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Microbial profile of burn wound injuries in the Northern West Bank – A retrospective cohort study

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ABSTRACT

Background: Determining frequently colonizing microorganisms and typical demographics affected by burns in the West Bank is essential to aid timely and effective injury management.
Methods: This study included n = 435 patients with burn injuries between January 2018-December 2021 at a tertiary center in Nablus. Eligible medical records were reviewed, and relevant data extracted.
Results: n = 244 males and n = 191 females, average age 14.5 years were included. n = 227 had wound swab cultures, n = 80 which were positive. Scald injuries were the most common mechanism of injury (n = 314, n = 162 in males ($p < 0.001$), average age of 10.5 years). The most common organisms isolated were *Pseudomonas aeruginosa* (n = 17) and *Staphylococcus aureus* (n = 18). n = 17 multidrug resistant (MDR) organisms were cultured, MRSA most commonly (n = 9), followed by *K. pneumoniae* (ESBL) (n = 5). Overall length of stay (LOS) was 17.27 days in all patients and 28.2 days in those with MDR, with increasing LOS significantly associated with positive culture and MDR development of MDR ($p < 0.001$).
Conclusions: Younger male demographics and longer hospital admission increase the risk of burn wound colonization and MDR development in the Northern West Bank. *Pseudomonas aeruginosa* and *Staphylococcus aureus* were prevalent organisms isolated. MDR development represents a significant challenge in the effective management of injuries in an immunologically vulnerable cohort.

1. Introduction

Burns, which injure the skin or other organic tissues due to heat, radiation, radioactivity, electricity, friction, or chemicals, are a significant global public health issue, accounting for an estimated 180,000 deaths annually [1]. The majority of these injuries occur in low- and middle-income countries, most significantly in regions designated by the World Health Organization (WHO) as the African and South-East Asia areas, which account for two-thirds of burn injuries [1,2]. Burns are a major cause of morbidity and mortality in developing countries, resulting from injury related disfigurement, disability, and extended hospital stays. These outcomes are frequently associated with stigma and social rejection [2,3].

Burn wound eschars provide a protein-rich, avascular environment conducive to the colonization and proliferation of both endogenous and exogenous microorganisms. This increases the risk of microbial colonization and secondary infections due to compromised immune regulation, loss of the cutaneous barrier, and systemic release of pro-inflammatory mediators, disrupting both innate and adaptive immune responses [4]. Infection is a leading cause of death in severe burn injuries, with systemic sepsis and subsequent multi-organ failure accounting for 40–50 % of burn-related fatalities [4]. The presence of infection in burn wounds more than doubles mortality rate compared to injuries not complicated by infection [4,5].

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Mortality from burn wounds has decreased in high-income countries with advances in treatment of the injury and management of associated complications; mortality remains significantly higher in low- and middle-income countries, especially among children [2].

Burn wound colonization describes wounds with bacterial levels below 10^5 bacteria per gram of tissue, without signs of erythema or cellulitis. Risk factors include inhalation injury, prolonged hospital stays, and medical interventions such as intubation and catheterization. Diagnosis involves histological and culture testing of tissue or fluid samples [4,5]. If bacterial levels exceed 10^5 bacteria per gram and clinical signs of cellulitis are present—such as erythema, warmth, swelling, and tissue hardness—the wound is classified as infected. Diagnosis includes assessing symptoms like pain, color changes, and alterations in wound appearance [3,6,7].

The likelihood of developing invasive burn wound infections is influenced by the extent and depth of the burn injuries, host immune competence, and the quantity and virulence of microbial flora colonizing the wounds. Invasive infections are associated with high morbidity and mortality, particularly in those with additional risk factors for immunosuppression [6,8].

A diverse range of bacteria can be isolated from burn wounds. Gram-positive organisms are often involved in early colonization, while Gram-negative bacteria typically dominate later in the injury course or as the result of changes in microbiology over time [9,10,11]. Common pathogens in burn injuries include *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Klebsiella species*, and coliform rods, all of which are significant independent predictors of mortality. *S. aureus* is the most prevalent Gram-positive pathogen worldwide and is notably linked to higher morbidity and mortality in burn wounds, particularly with invasive infection [4,5].

