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Research Article

A cross-sectional study of pathogenic bacteria isolated from patient with burn injury in AL-Najaf City, Iraq

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Abstract

Background: Burns are a type of injury that occurs when the skin or other tissue is damaged by heat, chemicals, electricity, sunlight, or radiation.
Objective: The purpose of this study was to determine the frequency of extended-spectrum β-lactamase-producing (ESBL) and multidrug-resistant bacteria that were isolated from burn patients as well as the patterns of antibiotic sensitivity of each bacterial isolate.
Methodology: From June 2024 to January 2025, 86 burns swabs were collected from hospitalized patients at Al-Najaf Central Hospital in Al-Najaf City, Iraq. Standardized microbiological assays were used to identify every bacterial isolate that was generated. The disc diffusion technique was used to test for antibiotic susceptibility. Standardized procedures and criteria were followed in order to identify bacteria that were resistant to multiple drugs (MDR) and extensive drugs (XDR) those that produced extended-spectrum β-lactamases.
Results: Out of total 123 bacterial isolates; 44(36%) *S. aureus*, 28(23%) was *K. pneumonia*, 26(21%) *A. boumannii*, 13(10.5%) *P. aeruginosa* and 8(6.5%) *E. coli* (3.3%), 4(3%) *P. mirabilis*. Out of total 123 bacterial isolates, there were 113(92%) were MDR and 10(8%) were XDR. Out of total 79 gram negative bacteria, there were 25 isolates (32%) were ESBL and 54 isolates (68%) non-ESBL. Ten *K. pneumonia* isolates (36%) were ESBL, 11(42%) *A. boumannii* , 4(31%) *P. aeruginosa* and there were no any *E. coli* and *P. mirabilis* isolates recorded as ESBL.
Conclusion: This study concluded that *S. aureus* was the most common caused burns infections at Al-Najaf Hospital and the most prevalent ESBL bacteria were *K.pneumonia* and *A. boumannii*.

1. Introduction

Burns are a common type of injury that can occur in a variety of settings, and they can range in severity from minor to life-threatening [1]. The assessment and management of burn wounds are crucial for preventing complications and optimizing patient outcomes [2]. Burns are a devastating form of traumatic injury that can lead to significant morbidity and mortality. In the United States, over 2 million individuals sustain thermal injuries annually, with 5-7% requiring hospitalization and an estimated 12,000-15,000 burn victims dying from their injuries each year. One important consideration in burn care is the risk of necrotizing soft-tissue infections, which can be a serious complication of burn injuries. These infections are characterized by rapidly progressive tissue destruction and are associated with high morbidity and mortality [3]. To address this challenge, prompt diagnosis, immediate radical surgical debridement, and aggressive critical care management are essential.

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Burn injuries are a significant public health concern, affecting millions of individuals globally each year. Around 11 million patients require burn-related medical care annually, with approximately 10% of these cases involving burns covering 30% or more of the total body surface area [4]. The management of burn injuries remains a challenging endeavor, as these wounds are highly susceptible to infections that can lead to severe complications and increased mortality.

In fact, 42-65% of burn victims die from infections, making it the leading cause of death following burn injuries. Burns are a common type of injury that can lead to various complications, including infections caused by both gram-negative and gram-positive bacteria [5]. Effective topical antimicrobial chemotherapy and early burn wound excision have significantly reduced the overall occurrence of invasive burn wound infections [6]. However, individual patients, particularly those with extensive burns where wound closure is difficult to achieve, may still develop a variety of bacterial and nonbacterial burn wound infections [7]. Burn injury is a major challenge for the patient's immune system, leaving them immunocompromised and vulnerable to pathogens such as nosocomial bacterial infections and multidrug-resistant pathogens [8]. Infections caused by ESBL-producing bacteria in burn patients are associated with significantly higher mortality rates compared to infections with non-ESBL-producing strains. Proper infection control practices and prompt initiation of appropriate antibiotic therapy are essential to prevent the spread of these multidrug-resistant organisms and improve patient outcomes [9, 10].

The increasing prevalence of ESBL-producing bacteria is a major concern in the management of burn injuries, as these pathogens can cause life-threatening systemic infections and complicate patient care. Carbapenems are often considered the treatment of choice for severe ESBL-producing Enterobacteriaceae infections, although comparative clinical data are limited [11].

More research is needed to better understand the epidemiology, risk factors, and optimal management strategies for ESBL infections in the burn patient population. Vigilant surveillance, strengthening of infection control measures, and judicious antibiotic stewardship are crucial to mitigate the adverse impact of these problematic pathogens in burn care settings [12].

