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Isolation and Antibiotic Resistance Profiling of Gram-Negative Bacteria Recovered from Wound and Burn Infections

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Keywords: Wounds infection, Burns Infection, Antibiotics Resistance, Gram negative bacteria.

Article History

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Abstract:

Wound infection is one of the most important factors affecting the wound healing process, so its effective control is crucial to enhance the wound healing. With the increasing prevalence of multidrug-resistant bacterial strains, preventing and treating wound infections has now become more challenging, imposing heavy medical and financial burdens on the patients. This study aimed to isolate and identify Gram-negative bacteria from wounds and burns and investigate the resistance of these bacteria to various antibiotics. In this study, Gram-negative bacteria were isolated and identified from pus samples obtained from patients suffering from wound and burn infections who were admitted to Al-Salam Teaching Hospital, Mosul General Hospital, and the Mosul Center for Burns and Plastic Surgery. The ages of patients ranged from 5 days to 75 years, included both sexes. The sampling period extended from August 28, 2024, to November 23, 2024. Bacterial isolates were identified based on cultural, morphological, microscopic characteristics, and biochemical tests. A total of 88 bacterial isolates were obtained from 54 pus samples that showed growth on MacConkey agar media for Gram-negative bacteria. Identification was further confirmed using the VITEK-2 system to ensure accurate species determination. *Pseudomonas aeruginosa* and *Enterobacter cloacae* were the most prevalent

species, with 28 isolates for each one(31.81%), followed by *Klebsiella pneumoniae* with 10 isolates (11.36%), *Klebsiella aerogenes* with 6 isolates (7%), *Escherichia coli* with 7 isolates (8%), and *Proteus mirabilis*, *Proteus vulgaris*, and *Raoultella ornithinolytica* with 2 isolates each (2.20%). Additionally, *Acinetobacter baumannii*, *Serratia marcescens*, and *Salmonella spp.* were each represented by 1 isolate (1. 13%). Antibiotics susceptibility testing revealed a high level of resistance among Gram-negative bacteria to cephalosporin antibiotics, with resistance rates of 95.5% for ceftazidime, and 93% for both ceftriaxone and cefotaxime. Moreover, macrolide antibiotics, specifically azithromycin, showed a resistance rate of 75%. In contrast, chloramphenicol demonstrated the highest antibacterial efficacy among the tested antibiotics against Gram-negative isolates.

Keywords: Wounds infection, Burns Infection, Antibiotics Resistance, Gram negative bacteria.

عزل وتحديد مقاومة المضادات الحيوية للبكتيريا السالبة الغرام المعزولة من الجروح والحروق

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الخلاصة:

تُعدُّ عدوى الجروح من أهم العوامل المؤثرة على عملية التئامها، لذا فإن السيطرة عليها بفاعلية أمرٌ بالغ الأهمية لتعزيز عملية التئامها. ومع تزايد انتشار سلالات البكتيريا المقاومة للأدوية المتعددة، أصبحت الوقاية من عدوى الجروح وعلاجها أكثر صعوبة، مما يُثقل كاهل المرضى بأعباء طبية ومالية باهظة. هدفت هذه الدراسة إلى عزل وتحديد البكتيريا سالبة الغرام من الجروح والحروق ودراسة مقاومة هذه البكتيريا للمضادات الحيوية المختلفة. تضمنت هذه الدراسة عزل وتشخيص البكتريا السالبةا لغرام المعزولة من عينات القيح التي جمعت من المرضى المراجعين الى مستشفيات السلام التعليمي ومستشفى الموصل العام ومركز الموصل للحروق والجراحة التجميلية المصابين بالتهابات الجروح والحروق وبأعمار تراوحت من (٥ يوم -٧٥ عام) ولكلا الجنسين للمدة ٢٠٢٤\٨\٢٨ لغاية ٢٠٢٤\١١\٢٣ ،تم تشخيص العُزلات البكتيرية بالاعتماد على الصفات الزرعية، الظاهرية، المجهرية، الاختبارات الكيموحيوية تم الحصول على (٨٨) عزلة من مجموع (54) عينة قيح أعطت نموا على وسط اكار الماكونكي والانتخابية للبكتريا السالبة لغرام وكانت بكتريا *p. aeruginosa* و *E. cloacae*أكثر انتشاراً ٢٨عزلة بكتيرية وبنسبة (٣١,٨١٪) يليه بكتريا *K. pneumoniae* ١٠عزلة وبنسبة (١١,٣٦%) يليه بكتريا *K. aerogenes* ٦عزلة بنسبة (٧٪) يليه بكتريا *E. coli* ٧عزلة وبنسبة (٨٪) يليه بكتريا *P. mirabilis*، *P. vulgaris, R. ornithinolytica*٢(٢,٢٠٪) يليه بكتريا *A. baumannii ,S. marcescens,Salmonella spp* بنسبة ١(١,١٣٪). وتم دعم نتائج التشخيص باستخدام نظام فايتك -٢ للتاكد من تحديد الأنواع بعدها تم اجراء فحص مقاومة وحساسية

