Infectious Features of Burn Wounds and Their Influence on the Course of Clinical Outcomes in Burn Victims

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ABSTRACT

OBJECTIVES: **This study sought to determine the interactions between infectious features of burn wounds and in-hospital clinical outcomes among patients treated at our burn center.**

MATERIALS AND METHODS: **Our study group included 192 inpatients seen from 2020 to 2023. We collected data on age, sex, etiology, total body surface area burned, length of hospital stay, documentation of isolated microorganisms at admission and during hospitalization, requirement of antibiotic therapy, and mortality. We evaluated data among 3 subgroups: group 1 (length of hospital stay of 0-10 days), group 2 (length of hospital stay of 11-30 days), and group 3 (length of hospital stay of >30 days).**

RESULTS: **Mean ± SE age was 32.2 ± 1.6 years (range, 0-86 y), and male-to-female patient ratio was 2.1:1. Mean ± SE total body surface area burned was 12.6 ± 1.3% (range, 1%-85%). Scalds were the most common burn cause. Mean ± SE length of hospital stay was 17 ± 2.4 days (range, 1-363 d). Among the 27 positive wound swab cultures at admission, 9 were resistant. Gram-positive bacteria were the most common at admission. During hospitalization, microorganisms were isolated in wound swabs or tissues in 48 cases. *Staphylococcus epidermidis* and multidrug-resistant Acinetobacter baumannii were the most common bacteria. Therapeutic antibiotherapy was needed for 83.3% of group 3, 53.1% of group 2, and 20.2% of group 1. Mortality rate was 3.6% (n = 7/192 patients), with 3 patients in group1, 2 patients in group 2, and 2 patients in group 3 who had at least 1 microorganism at admission.**

CONCLUSIONS: **Evaluations of microflora in burn centers and precautions against wound contamination during emergency and transport phases can contribute to informed decisions at burn centers.**

KEY WORDS: *Burns, Hospitalization, Microorganisms, Wound contamination, Wound infection*

INTRODUCTION

Infections remain the most common cause of morbidity and mortality in patients with burn trauma. In patients with burn injuries of >40% total body surface area (TBSA), 75% of mortality is estimated to be related to infections. Delays in burn wound excision, extremes in age (very old, very young), and impaired immunity are frequent risk factors; patients with burns of >20% TBSA are at particularly high risk for wound sepsis. Burn wound infection and sepsis can also occur in burns of small TBSA because of microbial factors, such as type and number of organisms and enzyme and toxin production.[1] The most common bacterium in burn wounds is *Staphylococcus aureus*. However, burn wound sepsis, which results in death, is frequently a result of gram-negative bacteria such as *Pseudomonas* and *Acinetobacter* species.[2]

Patients with infectious complications at burn wounds may also have increased pain, delayed wound healing, and increased numbers of urgent and difficult surgical procedures. Emergency needs for debridement, delayed skin graft procedures, and/or unwanted extremity losses may occur.[3] A recent systematical review that aimed to develop a minimum set of indicators for reporting the presence of burn wound infection stated that there is no objective method for detecting burn wound infection and that different studies use different methods for diagnosis.[4] For this reason, every burn center must determine the presence of microflora in their center with cognizance of time-related changes, which can prevent complications

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and avoid prolonged hospital stays. Routine qualitative or quantitative burn wound cultures, including surface swabs and tissue samples, can contribute to improved monitoring during patient hospitalization.[5] Detection of invasive burn wound infection requires continuous evaluations of wounds in association with clinical and histopathological evidence.[1] In this regard, we analyzed interactions between infectious characteristics of burn wounds and clinical outcomes during patients' hospital stays, as a way to establish new strategies for infection prevention and early treatment of wound-related complications. Our aims were to identify infectious features of burn wounds and their effects on in-hospital clinical outcomes of patients treated at our burn center in the recent 3 years.

MATERIALS AND METHODS

We retrospectively documented 192 adult and pediatric burn victims who were hospitalized at our burn center from January 2020 (the date on which our architecturally renovated burn center started service at its new building) to May 2023. Data collected for each patient included age, sex, etiology, TBSA of burn, length of hospital stay (LHS), and records on burn wound cultures (surface swab cultures and tissue cultures), which were obtained according to our institutional "microbiological burn wound monitoring protocol for inpatients" (Figure 1). Burn wound surface swab cultures obtained on the same day of admission were considered as data at admission. Requirements of systemic antibiotherapy were documented, and overall and wound-related mortality rates were investigated. We excluded exceptional burn wound cases with nonstandard timing and nonstandard body sites and surveillance samples of nonburn areas.