The purpose of this study was to determine the frequency of multi-drug resistant bacteria and extended-spectrum β-lactamase-producing bacteria that were isolated from burn patients at Al-Najaf Central Hospital in Al-Najaf City, Iraq. This goal was to improve our knowledge of the most common bacteria and their resistance to various antimicrobials in order to stop these isolates from reoccurring in the future.

2. Methods

Ethical Considerations

We certify that we have obtained consent for this study, including consent from participants and patient swabs. After receiving consent from the hospital's treatment and care team, the doctor took all of the swabs and gave them to us. The participants' doctor at the Burns Department of Al-Najaf Central Hospital in Al-Najaf City provided all of the swabs. All swabs were sent right away for processing to the University of Kufa's Faculty of Science's Laboratory of Microbiology. Note: The following information was written on each swab: age, sex, and length of hospital stay following burning. Since Al Najaf Central Hospital is a member of the University of Kufa, a pre-existing agreement between the hospital and the university governing the collecting of clinical samples meant that written clearance was not required. Every patient gave their oral consent to be sampled.

Study Design, Burns Swabs Collection and Bacterial Identification

From June 2024 to February 2025, a cross-sectional descriptive research was conducted at the Al-Najaf Central Hospital in Al-Najaf City, Iraq. Three swabs were taken from each patient at the end of their seven-day stay. A total of 86 swabs (emulsion with normal saline) were taken from the burned area of hospitalised patients with second-degree burn infections (who displayed signs of infection during the changing of dressings) who ranged in age from 18 to 45. To promote bacterial growth, all obtained swabs were immediately cultured with brain heart infusion broth for 24 hours at 37°C. They were then streaked onto blood agar using a swab and the chocolate agar surface, and they were incubated aerobically for 24 to 48 hours at 37°C. Standard microbiological tests, including colony morphology, blood haemolysis onto the blood agar surface, gramme stain, oxidase, catalase, imvic, motility, coagulase, growth on MacConkey agar, and Mannitol salt agar, were used to identify all emerged bacterial isolates.

Antimicrobials Susceptibility Test

The disc diffusion method, which follows the Kirby-Bauer method [13], was used to examine the antimicrobials' susceptibility on the Mueller Hinton agar surface. In this investigation, fourteen distinct antimicrobial discs from Oxoid were utilised, USA as follow: penicillin 10IU (P), amoxicillin 25μg (AX), Amoxiclav 30μg (AMC), ceftriaxone 30μg (CRO), cefotaxime 30μg (CTX), ceftazidime 30μg (CAZ), gentamicin 10μg (GM), tobramycin 10μg (TM), amikacin 30μg (NA), ciprofloxacin 5μg (CIP), imipenem 10μg (IMP), Streptomycin 10μg (S), erythromycin 30μg (E), tetracycline 30 μg (TE). The diameters of inhibition zones (mm) were measured using a caliper measure each zone with the unaided eye, and compared with clinical and laboratory standards institute (CLSI) guideline 2024 [14]. A bacterial isolate was classified as extensive-drug resistant (XDR) if it was resistant to all but two or three antimicrobial classes or as MDR if it was resistant to at least three distinct antimicrobial classes [15].

Phenotypic Detection of Extended Spectrum Betalactamase-Producing Bacteria

AMC disc 30μg was placed in the centre of the agar plate, and CRO 30μg, CTX 30μg, and CAZ 30μg were placed around AMC disc 30μg (15 mm from centre to centre). All bacterial isolates (turbidity was adjusted according to McFarland tube 0.5) were streaked onto Mueller Hinton agar surface using a sterile swab. This test was conducted in accordance with the modified double disc synergy test (MDDST) [16]. Every plate was incubated for 24 hours at 37°C in an aerobic environment. A favourable result for the extended spectrum beta-lactamase was defined as any increase in the inhibition zone towards AMC disc 30μg.

Statistical Analysis

Percentages were used in this study to compare between the prevalence of pathogenic bacteria and their resistant to antimicrobials using Graphpad-prism V.10 computer software [17].

3. Results

Total Burns Swabs and Total Bacterial Isolates

In this study, 86 burns swabs were collected from 86 patients infected with burns infections; 52 male and 34 female. The results of the current study showed that out of total 86 burns swabs, there were 123 positive bacterial cultures; 79 gram negative bacteria (64%) and 44 gram positive bacteria (36%). Out of 123 total bacterial growth, there were 88 (71.5%) were mixed growth and 35 (28.5%) were single growth Table 1.

