National Journal of Biological Sciences

Received: 18th June, 2025
Revised: 22nd August, 2025
Accepted: 30th October, 2025
Published: 29th December, 2025

DOI: https://doi.org/10.37605/v6i2/1

RESEARCH ARTICLE

TITLE:

ANTIBIOTIC RESISTANCE OF ISOLATED BACTERIA FROM BURN INFECTIONS

Authors: Aneeqa Shafqat[1], Sumbal Nazir[1*] Ishrat Perveen[2], Muhammad Usama Rehman[3]

AFFILIATIONS

[1] School of Biology, Minhaj University Lahore

[2]Food and Biotechnology Research Centre, Pakistan Council of Scientific and Industrial Research Centre, Lahore, Pakistan.

[3]Department of Biosciences, COMSATS University Islamabad.

[*]**Corresponding author:** sumbalnazir.zoology@mul.edu.pk

ANTIBIOTIC RESISTANCE OF ISOLATED BACTERIA FROM BURN INFECTIONS

Aneeqa Shafqat[1], Sumbal Nazir[1*] Ishrat Perveen[2], Muhammad Usama Rehman[3]

Email: sumbalnazir.zoology@mul.edu.pk

Abstract

Objectives: Bacterial colonies proliferate in wounds and cuts of burn infections. These bacterial strains are the main cause of burn infections because they enter the body and multiply, leading to infection. The present study was to isolate the bacterial strains from the burn infected patients and also find the antibiotic susceptibility of the isolated bacterial strains.

Methods: Eight bacterial strains i.e., *Staphylococcus aureus, Klebsiella oxytoca, P. aeruginosa*,

Coagulase negative Staphylococcus species, Proteus mirabilis,MRSA, and other *Pseudomonas species* were detected from burn wounds infections. Fifteen burn patients of both sexes had their burn wounds sampled. The average age of the four female and eleven male patients hospitalized in burn unit of Jinnah hospital Lahore was between 17 and 58 years old.

Results: The best dominant bacterial species was *Staphylococcus aureus* (90.90%) followed by *Coagulase-negative Staphylococcus species* (36.36%), *Proteus mirabilis* (36.36%), *Pseudomonas aeruginosa* (54.54%), *Klebsiella oxytoca* (63.63%), *Methicillin resistant Staphylococcus aureus (MRSA)* (18.18%), *Pseudomonas species* (54.54%). Antimicrobial susceptibility testing was carried out to the burn *infections* bacterial isolates. Gentamicin was found to be the most effective drug against most of the Gram positive and Gram negative isolates Tetracycline least effective. Amikacin and Ciprofloxacin showed highest resistance, and Tetracycline and Chloramphenicol showed lowest resistance against burn wound infections. *Staphylococcus aureus* showed *Pseudomonas species* or *Methicillin-resistant Staphylococcus aureus* (81.81%) had the highest percent for extensive drug resistance and multi drug resistance (90.90%) among the bacteria species. No Pan drug resistant (PDR) were observed in isolated bacterial strains of burn infections.

Conclusion: It is concluded that for treating infections caused by burns, Mezlocillin, gentamicin, and oxacillin are examples of antibiotics highly effective against burn infections.

Keywords: Burn wounds, Infectious bacteria, Antibiotic susceptibility, *Staphylococcus aureus*, Gentamicin

Introduction

Antibacterials are vital medications that treat bacterial infections by killing or inhibiting bacteria, effective against both minor and severe conditions like sepsis. (Singh,*et al*., 2023). Factors that increase the risk of infections within burn clients include skin barrier damage, extensive burns, weakened immune systems, and prolonged hospital stays. (Bacanli *et al*., 2019). Because burns are prone to infections, they can sometimes lead to a severe condition known as sepsis in those affected. (Rani *et al.,* 2024). Antibiotic resistance occurs when microorganisms withstand treatment, making it essential to use antibiotics only when absolutely necessary. (Uluseker *et al*., 2021). Antibiotic resistance arises from overuse, and antibiotics are ineffective against viral sore throats. (Blanco *et al.,* 2024). Burn infections arise when bacteria like Staphylococcus aureus invade and multiply in wounds, causing complications. (Vanamala *et al*., 2021). Severe burn infections require aggressive surgery to remove all dead tissue and prevent infection spread, especially in extensive burns with weakened immune systems. (Asuku *et al*., 2023). Small burns, such as sunburns, can be treated at home as they only damage the outer layer of skin. Second-degree burns damage both

the outer and underlying skin layers, causing peeling, pain, potential scarring, and possible numbness. (Kelly *et al*., 2022).