Typical bacteria colonizing burn wounds has changed over time due to changes in antibiotic use and resistance patterns. Severe burns can alter antibiotic concentrations in tissues, reducing treatment effectiveness and promoting resistance. Multi-drug resistant (MDR) bacteria, including Methicillin-resistant *S. aureus* (MRSA), *Enterococcus*, *Pseudomonas*, and *Acinetobacter* species, are increasingly common and complicate burn wound management [12]. MDR organisms increase the risk of invasive infections and mortality, particularly in immunocompromised patients. Risk factors for MDR development include prolonged hospital stays, severe burns, invasive medical devices, and immunosuppressive comorbidities such as diabetes mellitus [12,13].

Complete eradication of pathogens in burn wounds is challenging; however, regular microbiological surveillance in burn centers is essential for monitoring pathogen prevalence, antibiotic sensitivity, and supporting early diagnosis and treatment [2,3]. Understanding local microbial risks and resistance patterns is crucial for optimizing management strategies, particularly in regions like the Northern West Bank, where burn injuries are prevalent [14]. The Ministry of Health (MoH) reports approximately 7,600 annual burn injuries in the West Bank and 8,685 in the Gaza Strip, with 65 % involving children. A review by Al-Najjar and Abu-Rahmeh (2022) highlighted the high prevalence of burn injuries, particularly among children and young adults, and noted the lack of comprehensive data and research on burn injuries in Palestine [14].

Drawing from the information discussed, this study, undertaken at a leading referral center for complex burn cases, focuses on analyzing the demographics and microbiological characteristics of burn injuries in the Northern West Bank. The findings aim to provide important insights for optimizing burn wound infection management in this region and to present updated data on the epidemiology of burns and related complications in the West Bank. Ongoing monitoring of microbial isolation patterns and susceptibility profiles in burn wounds is crucial for refining preventive and therapeutic strategies.

2. Materials and methods

A retrospective cohort study was conducted at a single institution, focusing on acute burn patients admitted to a tertiary burn center between January 2018 and December 2021. All burn patients during this period were included, except for specific groups. These included patients with only inhalational burns, where wound cultures were not possible, individuals with immunodeficiencies such as HIV, congenital immune disorders, or chronic conditions causing immunosuppression (e.g., diabetes, cancer, emphysema, or heart failure). Additionally, patients receiving treatments like chemoradiotherapy, immunosuppressants, or glucocorticoids, as well as those hospitalized for over seven days at another facility before transfer were also omitted. These criteria were implemented to prevent confounding factors that might distort the microbiological profile of burn wounds, ensuring a more accurate representation of local microbial epidemiology.

Sociodemographic information was extracted from patients' files using the hospital's electronic system, while wound culture results were accessed from laboratory records. In accordance with the updated national protocols for burn care and management [15], wound samples are routinely collected from all patients based on clinical assessment. Infection diagnosis is traditionally based on visual inspection, clinical criteria, and confirmation through wound cultures, supplemented by various laboratory markers. Cultures were performed where clinical evidence of infection was present. A positive culture, indicating infection, is defined by the growth of $> 10^5$ bacteria per gram of tissue from the samples. All patients with positive wound cultures were treated with antibiotics tailored to the sensitivities of the identified organisms [16,17].

A descriptive analysis was conducted to examine the distribution of demographic factors (age and gender), key burn characteristics, and the microbiological profiles of collected samples. Bivariate analysis, including chi-square tests, was employed to explore potential associations between patient and burn characteristics and the demographic data of the patients. Ethical approval for the study was granted by the Institutional Review Board (IRB) at An-Najah National University.

3. Results

This study included 435 patients who sustained thermal, electrical, and chemical burn injuries. Of the total cohort, 244 (55.9 %) were male and 191 were female, with a mean age of 14.5 years (SD 18.41). Wound swab cultures were performed on 227 patients, with 80 (35.3 %) testing positive for infection, while 147 (64.7 %) were negative. The highest incidence of burns occurred in children under 10 years of age (277 cases, 64.1 %), followed by the 11–20 age group (45 cases, 10 %). The lowest incidence was observed in individuals over 70 years old (3 cases, 1.4 %).

Thermal burns were the predominant cause, accounting for 95.6 % of the cases (411), followed by chemical burns (12 cases, 1.6 %). Second-degree burns were present in 92.4 % of cases (400 patients), while third-degree burns occurred in 4.6 % (20 patients). Surgical debridement or graft was required for 97 cases, with 62 patients undergoing wound debridement and 35 managed with skin grafts.