العزلات للمضادات الحيوية بينت النتائج امتلاك الجراثيم السالبة لغرام مقاومة عالية لمضادات السيفالوسبورينات (*Ceftazidim*) بنسبة ٩٥,٥٪ و(*Ceftraxone* و*Cefotoxime*) بنسبة ٩٣٪ ومضادات المايكروليدات المتمثلة بالـ *Azythromycin* بنسبة ٧٥٪. كذلك أظهرت النتائج ان مضادات الكلورمفينيكولات المتمثلة بالمضاد *Chlormphenicol* كانت من أكثر المضادات فعالية ضدالبكترياالسالبة لغرام.

الكلمات المفتاحية: التهاب الجروح، التهاب الحروق، مقاومة المضادات الحيوية، الجراثيم السالبة لغرام.

1. Introduction:

Wound infection is one of the most important factors affecting the wound healing process, so its effective control is crucial to enhance the wound healing process. With the increasing prevalence of multidrug-resistant bacterial strains, preventing and treating wound infections has now become more challenging, imposing heavy medical and financial burdens on the patient [1]

Wound and burn injuries are among the most difficult problems that hinder surgical medical progress and cause death for patients because they destroy tissues and lose the skin barrier. The presence of dead tissue, the presence of antibiotic-resistant microbes, the ability of these microbes to form biofilms, and the weakness of antibiotic treatment - all these factors lead to delayed recovery of the patient, especially patients carrying other chronic systemic diseases [2,3,4]

Over time, microorganisms were exposed to antibiotics, which led to bacteria adapting to resist these antibiotics. This adaptation, along with the lack of drug development, has led to a reduction in treatment options against bacterial infections [5] The World Health Organization (WHO) has stated that the emergence and spread of antibiotic-resistant bacteria is one of the most important health problems of our time and poses a threat to the treatment of diseases. This leads to an increase in the patient's length of stay in the hospital and an increase in treatment costs [6]

Some previous studies have shown that the most common Gram-negative bacteria that have been identified as pathogens causing wound and burn infections are *Pseudomonas aeruginosa*, *Enterobacter cloacae*, *Klebsiella pneumoniae*, *Klebsiella aerogenes*, and *E. coli* .[7,8,9]

2. Material and methods:

2.1 Sample Collection: 103 pus samples were collected, from patients with wound and burn infections (including, both male and female, who were admitted to Mosul hospitals (Mosul General Hospital, Al-Salam Teaching Hospital, and Mosul Center for Burns and Plastic Surgery) between 28, August, 2024 and 23, November, 2024[10].

2.2 Isolation and diagnosis: Samples were cultured on plates containing MacConkey agar medium, and then selective media were used to identify bacterial species, such as cetrimidine agar and eosin methyl blue agar. The plates were then incubated for 24 hours at 37°C. The morphological characteristics of the cultures on the plates and microscopic examinations were used to determine the shape and arrangement of these bacterial species. Then, biochemical tests were used, which were (catalase, oxidase, and IMVC tests) [10]. To confirm the diagnosis results, the Vitek-2 system produced by the French company (Biomerrux) was used (We learned that the diagnosis with the Vitek-2 device was performed in an external laboratory).

- **2.3 Antibiotics susceptibility test**: The disk diffusion method based on the Kirby-Bauer Disk method [11] was used to examine the susceptibility of bacterial isolates to the antibiotics shown in Table 1, it was Compared the antibiotic susceptibility test results with the standard reference tables, the CLSI table, in terms of bacteria being sensitive, resistant, or intermediate which were prepared by the Turkish company (Bioanlyase). Mueller-Hinton medium prepared by the Indian company (Himedia) was used in this test and was prepared according to the company's instructions. the bacterial suspension was prepared and adjusted to match the 0.5 McFarland standard. Then, 100 µL of the suspension was spread evenly on the surface of Mueller-Hinton agar using a sterile cotton swab. After allowing the plates to dry for about 15 minutes, antibiotic discs were placed on the surface and the plates were incubated at 37°C for 18–24 hours.