Table 1: Total single and mixed bacterial isolates from patient infected with burns infections.

Gram stain	Single isolates	Mixed growth	Total (%)
Gram-negative	25	54	79(64%)
Gram-positive	10	34	44(36%)
Total (%)	35(28.5%)	88(71.5%)	123(100)

Patients and Age Groups

The current study demonstrated that out of total 86 patients, there were 52 male (60%) and 34 female (40%). Age group 21-30 was the most age infected with burns infections with 29 cases (34%): 17 male and 12 female followed by age group 31-40 with 20 cases (23%): 10 male and 10 female, while, there were 13 cases (15%) for each age groups 1-10 and 11-20, and 6, 4 and 1 case for age groups 41-50, 51-60, 61-70 respectively Table 2.

Table 2: Total number of male and female patient infection with burn according to age groups.

Age / year	1-10	11-20	21-30	31-40	41-50	51-60	61-70	Total (%)
Male	8	11	17	10	4	2	0	52 (60)
Female	5	2	12	10	2	2	1	34 (40)
Total	13 (15)	13 (15)	29 (34)	20 (23)	6 (7)	4 (5)	1 (1)	86 (100)

Patients and Total Bacterial Growth

The results of the present study showed that out 123 total bacterial isolates, there were 67 (54.5%) isolated from 52 male patients; 44 gram negative bacteria (17 single growth, 27 mix growth) and 23 gram positive bacteria (6 single growth, 17 mix growth). While 56 bacterial isolates (45.5%) from 34 female patients; 35 gram negative bacteria (8 single growth, 27 mix growth) and 21 gram positive bacteria (4 single growth, 17 mix growth) Table 3.

Table 3: Total bacterial growth isolated from male and female infected with burns infections.

Male 52				Female 34				Total
Gram-negative		Gram-positive		Gram-negative		Gram-positive		
Single growth 17	Mix growth 27	Single growth 6	Mix growth 17	Single growth 8	Mix growth 27	Single growth 4	Mix growth 17	
44		23		35		21		123 (100%)
Total: 67 (54.5%)				Total: 56 (45.5%)				

Numbers and Percentages of Total Bacterial Isolates

The results of the current study revealed that out of total 123 bacterial isolates; there were 44(36%) *S. aureus* isolates from women's urine infected with UTI (10 isolates from single growth and 34 from mixed growth), 28(23%) was *K. pneumonia* (one isolate from single growth and 27 from mixed growth), 26(21%) *A. boumannii* (14 isolates from single growth and 12 from mixed growth), 13(10.5%) *P. aeruginosa* (9 isolates from single growth and 4 from mixed growth), 8(6.5%) was *E. coli* (one isolate from single growth and 7 from mixed growth), (3.3%), 4(3%) was *P. mirabilis* from mixed growth Figure 1, 2.

Antibiotics Resistance

Table 5 revealed the numbers and percentages of gram negative bacteria that were sensitive and resistant to 12 antibiotics.

Table 4: Numbers and percentages of bacterial isolates from patient infected with burns infections in this study.

Bacterial isolates	Single growth	Mix growth	Total
S. aureus	10	34	44 (36%)
K.pneumonia	1	27	28 (23%)
A. boumannii	14	12	26 (21%)
P. aeruginosa	9	4	13 (10.5%)
E. coli	1	7	8 (6.5%)
P. mirabilis	0	4	4 (3%)
Total	35 (28%)	88 (72%)	123 (100%)

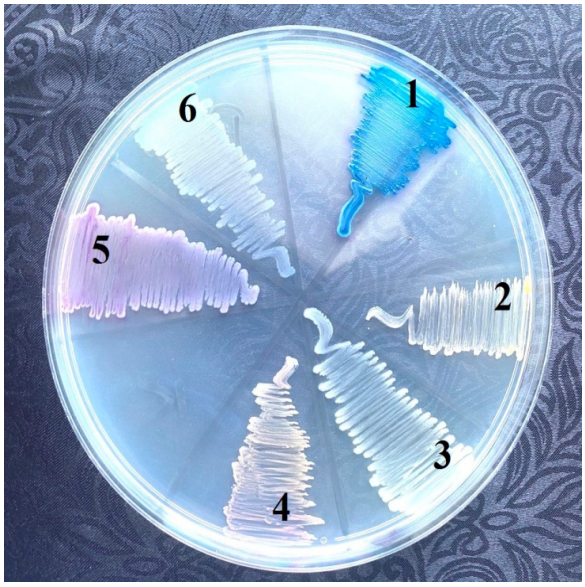

Figure 1: Bacterial growth onto CHROMagar agar medium at 37° C for 24 h. *1: K.pneumoniae*, *2: S.aureus*, *2: E.coli*, *3: A. boumannii, 4: P.mirabilis, 5: E.coli, 6: P.aeruginosa*