The most common anatomical locations of injury were the head, neck, and trunk ($n = 55$), followed by the lower limbs ($n = 50$). Males were more likely than females to suffer flame or electrical injuries.

Using the total body surface area (TBSA) classification, which defines burns affecting 10 % or less of TBSA as minor, 10–20 % as moderate, and over 20 % as severe, it was found that the majority of cases (274, 63.3 %) were classified as minor burns, with only 7.2 % (31 cases) categorized as severe.

There was no significant association between total body surface area (TBSA), burn degree, or the need for surgery and gender ($p = 0.565$, $p = 0.251$, and $p = 0.085$, respectively). Similarly, these factors were not significantly linked to age ($p = 0.627$, $p = 0.185$, and $p = 0.132$, respectively). However, the type of burn injury (thermal, chemical, or

Table 1
Demographic and burn injury characteristics of the study population.

Variable	Number	Percentage (%)
Sex		
Male	242	55.9
Female	191	44.1
Source of burn		
Thermal	411	94.9
Chemical	12	2.8
Electrical	7	1.6
Degree of burn		
First	13	3
Second	400	92.4
Third	20	4.6
Site of burn		
Head and neck	247	57.04
Chest	123	28.41
Abdomen	67	15.47
Back	38	8.77
Genitalia	31	7.15
Upper limb	214	49.42
Lower limb	135	31.17
Total Burn Surface Area		
Minor (<10 %)	274	63.3
Moderate (10–20 %)	128	29.6
Severe (>20 %)	31	7.2

electrical) was significantly associated with age ($p = 0.002$).

Table 1 provides an overview of the demographic and burn injury characteristics of the study population.

The mean time to the initial wound culture was 3.98 days. Follow-up cultures were conducted in cases where the initial culture was positive, and signs of infection persisted despite antibiotic treatment. Additionally, patients with initially negative cultures underwent further testing if they exhibited ongoing or worsening local or systemic indicators of burn wound infection. All patients whose cultures revealed multidrug-resistant (MDR) organisms had repeat cultures. In one case of persistent infection, up to 10 cultures were performed (Table 2).

The most commonly observed pathogens were *P. aeruginosa* (n = 17) and *S. aureus* (n = 18). MDR organisms were detected in 11 of the first cultures, with methicillin-resistant *S. aureus* (MRSA) being the most prevalent, found in 7 cases. Other MDR pathogens included *Acinetobacter baumannii* (n = 1), *Enterobacter* (extended-spectrum beta-lactamase; ESBL) (n = 1), *Escherichia coli* (ESBL) (n = 1), and methicillin-resistant *Staphylococcus epidermidis* (MRSE) (n = 1) (Fig. 1).

In the subsequent cultures, *A. baumannii* (n = 9) and *P. aeruginosa* (n = 10) emerged as the most prevalent organisms. For patients with an initial positive culture, the dominant organisms in the second culture were *A. baumannii* (n = 7, 31.8 %) and *P. aeruginosa* (n = 5, 22.7 %). Conversely, in those with an initially negative culture, *P. aeruginosa* (n = 5, 30 %) and coagulase-negative staphylococci (CNS) (n = 3, 20 %) were most commonly identified. MDR organisms appeared in three cases, including *A. baumannii* (MDR) and *K. pneumoniae* (CRE) in patients with previously positive cultures, and *E. coli* (ESBL) in one patient with an initially negative culture (Fig. 2).

A total of 49 third cultures were performed, with 19 (38.8 %) yielding positive results. *P. aeruginosa* (n = 9) was the most frequently identified pathogen, affecting three patients with initially negative cultures, two with two previously negative cultures, and three with two negative cultures. Among the MDR organisms found, there were one *E. coli* (ESBL), one *K. pneumoniae* (CRE), and two *K. pneumoniae* (ESBL). Notably, *K. pneumoniae* (ESBL) appeared in patients who had previously tested negative in the second culture following antibiotic treatment for an initial positive culture (Fig. 3). In select cases, up to ten cultures were conducted, revealing a diverse range of organisms. MDR organisms were seen across the 1st-5th cultures. Seventeen MDR organisms overall were cultured across the study sample. MRSA was the most common organism seen (n = 9), followed by *K. pneumoniae* (ESBL) (n = 5) (Table 3).

MDR infections occurred in 10 females and 7 males. Older males, with an average age of 18 years and a higher average total body surface area (TBSA) affected (25.7 %), were more likely to develop MDR

Table 2
Wound cultures.

