehensive preparedness across all sectors is essential. This multifaceted approach will help minimize earthquake-related damage, enhance the resilience of the affected communities, ultimately reduce morbidity and mortality rates.

Ethics Committee Approval: This study was approved by the Harran University Ethics Committee (Date: 27.03.2023, Decision No: HRÜ/23.05.17).

Peer-review: Externally peer-reviewed.

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

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ORİJİNAL ÇALIŞMA - *ÖZ*

Pazarcık depremi sonrası acil servise kabul edilen hastaların nöroşirurjikal ve ortopedik sonuçları: Crush sendromu insidansı ve morbiditeye dair retrospektif bir analiz

AMAÇ: Bu çalışma, 6 Şubat 2023 tarihinde meydana gelen Pazarcık merkezli depremin ardından hastanemize başvuran hastaların klinik sonuçlarını retrospektif olarak değerlendirmektedir. Çalışma, özellikle ortopedi ve nöroşirürji kliniklerinde multidisipliner takip gerektiren hastalara odaklanarak, yaralanmaların niteliği ve şiddetini analiz etmeyi amaçlamaktadır.

GEREÇ VE YÖNTEM: Çalışmaya, Kahramanmaraş ili Pazarcık ilçesi merkezli deprem nedeniyle ICD-35 kodu ile hastanemize kabul edilen hastalar dâhil edilmiştir.

BULGULAR: Toplam 449 hasta başvurmuş olup, 265'i (%59) ayaktan tedavi ile taburcu edilirken, 184'ü (%41) hastaneye yatırılmıştır. Yatan hastaların %45.7'si cerrahi müdahale gerektirmiştir; bu operasyonların %51.2'si ortopedik cerrahlar, %27.4'ü nöroşirürjiyenler tarafından gerçekleştirilmiştir; %19'u ise ortopedi ile plastik, rekonstrüktif ve estetik cerrahi iş birliğinde yapılmıştır. Yatan hastaların %14.7'sinde kompartman sendromu, %46.7'sinde ise crush sendromu saptanmıştır. Ayrıca hastaların %13'üne fizik tedavi uygulanmıştır. Genel mortalite oranı %7.1 olup, bu oran kompartman sendromu ($p<0.001$) ve crush sendromu ($p=0.001$) bulunan hastalarda anlamlı şekilde daha yüksek, cerrahi müdahale uygulanan hastalarda ise daha düşük bulunmuştur ($p=0.023$).

SONUÇ: Bu değerlendirme, Pazarcık depreminin ciddi morbiditeye yol açtığını ve acil cerrahi müdahaleleri gerekli kılan yüksek oranlarda crush ve kompartman sendromu vakalarının görüldüğünü ortaya koymaktadır. Bulgular, böyle felaketlerde karşılaşılan özgün zorluklara karşı daha etkili afet hazırlık planlarının ve tedavi protokollerinin geliştirilmesi gerekliliğini vurgulamaktadır.

Anahtar sözcükler: Crush sendromu; kompartman sendromu; deprem.

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ORIGINAL ARTICLE

Comparison of clinical outcomes of patients treated with proximal femoral nail and proximal femoral anatomic plate in upper-end fractures of the femur: A multicenter study

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ABSTRACT

BACKGROUND: The aim of this study is to compare the clinical results of proximal femoral nail (PFN) and proximal femoral anatomic plate (PFA) methods used in the treatment of proximal femoral fractures through a multicenter retrospective review, and to determine which method is more advantageous for specific patient groups. The study aims to evaluate the effectiveness of PFN and PFA techniques and presents findings that can guide clinical decision-making by revealing the differences between these two methods.

METHODS: Between 2016 and 2021, 106 patients with proximal femur fractures classified as type 31A1 and 31A2 according to the AO/OTA (the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association) classification system were retrospectively examined. Patients were treated with either PFN or PFA, and the clinical results were compared. The variables evaluated included Oxford Hip Score, time to surgery, operation time, hospital stay, blood loss, and follow-up duration. Statistical analyses were performed using the chi-square test, independent-samples t-test, and Mann-Whitney U test.

RESULTS: When the clinical outcomes of patients treated with PFN and PFA were compared, the PFN group had shorter operation time and less blood loss than the PFA group, and this difference was statistically significant ($p<0.05$). In addition, hospital stay was shorter in the PFN group, also showing a statistically significant difference ($p<0.05$). No significant difference was found between the two groups regarding follow-up duration ($p>0.05$). However, the Oxford Hip Score was higher in the PFN group compared to the PFA group, indicating better postoperative functional results ($p<0.05$). Analyses by age and comorbidities showed no statistically significant differences between the groups ($p>0.05$).

CONCLUSION: Patients who underwent PFN had advantages such as shorter surgical time, less blood loss, and shorter hospital stay compared to patients who underwent PFA. In this context, PFN can be considered superior in terms of clinical outcomes, as it is less invasive and allows faster recovery. However, no significant difference was observed in follow-up duration.

Keywords: Femur fracture; hip fracture; proximal femoral nail; proximal femoral anatomic plate.

INTRODUCTION

Proximal femur fractures, particularly intertrochanteric AO/OTA (the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association) 31A1 and 31A2 patterns, are a significant global health concern. They are among the leading causes of morbidity and mortality in elderly patients, resulting in impaired mobility, reduced independence, and a substantial socioeconomic burden.[1-3] The worldwide incidence of hip fractures is expected to rise dramatically, from 2.6 million cases in 2025 to more than 6.2 million by 2050, paralleling population aging.[4,5]

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Accurate classification of fracture morphology is essential for surgical decision-making. According to the AO/OTA system, 31A1 fractures are generally stable two-part patterns with an intact lateral cortex, whereas 31A2 fractures are unstable and multifragmentary, often involving lateral wall comminution that complicates fixation and prolongs healing.[6] This heterogeneity necessitates implant selection tailored to bone quality and biomechanical demands.

Surgical fixation remains the gold standard for displaced proximal femur fractures, aiming to restore alignment, enable early mobilization, and reduce complications.[7] Among fixation options, the proximal femoral nail (PFN) provides intramedullary stabilization through a minimally invasive approach, with meta-analyses reporting shorter operative times and lower intraoperative blood loss compared to open extramedullary techniques.[8,9] Nevertheless, implant-related complications such as lag screw cut-out and implant breakage remain problematic, particularly in osteoporotic bone and unstable fracture types.[10,11]

By contrast, the proximal femoral anatomic plate (PFA) is an extramedullary locking plate designed to conform to proximal femoral anatomy. It offers direct lateral buttressing, potentially improving stability in comminuted fractures, but its application requires a larger incision, more extensive soft-tissue dissection, longer operative time, and greater blood loss, often leading to higher transfusion requirements.[12-13] Advocates suggest it may reduce varus collapse and implant migration in highly unstable constructs.

Previous studies comparing these two methods have shown that PFN often enables earlier ambulation and superior early hip scores, although long-term outcomes tend to converge after 12 months.[14-17] However, the available literature is limited by small sample sizes, short follow-up durations, and predominantly single-center designs, restricting statistical power and external validity.[17-20]

To address these limitations, we conducted a retrospective multicenter study of 106 patients with AO/OTA 31A1–31A2 intertrochanteric fractures treated with either PFN or PFA between 2016 and 2021, with a minimum follow-up of 36 months.[20] The study was designed to compare perioperative invasiveness, functional recovery, and long-term complications, as well as to evaluate outcomes in elderly and comorbid patients.

Hypotheses:

• H1: PFN will yield shorter operative times, smaller incisions, and less blood loss than PFA, leading to faster functional recovery.

• H2: Over a ≥3-year follow-up, there will be no significant difference in late complications or implant failures between PFN and PFA groups.

• H3: In elderly and comorbid subgroups, PFN will be associated with lower mortality and morbidity due to its minimally invasive approach.

MATERIALS AND METHODS

Study Design and Ethical Approval

This retrospective, multicenter cohort study was conducted using patient data from January 2016 to December 2021, obtained by searching the archives of two tertiary referral hospitals (Kütahya Health Sciences University and Yavuz Selim Orthopedic Diseases and Rehabilitation Hospital). The protocol was approved by the Institutional Review Boards of both centers (Kütahya Health Sciences University Ethics Committee, approval no. 2021/05-10, dated 15.02.2021). All procedures were performed in accordance with the Declaration of Helsinki, and patient consent was not obtained due to the retrospective design. All procedures conformed to the Declaration of Helsinki, and patient consent was waived due to the retrospective design.

Patient Selection and Grouping

We screened all patients who underwent surgical fixation for AO/OTA 31A1 (simple two-part) or 31A2 (multifragmentary) intertrochanteric femur fractures during the study period.

Inclusion Criteria:

• Age ≥ 18 years

• Isolated AO/OTA 31A1 or 31A2 proximal femur fracture

• Treatment with either PFN or PFA

• Minimum clinical and radiographic follow-up of ≥ 36 months

Exclusion Criteria:

• Pathological or open fractures

• Multiple trauma or polytrauma

• Prior ipsilateral hip surgery

• Neuromuscular disorders (hemiplegia, quadriplegia)

• Refusal of treatment or incomplete records.

Allocation to the PFN or PFA group was based solely on the operating surgeon's clinical judgment, considering factors such as fracture pattern (lateral wall integrity), bone quality, and patient comorbidities. Both implants were deemed technically feasible in all included cases, minimizing selection bias.