Table 1: Antibiotics used in the study

Tablet/Concentration Microgram	Code	Antibiotic	Antibiotic Classes
10µg/disc	CRO	Ceftriaxone	Cephalosporin's
10µg/disc	CTX	Cefotaxime	
30µg/disc	CAZ	Ceftazidme	
10µg/disc	MEM	Meropenem	Carbapenems
10µg/disc	IPM	Imipenem	
10µg/disc	GN	Gentamycin	Aminoglycosides
15µg/disc	AZM	Azithromycin	Macrolides
10µg/disc	CIP	Ciprofloxacin	Fluoroquinolones
10µg/disc	TE	Tetracycline	Tetracycline's
10µg/disc	C	Chloramphenicol	Chloramphenicol

3. Results and Discussion

Laboratory and phenotypic diagnosis: After culturing the samples on MacConkey agar medium and incubating for 24 hours at a temperature of 37°C, as shown in Figure (1).



E. coli ***P. aeruginosa*** ***E. cloacae***

Figure 1: McConkey agar

Gram stain microscopy was performed to identify the shapes and arrangement of bacteria. Then, the lactose fermented samples, which appeared pink in color, were transferred to MacConkey agar medium and cultured on eosin methyl blue agar medium for the purpose of identifying *E. coli* isolates, as shown in Figure (2).



Figure 2: *E. coli* bacteria on Eosin blue medium

While the pale-colored isolates on MacConkey agar were cultured on cetrimid agar medium for the purpose of diagnosing *P. aeruginosa* isolates, which appear green as a result of their production of pyocyanin pigment, as shown in Figure (3).

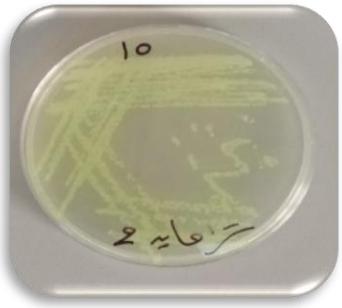


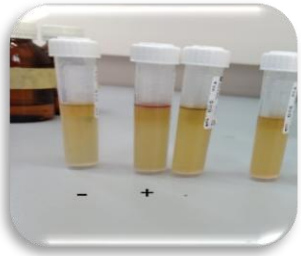
Figure 3: P. aeruginosa on cetrimid agar

The results of the biochemical tests are shown in Table, (2) and Figure, (4).

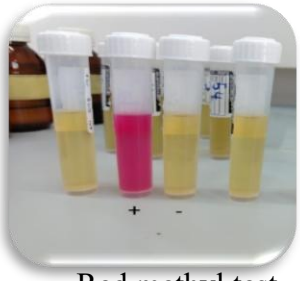
Table2: the biochemical tests of bacterial isolates

IMVIC Test				Catalase	Oxidase	the name of the bacteria
IND	MR	VP	CIT			
-	-	-	+	+	+	*P .aeruginosa*
+	+	-	-	+	-	*E.coli*
-	+	-	+	+	-	*P .mirabilis*
-	+	-	-	+	-	*k. pneumoniae*
-	-	+	+	+	-	*E .cloacae*

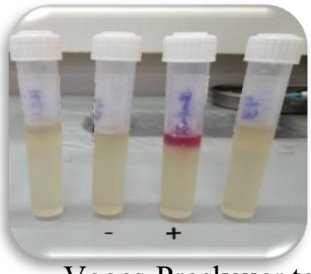
(+) positive, (-) negative



Indole test



Red methyl test



Voges-Proskauer test





Citrate utilization test Oxidase test for the right and catalase test for the left

Figure 4: Results of biochemical tests

It was identical to the approved specifications for the diagnosis of Gram-negative bacteria shown in [10]. Then, all the isolates isolated in this study were confirmed using the Vitek-2 system, as the results showed that all isolates were consistent with the traditional diagnostic methods and showed a level of diagnostic probability between (89%-95%) for *Enterobacter cloacae* isolates and (86%-99%) for *Klebsiella pneumoniae* isolates and (93%) for *Pseudomonas aeruginosa* isolates and (94%-95%) for each of *Klebsiella aerogenes* and *E. coli* and (91%) for *Raoultella ornithinolytica* isolates and (99%) for each of Proteus mirabilis, Proteus vulgaris, *Acinetobacter baumannii* and *Serratia marcescens* isolates

Bacterial Isolation Out of a total of 103 samples, 54 samples were obtained that showed growth on Macon key agar and selective media for Gram-negative bacteria representing a percentage of (53.39%). These samples were distributed among (23) wound samples (17 male samples and 6 female samples). As for burn samples, there were (31) samples, distributed among (13 male samples and 18 female samples) as in table 3.