Multidrug resistance occurs when bacteria are immune to multiple antibiotics due to various resistance genes, though no standard definition exists. (Terreni *et al*., 2021). XDR organisms resist a wider array of drugs than multidrug-resistant microbes, necessitating more toxic treatments or higher doses. Pan drug resistance (PDR) indicates resistance to all antibiotics, with varying definitions across sources.(Karakonstantis *et al*., 2020). Identifying multidrug-resistant (MDR) bacteria is crucial due to the growing issue of antibiotic resistance. (Cosentino *et al*., 2023). It will elaborate MDR, XDR, and PDR bacteria in the context of bacterial isolates.

Materials and Methods

Fifteen burn wound swabs from 11male and 4 female patients, aged 17-58, were collected from Jinnah Hospital Lahore, with a focus on upper and lower extremities. Bacterial samples were collected with protective gear, transported in sterile containers, and cultured on nutrient agar for 24 hours and 37°C to assess microbial expansion. Bacterial species were identified using morphology, Gram staining, and various biochemical tests as Bergey's Manual 2015. Antibacterial sensitivity was tested using the disk diffusion method with antibiotic discs to assess bacterial resistance. Bacterial species were cultured with antibiotic discs, and after 24 hours at 37°C, inhibition zones were measured to assess sensitivity. MDR, XDR, and PDR indices reflect increasing levels of antibiotic resistance, from three classes to nearly all, respectively. Antibiotics of various classes includes such as Beta-lactams, Penicillins, and Macrolides, each with distinct antibiotics of antibacterial susceptibility.

Results

Eight bacterial strains from burn wound samples were tested for antibiotic susceptibility using various discs. *Proteus mirabilis* isolates were mostly resistant to several antibiotics but sensitive to Cefoperazone-sulbactam, Imipenem, Meropenem, and Piperacillin-tazobactam, with 63.6% resistance, 18.2% sensitivity, and 18.2% intermediate sensitivity overall. (Figure 1)

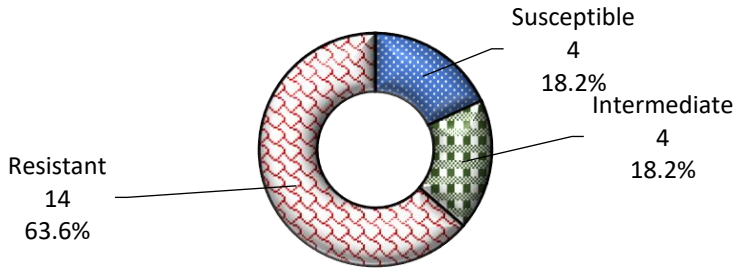

Figure 1 Antibacterial sensitivity of *Proteus mirabilis*

Coagulase-negative Staphylococcus species were resistant to 73.7% of antibiotics, with 26.3% showing effectiveness and no intermediate sensitivity. (Figure 2)

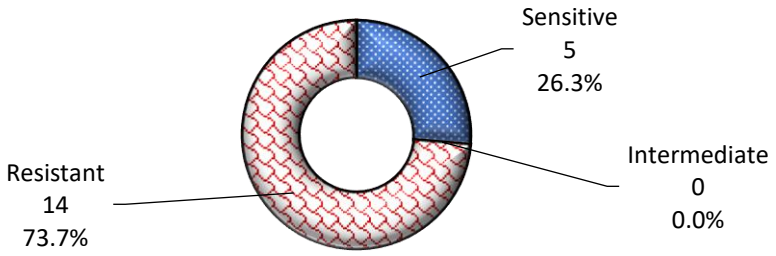

Figure 2 Antibacterial sensitivity of *Coagulase negative Staphylococcus species*