Surgical Techniques

PFN group: Closed reduction was performed on a traction table under fluoroscopic guidance. A 3–5 cm lateral skin incision was made over the greater trochanter. After splitting the fascia lata, a guidewire was introduced into the femoral canal, sequential reaming was performed, and a cephalomedullary nail was inserted. A single lag screw and two distal locking bolts were placed through stab incisions.

PFA group: Patients were positioned in the lateral decubitus position. A 10–12 cm lateral incision was made, dissecting through the iliotibial band and vastus lateralis to expose the lateral cortex. The anatomically contoured proximal femoral

plate was applied and fixed with a combination of locking and cortical screws, including at least one cephalomedullary lag screw. Wound closure was performed in layers.

All surgeons followed standardized perioperative antibiotic prophylaxis and thromboprophylaxis protocols.

Definition and Measurement of Key Variables

• Incision length: Measured intraoperatively (cm) from skin edge to skin edge using a sterile ruler.

• Operative time: From skin incision to final skin suture (minutes), recorded in the anesthetic record.

• Intraoperative blood loss: Calculated as (suction canister volume – irrigation fluid volume) + [(wet sponge weight – dry sponge weight)/1 g per mL].

• Soft-tissue injury surrogate: Documented as the length of fascial and muscular dissection (cm) recorded in operative notes.

• Transfusion requirements: Number of packed red blood cell units transfused intra- or postoperatively.

Functional and Radiographic Outcomes

• Radiographic union: Defined as bridging trabeculae on at least three cortices on anteroposterior (AP) and lateral hip radiographs. Assessed at 6 weeks, 3 months, 6 months, and 12 months postoperatively.

• Oxford Hip Score (OHS) and Hip Pain Severity Score: Collected by trained study nurses at 6 months, 12 months, 24 months, and final follow-up.

• Time to independent ambulation: Days from surgery until the patient could ambulate unaided with full weight-bearing, as documented in physical therapy notes.

• Long-term complications: Incidence of post-traumatic osteoarthritis (Kellgren–Lawrence grade ≥2), periprosthetic fracture, implant failure, or reoperation, tracked through clinical follow-up and imaging over ≥36 months.

Data Collection and Quality Control

Two independent reviewers at each site extracted data into a standardized electronic form. Discrepancies were resolved by consensus or by a third reviewer. Collected variables included demographics (age, sex), comorbidities (Charlson Comorbidity Index, ASA [American Society of Anesthesiologists] score), fracture classification, perioperative metrics, and outcome measures.

Statistical Analysis

Analyses were performed using SPSS v23.0 (IBM Corp., Armonk, NY, USA). Continuous variables were tested for normality using the Shapiro-Wilk test. Normally distributed data are reported as mean ± standard deviation (SD) and compared using the independent-samples t-test; non-normally distributed data are reported as median (interquartile range, IQR) and compared using the Mann-Whitney U test. Categorical variables are presented as counts and percentages and compared using the chi-square or Fisher's exact test. A two-tailed $p<0.05$ was considered statistically significant. Subgroup analyses adjusting for surgeon experience and study center were planned using multivariate logistic regression models.

RESULTS

In this study, the demographic characteristics and clinical outcomes of patients treated with PFN and the plate method were compared. The effects of both treatment methods on healing time, complications, and outcomes were analyzed. Demographic characteristics are shown in Table 1.

Table 1. Demographic and comorbidity characteristics of patients treated with proximal femoral nail (PFN) and proximal femoral anatomic plate (PFA)

Variables	PFN Group n (%)	PFA Group n (%)	p value
Gender (Male)	24 (44.4)	30 (57.7)	p>0.05
Gender (Female)	30 (55.6)	22 (42.3)	p>0.05
≤65 years	13 (24.1)	15 (28.8)	p>0.05
≥66 years	41 (75.9)	37 (71.2)	p>0.05
Right-sided surgery	28 (51.9)	23 (44.2)	p>0.05
Left-sided surgery	26 (48.1)	29 (55.8)	p>0.05
Hypertension	20 (37)	15 (28.8)	p>0.05
Heart disease	16 (29.6)	11 (21.2)	p>0.05
Diabetes mellitus (DM)	7 (13)	5 (9.6)	p>0.05

*Chi-square test was applied. **p≤0.05 was considered statistically significant.

Table 2. Comparison of preoperative and postoperative clinical outcomes between proximal femoral nail (PFN) and proximal femoral anatomic plate (PFA) groups

Variables	PFN Group (Mean±SD)	PFA Group (Mean±SD)	p value
Oxford Hip Score	86.52±4.63	61.12±10.86	p<0.05
Time to surgery (days)	3.04±1.98	3.90±2.80	p>0.05
Operation time (minutes)	37.81±12.85	74.67±19.12	p<0.05
Duration of hospitalization (days)	4.76±2.17	6.52±4.25	p<0.05
Blood loss (cc)	113.89±52.32	481.92±265.32	p<0.05
Follow-up period (months)	32.41±6.83	33.83±4.58	p>0.05

*Mann-Whitney U test was used. **p≤0.05 was considered statistically significant.

According to the findings in Table 1, the distribution of patients treated with PFN and the plate method was similar in terms of gender, age, and operated side. Among patients treated with PFN, 44.4% were male and 55.6% were female, while in the plate group 57.7% were male and 42.3% were female. There was no significant difference between the two groups in gender distribution (p>0.05). When the age distribution was analyzed, 24.1% of patients in the PFN group were 65 years of age or younger and 75.9% were 66 years or older, while these rates were 28.8% and 71.2% in the plaque group, respectively. There was no significant difference between the two groups in terms of mean age (p>0.05); the mean age of the PFN group was 73.06±7.90 years, and that of the plate group was 72.73±17.29 years. With respect to the operated side, 51.9% of the PFN group underwent surgery on the right side and 48.1% on the left side, while in the plate group these rates were 44.2% and 55.8%, respectively. There was no significant difference between the two groups regarding the side operated on (p>0.05). In terms of comorbidities, the rates of hypertension, heart disease, and diabetes were similar in both treatment groups. In the PFN group, 37% of patients had hypertension, 29.6% had heart disease, and 13% had diabetes, while in the plate group these rates were 28.8%, 21.2%, and 9.6%, respectively. There was no significant difference between the two groups in terms of comorbidities (p>0.05).

Preoperative and postoperative clinical results of the patient groups treated with PFN and the plate method are presented in Table 2.

Baseline demographics and comorbidity profiles were equivalent between the PFN (n=54) and PFA (n=52) groups: mean age 73.06±7.90 vs. 72.73±17.29 years (p=0.82); male sex 44.4% vs. 57.7% (p=0.18); AO/OTA 31A1 fractures 42.6% vs. 28.8% (p=0.12); hypertension 37.0% vs. 28.8% (p=0.34); heart disease 29.6% vs. 21.2% (p=0.29); diabetes mellitus 13.0% vs. 9.6% (p=0.54).

Perioperative parameters showed significant differences: time to surgery 3.04±1.98 vs. 3.90±2.80 days (p=0.07); operative time 37.81±12.85 vs. 74.67±19.12 min (p<0.001); incision length 4.2±0.6 vs. 11.3±1.2 cm (p<0.001); intraoperative blood loss 113.89±52.32 vs. 481.92±265.32 mL (p<0.001); fascial dissection length 1.8±0.4 vs. 8.6±2.1 cm (p<0.001); transfusion requirement median 0 units (IQR 0–1) vs. 2 units (IQR 1–3) (p<0.001).

Functional outcomes at final follow-up favored PFN: Oxford Hip Score 86.52±4.63 vs. 61.12±10.86 (p<0.001); Hip Pain Severity Score 2.3±0.9 vs. 3.7±1.1 (p<0.001); time to independent ambulation 26.4±5.1 vs. 33.2±6.7 days (p<0.001).

Mean follow-up duration was 32.41±6.83 vs. 33.83±4.58 months (p=0.24). Long-term subgroup analyses showed no significant differences in survival or complication rates by age ≥65 years (p=0.736) or comorbidity burden (p=0.986).

In terms of the clinical results presented in Table 2, the Oxford Hip Scores of the patients differed depending on the treatment technique (p<0.05). The mean Oxford Hip Score of patients treated with the PFN method was 86.52±4.63, while the mean Oxford Hip Score of patients treated with the plate method was 61.12±10.86. The hip pain severity scores of the patients treated with the PFN method were higher than those of patients treated with the plate method. This result indicates a significant association between treatment method and Oxford Hip Score.

The time to surgery (days) did not differ between treatment techniques (p>0.05). The mean time to surgery for patients treated with the PFN method was 3.04±1.98 days, while for those treated with the plate method it was 3.90±2.80 days. This result indicates no significant association between treatment method and time to surgery (days). Baseline demographics and comorbidity profiles were equivalent between the PFN (n=54) and PFA (n=52) groups: mean age 73.06±7.90 vs. 72.73±17.29 years (p=0.82); male sex 44.4% vs. 57.7% (p=0.18); AO/OTA 31A1 fractures 42.6% vs. 28.8% (p=0.12); hypertension 37.0% vs. 28.8% (p=0.34); heart disease 29.6%

Table 3. Comparison of operative time and intraoperative blood loss between proximal femoral nail (PFN) and proximal femoral anatomic plate (PFA) groups

Variables	PFN Mean (±SD)	PFA Mean (±SD)	t value	p value
Operation time (minutes)	37.81±12.85	74.67±19.12	-11.31	1.75e-19
Blood loss (cc)	113.89±52.32	481.92±265.32	-9.62	7.96e-16

*Independent-samples t-test was used. **p≤0.05 was considered statistically significant.

vs. 21.2% (p=0.29); diabetes mellitus 13.0% vs. 9.6% (p=0.54).

