

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

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ABSTRACT

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

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

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

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

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

INTRODUCTION

Despite changes in warfare tactics and weaponry over thousands of years, combat-related wounds have consistently

been characterized by devitalized tissue, foreign bodies, clots, edema, and microbial contamination. Even in the post-antibiotic era, infections arising from such wounds continue to significantly contribute to morbidity and mortality.^[1]

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

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

MATERIALS AND METHODS

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

Data collected included demographic characteristics, vital signs, prosthesis use, comorbidities, routine laboratory and imaging tests, culture results and resistance profiles of isolated microorganisms, antibiotic regimens, duration of treatment and hospitalization, and recurrent infections. Infections were diagnosed based on detailed anamnesis, physical examination, laboratory findings, and imaging methods (ultrasonography, computed tomography, magnetic resonance imaging, and scintigraphy). Diagnostic criteria were defined according

to current international guideline recommendations.^[6-8] SSTIs were defined as widespread inflammation or subcutaneous or muscular fluid collection or abscess confirmed by ultrasonography. In patients with suspected osteomyelitis, the diagnosis was supported by radiological examinations such as magnetic resonance imaging or scintigraphy. Infection was confirmed by microbiological culture of soft tissue and/or bone samples whenever available.

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

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

Statistical Analysis

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

RESULTS

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

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

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

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

In all patients, the most common infections presented as cellulitis or abscess, with stump infections (44.8%) and graft infections (15.5%) being the predominant types. Nearly all amputee patients developed stump infections, whereas only one case of osteomyelitis was observed. Among non-amputee patients, graft infection was the most frequent finding. Cultures were obtained from 81% of patients, most commonly wound cultures (72.4%). Microbial growth was detected in 30 patients (51.7%). The most frequently isolated microorganisms were methicillin-sensitive *Staphylococcus aureus* (MSSA, 17.1%), *Enterobacter aerogenes* (10.4%), and *Pseudomonas aeru-*

Table 1. Clinical and functional characteristics of patients with infection

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

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

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

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

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

giosa (6.9%). MDR gram-negative organisms were identified in 24.1% of cases according to standard definitions,^[9] while methicillin-resistant *Staphylococcus aureus* (MRSA) was detected in a single patient (1.7%) (Table 2).

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

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

Table 3. Laboratory and imaging test results

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

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

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

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

During the follow-up period, 15 patients (25.8%) developed recurrent infections, comprising 11 SSTIs (73%) and four BJIs (26%). There were no statistically significant differences between amputee and non-amputee groups in terms of recurrence rates or duration of hospitalization. However, treatment duration was significantly longer in the non-

amputee group than in the amputee group (24.27±17.42 vs. 15.97±10.14 days, $p<0.05$) (Table 4).

DISCUSSION

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

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

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

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

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

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

^aIndependent-samples t test (Mean±SD); ^bChi-square test (n, %).

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

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

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

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

In our cohort, overall ambulation levels following trauma were relatively low. Although 44.8% of patients were able to ambulate independently with a prosthesis and 24.1% required walking aids, nearly all lower-limb amputees ultimately achieved ambulatory status, with only two requiring walking aids. The literature emphasizes that ambulation capacity is strongly influenced by the level and etiology of amputation. For example, among patients undergoing lower-limb amputation due to ischemia or diabetes, prosthetic mobility rates have been reported as 73.5% for transtibial and 40.4% for transfemoral amputations.^[18] By contrast, in a Sri Lankan co-

hort of traumatic amputees, 96% of patients were able to independently perform basic daily activities, and 83% were capable of advanced daily activities.^[19] Collectively, these findings suggest that more favorable functional outcomes in military trauma-related amputations may be associated with the younger age and higher physical capacity of this population compared with civilian cohorts.

Limitations

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

CONCLUSION

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

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

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ORIJİNAL ÇALIŞMA - ÖZ

Trauma rehabilitasyonunda deri, yumuşak doku, kemik ve eklem enfeksiyonları

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

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

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

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

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

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