The results showed that all bacterial isolates were highly resistance to the most antibiotics. *K. pneumoniae, A. boumannii* and *P. aeruginosa* were highly resistance to amoxicillin while *E.coli* and *P. mirabilis* was resistance with moderate percentages. On the other hand, the results showed that there were out of total 26 *A. boumannii* isolates, there were 2 isolates (8%) that were resistance to Imipenem.

The results of the present study showed that out of 44 *S. aureus* isolates there were 30(68%) were resistance to erythromycin, minocycline, ciprofloxacin and tetracycline Figure 2. While, there were 22 isolates (50%) resistant to azithromycin, 20 isolates (45.5%) were resistant to gentamicin, doxycycline and levofloxacin.

Table 5: Association between Butchers' Socio-Demographic Factors and the Prevalence of Intestinal Worms.

AB	*K.pneumonia* 28NO.(%)		*A. boumannii* 26NO.(%)		*P. aeruginosa* 13NO.(%)		*E. coli* 8NO.(%)		*P. mirabilis* 4NO.(%)	
	S	R	S	R	S	R	S	R	S	R
AX	8(28.8)	20(71.5)	4(15)	22(85)	3(23)	10(77)	3(37.5)	5(62.5)	3(75)	1(25)
AMC	8(28.8)	20(71.5)	3(12)	23(88)	3(23)	10(77)	3(37.5)	5(62.5)	2(50)	2(50)
CTX	13(46)	15(54)	6(23)	20(77)	4(31)	9(69)	3(37.5)	5(62.5)	3(75)	1(25)
CRO	13(46)	15(54)	6(23)	20(77)	4(31)	9(69)	5(62.5)	3(37.5)	3(75)	1(25)
CAZ	13(46)	15(54)	6(23)	20(77)	5(38)	8(62)	5(62.5)	3(37.5)	3(75)	1(25)
LIV	10(36)	18(64)	4(15)	22(85)	3(23)	10(77)	5(62.5)	3(37.5)	2(50)	2(50)
CN	7(25)	21(75)	6(23)	20(77)	6(46)	7(54)	4(50)	4(50)	2(50)	2(50)
CIP	6(21)	22(79)	11(42)	15(58)	5(38)	8(62)	4 (50)	4 (50)	2(50)	2(50)
TE	6(21)	22(79)	11(42)	15(58)	3(23)	10(77)	4(50)	4(50)	2(50)	2(50)
AK	13(46)	15(54)	6(23)	20(77)	3(23)	10(77)	5(62.5)	3(37.5)	3(75)	1(25)
TM	13(46)	15(54)	6(23)	20(77)	4(31)	9(69)	4(50)	4(50)	2(50)	2(50)
IMP	28(100)	0(0.0)	24(92)	2(8)	13(100)	0(0.0)	8(100)	0(0.0)	4(100)	0(0.0)

AB: Antibiotics, S: Sensitive, R: Resistance, AX: Amoxicillin 25μg
AMC:Amoxicillin+clavulanic acid 325/10μg,CTX: Cefotaxime 30μg, CRO: Ceftriaxone 30μg, CAZ: Ceftazidime 30μg, LIV: Levofloxacin 5μg,
CN: Gentamicin 15μg, CIP: Ciprofloxacin 5μg, TE: Tetracycline 30 UI
AK: Amikacin 30μg, TM: Tobramycin 10μg,IMP: Imipenem 10μg