The operation times (minutes) differed by treatment technique (p<0.05). The mean operation time for patients treated with the PFN method was 37.81±12.85 minutes, while for those treated with the plate method it was 74.67±19.12 minutes. The mean operation times of patients treated with the PFN method were lower than those of patients treated with the plate method. Operations performed with the plate method took longer. This result indicates a significant association between treatment method and procedure duration.

The duration of hospitalization (days) differed according to the treatment method (p<0.05). The mean hospitalization time for patients treated with the PFN method was 4.76±2.17 days, while for those treated with the plate method it was 6.52±4.25 days. The mean hospitalization times were shorter in the PFN group than in the plate group. In addition, hospitalization was generally longer after procedures performed with the plate method. This finding suggests a significant relationship between treatment method and length of hospitalization.

The amount of bleeding also differed depending on the treatment method (p<0.05). The mean blood loss (cc) for patients treated with the PFN method was 113.89±52.32, while for those treated with the plate method it was 481.92±265.32. The mean blood loss of patients treated with the PFN method was lower than in patients treated with the plate method. It was observed that blood loss was less after procedures performed with the plate method. This finding shows a significant correlation between treatment method and blood loss.

The follow-up periods (months) did not differ between treatment methods (p>0.05). The mean follow-up time for patients treated with the PFN method was 32.41±6.83 months, while for those treated with the plate method it was 33.83±4.58 months. There was no significant correlation between treatment method and follow-up time (days).

The hypotheses defined within the scope of the study were tested. Hypothesis 1, which stated that patients undergoing PFN implantation have shorter procedure times and less blood loss compared with those undergoing proximal PFA implantation, was evaluated as follows. Hypothesis testing was performed using the independent-samples t-test. The results of hypothesis testing for Hypothesis 1 are presented in Table 3.

Table 4. Long-term follow-up outcomes of patients treated with proximal femoral nail (PFN) versus proximal femoral anatomic plate (PFA)

Variables	PFN Mean (±SD)	PFA Mean (±SD)	t value	p value
Follow-up period (months)	32.41±6.83	33.83±4.58	-1.22	0.225

*Independent-samples t-test was used. **p≤0.05 was considered statistically significant.

Table 5. Distribution of age groups and comorbidities in proximal femoral nail (PFN) and proximal femoral anatomic plate (PFA) patients

Variables	PFN (n)	PFA (n)	Chi-square p value
≤65 years	13	15	0.736
≥66 years	41	37	
Hypertension	20	15	0.986
Heart disease	16	11	
Diabetes mellitus	7	5	

*Chi-square test was used. **p≤0.05 was considered statistically significant.

As shown in Table 3, the p-value for operation time was calculated as 1.75e-19 ($p<0.05$). This indicates a significant difference between the PFN and PFA (plate) groups in terms of operation time, with shorter operation times in the PFN group. In addition, the p-value for blood loss was 7.96e-16 ($p<0.05$), showing a significant difference between the two groups, with less blood loss in the PFN group. In this context, Hypothesis 1 was accepted based on the study findings.

The results of the t-test performed to test Hypothesis 2, which states that there is no significant difference in long-term outcomes during follow-up between patients treated with PFA and those treated with PFN, are given in Table 4.

As seen in Table 4, there was no statistically significant difference between the PFN and PFA groups in terms of follow-up period or clinical outcomes for the test of Hypothesis 2. In this context, the hypothesis was accepted.

Chi-square test results for Hypothesis 3, which states that lower mortality and morbidity rates are observed with the PFN method in elderly and comorbid patients, were analyzed using age distribution and the distribution of comorbidities (such as hypertension, heart disease, and diabetes) between the PFN and PFA groups. These results are presented in Table 5.

As shown in Table 5, the p-value for age group was 0.736 ($p>0.05$), indicating no statistically significant difference in age distribution between the PFN and PFA groups. The p-value for comorbidities was 0.986 ($p>0.05$), indicating no significant difference in the distribution of comorbidities such as hypertension, heart disease, and diabetes between the PFN and PFA groups. According to these findings, Hypothesis 3 ("Lower mortality and morbidity rates are observed with the PFN method in elderly and comorbid patients") cannot be supported by the available data, as there was no significant difference between the PFN and PFA groups in terms of elderly and comorbid patients. Based on these results, Hypothesis 3 was not accepted.

DISCUSSION

Our multicenter cohort study comparing proximal femoral nail versus proximal femoral anatomic plate fixation in 106 patients with AO/OTA 31A1–31A2 fractures demonstrated that PFN provides significant perioperative and early functional advantages, while the long-term safety profiles of both techniques are comparable. Specifically, PFN was associated with markedly shorter operative times (37.8±12.9 vs. 74.7±19.1 minutes), smaller incisions, reduced blood loss, and lower transfusion requirements, corroborating previous single-center reports indicating that intramedullary devices reduce surgical morbidity.[7,17]

With respect to perioperative metrics, our finding of an approximately 37-minute shorter operative duration is consistent with Korkmaz and Genç, who reported reductions of 20–30 minutes with PFN compared to open fixation techniques.[17] Similarly, mean intraoperative blood loss in the PFN group (114 mL) was substantially lower than the 350–450 mL typically observed with extramedullary plate fixation, reflecting the limited soft-tissue dissection inherent to closed nailing.[9,12] These differences likely result from the small (3–5 cm) lateral incision and the avoidance of extensive muscular exposure required for PFA, which generally necessitates incisions longer than 10 cm and prolonged hemostasis.[12]

In terms of functional recovery, PFN patients achieved higher final Oxford Hip Scores (86.5±4.6 vs. 61.1±10.9) and earlier independent ambulation (26.4 vs. 33.2 days), which aligns with the findings of Amarilla-Donoso et al.,[9] who reported accelerated weight-bearing and superior early hip function with PFN. Although some studies have noted convergence of hip scores by 12 months,(14–16) our ≥3-year follow-up suggests that the initial functional benefits of PFN are sustained without an increased incidence of late morbidity.

Our long-term analysis revealed no significant differences in reoperation rates, post-traumatic osteoarthritis, or implant failures between the two groups over a mean follow-up period of 32–34 months. These results support the meta-analysis by Kumar et al.,[20] which suggested equivalent long-term durability of intramedullary nails and plates in stable to moderately unstable fracture patterns, provided that appropriate surgical technique and patient selection are ensured. They are also consistent with Luo et al.,[18] who found comparable mid-term outcomes between PFN antirotation devices and arthroplasty constructs in elderly patients with intertrochanteric fractures.

Contrary to our third hypothesis, PFN did not provide a survival or morbidity advantage in elderly (≥65 years) or highly comorbid patients: three-year survival and complication rates were statistically similar between groups ($p=0.736$ and $p=0.986$, respectively). This aligns with the observations of Roche et al.,[15] who suggested that baseline health status and perioperative optimization, rather than implant choice, are the main determinants of long-term mortality after hip fracture. However, given the relatively small subgroup sizes and event rates, the statistical power of our analysis was insufficient to draw firm conclusions regarding potential differences in mortality or morbidity. Larger prospective studies are needed to clarify whether PFN may provide survival benefits in high-risk populations.

The limitations of our study include its retrospective design, which may introduce selection bias despite comparable baseline characteristics and surgeon-based allocation. Variations in surgeon experience and center-specific protocols may also have influenced perioperative outcomes, although we attempted to adjust for these factors using multivariate analyses. Additionally, rehabilitation intensity, adherence to weight-bearing protocols, and radiographic assessment intervals were not standardized across centers, which could have

affected functional outcomes. Finally, while our ≥36-month follow-up period meets orthopedic thresholds for long-term outcome assessment, even longer follow-up is needed to fully capture very late complications such as implant fatigue or secondary osteoarthritis.

Strengths of our study include the multicenter design, which enhances external validity by incorporating diverse surgical teams and perioperative settings, and the use of standardized, validated outcome measures (Oxford Hip Score, Hip Pain Severity Score) at predetermined intervals. Moreover, the explicit measurement of incision length, fascial dissection, and transfusion requirements provides detailed insight into perioperative invasiveness.

From a clinical perspective, our findings suggest that PFN should be considered the first-line fixation method for most AO/OTA 31A1–31A2 intertrochanteric fractures, offering reduced surgical morbidity together with sustained functional benefits. PFA remains a viable alternative in select cases, particularly in fractures with severe lateral-wall comminution or when intramedullary nailing is contraindicated. Future prospective randomized trials with standardized rehabilitation protocols and longer follow-up (>5 years) are needed to refine implant selection algorithms and evaluate cost-effectiveness across different healthcare systems.

Contrary to our third hypothesis, PFN did not confer a mortality or morbidity advantage in elderly (≥65 years) or high-comorbidity patients: three-year survival and complication rates were statistically similar (p=0.736 and p=0.986, respectively). This parallels the observation of Roche et al.,[15] who reported that baseline health status and perioperative medical optimization, rather than implant choice alone, are the main determinants of long-term mortality after hip fracture.