S. aureus was highly sensitive to antibiotics, with only 5.3% resistance and no intermediate sensitivity. (Figure 3)

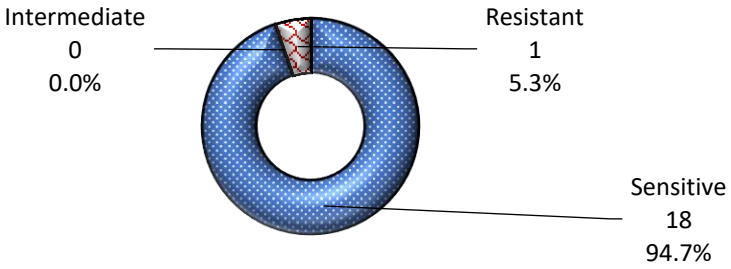

Figure 3 Antibiotic suspectibility of *Staphylococcus aureus*

Klebsiella oxytoca exhibited a rate of seventeen point six percent resistance, seventeen point six percent sensitivity, or eleven point eight percent intermediate sensitivity to the antibiotics tested. (Figure 4)

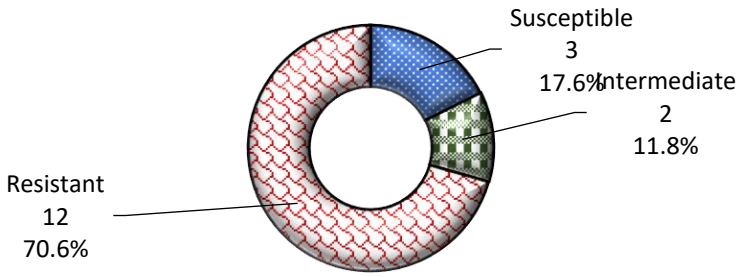

Figure 4 Antibacterial sensitivity of *Klebsiella oxytoca*

Thirty percent *Pseudomonas aeruginosa* resistance, twenty percent intermediate sensitivity, or fifty percent sensitivity to the antibiotics tested. (Figure 5)

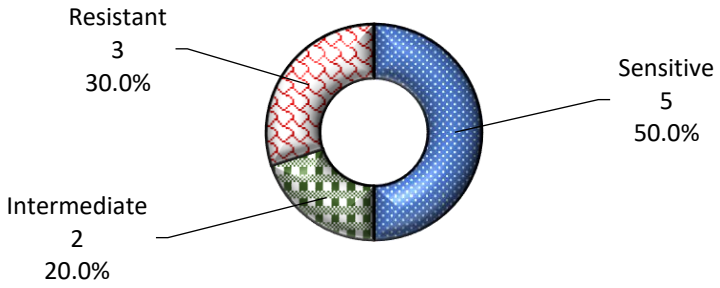

Figure 5 Antibiotic suspectibility of *Pseudomonas aeruginosa*

Methicillin-resistant Staphylococcus aureus was seventy three point three percent resistant or twenty six point seven percent susceptible to the medicines, with not intermediate sensitivity. (Figure 6)

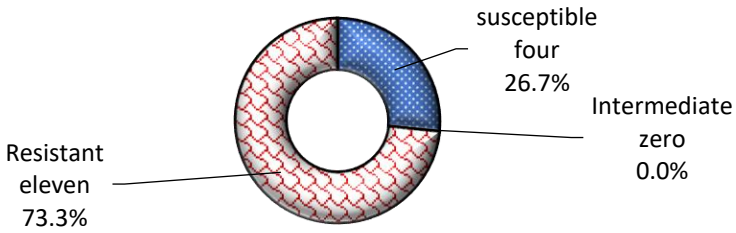

Figure 6 Antimicrobial sensitivity of *Methicilline resistant Staphylococcus aureus (MRSA)*

Pseudomonas species had 30% resistance, 20% intermediate sensitivity, and 50% sensitivity to the antibiotics tested. (Figure 7)

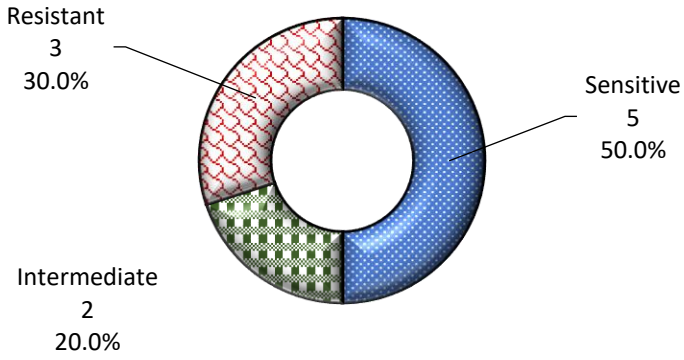

Figure 7 Antibiotic suspectibility of *Pseudomonas species*

The box plot revealed that 62% of bacteria from burn wounds were antibiotic-resistant and 38% were sensitive. (Figure 8)