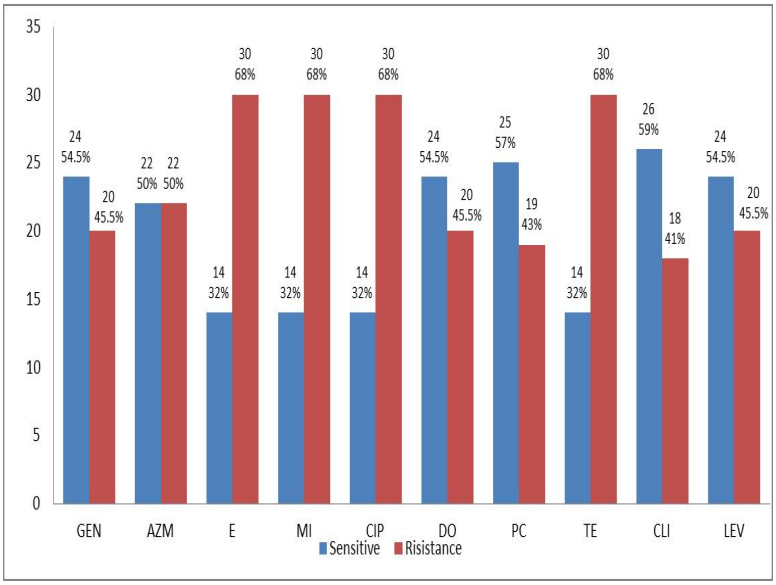

Figure 2: Forty four *S. aureus* isolates from patients infected with burns infections that were sensitive and resistance to antibiotics. GEN: gentamicin 10 mg, AZM: azithromycin 15mg, E: erythromycin 15mg, MI: minocycline 30mg, CIP: ciprofloxacin 30mg, DO: doxycycline hydrochloride 30mg, PC: piperacillin 100mg, TE: tetracycline 30mg, CLI: clindamycin 2mg, LEV: levofloxacin5mg

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Type of Resistance

The results of the current study showed that there were two resistance types of bacterial isolates from patients infected with burns infections Table 6. The antibiotic sensitivity pattern indicated that out of total 123 bacterial isolates, there were 113(92%) were MDR and 10(8%) were XDR.

The results showed that out of total 44 *S. aureus* isolates, there were 38(86%) MDR and 6 isolates (14%) XDR, out of total 28 *K. pneumonia* isolates, there were 27(96%) MDR and 1(4%) was XDR. While, out of total 26 *A. boumannii* isolates, there were 24(92%) MDR and 2(8%) were XDR, of the total 13 *P. aeruginosa* isolates, there were 12(92%) were MDR and 1(8%) was XDR. On the other hand, all 8 *E.coli* isolates and all 4 *P. mirabilis* were MDR Table 6.

Table 6: Type of resistance of bacterial isolates from patients with burns infections in this study.

Bacterial isolates	MDR	XDR	Total
S. aureus	38(86%)	6(14%)	44(36%)
K.pneumonia	27(96%)	1(4%)	28(23%)
A. boumannii	24(92%)	2(8%)	26(21%)
P. aeruginosa	12(92%)	1(8%)	13(10.5%)
E. coli	8(100%)	0	8(6.5%)
P. mirabilis	4(100%)	0	4(3%)
Total	113(92%)	10(8%)	123(100%)

Extended Spectrum Beta Lactamase Producing Gram Negative Bacteria

The results of the current study demonstrated that out of total 79 gram negative bacteria, there were 25 isolates (32%) were ESBL- producing gram negative bacteria 54 isolates (68%) were non-ESBL producing gram negative bacteria according to phenotypic detection method.

Of the 28 *K. pneumonia* isolates, there were 10(36%) were ESBL-producing bacteria and 18(64%) were non-ESBL. Out of total 26 *A. boumannii*, 11(42%) were ESBL Figure 3 and 15(58%) non-ESBL, while, of the 13 *P. aeruginosa* isolates, there were 4(31%) were ESBL and 9(69%) non ESBL. On the other hand, the results proved that, there were no any *E. coli* and *P. mirabilis* isolates recorded as ESBL Table 7.

Table 7: Total ESBL-producing gram negative bacteria in this study.

Bacterial isolates	**ESBL**	**Non ESBL**	**Total**
K.pneumonia	10(36%)	18(64%)	28(23%)
A.boumannii	11(42%)	15(58%)	26(21%)
P.aeruginosa	4(31%)	9(69%)	13(10.5%)
E.coli	0(0.0%)	8(100%)	8(6.5%)
P.mirabilis	0(0.0%)	4(100%)	4(3%)
Total	25(32%)	54(68%)	79(100%)

Figure 3: Positive result of phenotypic test of ESBL-producing *A. boumannii* isolated from patients with burn infection (Isolate No. 6)

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4. Discussion

Burn infections are a serious concern for individuals who have suffered from severe burns. According to reports, around 11 million patients need burn-related medical care every year, with approximately 10% of those burn injury patients suffering from burns covering 30% or more of their entire body surface [18]. Burn victims with infections have a fatality rate that is twice as those without infections, as a dysregulated immune system increases the risk for infection in patients. Burn injury is a major challenge for the patient's immune system, leaving them immunocompromised and vulnerable to pathogens such as nosocomial bacterial infections and multidrug-resistant pathogens [19]. Consequently, the entirety of the burn wound must be examined on a daily basis by the attending surgeon, as any change in wound appearance, with or without associated clinical changes, should be evaluated by biopsy [20]. Even so, effective topical antimicrobial chemotherapy and early burn wound excision have significantly reduced the overall occurrence of invasive burn wound infections. The wound severity and prognosis depend on various factors, such as the surface area of the burn, the degree of the burn, the patient's medical history, and their age [21].