Table 3: Distribution of samples between males and females

Insulation source	Sex	Culture positive	Culture negative	Total number of samples
Wounds	Male	17	16	33
	Female	6	12	18
Burns	Male	13	10	23
	Female	18	11	29
The total	-	54	49	103

The total number of bacterial isolates obtained was 88 (This number of bacterial isolates is due to the growth of more than one type of bacteria in a single sample) and these results were close to the study [8]. In the city of Maysan the percentage in his study reached (86.9%), and the study [7] If their isolation rate is (81.7) out of a total of 100 samples. and the results are different [12] The isolation rate was 132% of the total 800 samples and the study [13] The isolation rate was 100% for a total of 40 samples. The results showed that the bacterial isolates were distributed among the different types, with 28 isolates (31.81%) for each of *Pseudomonas aeruginosa* and *Enterobacter cloaca*, 10 isolates (11.39%) for *Kleebsiella pneumonia*, 6 isolates (7%) for *Klebsiella aerogenes*, 7 (8%) for *E. coli*, 2 (2.20%) for each of *Proteus*

vulgaris, *Proteus mirabilis* and *Raoultella ornithinolytica*, 1 (1.13%) for each of Acinetobacter baumanni, Serratia marcescens and *Salmonella spp*., as shown in Table (4).

Table 4: Number and percentages of Gram-negative bacteria isolated from patients with wounds and burns

No.	Percentage of total Gram-negative bacteria	number	Gram-negativebacterial species
1	31.81%	28	*Pseudomonas aeruginosa*
2	31.81%	28	*Enterobacter cloacae*
3	11.36%	10	*Kleebsiella pneumoniae*
4	7%	6	*Klebsiella aerogenes*
5	8%	7	*E.coli*
6	2.20%	2	*Proteus vulgaris*
7	2.20%	2	*Proteus mirabils*
8	2.20%	2	*Raoultella ornithinolytica*
9	1.13%	1	*Acinetobacte baumanni*
10	1.13%	1	*Serratia marcescens*
11	1.13%	1	*Salmonella spp*
	100%	88	the total

The results showed that *P. aeruginosa* isolates were the most prevalent. This percentage was close to a study in the city of Maysan **[8].** Also, a study in Libya, **[7]** The results of this study did not agree with a study conducted in Dohuk, **[14]** In other studies in India and Libya, **[12,13]** respectively. The reason for the dominance of this bacterial species is that *P. aeruginosa* is one of the most common Gram-negative bacteria associated with hospital-acquired infections. This is due to its possession of multiple virulence factors, including the possession of biofilms, efflux pumps, and its ability to resist various antibiotics due to the possession of mobile genetic elements such as jumping genes (Trausposouses, Integrones,Plasmids) **[9,15,16]** As for the *Enterobacter cloacae* isolates, their percentage within the total number of isolates reached (31.81%) within the total negative group. This percentage was different from a previous study **[8,15]** respectively *Enterobacter spp*. are anaerobic Gram-negative bacteria widely distributed in nature and have raised increasing concern in recent years due to their association with hospital-acquired infections, especially in immunocompromised individuals **[17].**

In the present study, *Klebsiella pneumonia* bacteria were isolated at a rate of 10 (11.39%) and *Klebsiella aerogenes* at a rate of 6 (7%). These results were consistent with what was reached by a study in Libya, [7] It is consistent with another study [13] It was slightly higher than another study [8] This genus plays an active role in causing burn and wound infections. It is found in hospitals and is considered a major pathogen due to its possession of many genes that have the ability to resist antibiotics [18]. As for the *E. Coli* species, the isolation rate was 7 (8%). This result was similar to a local study and another Arab study [7,8] respectively It contradicted another study, [12] The digestive system is the natural home for *E. Coli*, but infection occurs after it leaves the system [7] Or as a result of low immunity, especially for immunocompromised patients, the elderly, and children. As for the genus *Proteus spp*, *Proteus vulgaris* was isolated at a rate of 2 (2.20%) and *Proteus mirabilis* at a rate of 2 (2.20%), which was close to the study [12] Contrasting with another study [8]. Factors contributing to differences in bacterial isolation rates between countries vary, including environment, health practices, antibiotic use, bacterial genetic diversity, social and economic factors, and laboratory techniques.

Antibiotics sensitivity test: A sensitivity test was conducted on the (88) bacterial isolates under study, which caused wound and burn infections, against 10 antibiotics, as shown in Table (5). The results showed high resistance to cephalosporin's, with 84% (95.5%) against Ceftazideme and 82% (93%) against both Ceftriaxone and Cefotaxime. Regarding carbapenem antibiotics, Meropenem was more effective against the isolates, with a sensitivity rate of 37%, compared to Imipenem, which the isolates showed high resistance to, reaching 69.3%) Regarding aminoglycosides represented by the antibiotic Gentamycin, the isolates showed medium resistance, as the resistance rate reached (69%). As for macrolides represented by the antibiotic Azythromycin, the resistance rate of the isolates was (75%), and (72.8%) for the antibiotic Ciprofloxacin from fluoroquinolones, while the resistance rate towards tetracyclines represented by the antibiotic Tetracycline was low, reaching (47.7%). As for the results of the sensitivity of the isolates towards chloramphenicol represented by the antibiotic Chlormphenicol, the number of sensitive isolates reached 53 isolates, at a rate of (60%).