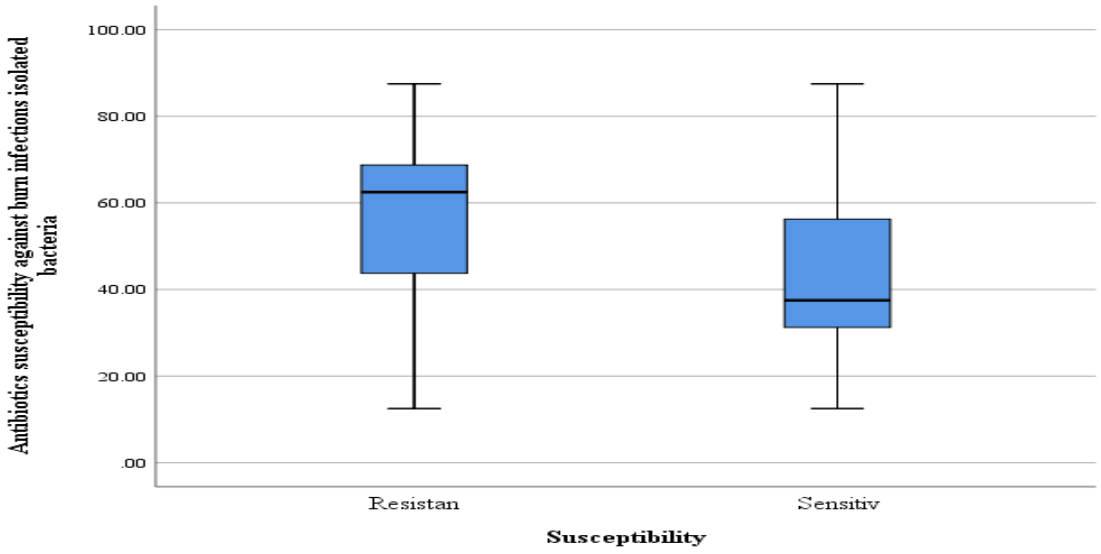

Figure 8 Box Plot for Antibiotics susceptibility against burn infections isolated bacteria

The box plot revealed that multidrug resistance (MDR) varied from 24% to 59%, and extensive drug resistance ranged from forty one percent to seventy five percent of bacteria found in burn infections. (Figure 9).

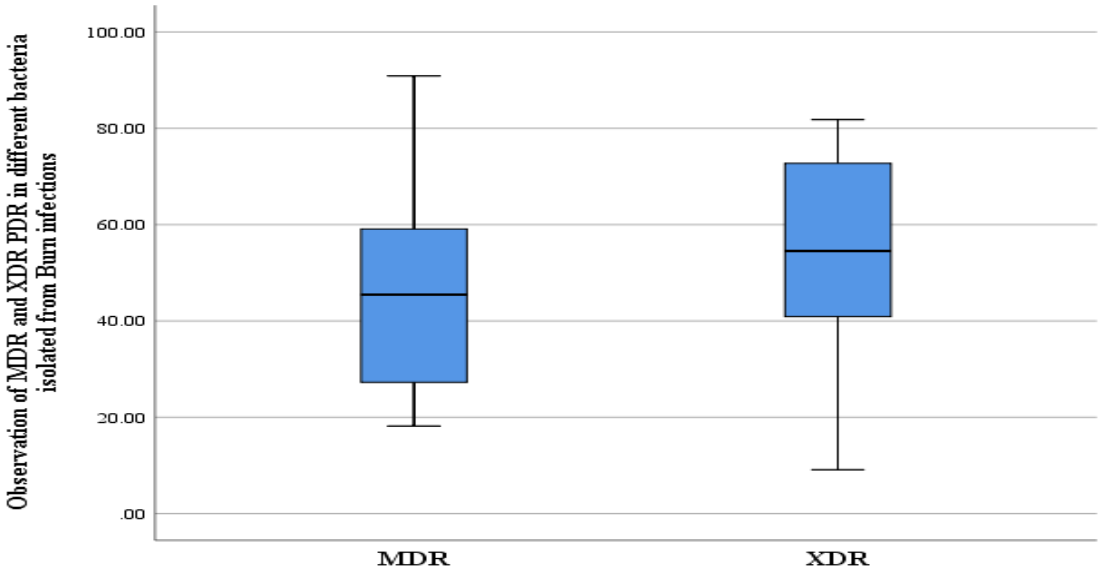

Figure 9 Box Plot showing the distribution of MDR, XDR, and PDR strains among various bacteria isolated from burn infections