Culture	*1st (n)*	*2nd (n)*	*3rd (n)*	*4th (n)*	*5th (n)*	*6th (n)*	*7th (n)*	*8th (n)*	*9th (n)*	*10th (n)*
Yes	227	87	49	20	9	3	2	2	2	1
Positive	80	37	19	7	5	3	2	1	1	0
Negative	147	50	30	13	4	0	0	1	1	1

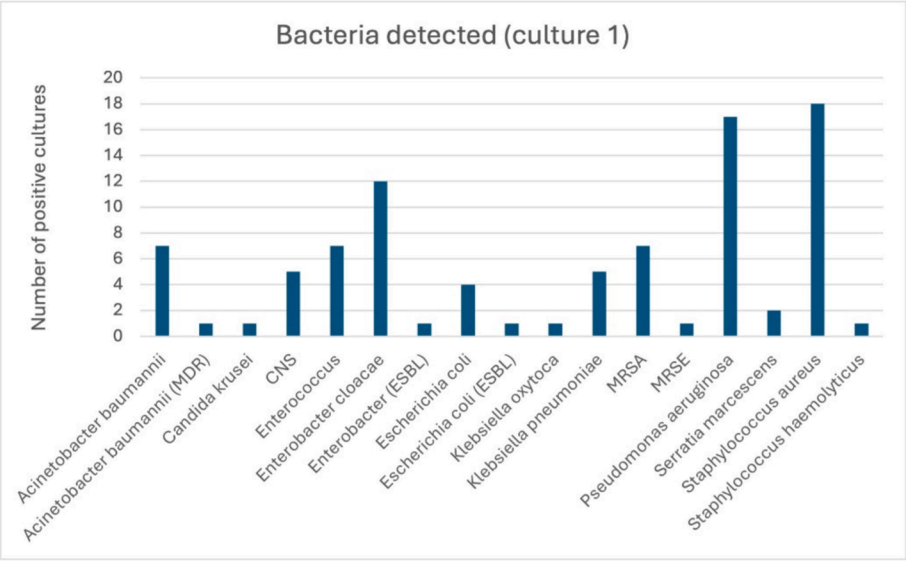

Fig. 1. Bacteria detected in the first culture.