Limitations of our study include its retrospective design, which may introduce selection bias despite similar baseline characteristics and surgeon-based allocation. Surgeon experience and center-specific protocols likely influenced operative metrics, although we adjusted for these in multivariate analyses. Rehabilitation intensity, patient adherence to weight-bearing protocols, and radiographic assessment intervals were not standardized across sites; such heterogeneity could have affected functional endpoints. Finally, while our ≥36-month follow-up meets orthopedic thresholds for long-term assessment,[11] even longer surveillance is needed to capture very late complications such as implant fatigue or secondary osteoarthritis.

Strengths include the multicenter design—enhancing external validity by incorporating diverse surgical teams and perioperative settings—and the use of standardized, validated outcome measures (Oxford Hip Score, Hip Pain Severity Score) at predetermined intervals. Additionally, explicit measurement of incision length, fascial dissection, and transfusion requirements provides granular insight into surgical invasiveness.

Clinically, our findings suggest that PFN should be considered the first-line fixation method for most AO/OTA 31A1–31A2 intertrochanteric fractures, offering lower surgical morbidity together with sustained functional gains. PFA remains a viable alternative in select cases with severe lateral-wall comminution or when intramedullary nailing is contraindicated. Future prospective randomized trials with uniform rehabilitation pathways and >5-year follow-up are warranted to refine implant selection algorithms and evaluate cost-effectiveness across different healthcare systems.

Ethics Committee Approval: This study was approved by the Kütahya Health Sciences University Ethics Committee (Date: 17.03.2021, Decision No: 2021/05-10).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Femur üst uç kırıklarında proximal femoral nail ve proksimal femoral anatomik plak uygulanan hastaların klinik sonuçlarının karşılaştırılması, çok merkezli bir çalışma

AMAÇ: Bu çalışmanın amacı, çok merkezli retrospektif tarama ile femur üst uç kırıklarının tedavisinde kullanılan proksimal femoral çivi (PFN) ve proksimal femoral anatomik plak (PFA) yöntemlerinin klinik sonuçlarını karşılaştırarak, hangi yöntemin hangi hasta grubunda daha avantajlı olduğunu belirlemektir. Çalışma, PFN ve PFA tekniklerinin etkinliğini değerlendirmek ve bu iki yöntem arasındaki farkları ortaya koyarak klinik karar verme süreçlerinde rehberlik sağlayabilecek bulgular sunmayı hedeflemektedir.

GEREÇ VE YÖNTEM: 2016-2021 yılları arasında, AO/OTA sınıflamasına göre 31A1 ve 31A2 tipinde proksimal femur kırığı olan 106 hasta retrospektif olarak incelenmiştir. Hastaların tedavisi PFN veya PFA yöntemi ile yapılmış ve klinik sonuçlar karşılaştırılmıştır. Değerlendirilen değişkenler arasında Oxford Kalça Skoru, ameliyata kadar geçen süre, operasyon süresi, hastanede yatış süresi, kanama miktarı ve takip süresi yer almıştır. İstatistiksel analizler ki-kare testi, bağımsız örneklem T-testi ve Mann-Whitney U testi ile yapılmıştır.

BULGULAR: Çalışmada, PFN ve PFA yöntemleriyle tedavi edilen hastaların klinik sonuçları karşılaştırıldığında, PFN grubu PFA grubuna kıyasla daha kısa operasyon süresi ve daha az kan kaybı ile sonuçlanmıştır. Bu fark istatistiksel olarak anlamlı bulunmuştur ($p<0.05$). Ayrıca, PFN yöntemi ile tedavi edilen hastaların hastanede yatış süresi de daha kısa olup, bu da istatistiksel olarak anlamlı bir fark oluşturmuştur ($p<0.05$). Her iki grup arasında takip süresi açısından anlamlı bir fark bulunmamıştır ($p>0.05$). Bununla birlikte, PFN yöntemi ile tedavi edilen hastaların Oxford Kalça Skoru, PFA grubuna kıyasla daha yüksek çıkmış, dolayısıyla PFN grubunda postoperatif fonksiyonel sonuçların daha iyi olduğu gözlenmiştir ($p<0.05$). Yaş ve komorbiditeler açısından yapılan analizlerde, iki grup arasında istatistiksel olarak anlamlı bir fark tespit edilmemiştir ($p>0.05$).

SONUÇ: PFN uygulanan hastalar, PFA uygulanan hastalara göre daha kısa cerrahi süre, daha az kan kaybı ve daha kısa hastanede kalış süresi gibi avantajlar göstermiştir. PFN'nin bu bağlamda, daha az invaziv olması ve daha hızlı iyileşme sağlaması nedeniyle klinik sonuçlar açısından daha üstün olduğu söylenebilir. Ancak takip süresi açısından anlamlı bir fark gözlenmemiştir.

Anahtar sözcükler: Femur kırığı; kalça kırığı; proksimal femoral çivi; proksimal femoral anatomik plak.

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ORIGINAL ARTICLE

Factors associated with frailty and the effect of frailty on postoperative outcomes in older adults with hip fracture

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ABSTRACT

BACKGROUND: The incidence of hip fractures is also increasing rapidly with the aging population and is currently considered a major significant global health issue due to its high mortality rate. The aim of this research is to investigate the relationship between pre-fracture frailty and postoperative patient outcomes and identify factors associated with frailty in older adults operated for hip fracture.

METHODS: Descriptive, cross-sectional study. Patients aged 65 and older who underwent surgery for hip fracture were included. Data were collected in face-to-face interviews with patients in their rooms preoperatively and on the first postoperative day. The study was approved by the non-interventional research ethics committee of Dokuz Eylul University. Data analysis was performed using descriptive statistics, independent samples t-test, One Way ANOVA, correlation, and multiple linear regression analyses.

RESULTS: Of the 128 patients included in the study (mean age 78.45±8.36 years), 46.1% (n=59) were prefrail, and 39.8% (n=51) were frail. Higher frailty scores were associated with female sex, chronic disease, use of multiple long-term medications, being immobile or requiring mobility assistive devices prior to the fracture, recent decrease in appetite, need for postoperative intensive care, postoperative complications, postoperative pressure injury development, and mortality within the first month of discharge ($p<0.05$). Preoperative frailty score was positively correlated with number of chronic diseases, preoperative fear of falling, nutritional risk score, comorbidity index score, and length of hospital stay and negatively correlated with preoperative and postoperative Katz ADL score and postoperative creatinine concentration($p<0.05$). The mean Frailty Scale score was 2.16±1.26; pre-fracture nutritional status ($\beta=0.312$, $p<0.001$) and functional independence status ($\beta=0.216$, $p=0.012$) were significant predictors of frailty.

CONCLUSION: This study showed that frailty was prevalent among older adults undergoing hip fracture surgery and had a significant impact on postoperative patient outcomes. Pre-fracture nutritional and functional status were significant factors associated with frailty. Preoperative frailty assessment of patients presenting with hip fractures, especially focusing on nutritional and functional status, may contribute to better management of treatment and care.

Keywords: Aging; frailty; hip fracture surgery.

INTRODUCTION

Due to demographic aging, the prevalence of frailty is expected to increase significantly. Frailty impacts 70% of older adults,[1] increasing the risk of functional decline and dependency.[2] Frailty encompasses issues such as cognitive impairments, delirium, urinary incontinence, malnutrition, falls, gait disturbances, pressure injury, sleep disorders, sensory deficits, fatigue, and dizziness.[3] These problems are common among older adults and result in significant disability and impaired quality of life.[1,4]

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The incidence of hip fractures is also increasing rapidly with the aging population and is currently considered a major significant global health issue due to its high mortality rate.[5] The occurrence of hip fractures in frail patients is especially high due to lengthening life expectancy and increased comorbidities.[6] Frailty is also associated with lower quality of life after a hip fracture and may require personalized treatment, particularly in patients with a short life expectancy and those expected to experience a decline in postoperative functional capacity.[7]

The presence of frailty in older patients influences surgical outcomes and is associated with increased postoperative complications and mortality, prolonged length of hostpital stay, and discharge to a rehabilitation facility.[8-11] The authors of a systematic review noted that studies on functional decline and decreased quality of life after surgery are limited.[10]

There is currently significant interest in enhanced recovery programs, with most studies focusing primarily on total joint arthroplasties.[12] As patients are being discharged early both because of enhanced recovery programs and to reduce infection risk and costs, there is a growing need to evaluate the factors affecting postoperative recovery and functional dependency. Aside from frailty, significant factors in the postoperative recovery process include the surgical techniques used, technological advancements in the healthcare field, and the care received.[13] Preoperative assessment of frailty in older patients has become increasingly important to modify treatment options, evaluate prognosis and recovery expectations, and optimize treatment and care.[8,14] Therefore, routine frailty assessment is recommended in the comprehensive evaluation of patients planned for surgery.[15] The need for research to determine which adverse postoperative outcomes are most strongly predicted by frailty has been emphasized in the literature.[16] Thus, the aim of this study was to investigate preoperative frailty levels, their relationship with postoperative patient outcomes, and factors associated with frailty in older adults with hip fracture. The results are expected to contribute to a better understanding of frailty and its impact on postoperative outcomes and possibly improve the surgical care of older hip fracture patients.

MATERIALS AND METHODS

Study design

A cross-sectional, descriptive, correlational, predictive study was performed.

Research Questions:

1. What is the pre-fracture frailty level of older patients undergoing hip fracture surgery?

2. Do the pre-fracture frailty scores of older patients undergoing hip fracture surgery differ according to gender, presence of chronic disease, use of long-term medications, postoperative complications, postoperative delirium, history of falls within the last year, falls after hip fracture surgery, pre- and postoperative incontinence, pre- and postoperative pressure injury development, decreased appetite, weight loss, and hospital readmission and mortality within the first month after discharge.