Staphylococcus aureus had the highest MDR at 90.90%, while *Pseudomonas species* or *Methicillin-resistant Staphylococcus aureus* and had their greatest XDR at 81.81%, and *Staphylococcus aureus* had the lowest XDR at 9.09%. (Table 1)

Table 1 Frequency for Multi drug resistance, Extensively drug resistance, or Pan drug resistance strains within various microbe separated for burning injuries

Microbe Name	**Multidrug resistance**	**Extensive drug resistance**	**Pan drug resistance**
Pseudomonas species	2(18.18 %)	9(81.81%)	-
Methicillin resistant Staphylococcus aureus (MRSA)	2 (18.18%)	9(81.81%)	-
Pseudomonas aeruginosa	6 (54.54%)	5(45.45%)	-
Klebsiella oxytoca	7 (63.63%)	4(36.36%)	-
Staphylococcus aureus	10(90.90%)	1(9.09%)	-
Coagulase negative Staphylococcus species	4(36.36%)	7(63.63%)	-
Proteus mirabilis	4(36.36%)	7(63.63%)	-

Proteus mirabilis showed varying resistance rates to different antibiotics: 63.6% to Gentamicin, 75% to Amikacin, 50% to Penicillin, 62.5% to Amoxicillin, 50% to Streptomycin, 62.5% to Kanamycin, 12.5% to Tetracycline, 75% to Ciprofloxacin, 87.5% to Ampicillin, 12.5% to Chloramphenicol, and 62.5% to Erythromycin. (Figure 10)

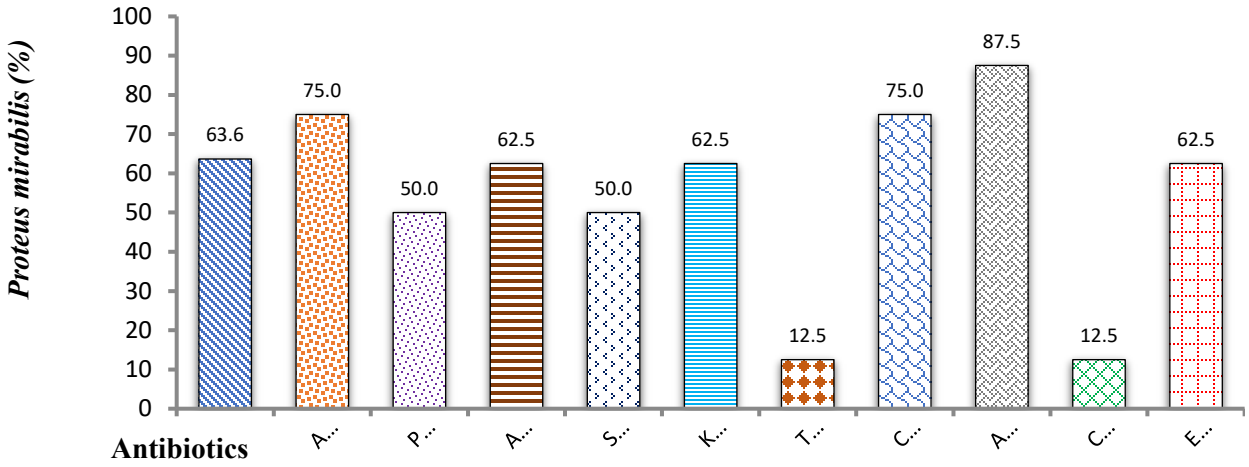

Figure 10 Percentage of antibiotic resistance among different bacterial separates from burn illnesses

Proteus mirabilis and *coagulase-negative Staphylococcus aureus* had 63.6% Gentamicin resistance, *MRSA* 81.8%, while *Staphylococcus aureus* had 9.1%, *Klebsiella oxytoca* 36.4%, *Pseudomonas aeruginosa* 45.5%, and *Pseudomonas species* 45.4%. (Figure 11)