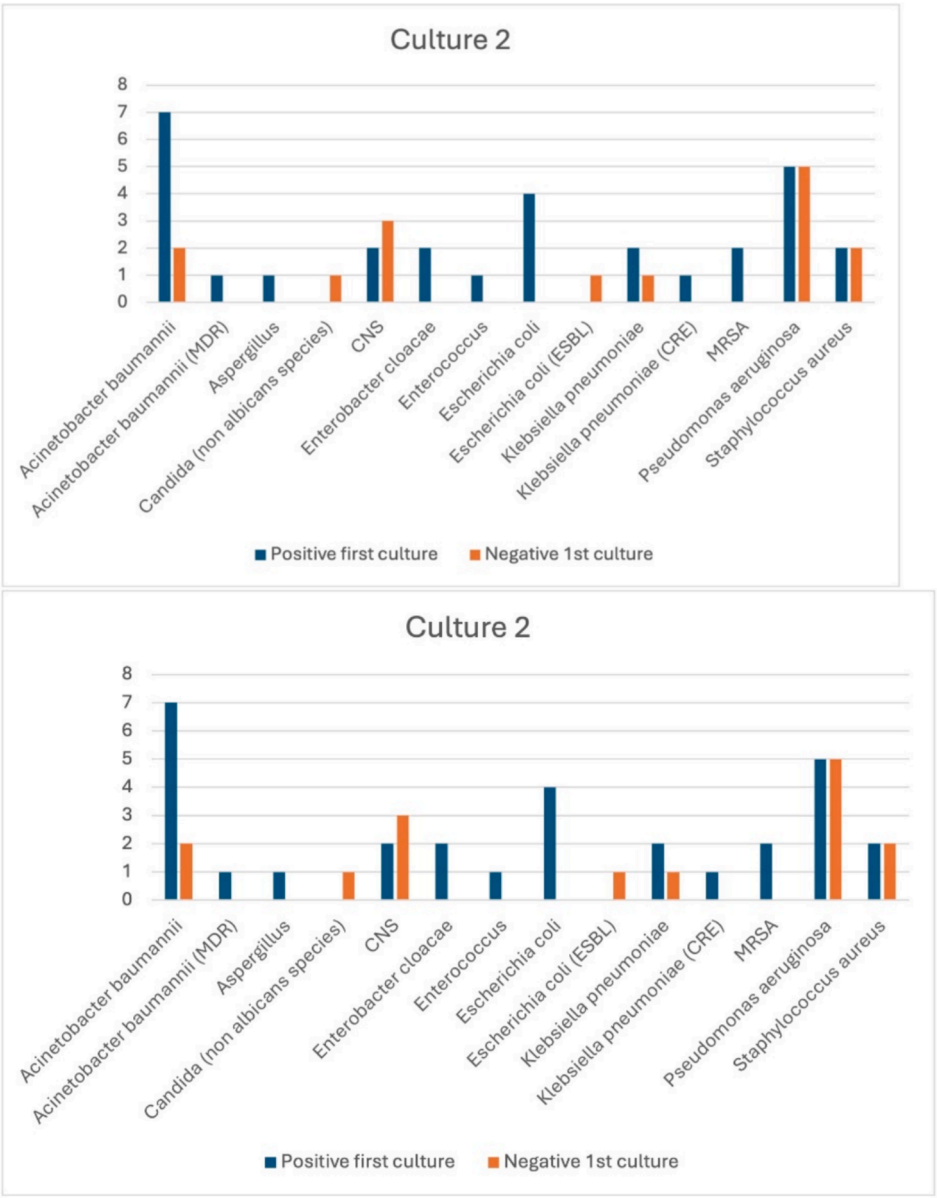

Fig. 2. Bacteria detected in the second culture.

compared to younger females, who averaged 11.1 years old and had a lower TBSA affected (18.6 %). Scald injuries were the most common cause of MDR, followed by flame injuries, reflecting the overall injury types in the study. Patients with MDR had a significantly higher average TBSA (22 %) than those with any positive cultures (13 %) ($p < 0.001$). Additionally, MDR developed in patients who were slightly younger (13.9 years) compared to the overall study group (14.5 years). The average length of stay (LOS) for patients with MDR was 28.2 days, significantly longer than the overall LOS and those with non-MDR infections ($p < 0.001$).

From an infectious disease perspective, the timeline and development of MDR organisms in burn patients provide critical insights into the dynamics of infection progression, resistance patterns, and the effectiveness of treatment protocols. Fig. 4 shows how MDR organisms progressed and changed in the 17 cases where they developed. Methicillin-resistant *S. aureus* (MRSA) was found in 7 of the first cultures but cleared in 5 cases by the second culture. In 2 cases, MRSA emerged during the second culture, replacing *Enterococcus* and *A. baumannii*. While in 2 instances MDR organisms evolved into other MDR strains, in most cases, MDR developed either from non-MDR organisms (4 cases) or from previously negative cultures (3 cases). *K. pneumoniae* (MDR), including carbapenem-resistant (CRE) and extended-spectrum beta-lactamase (ESBL) strains, usually appeared later, between the second and fifth cultures.

Surgery was performed in n = 97 cases, with n = 62 patients undergoing wound debridement and n = 35 managed with skin grafts. The average TBSA% in patients undergoing debridement was 14 % and 14.5 % in those managed with skin grafts. Wound grafting had a significant association with positive culture, suggesting that more extensive injuries were more likely to develop bacterial colonization or infection. Patients not managed surgically received regular dressings and wound care until their injury could be safely managed in the community (Table 4).

4. Discussion

Burn injuries are a significant cause of morbidity and mortality amongst populations within the Northern West Bank of Palestine. Despite challenges in the Palestinian health system, the Ministry of Health has made efforts to improve care, recently updated the national burn care protocol. However, few studies have detailed burn patient