Table 5: Total numbers and percentages of bacterial isolates resistant and sensitive to antibiotics

No.	Antibiotic	Antibiotic Classes	sensitive isolates		Moderate isolates		resistant isolates		code
			(%)	No.	(%)	No.	(%)	No.	
1.	*Ceftriexone*	Cephalosporin's	7%	6	0%	0	93%	82	CRO
	Cefotaxime		7%	6	0%	0	93%	82	CTX
	Ceftazidem		4.5%	4	0%	0	95.5%	84	CAZ
2.	*Meropenem*	Carbapenems	37%	33	7%	6	56%	49	MEM
	Imipenem		27.3%	24	3.4%	3	69.3%	61	IPM
3.	*Gentamycin*	Aminoglycosides	16%	14	15%	13	69%	61	GN
4.	*Azythromycin*	Macrolides	25%	22	0%	0	75%	66	AZM
5.	*Ciprofloxacin*	Fluoroquinolones	13.6%	12	13.6%	12	72.8%	64	CIP
6.	*Chlormphenicol*	Chloramphenicol	60%	53	8%	7	32%	28	C
7.	*Tetracycline*	Tetracycline's	40.95%	36	11.35%	10	47.7%	42	TE

The above results show that the antibiotic Chloramphenicol was one of the most effective antimicrobials against Gram-negative bacterial isolates. The reason is due to the mechanism of action of Chloramphenicol, which works to prevent the synthesis of proteins inside the cell [20] In general, the results of the study showed the resistance of negative bacteria to most antibiotics, especially cephalosporin's. This result is consistent with another study (which confirmed in their results the resistance of most negative bacteria to most of the antibiotics used) [13,14,21] The increasing, indiscriminate, and irregular use of antibiotics leads to the failure to kill bacteria, making them more resistant and encouraging them to develop resistance mutations, which increases the incidence of hospital infections. Despite efforts to combat hospital infections, the morbidity and mortality rates are very high, increasing healthcare costs and thus leading to an economic crisis. The problem is further complicated by the emergence of multidrug-resistant microorganisms that are difficult to treat in the hospital environment [19,22] Studies have shown that patients with medical records who take antibiotics for long periods may kill the natural flora that acts as the body's immune system and cause the death of sensitive bacteria. This leaves only resistant bacteria that carry resistance genes. These genes can be spread via plasmids to other types of bacteria. This results in the proliferation of antibiotic-resistant bacteria at the expense of the body's natural flora [23] Table (6) shows the results of antibiotics sensitivity for each isolate separately.

Table 6: shows the biological response of Gram-negative bacteria to the antibiotics used under study