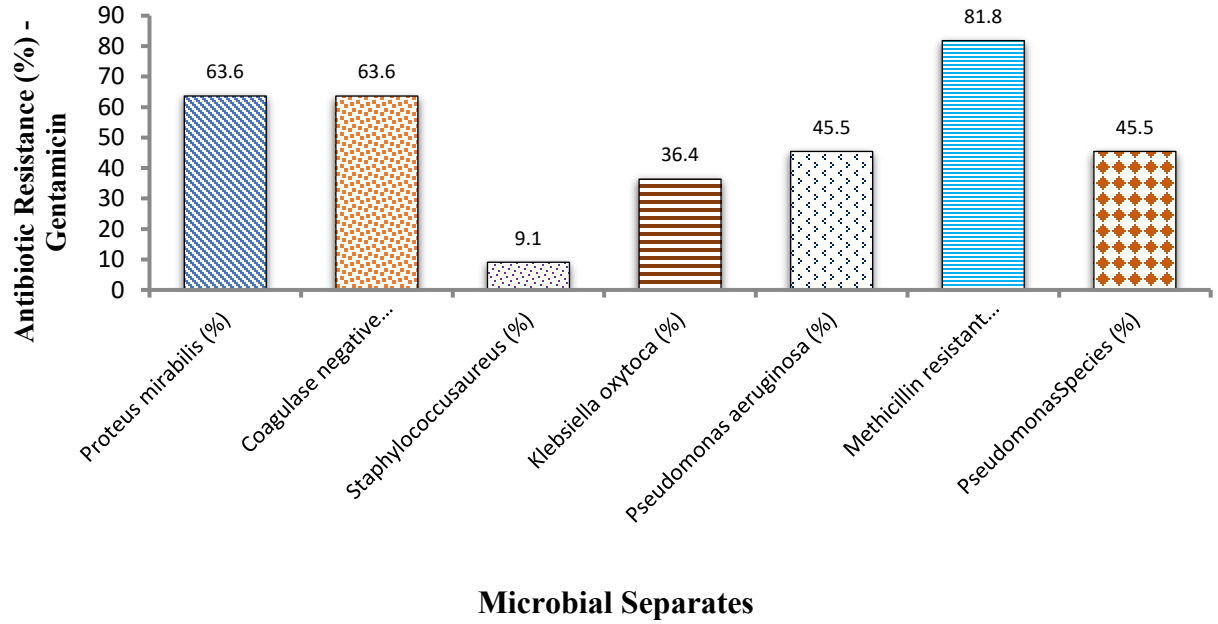

Figure 11 The percentage of antibiotic resistance among different bacterial strains found in burn infections

Proteus mirabilis had significant resistance to various antibiotics, with notable rates of 63.63% to Gentamicin and 87.5% to Ampicillin, while *MRSA* had the highest Gentamicin resistance at 81.81%, and *Staphylococcus aureus* had the lowest at 9.09%. (Table 2)

Table 2 Percentage of antibiotic resistance in different bacterial strains separated from burn infections

Antibiotic Resistance (%) of Various Bacterial Isolates of Burn Infections								
Sr No	**Antibiotics**	***Proteus mirabilis* (%)**	***Coagulase negative Staphylococcus species* (%)**	***Staphylococcus aureus* (%)**	***Klebsiella oxytoca* (%)**	***Pseudomonas aeruginosa* (%)**	***Methicillin resistant Staphylococcus aureus (MRSA) (%)***	***Pseudomonas Species* (%)**
1	**Gentamicin**	63.63	63.63	9.09	36.36	45.45	81.81	45.45
2	**Ciproflox acin**	75	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive
3	**Amikacin**	75	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive
4	**Ampicillin**	87.5	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive
5	**Amoxicillin**	62.5	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive
6	**Tetracycline**	12.5	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive
7	**Pencillin**	50	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive
8	**Kanamycin**	62.5	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive

9	**Erythromycin**	62.5	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive
10	**Chloramphenicol**	12.5	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive
11	**Streptomycin**	50	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive

Discussion

Antibacterial response, where bacteria and fungi become immune to treatments, is a significant global health issue affecting all age groups. (Forson *et al*., 2017). Burn infections from heat, chemicals, electricity, or radiation cause severe tissue damage and pose a major risk to patients, making them a critical concern in healthcare. (Pruitt *et al*., 2012). The study identified eight bacterial species, including *MRSA* and *Pseudomonas,* as key causes of burn wound infections, with MDR bacteria posing a major global health threat due to their survival in low-nutrient environments and varying resistance patterns. (Muchesa, 2017).