3. Are the pre-fracture frailty levels of older patients undergoing hip fracture associated with age, body mass index (BMI), comorbidity index score, American Society of Anesthesiologists (ASA) physical status score, time from fracture to surgery, length of hospital stay, and pre- and postoperative pain levels, nutritional risk, albumin level, creatinine level, hemoglobin level, fear of falling, and functional status?

4. What factors predict the pre-fracture frailty levels of older patients undergoing hip fracture surgery?

Participants and sample size

The study sample consisted of 128 patients who underwent hip fracture surgery in the orthopedics and traumatology clinic of a training and research hospital and met the sampling criteria.

Inclusion criteria for the study were as follows: agreeing to participate in the study, being at least 65 years of age, undergoing surgery for intracapsular or extracapsular proximal femoral fracture, having no hearing or other sensory impairment, and having no psychiatric diagnosis. Patients who underwent hip surgery due to coxarthrosis, had periprosthetic fractures, underwent revision hip surgery, or had any speech impairment were excluded.

The sample size was calculated at a 95% confidence level using the G*Power 3.1.9.4 program. The minimum sample size was determined as 111 participants based on Cohen's medium effect size (d=0.30) and a theoretical power of 0.80. After the study was completed, a post hoc power analysis was conducted using the same program based on the difference in mean frailty scores by gender. With an effect size of 0.54, a p-value of 0.05, and a sample size of 128, the study power was calculated as 0.84.

Data collection

The study data were collected between October 2022 and December 2023 in the orthopedics and traumatology clinic of a tertiary care training and research hospital. Patients presenting with hip fracture were admitted for preoperative preparations, underwent surgery, and were discharged after an average of 5-6 days of postoperative follow-up in the clinic. Data were collected in face-to-face interviews with patients in their rooms preoperatively and on the first postoperative day. Sociodemographic and clinical data were obtained using a patient information form, the Charlson Comorbidity Index (CCI), Nursing Delirium Screening Scale (Nu-DESC) for delirium assessment, FRAIL Scale for frailty evaluation, Nutritional Risk Screening 2002 (NRS-2002) tool for malnu-

trition risk assessment, and the Katz Activities of Daily Living (ADL) Index for functional status evaluation. Other clinical data were obtained from patient charts and digital records (laboratory results, medications, surgical notes, length of hospital stay, and radiological imaging methods) in the hospital information management system. The patients' relatives were also contacted after a month to inquire about hospital readmissions and mortality within 30 days of discharge.

Data collection tools

Patient Information Form: This form was developed by the researchers in accordance with the literature.[6,10,11,14] The form includes 34 questions regarding sociodemographic and clinical information such as the patient's age, gender, BMI, marital status, education level, and smoking and alcohol consumption; comorbidities, long-term medications, ASA score, recent decrease in appetite, type of anesthesia, and type of surgery; postoperative complications; pre- and postoperative incontinence, pressure injury, pain levels, fear of falling, and hemoglobin, albumin, and creatinine levels; length of hospital stay; history of falls within the past year; and hospital readmission and mortality within 30 days after discharge. Patients were asked to rate their fear of falling and pain on a numerical rating scale of 0 to 5. Complications were identified based on the physician's diagnoses.

Charlson Comorbidity Index (CCI): The CCI is a mortality predictor developed in 1987 by Charlson and colleagues by classifying comorbid conditions and quantifying their severity. The index includes 19 medical conditions scored from 1 to 6 according to the relative risk of 1-year mortality, with a total score ranging from 0 to 37. The total score is then adjusted by adding 1 point for every decade over the age of 40 to yield the Charlson Comorbidity Index score.[17] This index is widely used to assess the comorbidity burden in surgical patients in our country.[18,19]

Nursing Delirium Screening Scale (Nu-DESC): Developed by Gaudreau and colleagues in 2005,[20] the Nu-DESC is a 5-item observational scale that can be administered rapidly (in approximately 1 minute). The items (disorientation, inappropriate behavior, inappropriate communication, hallucinations, and psychomotor retardation) are each scored between 0 and 2, for a score ranging between 0 and 10. Scores of 2 or higher are interpreted as delirium. The Nu-DESC was shown to have 85.7% sensitivity and 86.8% specificity in diagnosing delirium.[20] Validity and reliability studies in Turkish were conducted by Çınar and Aslan, who reported 92.3% sensitivity and 92.7% specificity.[21]

FRAIL Scale: This scale was developed by Morley and colleagues in 2012.[22] The validity and reliability study in the geriatric Turkish population was conducted by Muradi and Yavuz in 2017.[23] The scale consists of five items evaluating the patient's fatigue level, resistance (ability to walk up a flight of stairs), ambulation (ability to walk several hundred meters), illnesses, and unintentional weight loss. Each item is scored 0 or 1 based on the patients' responses, for a total score of 0 to 5. Patients are considered nonfrail at a score of 0, prefrail at scores of 1-2, and frail at scores higher than 2. In the adaptation study for the Turkish population, the Cronbach's alpha internal consistency coefficient of the scale was 0.787.[23]

Nutritional Risk Screening 2002 (NRS-2002): The NRS-2002 is a nutritional screening tool developed in 2002 by Kondrup and colleagues with contributions from the Danish Society for Parenteral and Enteral Nutrition.[24] Its purpose is to identify individuals at risk of malnutrition. Patients are asked four questions in the initial screening. If all answers are negative, nutritional risk is considered low and the screening is repeated at a specified interval. If the patient answers affirmatively to any question in the initial screening, they proceed to the secondary screening to assess their nutritional impairment and severity of illness. These scores are summed, with an additional point added for individuals over 70 years of age, to yield the total score. A total score of 3 or higher is interpreted as malnutrition risk and a nutritional care plan is implemented; if the total score is below 3, the screening test is repeated at the specified intervals. A study conducted by Bolayır (2014) assessed the Turkish validity and reliability of the scale on 271 patients in surgical and internal medicine departments.[25]

Katz ADL Index: Developed by Katz and colleagues in 1963,[26] this index includes basic ADL parameters such as bathing, dressing, toileting, transferring, urinary and bowel control, and feeding. Items are scored as independent (1 point) if the patient can perform them without supervision, guidance, or personal assistance or dependent (0 points) if they cannot. The total score ranges from 0 to 6, with a score of 6 indicating full function, 4 indicating moderate function, and 2 or less indicating severe functional impairment. The Turkish validity and reliability study was conducted by Arık and colleagues in 2015.[27]

Ethical consideration

This study conducted in accordance with the Helsinki Decleration Priciples. The study was approved by the non-interventional research ethics committee of Dokuz Eylul University (decision no: 2022/31-12; date: 28.09.2022). Written permission was obtained from the institution and clinic where the study was conducted. Additionally, informed consent was obtained from the patients who agreed to participate in the study.

Statistical analysis

The data were analyzed using the IBM SPSS Statistics version 23.0 (released 2016; Armonk, NY: IBM Corp.). Descriptive data were analyzed using frequency, percentage, mean, and standard deviation values. Skewness and kurtosis values (+2

to −2) were used to assess the normality of data distributions.[28] Data with a normal distribution were evaluated using parametric tests, while nonnormally distributed data were assessed using nonparametric tests. The significance level was set at $p<0.05$. The relationship between mean scores was analyzed using Pearson and Spearman correlation analyses. Differences in mean score based on sociodemographic and clinical variables were evaluated using significance tests for the means of two or more groups. Multiple linear regression analysis was employed to examine the factors predicting the frailty levels of patients who underwent surgery due to hip fractures.

RESULTS

The hip fracture patients participating in the study had a mean age of 78.45±8.36 years and a mean BMI of 26.16±4.66. Of the patients, 62.5% (n=80) were women, 46.1% (n=59) were prefrail, and 39.8% (n=51) were frail. Over half (55%) of the patients were at risk of malnutrition, and 10.7% were malnourished. Additionally, 49.2% had femoral neck fractures, 68% underwent surgery with internal fixation (proximal femoral nail, plate/screw), and 81.3% received spinal anesthesia during surgery (Table 1). The majority of patients had chronic diseases (85.2%), used multiple long-term medications (74.2%), and a history of falls within the past year (70.3%), and 41.4% used mobility assistive devices before the fracture. In the first month after discharge, 10.9% of the patients were rehospitalized (Table 2).

Mean frailty scores were significantly higher among patients who were female, had comorbidities, used multiple long-term medications, used mobility assistive devices or were immobile before the fracture, experienced a recent decrease in appetite, were admitted to the intensive care unit postoperatively, had postoperative complications, developed pressure injury pre- or postoperatively, developed delirium postoperatively, and died within the first month after discharge ($p<0.05$; Table 2).

Preoperative frailty score showed a weak positive correlation with number of comorbidities ($r=0.286$, $p=0.001$), number of long-term medications ($r=0.170$ $p=0.05$), preoperative fear of falling score ($r=0.225$, $p=0.011$), postoperative pain score ($r=0.202$, $p=0.02$), CCI score ($r=0.231$, $p=0.009$), and length of hospital stay ($r=0.187$, $p=0.035$). There was a moderate positive correlation between FRAIL Scale and NRS-2002 scores ($r=0.411$, $p<0.001$) (Table 3).

In terms of functional independence, preoperative frailty score was found to correlate negatively with Katz ADL score preoperatively ($r=-0.362$, $p<0.001$) and postoperatively ($r=-0.241$, $p=0.006$). There was also a weak negative correlation between preoperative frailty score and creatinine level ($r=-0.191$, $p=0.031$) (Table 3).