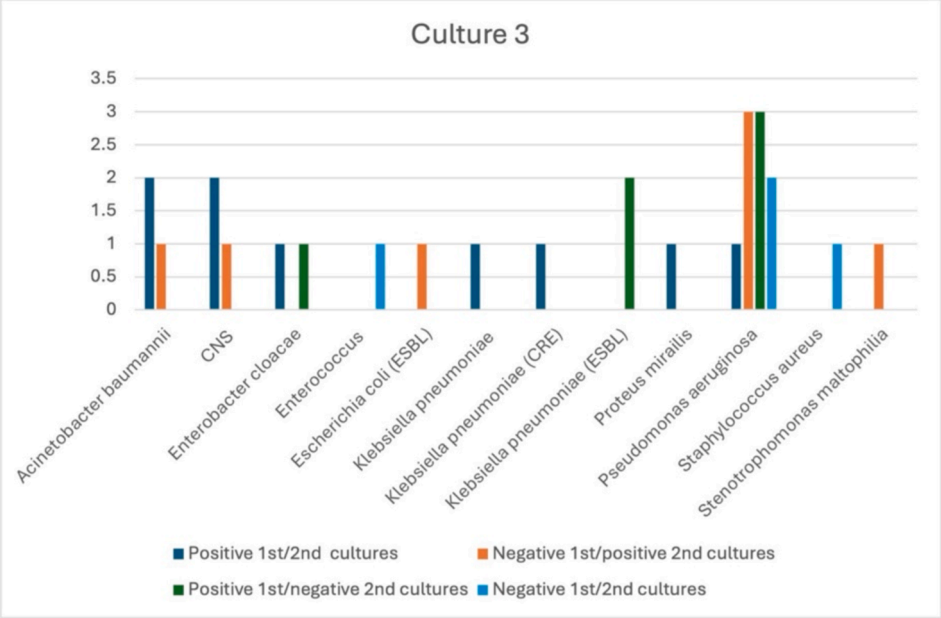

Fig. 3. Bacteria detected in the third culture.

Table 3
MDR organisms.

Culture	1st	2nd	3rd	4th	5th
Total	11	5	8	0	1
Acinetobacter baumannii (MDR)	1	1			
Enterobacter (ESBL)	1				
Escherichia coli (ESBL)	1	1	2		
Klebsiella pneumoniae (CRE)		1	2		
Klebsiella pneumoniae (ESBL)			4		1
MRSA	7	2			
MRSE	1				

characteristics, particularly regarding microbial infections, which are crucial for guiding treatment. The study was conducted to ascertain the characteristics of burn patients and examine the associated microbial profile in the referral center in the North of West Bank during the period 2018–2021.

The study found that burn injuries in this region mostly affect young males, with scalds being the leading cause. This aligns with other regional studies showing a higher prevalence of burns in males (56 % to 72.2 %) and younger populations [18,19]. These findings highlight the need for greater community awareness, especially among caregivers of children. The results may also reflect socio-economic challenges in Palestine, where poverty, unemployment, and overcrowded homes increase the risk and severity of burns, leading to worse outcomes [20–23].

Thermal and electrical burns were more common among slightly older individuals, aged 22–25, while chemical burns typically affected men over 30. This suggests that many of these injuries likely occur outside the home, possibly due to workplace accidents or incidents related to ongoing regional conflict, such as blast trauma or weapon-related injuries. However, at the time of this study, no official data on the number or characteristics of workplace-related burn injuries was available. Additionally, the demographic data only includes patients who reached the hospital, excluding those in rural or refugee communities without access to care, those who sought private healthcare or were referred abroad, or individuals who tragically died before receiving medical attention. This limits the generalizability of study findings to the broader Palestinian population.

In Palestine, understanding the pattern of burn injury patterns is important to understand the influence of conflict and limited healthcare resources on injury acquisition. The data shows that most burn cases—63.3 %—are classified as minor, with only 7.2 % considered severe. This suggests that many individuals could receive care in local clinics, which would reduce the pressure on hospitals already significantly resource constrained and impacted by regional conflicts.

Interestingly, while burn severity did not appear differ significantly by age or gender, the type of burn does relate to age. Children are often more vulnerable to thermal burns from household accidents, while adults might face greater risks from chemical or electrical burns, often tied to work-related hazards. Recognizing these differences can guide tailored prevention efforts, such as educational campaigns that emphasize safety at home and in the workplace. By focusing on targeted strategies, healthcare professionals can work towards reducing the impact of burns on communities throughout Palestine.