Erythromycin inhibits bacterial protein synthesis by binding to the 50S ribosomal division, targeting ribosomes from bacteria while minimizing side effects on human cells.(Farzam, Nessel, *et al*., 2023). *Pseudomonas aeruginosa*, a common skin bacterium, poses a major risk in burn infections and spreads via direct contact, contaminated surfaces, or airborne droplets.(Wood *et al*., 2023). *MRSA* resists beta-lactam antibiotics via PBP2a production, while *Pseudomonas species* evade multiple antibiotics through efflux pumps, low permeability, and mutations.(Jubeh *et al*., 2020). *Staphylococcus aureus* commonly colonizes the throat, hair, and hands, and can be found in animals; vancomycin is used for severe infections, but no pan-drug-resistant bacteria were detected in burn wounds. *Proteus mirabilis*, a gram-negative bacterium with swarming motility, forms biofilms on catheters, while Augmentin, a broad-spectrum antibiotic, disrupts cell wall synthesis in both gram-negative and gram-positive bacteria. (Jamil *et al*., 2023). Tetracycline and chloramphenicol are less effective against burn wound infections due to rising bacterial resistance and adaptation.(Hall, 2017). Ampicillin, a penicillin-type antibiotic, effectively treats burn infections by stopping bacterial growth but is not effective against viruses. (Bottalico *et al*., 2022). Amikacin and ciprofloxacin are effective against burn wound infections, especially those from *Pseudomonas aeruginosa* and *Escherichia coli*, while tetracycline and chloramphenicol are less effective. (Khandekar *et al*., 2018).

Gentamicin is an aminoglycoside antibiotic that treats serious infections from aerobic gram-negative bacteria like *Pseudomonas aeruginosa* and *Escherichia coli* but is ineffective against anaerobes. (Chaves, 2023). Penicillin kills bacteria by disrupting peptidoglycan cross-linking in the cell wall, causing the cell to weaken and burst. (Chow, 2023). Amoxicillin mainly inhibits bacterial growth by disrupting cell wall synthesis, is especially effective against gram-positive bacteria, and is highly effective when taken orally. (Karaman *et al*.,2015). Streptomycin prevents protein production in mycobacteria by attaching to their 30S ribosomal subunit, with resistance often resulting from mutations in 16S rRNA or protein S12. (Ruiz *et al*., 2002).

Kanamycin binds to the 30S ribosomal subunit, causing misreading of tRNA codons and bacterial cell death. (Bashir, Imran, *et al*., 2016). Aztreonam binds to PBP3, disrupting the final stages of cell wall synthesis and leading to bacterial cell death. (Auer, Oliver, *et al*., 2019). Cefepime interferes with bacterial cell wall synthesis by targeting the

enzymes responsible for the final stage of peptidoglycan formation, resulting in cell death. Cefixime disrupts bacterial cell wall synthesis, leading to cell breakdown and death, making it effective against various infections. (Ibrahim, Aljeburi, *et al*., 2018). Cefotaxime binds to penicillin-binding proteins, preventing cell wall synthesis and causing bacterial death. (Padda, 2023). Ceftazidime is a bactericidal antibiotic that blocks bacterial cell wall synthesis, making it effective against a variety of infections. Its resistance to certain beta-lactamases allows it to target a wide range of bacteria. (Pandey *et al*., 2020).

Ceftriaxone and cefuroxime are both bactericidal cephalosporins effective against a wide range of bacteria, including those producing beta-lactamases. (Wellington *et al*., 2003). Colistin disrupts the outer membrane of gram-negative bacteria by targeting lipopolysaccharides, causing leakage and damage, which helps it fight multidrug-resistant infections. (Ahmed *et al*., 2020). Doxycycline disrupts bacterial protein synthesis by binding to the 30S ribosomal subunit, and cross-resistance within tetracyclines means resistance to one often implies resistance to others. (Patel et al., 2023). Levofloxacin kills bacteria by inhibiting DNA gyrase, which disrupts DNA replication and leads to cell death. (Malik *et al*., 2024). Multi-drug resistance (MDR) complicates infection management by allowing pathogens to resist multiple treatments, driven by antibiotic misuse, poor hygiene, and inadequate infection control. (Tanwar *et al*., 2014). Extensive drug resistance (XDR) can be mistaken for pan-drug resistance (PDR) due to incomplete testing, but identifying XDR markers helps labs improve and expand their testing methods for resistant bacteria.