Sensitivity Pattern		C N (%)	CIP N (%)	AZM N (%)	TE N (%)	GN N (%)	IPM N (%)	MEM N (%)	CAZ N (%)	CTX N (%)	CRO N (%)
S I R	*P. aeruginosa* (N=28)	9(32%) 0(0%) 19(68%)	4(14%) 5(18%) 19(68%)	3(11%) 0(0%) 25(89%)	8(28.5%) 2(7%) 18(64.5%)	4(14%) 0(0%) 24(86%)	8(28%) 1(4%) 19(68%)	12(43%) 0(0%) 16(57%)	1(3.5%) 0(0%) 27(96.5%)	1(3.5%) 0(0%) 27(96.5%)	1(3.5%) 0(0%) 27(96.5%)
S I R	*E. cloacae* N=28	20(71%) 3(11%) 5(18%)	1(4%) 2(7%) 25(89%)	4(14%) 0(0%) 24(86%)	11(39%) 5(18%) 12(43%)	2(7%) 5(18%) 21(75%)	2(7%) 0(0%) 26(93%)	3(11%) 3(11%) 22(78%)	0(0%) 0(0%) 28(100%)	1(3.5%) 0(0%) 27(96.5%)	1(3.5%) 0(0%) 27(96.5%)
S I R	*K.pneumoniae* N=10	9(90%) 1(10%) 0(0%)	4(40%) 2(20%) 4(40%)	6(60%) 0(0%) 4(40%)	6(60%) 1(10%) 3(30%)	5(50%) 2(20%) 3(30%)	9(90%) 0(0%) 1(10%)	8(80%) 0(0%) 2(20%)	2(20%) 0(0%) 8(80%)	2(20%) 0(0%) 8(80%)	2(20%) 0)0%) 8(80%)
S I R	*K .aerogenes* N=6	3(50%) 1(17%) 2(33%)	1(17%) 0(0%) 5(83%)	1(17%) 0(0%) 5(83%)	1(17%) 0(0%) 5(83%)	0(0%) 2(33%) 4(67%)	1(17%) 0(0%) 5(83%)	2(33%) 0(0%) 4(67%)	0(0%) 0(0%) 6(100%)	0(0%) 0(0%) 6(100%)	0(0%) 0(0%) 6(100%)
S I R	*E. coli* N=7	7(100%) 0(0%) 0(0%)	1(14%) 0(0%) 6(86%)	5(71%) 0(0%) 2(29%)	5(71%) 0(0%) 2(29%)	1(14%) 2(29%) 4(57%)	1(14%) 0(0%) 6(86%)	2(48.5%) 3(43%) 2(28.5%)	0(0%) 0(0%) 7(100%)	0(0%) 0(0%) 7(100%)	0(0%) 0(0%) 7(100%)
S I R	*P.miabils* N=2	1(50%) 1(50%) 0(0%)	1(50%) 0(0%) 1(50%)	1(50%) 0(0%) 1(50%)	0(0%) 1(50%) 1(50%)	1(50%) 0(0%) 1(50%)	1(50%) 0(0%) 1(50%)	1(50%) 0(0%) 1(50%)	0(0%) 0(%) 2(100%)	0(0%) 0(0%) 2(100%)	0(0%) 0(0%) 2(100%)
S I R	*P. vulgaris* N=2	1(50%) 0(0%) 1(50%)	0(0%) 0(0%) 2(100%)	0(0%) 0(0%) 2(100%)	0(0%) 1(50%) 1(50%)	0(0%) 1(50%) 1(50%)	0(0%) 1(50%) 1(50%)	1(50%) 0(0%) 1(50%)	0(0%) 0(0%) 2(100%)	0(0%) 0(0%) 2(100%)	0(0%) 0(0%) 2(100%)
S I R	*Raoultella ornithinolytica* N=2	1(50%) 1(50%) 0(0%)	0(0%) 1(50%) 1(50%)	1(50%) 0(0%) 1(50%)	0(0%) 0(0%) 2(100%)	0(0%) 0(0%) 2(100%)	0(0%) 1(50%) 1(50%)	2(100%) 0(0%) 0(0%)	0(0%) 0(0%) 2(100%)	0(0%) 0(0%) 2(100%)	0(0%) 0(%) 2(100%)
S I R	*Acinetobacter baumanni* N=1	0(%) 0(0%)	0(0%) 0(0%)	0(0%) 0(0%)	1(100%) 0(0%) 0(0%)	0(0%) 0(0%)	0(0%) 0(0%)	0(0%) 0(0%)	0(0%) 0(0%) 1(100%)	0(0%) 0(0%) 1(100%)	0(0%) 0(0%) 1(100%)

		1(100%)	1(100%)	1(100%)		1(100%)	1(100%)	1(100%)			
S I R	*Serratia marcescens* N=1	1(100%) 0(0%) 0(0%)	1(100%) 0(0%) 0(0%)	0(0%) 0(0%) 1(100%)	1(100%) 0(0%) 0(0%)	0(0%) 1(100%) 0(0%)	1(100%) 0(0%) 0(0%)	1(100%) 0(0%) 0(0%)	0(0%) 0(0%) 1(100%)	1(100%) 0(0%) 0(0%)	1(100%) 0(0%) 0(0%)
S I R	*Salmonella spp* N=1	1(100%) 0(0%(0(0%)	0(0%) 1(100%) 0(0%)	1(100%) 0(0%) 0(0%)	1(100%) 0(0%) 0(0%)	1(100%) 0(0%) 0(0%)	1(100%) 0(0%) 0(0%)	1(100%) 0(0%) 0(0%)	1(100%) 0(0%) 0(0%)	1(100%) 0(0%) 0(0%)	1(100%) 0(0%) 0(0%)

P. aeruginosa isolates showed high resistance to cephalosporin antibiotics. The reason is due to their possession of mechanisms to resist these antibiotics, including carrying a chromosomal gene that encodes *AmpC*, an enzyme capable of breaking down cephalosporins, including the second and third generation, and their possession of efflux pumps that work to expel antibiotics outside the cells. Lack of permeability occurs due to mutations or a decrease in the secretion of Porins, as the loss or mutation of the *oprD* gene leads to strong resistance to cephalosporins. Mutations in beta-lactam-binding proteins such as PBP3 affect the effectiveness of cephalosporin antibiotics. Bacteria can also obtain ESBL genes through horizontal transfer (plasmids), thus acquiring resistance to the third and fourth generation of cephalosporins. Finally, *P. aeruginosa* forms biofilms that block and reduce interaction with antibiotics **[24]** *E. caloaceae* isolates also showed high resistance to cephalosporin's, as these bacteria possess an inducible chromosomal gene *ampC*, which when mutated with other genes such as *ampD* or ampR leads to the production of the AMPC enzyme, which destroys the third generation of cephalosporin's. Resistance genes may be transferred to them via plasmids, making them more resistant. They may acquire mutations that result in the loss or reduction of the outer membrane, which increases resistance. They possess efflux pumps **[25].** *K. pneumoniae*, *E. Coli*, and *K. aerogenes* isolates have also shown resistance to cephalosporin antibiotics due to their formation of biofilms, the possession of efflux pumps, the production of beta-lactamase enzymes, or transmission via plasmids from other bacteria and mutations that lead to reduced permeability **[26,27,28].**