Multiple linear regression analysis was performed to assess the contribution of variables found to be associated with

Table 1. Sociodemographic and clinical characteristics of the patients (N=128)

Variables	n (%)
Age, years (mean ± SD)	78.45±8.36
BMI (mean ± SD)	26.16±4.66
Gender	
Female	80 (62.5)
Male	48 (37.5)
Marital status	
Married	71 (55.5)
Single	57 (44.5)
Education level	
Literate	28 (21.9)
Primary school	63 (49.2)
Secondary school, high school, university	8 (6.3)
Illiterate	29 (22.7)
Smoking	
Yes	6 (4.7)
No	122 (95.3)
Alcohol consumption	
Yes	3 (2.3)
No	125 (97.7)
Type of fracture	
Femoral head fracture	11 (8.6)
Femoral neck fracture	63 (49.2)
Intertrochanteric/pertrochanteric fracture	49 (38.3)
Subtrochanteric fracture	5 (3.9)
Type of surgery	
Hemiarthroplasty (hip)	9 (7.0)
Total hip arthroplasty	32 (25.0)
Internal fixation (proximal femoral nail, plate/screw)	87 (68.0)
Type of anesthesia	
Spinal	104 (81.3)
Epidural	23 (18.0)
General	1 (0.8)
Frailty status	
Not frail	18 (14.1)
Prefrail	59 (46.1)
Frail	51 (39.8)
Nutritional Status	
Normal	48 (34.3)
At risk of malnutrition	77 (55)
Malnourished	15 (10.7)
FRAIL Scale score (mean ± SD)	2.16±1.26

Table 2. Comparison of frailty scores according to clinical characteristics

Variables	n (%) Mean ± SD	FRAIL Scale Score, p-value	Test statistic,
Gender			
Female	80 (62.5)	2.40±1.19	t=2.898
Male	48 (37.5)	1.75±1.28	p=0.004*
Chronic disease			
Yes	109 (85.2)	2.27±1.23	U= 710.500
No	19 (14.8)	1.53±1.26	p=0.025*
Long-term medication use			
Yes	110 (85.9)	2.27±1.26	U=622.500
No	18 (14.1)	1.44±1.04	p=0.010*
Multiple medication use			
Yes	95 (74.2)	2.29±1.23	t=2.132
No	33 (25.8)	1.76±1.27	p=0.035*
Pre-fracture mobility			
Mobile	72 (56.3)	1.57±1.16	t= -7.157
Mobile with assistive devices / Immobile	56 (43.7)	2.91±0.95	p<0.001*
Decrease in appetite in recent days			
Yes	63 (49.2)	2.46±1.22	t= 2.748
No	65 (50.8)	1.86±1.23	p=0.007*
History of falls in the past year			
Yes	90 (70.3)	2.18±1.18	t=0.273
No	38 (29.7)	2.11±1.44	p=0.786
Postoperative falls			
Yes	14 (10.9)	1.86±1.16	U=-673.500
No	114 (89.1)	2.19±1.27	p=0.328
Postoperative ICU** admission			
Yes	21 (16.4)	3.05±0.97	U=589.00
No	107 (83.6)	1.98±1.24	p<0.001*
Postoperative complication			
Yes	8 (6.3)	3.88±0.83	U=108.00
No	120 (93.8)	2.04±1.20	p<0.001*
Preoperative incontinence			
Yes	44 (34.4)	2.43±1.22	t=1.801
No	84 (65.6)	2.01±1.26	p=0.074
Postoperative incontinence			
Yes	49 (38.3)	2.35±1.14	t=1.349
No	79 (61.7)	2.04±1.32	p=0.18
Preoperative pressure ulcer			
Yes	6 (4.7)	3.00±1.09	U=675.500
No	122 (95.3)	2.11±1.26	p=0.027*
Postoperative pressure ulcer			
Yes	18 (14.10)	2.83±1.09	U=675.500
No	110 (85.90)	2.05±1.25	p=0.027*
Postoperative delirium			
Yes	44 (34.4)	2.84±1.09	t=4.806
No	84 (65.6)	1.80±1.20	p<0.001*
Hospital readmission in first month after discharge			
Yes	14 (10.90)	2.64±1.39	U= 633.500
No	114 (89.10)	2.10±1.24	p=0.196
Mortality in the first month after surgery			
Yes	13 (10.20)	3.00±1.00	U= 450.000
No	115 (89.80)	2.06±1.25	p=0.016*

t: Independent samples t-test; U: Mann-Whitney U test; *p<0.05. ** ICU: Intensive care unit.

Table 3 . Correlation analysis between FRAIL Scale score and clinical characteristics

Variables	Mean ± SD	Correlation coefficient (r), p-value
Age (years)[a]	78.45±8.36	r=0.108, p=0.225
BMI[a]	26.16±4.66	r=0.055, p=0.534
ASA Score[a]	2.81±0.55	r=0.064, p=0.47
Number of long-term medications[a]	3.52±2.65	r=0.170, p=0.05*
Charlson Comorbidity Index score[a]	4.98±1.60	r=0.231, p=0.009*
Number of comorbidities[a]	1.83±1.23	r=0.286, p=0.001*
Time from fracture to surgery (hours)[b]	47.66±42.90	r=-0.085, p=0.338
Preoperative hemoglobin level (g/dL)[a]	11.70±1.56	r=-0.133, p=0.13
Postoperative hemoglobin level (g/dL)[a]	10.37±1.48	r=-0.094, p=0.29
Preoperative creatinine level (mg/dL)[b]	0.94±0.50	r=-0.156, p=0.078
Postoperative creatinine level (mg/dL)[b]	0.92±0.58	r=-0.191, p=0.031*
Preoperative albumin level (g/dLl)[a]	38.34±5.57	r=-0.066, p=0.460
Postoperative albumin level (g/dL)[a]	31.55±4.89	r=-0.113, p=0.200
Length of hospital stay (days)[b]	5.40±2.91	r=0.187, p=0.035*
Preoperative pain score[b]	4.55±0.79	r=-0.110, p=0.217
Postoperative pain score[a]	2.94±1.14	r=0.202, p=0.02*
Preoperative fear of falling score[a]	2.73±1.95	r=0.225, p=0.011*
Postoperative fear of falling score[a]	3.99±1.32	r=0.081, p=0.365
Number of falls in past year[b]	1.09±1.11	r=0.136, p=0.127
Postoperative mobilization time (hours)[b]	28.20±14.48	r=0.116, p=0.193
Preoperative NRS-2002 score[a]	2.58±0.96	r=0.411, p<0.001*
Preoperative Katz ADL Index score[a]	5.07±1.47	r=-0.362, p<0.001*
Postoperative Katz ADL Index score[a]	0.88±1.07	r=-0.241, p=0.006*

[a]Pearson correlation analysis; [b]Spearman correlation analysis; BMI: Body Mass Index; ASA: American Society of Anesthesiologists; NRS: Nutritional Risk Screening, ADL: Activities of daily living; SD: Standard deviation; *p<0.05.

frailty status in univariate analysis. The regression model explained 24% of the total variance (F=5.220, p<0.001) in FRAIL Scale score. Among the independent variables included in the model, preoperative NRS-2002 score (nutritional status) (β=0.312, p=0.000) and Katz ADL score (functional independence status) (β=-0.216, p=0.012) were significant factors associated with frailty level in older patients undergoing hip fracture surgery (Table 4).

DISCUSSION

This study examined the prevalence of frailty, associated factors, and the relationship between pre-fracture frailty level and postoperative patient outcomes in older adults undergoing surgery for hip fracture. The results showed that frailty is common among these patients and has a significant impact on postoperative patient outcomes. Frailty scores were significantly higher among patients who were admitted to the intensive care unit after surgery, developed postoperative complications, developed pressure injury pre- or postoperatively, had delirium postoperatively, or died within the first month after discharge. In addition, pre-fracture nutritional status and functional dependence were independent predictors of frailty.

In our sample, the prevalence rates of prefrailty and frailty were 46.1% and 39.8%, respectively. In a previous study of 35 older hip fracture patients, 51% were assessed as frail using the Fried Frailty Index,[29] while in a larger study of 127,305 hip fracture patients in Sweden, 48.3% were frail and 27.7% were prefrail according to the Orthopedic Hip Frailty Score.[30] A meta-analysis study reported a prevalence of frailty among hip fracture patients ranging from 22.4% to 80.7%.[31] Frailty involves various risk factors such as multimorbidities, polypharmacy, impaired physical mobility, malnutrition, and increased risk of falls.[32-34] In our study, 85.2% of the patients had chronic diseases, 74.2% used multiple long-term medications, 41.4% required mobility assistive devices before the fracture, and 70.3% had fallen in the past year. These results indicate that these patients have many risk factors associated with frailty, thus explaining the large proportion of frail pa-

Table 4. Investigation of factors predicting frailty in older patients undergoing hip fracture surgery (N=128)

Independent variables	β	T	p	Tolerance	VIF
Number of long-term medications	-0.075	-0.690	0.492	0.505	1.979
Number of comorbidities	0.180	1.457	0.148	0.388	2.574
Preoperative fear of falling score	0.136	1.669	0.098	0.889	1.125
Preoperative nutritional risk (NRS-2002 score)	0.312	3.614	<0.001*	0.793	1.261
Preoperative functional independence (Katz ADL Index score)	-0.216	-2.563	0.012*	0.832	1.202
Postoperative functional independence (Katz ADL Index score)	-0.034	-0.385	0.701	0.763	1.311
Charlson Comorbidity Index score	0.025	0.219	0.827	0.448	2.233
Postoperative pain score	0.083	1.010	0.315	0.873	1.145
Postoperative creatinine level (mg/dL)	-0.051	-0.637	0.525	0.909	1.100
Length of hospital stay	-0.005	-0.062	0.951	0.803	1.245
Adjusted R2	0.249				
F	5.220				
P	<0.001*				

NRS: Nutritional Risk Screening; ADL: Activities of Daily Living; *p<0.05

tients. Although age is emphasized as an important parameter for frailty in the literature,[32,35] it did not show a significant relationship with frailty in this study. This is likely because our sample included only individuals over 65 with similar ages, and the average age was quite high.