We investigated our findings among 3 subgroups. Group 1 consisted of patients with LHS of up to 10 days (n = 104). Group 2 included patients with LHS of between 11 and 30 days (n = 64). Group 3 included patients with LHS of >30 days (n = 24).

Statistical analyses

We used SPSS (SPSS Inc) version 25.0 for our analysis of data. $P < .05$ was considered statistically significant. We presented categorical values as frequency (number) and percentage. We determined mean ± SE and ranges (minimum and maximum) for variables.

Limitation of the research

The study period included the extraordinary conditions of the COVID-19 pandemic era. This co-occurrence may have affected the spectrum of the isolated bacteria, because patients could have confronted environments that were different from usual before they arrived at our burn center. Patients may have also confronted unusual transfer problems. In addition, COVID-19 precautions were strictly followed by the burn team during hospital stays throughout this period.[6]

RESULTS

Total study group

Demographic and burn trauma data.

Mean age was 32.2 ± 1.6 (range, 0-86 y), and male-to-female ratio was 2.1:1. Mean TBSA burned was 12.6 ± 1.3% (range, 1%-85%). The most common burn causes were scalds and flame burns. Mean LHS was 17 ± 2.4 days (range, 1-363 d), and overall mortality rate was 3.6% (n = 7/192 patients).

Microbiological results at admission.

Burn wound swab cultures were obtained from wounds of 83 of 192 patients (43.2%) on the same day with hospitalization. Microorganisms were isolated in 27 (32.5%) of these 83 wounds. Various gram-positive bacteria were isolated (Table 1).

Microbiological results during hospital stay.

Microorganisms were isolated in burn wound swabs and/or burn wound tissues of 48 cases. In 19 of these cases, wound swabs and tissue samples revealed multiple microorganisms. The most common microorganisms were *Staphylococcus epidermidis* and multidrug-resistant *Acinetobacter baumannii* (Table 1).

Subgroups

Demographic and burn trauma data. Mean age for group 1 was 25.9 ± 2 years, mean age for group 2 was 40.9 ± 2.8 years, and mean age for group 3 was 36.4 ± 5.3 years. Mean TBSA burned was 7.5 ± 1.3% (range, 1%-85%) in group 1,

TABLE 1. Microbiological Results of Burn Wound Surface Swab Cultures at Admission and During Hospital Stay

At Admission	During Hospital Stay
• *Staphylococcus epidermidis*	• *Staphylococcus epidermidis*
• *Staphylococcus aureus*	• *Staphylococcus aureus*
• Coagulase-negative *Staphylococcus*	• Coagulase-negative *Staphylococcus*
• *Staphylococcus hemolyticus*	• *Streptococcus* group A
• *Stenotrophomonas maltophilia*	• *Streptococcus* species
• *Klebsiella pneumoniae*	• *Klebsiella pneumoniae*
• *Proteus mirabilis*	• *Klebsiella* pneumonia
• *Enterococcus faecalis*	• *Escherichia coli*
• *Enterococcus faecium*	• *Enterococcus faecalis*
• *Enterobacter* species	• *Enterococcus faecium*
• *Pseudomonas aeruginosa*	• *Enterobacter* species
• *Bacillus* species	• *Enterobacter cloacae*
	• *Candida albicans*
	• *Pseudomonas aeruginosa*
	• *Acinetobacter baumannii*

14.1 ± 1.9% (range, 1%-70%) in group 2, and 30.3 ± 3.5% (range, 4%-72%) in group 3. Distribution of age and sex among the groups is shown in Figure 2. The most common burn cause was scalds in group 1, and flame burns were the most common burn causes in group 2 and group 3 (Table 2).

Microbiological results and resistance. Among the 27 positive wound swab cultures at admission, 9 were resistant bacteria. The number of various resistant bacteria isolated from swab cultures of burn wounds during hospitalization was 19, and all were confirmed by tissue cultures. Distribution of resistance status according to subgroups is listed in Table 3. Among the 48 overall positive microorganism cultures (including at admission and during hospital stays), 33 were contaminations and 15 were wound

FIGURE 1. Başkent University Ankara Burn Center Microbiological Burn Wound Monitoring Protocol for Inpatients