5. Conclusions

The results of the study showed that Gram-negative bacteria are among the main and common causes of wound and burn infections, and the most common isolates were: *Pseudomonas aeruginosa*, *Enterobacter cloacae Kleebsiella pneumonia*, *Klebsiella aerogenes*,

E. coli. These isolates showed a significant difference in their sensitivity to antibiotics, as they showed high resistance to a number of antibiotics, especially the cephalosporin class, and some isolates showed multi-drug resistance. This indicates the spread of resistant strains that pose a therapeutic challenge in the hospital environment. On the other hand, it was noted that some antibiotics, such as chloramphenicol and tetracycline, showed relative effectiveness against some isolates. These results indicate a need to reduce the indiscriminate use of antibiotics and recommend intensifying infection control programs and enhancing awareness of sound health practices within surgical and burn units. To reduce the spread of resistant bacteria.

References

[1] B. Wang, L. Du, B. Dong, E. Kou, L. Wang, and Y. Zhu, Current knowledge and perspectives of phage therapy for combating refractory wound infections. Int. J. Mol. Sci., 2024; 25: 5465, [Online]. Available: https://doi.org/10.3390/ijms25105465

[2] J. M. R. Alshara, Isolation and identification of bacterial wound infection isolates and their antibiotic susceptibility pattern, Al-Kufa Univ. J. Biol., 2018; 10(2): 49–63, doi: 10.36320/ajb/v10.i2.8126.

[3] P. Gupta, H. S. Singh, V. K. Shukla, G. Nath, and S. K. Bhartiya, Bacteriophage therapy of chronic nonhealing wound: Clinical study, Int. J. Low Extrem. Wounds, 2019, 18(2): 171–175, doi: 10.1177/1534734619835115.

[4] D. P. Nichols, S. Caceres, L. Caverly, C. Fratelli, S. H. Kim, K. C. Malcolm, et al., Effects of azithromycin in Pseudomonas aeruginosa burn wound infection, J. Surg. Res., 2013; 183(2): 767–776, 2013, doi: 10.1016/j.jss.2013.02.003.

[5] S. Dhingra, N. A. A. Rahman, M. R. Peile, M. Sartelli, M. A. Hassali, T. Islam, and M. Haque, Microbial resistance movements: an overview of global public health threats posed by antimicrobial resistance, and how best to counter, Front. Public Health, 2020; 8, 535668, doi: 10.3389/fpubh.2020.535668.

[6] V. Nagvekar, S. Sawant, and S. Amey, Prevalence of multidrug-resistant Gram-negative bacteria cases at admission in a multispeciality hospital, J. Glob. Antimicrob. Resist., 2020; 22: 457–461, doi: 10.1016/j.jgar.2020.02.030.

[7] A. M. Saeed and A. S. Azab, Identification of bacterial species causing wound infections in patients at Sabratha Hospital in western Libya, Int. Multiling. J. Sci. Technol., 2020; 10(5).

[8] R. Hateet, Isolation and identification of some bacteria contemn in burn wounds in Misan, Iraq, Arch. Razi Inst., 2021; 76(6): 1665–1670, doi: 10.22092/ari.2021.350367.1833.

[9] R. M. Younis and R. M. Faisal, Plasposon mutagenesis in Pseudomonas aeruginosa isolates illustrates the role of ABC transporter in intrinsic resistance to antibiotics, J. Appl. Nat. Sci.,2024; 16(3). doi: 10.31018/jans. v16i3.5856.

[10] P. M. Tille, Bailey & Scott's Diagnostic Microbiology, 1st ed., Philadelphia: Elsevier Health Sciences, 2015.

[11] P. M. Tille and S. Bailey, Diagnostic Microbiology, Missouri: Elsevier, 2014, pp. 202–927.

[12] A. Kurhade, S. Akulwar, M. Mishra, G. Kurhade, A. Justiz-Vaillant, K. Kurhade, S. Vuma, and S. Lakhdive, Bacteriological study of post-operative wound infections in a tertiary care hospital, J. Bacteriol. Parasitol., 2015; 6(6): 1000251, doi: 10.4172/2155-9597.1000251.