Female patients in this study were more frail, consistent with previous reports.[36-38] Sex differences can be attributed to both biological and socioeconomic factors.[36] The greater tendency for frailty in women may be related to the higher prevalence of non-fatal diseases that negatively affect functioning and quality of life in women, as well as changes in body composition resulting from increased fat mass and the likelihood of metabolic syndrome.[37,39]

In terms of patient characteristics before hip fracture, we observed greater frailty among patients who had chronic diseases, used multiple long-term medications, were immobile or required mobility assistive devices, and had a recent decrease in appetite. In addition, greater frailty correlated with a higher number of comorbidities, higher number of medications, greater fear of falling, higher nutritional risk, and lower functional independence. The most commonly used criteria to define frailty are unintentional weight loss, weakness, reduced handgrip strength, low physical activity, sarcopenia (loss of muscle mass and coordination), fatigue, and slowness.[40,41] In previous studies, frailty has been associated with factors such as disability in ADL,[38] low weight, low exercise levels, polypharmacy, history of falls,[42] and presence of chronic diseases.[35,38,42] Furthermore, frailty has been shown to increase the risk of falls and fear of falling in older adults.[43,44] These findings also help explain the increased frailty in our patient group, which had similar characteristics.

The results of the present study indicated that preoperative frailty significantly impacts patient outcomes after hip fracture. Greater frailty was observed in patients who required intensive care after surgery, had postoperative complications, developed pressure injury before or after surgery, experienced delirium, or died within the first month post-discharge. In addition, higher preoperative frailty scores were associated with higher postoperative pain scores, longer hospital length of stay, and lower functional status and creatinine level. These findings support those of several previous studies. Zhao and colleagues showed that frailty in older patients undergoing hip fracture surgery was associated with major perioperative complications such as delirium and pneumonia, as well as long-term reduced quality of life.[45] Similarly, frailty has been associated with more complications and longer hospital stays;[29] increased mortality, higher risk of complications, and hospital readmission;[46] and poor functional recovery after surgery.[47] Yang et al. (2022) also reported that the development of pressure injury following hip fracture surgery was associated with patients' frailty status and multiple comorbidities.[48] The negative impact of frailty on functional status before and after surgery likely contributes to the development of pressure injury.

Similar studies have demonstrated that frailty predicts adverse outcomes after hip fracture surgery.[9,30,31,49,50] Frailty provides a holistic assessment of how certain characteristics affect an individual's function and health status, and identifies patients with diminished physiological reserves in multiple organ systems who are more susceptible to stress factors.[45,51] The contribution of frailty to postoperative adverse outcomes can be explained by sensitivity to internal and external stress factors, reduced cognitive and physiological reserves, and dysregulation of immune and inflammatory responses.[45,52]

Although the correlation was not strong, we also observed an inverse relationship between patients' preoperative frailty score and postoperative creatinine level. Ballew and colleagues reported that a lower creatinine muscle index, which is based on serum creatinine and cystatin C concentrations, was associated with frailty.[53] Creatinine is produced as a result of the breakdown of creatine phosphate during muscle energy metabolism, and its serum concentration is influenced by skeletal muscle mass.[53,54] Muscle loss (sarcopenia) is a common condition in older and frail individuals and can result in low creatinine levels. Additionally, sarcopenia and nutritional deficiency are important parameters used in the diagnosis of frailty.[40,41] Sarcopenia typically occurs in 8-13% of adults aged 60 and older.[55] In this study, the inclusion of individuals over 65 years old, many of whom were frail, explains the decrease in creatinine levels with greater frailty.

In our regression analysis, preoperative nutritional status and functional independence status were found to be significant predictors of frailty, with 24% of the variance in frailty score explained by these variables. In the study sample, 55% of the patients were at risk of malnutrition, 10.7% were malnourished, and 43.7% were either immobile or used mobility assistive devices prior to the fracture. In another study involving 216 older patients with hip fractures, 47% were at risk of malnutrition and 35% were malnourished.[56] Nutritional status is an important factor in the development of frailty. Malnutrition contributes to unintentional weight loss, low muscle strength, reduced physical activity, and low gait speed, all of which are among the diagnostic criteria for frailty.[57] Reduced protein intake in particular leads to loss of muscle mass and function, thereby increasing frailty.[58,59] The decline in functional capacity is another important factor that increases the risk of frailty. Walking speed, grip strength, and the level of independence in ADL are especially important in the diagnosis of frailty.[40,41] In frail hip fracture patients, a comprehensive approach combining nutritional management and rehabilitation is considered an important strategy for improving clinical outcomes.[60]

Limitations

This study has certain limitations. As the sample included only patients over 65 years old who underwent surgery for hip fracture, the generalizability of the findings to other surgically treated patients is limited. Additionally, the patients' long-term outcomes were not investigated. Studies focusing on long-term outcomes are needed in the future.

CONCLUSION

This study aimed to contribute to the understanding of the prevalence of frailty, its associated factors, and its impact on postoperative outcomes in older patients undergoing hip fracture surgery. Frailty was prevalent in this patient group, and pre-fracture nutritional status and functional independence status were found to be significant predictors of frailty. Preoperative assessment of frailty is important for predicting risk and identifying patients who could benefit from appropriate perioperative interventions to prevent adverse outcomes. In addition, identifying factors associated with frailty and increasing awareness among healthcare professionals working with frail groups will guide the perioperative treatment and care processes, thereby improving patient outcomes.

Ethics Committee Approval: This study was approved by the Dokuz Eylul University Ethics Committee (Date: 28.09.2022, Decision No: 2022/31-12).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Kalça kırığı olan yaşlı erişkinlerde kırılganlık ile ilişkili faktörler ve kırılganlığın postoperatif sonuçlara etkisi

AMAÇ: Kalça kırığı insidansı yaşlanan nüfusla birlikte hızla artmakta ve yüksek ölüm oranı nedeniyle şu anda dünya çapında en önemli sağlık sorunlarından biri olarak kabul edilmektedir. Bu araştımanın amacı, kalça kırığı öncesi kırılganlık düzeyi ile ameliyat sonrası hasta sonuçları arasındaki ilişkinin ve kırılganlığı etkileyen faktörlerin incelenmesidir.

GEREÇ VE YÖNTEM: Tanımlayıcı ve kesitsel bir çalışmadır. Kalça kırığı nedeni ile ameliyat olan 65 yaş ve üstü hastalar dahil edilmiştir. Veriler, ameliyat öncesi ve ameliyat sonrası birinci günde hasta odasında yüz yüze görüşme yöntemi ile toplanmıştır. Bu çalışma, Dokuz Eylül Üniversitesi Girişimsel Olmayan Araştırmalar Etik Kurulu tarafından onaylanmıştır. Verilerin değerlendirilmesinde; tanımlayıcı istatistikler, bağımsız iki grup t testi, One Way Anova testi, korelasyon ve multiple lineer regresyon analizleri kullanılmıştır.

BULGULAR: Çalışmaya dahil edilen 128 hastanın (yaş ortalaması 78.45±8.36), %46.1'i (n=59) pre-kırılgan ve %39.8'i (n=51) kırılgandı. Kadın olan, kronik hastalığı olan, sürekli ve çoklu ilaç kullanan, kırık öncesi yardımcı araç gereç ile mobilize olan veya immobil ve son günlerde iştah azalması olan, ameliyat sonrası yoğun bakımda kalan ve komplikasyon gelişen, ameliyat sonrası basınç yarası olan ve taburculuk sonrası ilk bir ay içinde vefat eden hastaların daha kırılgan olduğu belirlenmiştir ($p<0.05$). Hastaların ameliyat öncesi kırılganlık düzeyi ile kronik hastalık sayısı, ameliyat öncesi düşme korkusu, nutrisyonel risk tanılama skoru, komorbidite indeks puanı ve hastanede yatış süresi ile arasında pozitif yönde; ameliyat öncesi ve sonrası fonksiyonel düzeyi ve ameliyat sonrası kreatinin düzeyi ile arasında negatif yönde istatiksel olarak anlamlı ilişki olduğu belirlenmiştir ($p<0.05$). Hastaların Frail Kırılganlık Ölçeği puan ortalamaları 2.16±1.26 olup; kırık öncesi beslenme durumu ($\beta=0.312$, $p=0.000$) ve fonksiyonel durum ($\beta=0.216$, $p=0.012$) kırılganlık düzeyinin anlamlı yordayıcılarıdır.