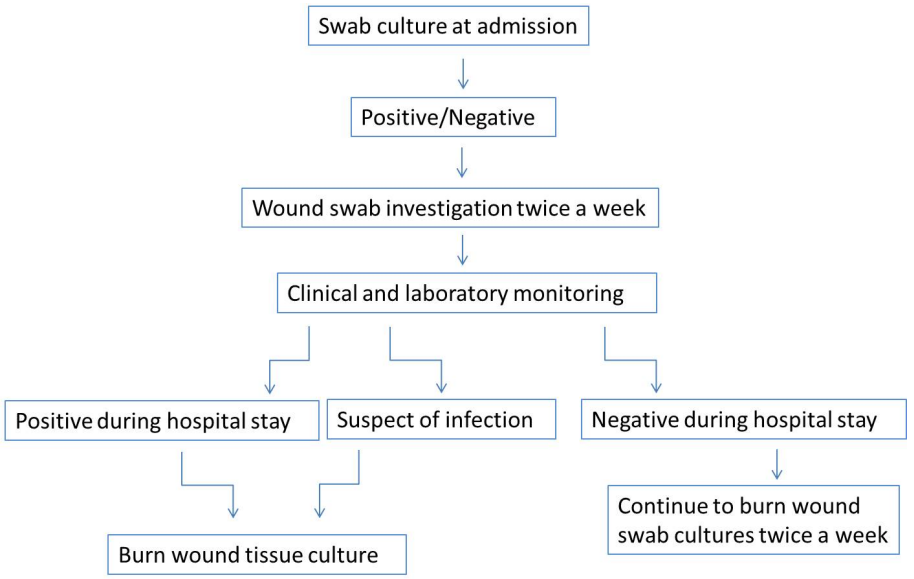
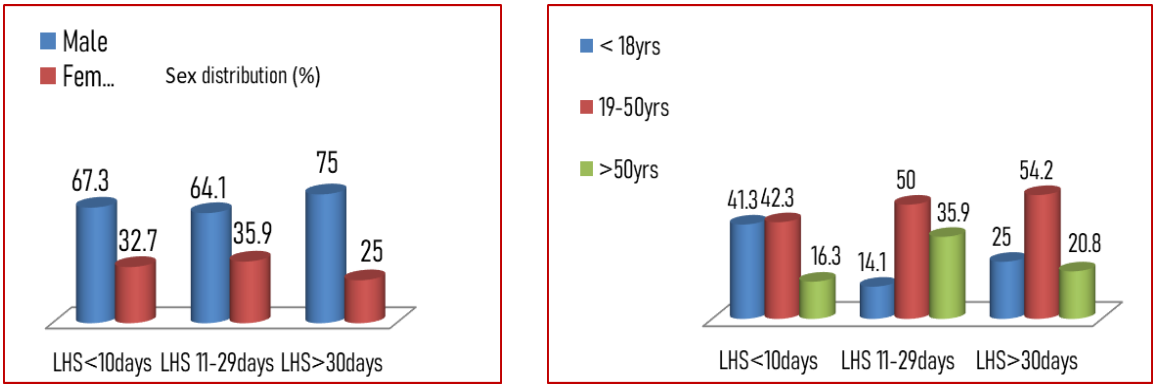


FIGURE 2. Distribution of Age and Sex Among the Study Groups\s\s



Abbreviations: Fem, female; LHS, length of hospital stay

TABLE 2. Distribution of Burn Causes Among the Study Groups

Group	Scalds, %	Flame, %	Contact, %	Electrical Injury, %	Chemical, %
1: LHS <10 days (n = 104)	46.2	30.8	17.3	3.8	1.9
2: LHS 11-29 days (n = 64)	31.3	39.1	15.6	10.9	3.1
3: LHS >30 days (n = 24)	16.7	54.2	4.2	20.8	4.2

Abbreviations: LHS, length of hospital stay

infections, with 5 leading to wound sepsis. Distribution of infectious clinical outcomes of inpatients in the subgroups is shown in Table 4.

Among patients who died, mean TBSA was 53% (range, 40%-85%). There were 3 cases of mortality in group 1, 2 cases of mortality in group 2, and 2 cases of mortality in group 3 with at least 1 microorganism isolated in wound swabs at admission; these deaths were as a result of wound-related sepsis. In other words, 85% of deaths were related to wound infections. In patients with mortality because of *Klebsiella pneumonia* sepsis, the microorganism was first isolated at admission. However, in the other patients who died from wound-related sepsis, all microorganisms isolated at admission were different from the ones that were detected during hospital stay (Table 5).