[13] M. Rotob and M. Abubakr, Study of bacteria causing surgical site infections at Misrata Central Hospital and evaluation of their antibiotic susceptibility, Acad. J. Sci. Publ. (AJSP), 2020; 26, Dec. 2, Available from: http://www.ajsp.ne

[14] A. M. Ahmad, Detection of the antibiotyping patterns of the most common bacterial pathogens susceptible to different antimicrobial agents causing wound infections in Duhok, Iraq, J. Univ. Anbar Pure Sci. (JUAPS), 2021; 15(1):21–25, doi: 10.37652/JUAPS.2021.15.1.3.

[15] I. K. F. Abdullah, Phenotypic and molecular study of efflux pumps and their inhibitors in some Gram-negative bacteria isolated from burn patients in Mosul city, M.S. thesis, Univ. of Mosul, College of Education for Women, Mosul, Iraq, 2023.

[16] N. D. Hameed, L. H. Mahdi, and K. H. Rasool, Antibiotic sensitivity and biofilm formation in Pseudomonas aeruginosa isolated from wound infections in Baghdad City, J. Coll. Basic Educ., 2024; 30(124): 43–56, 2024, doi: 10.35950/cbej.v30i124.11593.

[17] S. Santajit and N. Indrawattana, Mechanisms of antimicrobial resistance in ESKAPE pathogens, Biomed Res. Int.,2016; 2016: 2475067, doi: 10.1155/2016/2475067.

[18] Al-Gangrene, Comprehensive Knowledge Encyclopedia [Internet]. 2025; Available from: https://www.marefa.org.

[19] L. Kakoullis, E. Papachristodoulou, P. Chra, and G. Panos, Mechanisms of antibiotic resistance in important Gram-positive and Gram-negative pathogens and novel antibiotic solutions, Antibiotics, 2021; 10(4): 415, doi: 10.3390/antibiotics10040415.

[20] D. Chika, Chloramphenicol, MicrobiologyClass.net [Internet], Aug. 27, 2023. [cited: Jun. 28, 2025]. Available from: https://www.microbiologyclass.net

[21] S. Ali and M. Assafi, Prevalence and antibiogram of Pseudomonas aeruginosa and Staphylococcus aureus clinical isolates from burns and wounds in Duhok City, Iraq, J. Infect. Dev. Ctries., 2024; 18(1): 82–92, doi: 10.3855/jidc.18193.

[22] W. Bereket, K. Hemalatha, B. Getenet, T. Wondwossen, A. Solomon, A. Zeynudin, and S. Kannan, Update on bacterial nosocomial infections, Eur. Rev. Med. Pharmacol. Sci., 2012; 16(8): 1039–1044.

[23] K. Suryawan, I. S. Iswari, N. A. Tarini, N. N. D. Fatmawati, and N. S. Budayanti, Bacterial and antibiotic sensitivity patterns among Klebsiella pneumoniae patients at Sanglah Hospital Denpasar, Bali, Int. J. Med. Rev. Case Rep., 2020; 4(9): 1–7, doi: 10.5455/IJMRCR.bacterial-antibiotics.

[24] B. Schwartz, K. Klamer, J. Zimmerman, P. B. Kal_Pradhan, and A. Bhargava, Multidrug resistant Pseudomonas aeruginosa in clinical settings: a review of resistance mechanisms and treatment strategies, Pathogens, 2024; 13(11), doi: 10.3390/pathogens13110975.

[25] R. K. Shields, A. Iovleva, E. G. Kline, A. Kawai, C. L. McElheny, and Y. Doi, Clinical evolution of AmpC-mediated ceftazidime-avibactam and cefiderocol resistance in

Enterobacter cloacae complex following exposure to cefepime, Clin. Infect. Dis., 2020; 71(10): 2713–2716, doi: 10.1093/cid/ciaa355.

[26] Y. Li, S. Kumar, L. Zhang, and H. Wu, Characteristics of antibiotic resistance mechanisms and genes of Klebsiella pneumoniae, Open Med. (Wars), 2023; 18(1): 20230707, doi: 10.1515/med-2023-0707.

[27] J. Intra, D. Carcione, R. M. Sala, C. Siracusa, P. Brambilla, and V. Leoni, Antimicrobial resistance patterns of Enterobacter cloacae and Klebsiella aerogenes strains isolated from clinical specimens: a twenty-year surveillance study, Antibiotics (Basel), 203; 12(4). doi: 10.3390/antibiotics12040775.

[28] M. M. Walker, J. A. Roberts, B. A. Rogers, P. N. A. Harris, and F. B. Sime, Current and emerging treatment options for multidrug-resistant Escherichia coli urosepsis: a review, Antibiotics (Basel), 2022; 11(12): art. no. 1821, doi: 10.3390/antibiotics11121821.