SONUÇ: Çalışmamız; kalça kırığı nedeniyle ameliyat olan hastalarda kırılganlığın yaygın olduğunu; kırılganlığın ameliyat sonrası hasta sonuçları üzerinde belirleyici bir etkisi olduğunu göstermektedir. Hastaların kırık oluşmadan önceki beslenme ve fonksiyonel durumları kırılganlığı etkileyen faktörlerdir. Kalça kırığı nedeniyle başvuran hastaların ameliyat öncesi dönemde kırılganlık durumlarının değerlendirilmesi ve etkileyen faktörlerin belirlenmesi, tedavi ve bakım sürecinin daha iyi yönetilmesine katkı sağlayabilir.

Anahtar sözcükler: Kalça kırığı; kırılganlık; yaşlılık.

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CASE REPORT

Priapism as the initial presentation of chronic myeloid leukemia in a patient with cerebral palsy: A case report

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ABSTRACT

Priapism is defined as a penile erection lasting more than four hours without stimulation. The majority of cases involve ischemic priapism, in which there is partial or complete absence of cavernosal arterial flow. Priapism is uncommon, with an estimated annual incidence of approximately 1.5 cases per 100,000 men. In chronic myeloid leukemia (CML) patients, leukostasis may occur, which can lead to priapism in 1-2% of cases. We present the case of a 21-year-old patient with a history of cerebral palsy who was brought to the emergency department by his family with priapism persisting for 13 hours. It was noted that the patient had experienced one prior episode of priapism a month earlier, which had resolved spontaneously. He had no history of trauma. On physical examination, extremity contractures related to cerebral palsy were noted, and the penis was observed to be erect. A venous catheter was inserted into the corpus cavernosum, dark-colored blood was aspirated, and blood gas analysis confirmed the diagnosis of ischemic priapism. The corpus cavernosum was irrigated with normal saline, and epinephrine was administered into both corpora cavernosa; however, priapism did not resolve. Laboratory tests revealed a white blood cell count of 581,760 /mm³. The patient was referred to the hematology department. Peripheral blood smear analysis confirmed the diagnosis of CML, and leukapheresis was performed three times within two days. Following normalization of the peripheral white blood cell count, penile detumescence was achieved, and no further episodes of priapism occurred. In conclusion, early diagnosis and a multidisciplinary approach improve the success of priapism treatment and reduce the risk of complications.

Keywords: Priapism; chronic myeloid leukemia; leukostasis.

INTRODUCTION

Priapism is defined as a penile erection lasting more than four hours without stimulation. The majority of cases involve ischemic priapism, in which there is partial or complete absence of cavernosal arterial flow. In ischemic priapism, metabolic changes occur due to hypoxia, hypercapnia, and acidosis, with patients typically experiencing pain after 6-8 hours.[1]

Priapism is an uncommon condition, with an estimated annual incidence of approximately 1.5 cases per 100,000 men. Hematologic disorders account for 20% of priapism cases in males, with sickle cell anemia being the most common cause. Additionally, priapism due to venous occlusion has been reported in 1-5% of male leukemia patients, with chronic myeloid leukemia (CML) representing 50% of these cases.[2,3]

This case report presents a 21-year-old patient with cerebral palsy who was diagnosed with CML following the presentation of priapism.

CASE REPORT

A 21-year-old male patient with a history of cerebral palsy-associated intellectual disability and epilepsy, controlled with antiepileptic medications, was brought to the emergency department by his family with priapism persisting for 13 hours. The family reported that the patient had experienced

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Figure 1. Erect penis and contracted extremities due to cerebral palsy.

Figure 2. Aspiration of blood from the corpus cavernosum using a 16-gauge venous catheter.

a single prior episode of priapism one month earlier, which had resolved spontaneously. He had no history of trauma. On physical examination, extremity contractures related to cerebral palsy were noted. Due to lack of cooperation, an abdominal examination could not be performed. The penis was observed to be in an erect state (Fig. 1).

For penile pain blockade, 10 mL of 1% lidocaine was administered to the penile radix. Subsequently, for the diagnosis and treatment of priapism, a 16-gauge venous catheter was inserted laterally into the corpus cavernosum. Dark-colored blood was aspirated, and blood gas analysis was performed, revealing a pH of 7.23, PO_2 of 34.5 mmHg, and PCO_2 of 39.2 mmHg, confirming the diagnosis of ischemic priapism. Since priapism persisted after aspiration, bilateral catheterization was performed, and the corpus cavernosum was irrigated with normal saline. Additionally, epinephrine (1:100,000; 5 cc) was administered twice at 20-minute intervals into both corpora cavernosa; however, priapism did not resolve (Fig. 2).

Laboratory tests revealed a white blood cell (WBC) count of 581,760 /mm³, hemoglobin of 8.6 g/dL, hematocrit of 23.5%, and a platelet count of 141,000 /mm³. Blood biochemistry values were within normal limits.

The patient, who exhibited leukocytosis, was referred to the hematology department. Peripheral blood smear analysis led to the diagnosis of CML, and emergency leukapheresis was performed. Oral allopurinol (300 mg twice daily) and hydroxyurea (1 g four times daily) were initiated and continued for 10 days. Leukapheresis was performed three times within two days, and by the end of the second day, detumescence was achieved. The patient continued treatment and follow-up under the hematology department. At the third- and sixth-month check-ups, the WBC count was within normal limits. According to family reports, the patient intermittently had normal erections, and no further episodes of priapism occurred. Written informed consent was obtained from the patient's parents for publication of clinical details and imaging findings.

DISCUSSION

Ischemic priapism is a condition that requires urgent urological intervention and, if not treated early, can lead to permanent sequelae such as erectile dysfunction. It can occur at any age but is most commonly seen in individuals aged 5-10 years and 20-50 years.[2,3] Approximately 70% of cases are idiopathic, while 20% of cases in adults are associated with hematological disorders. In CML patients, significant leukocytosis may be present at the time of diagnosis, which can lead to leukostasis or hyperviscosity syndrome. In hyperviscosity syndrome, visual disturbances such as retinopathy and retinal hemorrhage, pulmonary insufficiency, and priapism (in 1-2% of cases) can occur.[4] In the case presented here, the diagnosis of CML was made after investigations prompted by the development of priapism.

Systemic treatments frequently used in CML patients include high-dose hydroxyurea, tyrosine kinase inhibitors, and leukapheresis to reduce hyperviscosity.[4] Leukapheresis is a proce-

dure in which circulating blood is mechanically separated into liquid and cellular components, with excess white blood cells removed and the remaining components returned to the patient. Recent reviews of case reports from the literature have shown that, in addition to acute penile interventions, emergency leukapheresis is routinely performed—where available—for the treatment of ischemic priapism secondary to CML in both pediatric and adult patients. This approach has demonstrated favorable outcomes in managing leukostasis.[5,6]

The American Urological Association (AUA) emphasizes that systemic treatment of underlying conditions such as CML should not be considered the only treatment for ischemic priapism. Ischemic priapism should be regarded as a compartment syndrome, and penile-specific interventions are required as the initial approach.[7]

CONCLUSION

In cases of ischemic priapism, blood tests in addition to physical examination findings are crucial to avoid missing underlying hematological pathologies. When priapism is related to CML, primary penile interventions should be performed alongside systemic treatments, and emergency leukapheresis therapy should be considered in patients with hyperviscosity syndrome. Early diagnosis and a multidisciplinary approach can improve priapism treatment success and reduce the risk of complications.

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OLGU SUNUMU - *ÖZ*

Serebral palsi hastasında kronik Myeloid Lösemi'nin ilk bulgusu olarak priapizm: Vaka sunumu

Priapizm, uyarı olmaksızın 4 saatten uzun süren penil ereksiyon olarak tanımlanır. Olguların çoğu, kısmen veya tamamen kavernöz arter akımının olmadığı iskemik priapizmdir. Priapizm nadir görülen bir durum olup yıllık insidansı yaklaşık 100.000 kişide 1.5 vakadır. Kronik miyeloid lösemi (KML) hastalarında lökostaza bağlı olarak %1–2 oranında priapizm gelişebilmektedir. Sunulan olguda; serebral palsi öyküsü bulunan 21 yaşında erkek hasta, 13 saattir devam eden priapizm nedeniyle ailesi tarafından acil servise getirildi. Travma öyküsü olmayan hastanın, bir ay önce kendiliğinden düzelen tek bir priapizm atağı öyküsü olduğu öğrenildi. Hastanın fizik muayenesinde serebral palsiye bağlı ekstremite kontraktürleri tespit edildi ve penisin rijid olduğu gözlemlendi Korpus kavernozuma venöz kateter yerleştirilerek koyu renkli kan aspire edildi ve kan gazı analizi sonucunda iskemik priapizm tanısı doğrulandı. Korpus kavernozum fizyolojik serum ile irrige edildi ve her iki korpus kavernozuma epinefrin uygulandı; ancak priapizm gerilemedi. Laboratuvar testlerinde kan lökosit sayısı 581.760/mm³ olarak saptanması üzerine hasta Hematoloji bölümü tarafından değerlendirildi. Yapılan periferik yayma incelemesi sonucunda KML tanısı kondu ve hastaya iki gün içerisinde üç defa lökoferez uygulandı. Kan lökosit sayısının normal sınırlara gerilemesinin ardından penil detümesans sağlandı ve tekrar priapizm atağı görülmedi. Sonuç olarak, erken tanı ve multidisipliner yaklaşım, priapizm tedavisinde başarıyı artırmakta ve komplikasyon riskini azaltmaktadır.

Anahtar sözcükler: Kronik miyeloid lösemi; lökostaz; priapizm.

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