Gram-negative bacterial infections have become a significant public health concern due to the increasing prevalence of antibiotic resistance, with many strains of bacteria exhibiting resistance to multiple classes of antibiotics. Gram-negative bacteria, such as Enterobacteriaceae, Pseudomonas, and Acinetobacter, are particularly problematic as they are often associated with serious nosocomial infections and are linked to high morbidity and mortality rates [22].

The study by Rhee et al. examined the prevalence of infections caused by four key carbapenem-resistant gram-negative pathogens in the United States, finding that these infections were predominated by Acinetobacter species. This aligns with the findings of other studies, which have highlighted the growing threat of Acinetobacter infections, with these bacteria accounting for a significant proportion of mortality due to multidrug-resistant healthcare-associated infections [23]. The high rates of antibiotic resistance among Acinetobacter isolates are particularly concerning, as they can limit the treatment options available to clinicians, leading to increased lengths of hospital stay and poorer patient outcomes [24].

Surveillance efforts are crucial for understanding the epidemiology of gram-negative, healthcare-associated infections and guiding the development of appropriate infection control measures. Phenotypic and genotypic methods for detecting resistance mechanisms, such as metallo-beta-lactamase production, are important tools for monitoring the spread of antibiotic resistance among these pathogens [25].

According to reports, around 11 million patients need burn-related medical care every year, with approximately 10% suffering from burns covering 30% or more of their entire body surface [26]. Burn injuries compromise the integumentary barrier, leaving patients immunocompromised and vulnerable to pathogens such as nosocomial bacterial infections and multidrug-resistant organisms. Patients with extensive burns in whom wound closure is difficult to achieve may develop a variety of bacterial and nonbacterial burn wound infections [27].

Effective topical antimicrobial chemotherapy and early burn wound excision have significantly reduced the overall occurrence of invasive burn wound infections, but individual patients may still develop a variety of bacterial and nonbacterial burn wound infections [28]. ESBLs are classified into several groups based on their amino acid sequence homology and they have become a global public health concern. *E.coli* and *K. pneumoniae* are the most common ESBL-producing bacterial species, although these enzymes have been detected in various other Enterobacteriaceae and Pseudomonadaceae [29]. Patients with infections caused by ESBL-producing Enterobacteriaceae should not be treated with beta-lactam antibiotics due to the high risk of therapeutic failure and increased infectiousness, which could result in death. Early detection of these multidrug-resistant bacteria is crucial in defining appropriate therapies and implementing proper infection control measures to prevent the spread of these pathogens and hospital-acquired infections or outbreaks in the community [30].

5. Conclusion

The most common bacteria that caused burn infections and had a high incidence of XDR-bacteria at Iraq's Al-Najaf Hospital were *Staphylococcus aureus*, *K. pneumonia* and *A. boumannii*. The most common bacteria that produced ESBLs were *K. pneumoniae*, *A.*

boumannii, and *P. aeruginosa*.

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References

[1] A. A. Aljanaby and I. A. Aljanaby. Prevalence of aerobic pathogenic bacteria isolated from patients with burn infection and their antimicrobial susceptibility patterns in al-najaf city, iraq-a three-year cross-sectional study. *F1000Research*, 7:1157, 7 2018. doi: 10.12688/f1000research.15088.1.

[2] W. Żwiereło, K. Piorun, M. Skórka-Majewicz, A. Maruszewska, J. Antoniewski, and I. Gutowska. Burns: Classification, pathophysiology, and treatment: A review. *International journal of molecular sciences*, 24(4):3749, 2 2023. doi: 10.3390/ijms24043749.

[3] J. L. Kiley and D. G. Greenhalgh. Infections in burn patients. *Surgical Clinics*, 103(3):427–37, 6 2023. Epub 2023 Apr 4. 10.1016/j.suc.2023.02.005.