Wound cultures performed in the management of burn wounds aided identification of microbial colonization and prompt antibiotic treatment. Despite this, persistence of and change in microbiology was demonstrated in several cases, with microbiological and MDR colonization developing in both those with previously negative cultures and despite antibiotic treatment. This highlights both the significant risk of microbial colonization of burn wounds and organism persistence and MDR development despite tailored antibiotic administration. Length of hospital stay was significantly associated with a positive burn wound culture and presence of MDR organisms, in line with the evidence suggesting that prolonged hospitalization is associated with an increasing risk of MDR development, with associated implications for effective pathogen eradication and morbidity and mortality of burn injuries [24–26]. It is of note that all patients with a wound culture with growth $> 10^5$ bacteria/grams of tissue received antibiotics in this population, without correlation between culture results and clinical features of infection. While burn wound infection is typically defined by quantitative culture with growth $> 10^5$ bacteria/grams of tissue, clinical correlation is essential, to avoid aberrant administration of antibiotics in wounds with a high bacterial load but without clinical features of infection. In patients with positive first cultures that demonstrated presence of non MDR organisms who subsequently developed MDR, clinical correlation is essential to reduce the likelihood of inappropriate antibiotic administration which may increase the risk of MDR development.

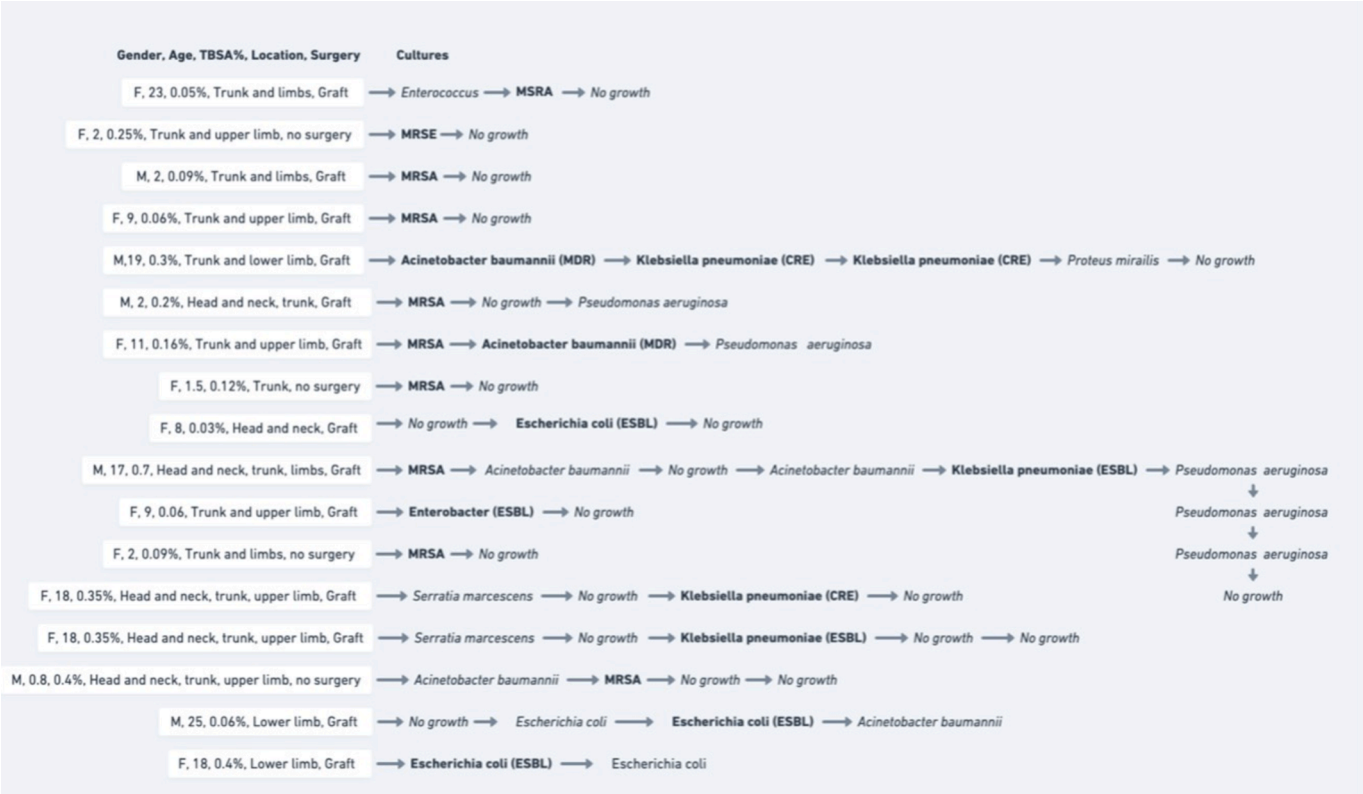

Fig. 4. Timeline of MDR organism development.

Table 4
Surgical management.