DISCUSSION

The different microorganisms that cause burn wound-related infections have different characteristics. For *Staphylococcus* species, the main source is the skin itself, and this bacterium may lead to opportunistic infections in burn victims. For *Pseudomonas* species, the main source seems to be the local environment and the endogenous enteral flora; *Acinetobacter* species has a high transfer capacity among patients, with an ability to survive in wet and dry environments.[2] The existence of these microorganisms in burn wounds of a patient at admission may result in infectious complications during the subsequent hospital stay. Furthermore, their presence may change the preexisting microflora content of the burn center with harm to other inpatients. Our results confirmed that various

TABLE 3. Distribution of Resistance Status of Microorganisms Among the Subgroups

Group	At Admission			During Hospital Stay		
	Positive Swab, No.	Sensitive, No. (%)	Resistant, No. (%)	Positive Swab or Tissue, No.	Sensitive, No. (%)	Resistant, No. (%)
1: LHS <10 days (n = 104)	6	3 (50.0)	3 (50.0)	13	8 (61.5)	5 (38.5)
2: LHS 11-29 days (n = 64)	14	11 (78.6)	3 (21.4)	18	10 (55.6)	8 (44.4)
3: LHS >30 days (n = 24)	7	4 (57.2)	3 (42.9)	17	11 (64.7)	6 (35.3)

Abbreviations: LHS, length of hospital stay

TABLE 4. Distribution of Infectious Clinical Outcomes Among Inpatients in the Subgroups

Group	Contamination/Infection	Sepsis	Systemic Antibiotic Therapy	Mortality From Wound Sepsis/Overall Mortality
1: LHS <10 days (n = 104)	10/3	3	21	3/3
2: LHS 11-29 days (n = 64)	15/3	3	34	1/2
3: LHS >30 days (n = 24)	8/9	2	20	2/2

Abbreviations: LHS, length of hospital stay

TABLE 5. Distribution of Microorganisms Among Cases With Mortality

Case Number	Group	At Admission	During Hospital Stay
1	Group 1	*Staphylococcus aureus, Bacillus species, Klebsiella pneumoniae*	*Klebsiella pneumoniae*
2	Group 1	*Klebsiella pneumoniae*	*Klebsiella pneumoniae*
3	Group 1	*Klebsiella pneumoniae*	*Klebsiella pneumoniae*
4	Group 2	*Stenotrophomonas maltophilia*	*Enterobacter cloacae*
5	Group 3	*Staphylococcus epidermidis*	*Acinetobacter baumannii*
6	Group 3	*Staphylococcus aureus*	*Pseudomonas aeruginosa, Acinetobacter baumannii, Candida species*
7	Group 3	*Staphylococcus epidermidis*	*Acinetobacter baumannii*

microorganisms were detected in burn wounds among our study patients, even at admission, and influenced the clinical outcomes during the subsequent hospital stay.

Crucial changes in bacterial flora were found with longer hospital stays. Multidrug-resistant *Klebsiella pneumonia* was common among patients in group 1 who died; however, multidrug-resistant *Acinetobacter baumannii* was observed in patients among the patients who died during longer in-hospital periods. This finding suggests that wound sepsis-related mortality from multidrug-resistant *Acinetobacter baumannii* seemed to originate from our preexisting microflora. In contrast, sources of multidrug-resistant *Klebsiella pneumoniae* sepsis seemed to be environments other than our burn center. *Klebsiella pneumoniae* was detected in burn wounds even at admission and caused deaths after a dramatical clinical deterioration in the initial 10 days, although it is an Enterobacteriaceae that in general causes urinary tract infections or pneumonia during prolonged hospital stays.[7] Our findings suggest that *Klebsiella pneumoniae* may be on the brink of becoming a serious problem for burn centers in the near future. As an Enterobacteriaceae, it mostly spreads quickly through person-to-person contact.[8]

Our findings, which revealed various bacteria detected at admission and during hospitalization, suggested that wound contaminations seemed to occur in patients both before they reached our center and during hospital stays. We believe that precautions are important against wound contaminations during emergency and transport phases, to prevent any subsequent challenges during stays at burn centers. Future strategies against the risk should be considered, not only for individual burn centers but also for nationwide burn care facilities.

Of note, previous reports from different countries, including Uganda, China, Pakistan, and Turkiye, revealed global difficulties in diagnosis of wound infections in many burn centers.[9-12] In a systematic review, Davies and colleagues stated that these difficulties arise from different definitions of burn wound infections. These differences result in varieties in outcomes; therefore, there is a need of a minimum set of indicators established by expert consensus.[4] Recent attempts to develop criteria specific to burn sepsis can help contribute to standardization of treatment in the future.[13,14] Positive burn wound cultures do not singly indicate wound infection. Association of clinical indicators is necessary. Our study confirmed a high number of positive wound cultures without clinical indicators that were considered as contamination; the high numbers of patients who required systemic antibiotherapy in our study may be explained by other clinical infectious manifestations, including central-catheter line infections, urinary tract infections, and pneumonia associated with or without wound contamination/infection.

CONCLUSIONS

Our results confirmed that, in the absence of a consensus of procedures, monitoring time-related changes of microflora found in an individual burn center with assessment of current sepsis criteria defined by different societies can be the most rational approach.

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