[4] M. M. Azevedo, C. Pina-Vaz, and A. G. Rodrigues. The role of phage therapy in burn wound infections management: advantages and pitfalls. *Journal of Burn Care Research*, 43(2):336–42, 3 2022. doi: 10.1093/jbcr/irab175.

[5] R. Shahriarirad, R. Shekouhi, S. S. Nabavizadeh, M. Zardosht, S. M. Tadayon, M. Ahmadi, and A. Keshavarzi. Cohort analysis of 50.

[6] D. Church, S. Elsayed, O. Reid, B. Winston, and R. Lindsay. Burn wound infections. *Clinical microbiology reviews*, 19(2):403–34, 4 2006. doi: 10.1128/CMR.19.2.403-434.2006.

[7] M. G. Jeschke, M. E. van Baar, M. A. Choudhry, K. K. Chung, N. S. Gibran, and S. Logsetty. Burn injury. *Nature reviews Disease primers*, 6(1):11, 2 2020. doi: 10.1038/s41572-020-0145-5.

[8] M. J. Nordlund, T. N. Pham, and N. S. Gibran. Micronutrients after burn injury: a review. *Journal of Burn Care Research*, 35(2):121–33, 3 2014. doi: 10.1097/BCR.0b013e318290110b.

[9] R. F. Polse, H. M. Khalid, and W. M. Mero. Distribution of bla oxa-10, bla per-1, and bla shv genes in esbl-producing pseudomonas aeruginosa strains isolated from burn patients. *Scientific Reports*, 13(1):18402, 10 2023. doi: 10.1038/s41598-023-45417-4.

[10] M. H. Haider, T. D. McHugh, K. Roulston, L. B. Arruda, Z. Sadouki, and S. Riaz. Detection of carbapenemases bla oxa48-bla kpc-bla ndm-bla vim and extended-spectrum--lactamase bla oxa1-bla shv-bla tem genes in gram-negative bacterial isolates from icu burns patients. *Annals of Clinical Microbiology and Antimicrobials*, 21(1):18, 5 2022. doi: 10.1186/s12941-022-00510-w.

[11] Y. T. Lin. What can we learn from the dissemination of carbapenem-resistantacinetobacter baumanniiin patients with burn injury? *Journal of the Chinese Medical Association*, 80(4):189–90, 4 2017. doi: 10.1016/j.jcma.2016.12.004. Epub 2017 Feb 12.

[12] R. Ranjbar and A. Farahani. Study of genetic diversity, biofilm formation, and detection of carbapenemase, mbl, esbl, and tetracycline resistance genes in multidrug-resistant acinetobacter baumannii isolated from burn wound infections in iran. antimicrobial resistance infection control. *8:1-1. eCollection*, 2019, 12 2019. doi: 10.1186/s13756-019-0612-5.

[13] A. W. Bauer, W. M. Kirby, J. C. Sherris, et al. Antibiotic susceptibility testing by a standardized single disk method. *Am J Clin Pathol*, 45(4):493–6, 1966.

[14] Clinical and Laboratory Standards Institute (CLSI). *Performance Standards for Antimicrobial Susceptibility Testing; 32ed.* Informational Supplement. PA, USA, 2024.

[15] A. A. Aljanaby and H. M. Alhasnawi. Research article phenotypic and molecular characterization of multidrug resistant klebsiella pneumoniae isolated from different clinical sources in al-najaf province-iraq. *Pak. J. Biol. Sci.*, 20(5):217–32, 2017. doi: 10.3923/pjbs.2017.217.232.

[16] D. R. Al-janabi and A. A. Aljanaby. Comparison of escherichia coli and proteus mirabilis in patients infected with chronic pyelonephritis in al-najaf governorate, iraq. In *InBIO Web of Conferences 2024 (Vol*, p. 06006). EDP Sciences, 2024. 139. doi: 10.1051/bioconf/202413906006.

[17] A. K. Mohammad and ŸA. Aljanaby. A key role of interleukin 34 in patients with chronic kidney disease and lupus nephritis. *Egyptian Journal of Medical Microbiology*, 34(1):289–93, 1 2025. URL https://ejmm.journals.ekb.eg/article_404828_1a6de2ea99588c8061145a2c916a9e07.pdf.

[18] R. Moraga. Elucidating the need for inclusion of burn in graduate and continuing dermatologic medical education. *Archives of Dermatological Research*, 317(1):344, 2 2025. doi: 10.1007/s00403-025-03853-4.