							Positive culture		
Surgery	n	Scald	Flame	Chemical	Electrical	TBSA%	n	%	p
No	338	260	64	10	2	10.3	47		
Debridement	62	34	26	0	2	14	18	29	0.567
Graft	35	20	7	2	4	14.5	15	42.6	0.012

MRSA and *Klebsiella* were commonly isolated MDR organisms in this study, in line with the prevalence of MDR organisms reported in the literature [24]. MDR more commonly developed in patients with a higher average TBSA% and younger age than the overall study sample. Extensive burn injuries further the disruption of the skin immunological barrier and exacerbate immunosuppression, exacerbating the potential negative consequences of colonization with MDR organisms in populations which are increasingly vulnerable and have an increased relative immunosuppression, including younger patients [27]. MDR organisms such as *MRSA* pose a significant risk of sepsis in these patients and other complications in healthcare settings, including antibiotic resistance and microbiological spread, posing a wider public health risk to the Palestine population, and highlighting the importance of their effective and timely identification and management.

Surgical management of burn wounds is typically required for full-thickness injuries, involving early wound excision with debridement of non-viable necrotic tissue, with potential requirement for subsequent reconstruction with skin grafting or free tissue transfer. Surgery was performed for patients with full-thickness injuries in this study, with debridement and subsequent grafting in wounds unsuitable to be managed with regular wound dressings and wound care alone. The association of grafting with positive culture suggests increased likelihood of infection with increasing depth of burn wounds, in line with the evidence that extent of soft tissue damage is associated with increased likelihood of wound colonization and infection, relating to compromised host defenses and more significant disruption of the skin barrier [28].

Learning points of this review include a need to discriminate more effectively clinically between burn wound colonization and infection at this center, to ensure appropriate antimicrobial stewardship and reduce the risk of iatrogenic MDR development. Confirming microbiological eradication following positive culture is also an important step in reducing the likelihood of MDR development, guiding the extent of antibiotic therapy required. Appreciating the risk of microbiological colonization of burn wounds is essential to prompt close monitoring of wounds and symptoms for features of infection. However, it is essential to appreciate that over administration of antibiotic therapy may risk further development and spread of MDR in this region, complicating management of burn wounds further, disproportionately affecting more severe injuries and more vulnerable groups, including younger patients higher TBSA%, as seen in this study.

5. Strengths and limitations

This study is a significant first step in characterizing and improving understanding of burn injuries at a major referral hospital in northern Palestine. It provides important context for future research that can provide deeper insights into how burn injuries are managed in the region. Moreover, it may help track changes in treatment outcomes after updated protocols are implemented, ultimately improving care for burn patients.

However, the study has limitations due to its retrospective design, which led to incomplete data for some patients. Cultures were only taken from those showing clinical evidence of infection, and while this shows a link between positive cultures and infection, does not clearly differentiate between colonization and infection or connect culture results to clinical outcomes.

6. Conclusions

This study highlights that burn wound injuries are a serious public health concern in the Northern West Bank of Palestine, with a significant risk of colonization by MDR organisms. This poses challenges for effective wound management and infection control. The range of bacteria affecting these wounds can vary over time, even with antibiotic treatment.

Timely wound cultures and accurate identification of pathogens are crucial for administering appropriate antibiotics, which can help prevent complications and the spread of MDR strains. Awareness of the risk of MDR development is vital for managing burn injuries, especially given the potential for severe infections in this vulnerable population.

Moreover, improved public health efforts to reduce burn injuries are essential, particularly among younger individuals who are disproportionately affected in this region. By focusing on prevention and education, we can decrease the frequency and severity of burn wounds, leading to better health outcomes and reduced morbidity and mortality in the Palestinian community.

7. Ethics approval and consent to participate

This study was conducted in accordance with local and international ethical principles, including those in the Declaration of Helsinki. The protocol of this study was approved by the Institutional Review Board (IRB) of An-Najah National University (Med. Nov 2021/12 approved on November 8, 2021).

Consent to participate was waived by the Institutional Review Board (IRB) of An-Najah National University.

8. Consent for publication

Not applicable.

9. Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Author contributions

SN, RK, SB, AA, AA, and RD contributed to the research idea, study design, data analysis, data interpretation, and drafting the first manuscript. SN, AA, AA, RD and AA were involved in the data acquisition. SN, HL and BD were involved in the data analysis, data interpretation, and critical revision of the manuscript. All authors approved the final manuscript.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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