[19] P. Wang, Q. Bai, X. Liu, M. Zhao, L. Chen, F. Hu, J. Ye, X. Chen, K. N. Wang, B. Liu, and D. Mao. Nucleus-targeting photosensitizers enhance neutrophil extracellular traps for efficient eradication of multidrug-resistant bacterial infections. *Advanced Materials*, 36(50): 2400304, 12 2024. doi: 10.1002/adma.202400304. Epub 2024 Nov 12.

[20] E. Opriessnig, H. Luze, C. Smolle, A. Draschl, R. Zrim, M. Giretzlehner, L. P. Kamolz, and S. P. Nischwitz. Epidemiology of burn injury and the ideal dressing in global burn care–regional differences explored. *Burns*, 49(1):1–4, 2 2023. doi: 10.1016/j.burns.2022.06.018. Epub 2022 Jul 1.

[21] A. Karaaslan, C. Çetin, M. T. Köle, M. Dereli, S. D. Tekol, G. Filinte, and Y. Akin. Infections in pediatric patients with burn injury: 6 years of experience. *The Pediatric Infectious Disease Journal*, 42(1):8–12, 1 2023. doi: 10.1097/INF.0000000000003741. Epub 2022 Oct 12.

[22] Y. Hu, D. Li, L. Xu, Y. Hu, Y. Sang, G. Zhang, and H. Dai. Epidemiology and outcomes of bloodstream infections in severe burn patients: a six-year retrospective study. *Antimicrobial Resistance Infection Control*, 10:1–8, 12 2021. doi: 10.1186/s13756-021-00969-w.

[23] E. K. Yeong and W. L. Huang. Risk factors for multidrug-resistant acinetobacter baumannii infections in a mass burn casualty incident. *Journal of Burn Care Research*, 40(6):823–7, 10 2019. doi: 10.1093/jbcr/irz092.

[24] D. Dehari, A. Chaudhuri, D. N. Kumar, R. Patil, M. Gangwar, S. Rastogi, D. Kumar, G. Nath, and A. K. Agrawal. A bacteriophage microgel effectively treats the multidrug-resistant acinetobacter baumannii bacterial infections in burn wounds. *Pharmaceuticals*, 16 (7):942, 6 2023. doi: 10.3390/ph16070942.

[25] M. Anvarinejad, A. Japoni, N. Rafaatpour, J. Mardaneh, P. Abbasi, M. A. Shahidi, M. A. Dehyadegari, and E. Alipour. Burn patients infected with metallo-beta-lactamase-producing pseudomonas aeruginosa: multidrug-resistant strains. *Archives of trauma research*, 3 (2), 6 2014. doi: 10.5812/atr.18182. ECollection 2014.

[26] M. Shahriari-Khalaji, M. Sattar, R. Cao, and M. Zhu. Angiogenesis, hemocompatibility and bactericidal effect of bioactive natural polymer-based bilayer adhesive skin substitute for infected burned wound healing. *Bioactive Materials*, 29:177–95, 11 2023. doi: 10.1016/j.bioactmat.2023.07.008.

[27] A. M. Lachiewicz, C. G. Hauck, D. J. Weber, B. A. Cairns, and D. van Duin. Bacterial infections after burn injuries: impact of multidrug resistance. *Clinical Infectious Diseases*, 65(12):2130–6, 11 2017. doi: 10.1093/cid/cix682.

[28] Y. Gong, P. Wang, R. Cao, J. Wu, H. Ji, M. Wang, C. Hu, P. Huang, and X. Wang. Exudate absorbing and antimicrobial hydrogel integrated with multifunctional curcumin-loaded magnesium polyphenol network for facilitating burn wound healing. *Acs Nano*, 17 (22):22355–70, 11 2023. doi: 10.1021/acsnano.3c04556. Epub 2023 Nov 6.

[29] X. Zhao, Y. Miao, F. E. Adam, H. Zhao, Z. Zhou, M. Su, R. Li, B. Yang, Z. Lv, S. Xiao, and X. Wang. Esbls-producing escherichia coli from sheep-origin: Genome-wide virulence genes identification and in vivo virulence assessment in mice and galleria mellonella. *Transboundary and Emerging Diseases*, 69(6):3606–17, 11 2022. doi: 10.1111/tbed.14729. Epub 2022 Oct 21.

[30] H. Cleland, L. M. Tracy, A. Padiglione, and A. J. Stewardson. Patterns of multidrug resistant organism acquisition in an adult specialist burns service: a retrospective review. *Antimicrobial Resistance Infection Control*, 11(1):82, 6 2022. doi: 10.1186/s13756-022-01123-w.