Conclusion

Burn injuries increasingly create environments where multidrug-resistant bacteria can thrive. Choosing the right antibiotics is essential for treating burn wound infections effectively and reducing the risk of complications and death associated with these resistant bacteria. Identifying these bacteria helps in selecting appropriate treatments, such as oxacillin, mezlocillin, and gentamicin. Ensuring a clean and sterile environment in burn units and hospitals is also crucial for preventing and controlling infections in burn patients.

References

1. Asuku, M., & Shupp, J. W. (2023). Burn wound conversion: clinical implications for the treatment of severe burns. *Journal of Wound Care*, *32*(5), 11-20.
2. Auer, G. K., Oliver, P. M., Rajendram, M., Lin, T. Y., Yao, Q., Jensen, G. J., & Weibel, D. B. (2019). Bacterial swarming reduces *Proteus mirabilis* and Vibrio parahaemolyticus cell stiffness and increases β-lactam susceptibility. *Mbio*, *10*(5), 10-1128.
3. Ahmed, E. F., Rasmi, A. H., Darwish, A. M., & Gad, G. F. M. (2023). Prevalence and resistance profile of bacteria isolated from wound infections among a group of patients in upper Egypt a descriptive cross-sectional study. *BMC Research Notes*, *16*(1), 106-107.
4. Bacanli, M., & Basaran, N. (2019). Importance of antibiotic residues in animal food. *Food and Chemical Toxicology*, *125*, 462-466.
5. Blanco, J.A., Vishwakarma, N., Lehr, C.M., Prestidge,C.A, Thomas,N., Roberts,R.J.. Thorn, R.J.,&Ana Melero (2024). Antibiotic resistance and tolerance: What can drug delivery do against this global threat? *Drug Delivery*

and Translational Research, *14*,1725–1734.

6. Bottalico, L., Charitos, I. A., Potenza, M. A., Montagnani, M., & Santacroce, L. (2022). The war against bacteria, from the past to present and beyond. *Expert Review of Anti-infective Therapy*, *20*, 681-706.
7. Bashir, K. M. I., & Cho, M. G. (2016). The effect of kanamycin and tetracycline on growth and photosynthetic activity of two chlorophyte algae. *BioMed research international*, *9*, 35-40.
8. Cosentino, F., Viale, P., & Giannella, M. (2023). MDR/XDR/PDR or DTR? Which definition best fits the resistance profile of *Pseudomonas aeruginosa*?. *Current Opinion in Infectious Diseases*, *36*(6), 564-571.
9. Chaves, B. J., & Tadi, P. (2023). Gentamicin. *StatPearls, Treasure Island (FL): StatPearls Publishing*, *8*, 90-110.
10. Chow, D. K., Leong, R. W., Lai, L. H., Wong, G. L., Leung, W. K., Chan, F. K., & Sung, J. J. (2008). Changes in Crohn's disease phenotype over time in the Chinese population: validation of the Montreal classification system. *Inflammatory bowel diseases*, *14*(4), 536-541.
11. Forson, O. A., Ayanka, E., Olu-Taiwo, M., Pappoe-Ashong, P. J., & Ayeh-Kumi, P. J. (2017). Bacterial infections in burn wound patients at a tertiary teaching hospital in Accra, Ghana. *Annals of burns and fire disasters*, *30*(2), 116-119.
12. Farzam, K., Nessel, T. A., & Quick, J. (2023). Erythromycin. In *StatPearls, 8,* 81-85.
13. Hall, C. W., & Mah, T. F. (2017). Molecular mechanisms of biofilm-based antibiotic resistance and tolerance in pathogenic bacteria. *FEMS microbiology reviews*, *41*(3), 276-301.
14. Ibrahim, H.H., Aljeburi, N.R., Jebar, M.S., Gayeb, M.A., Mahdi, S.S., Kudder, H.A., & Naseer, M.M. (2018). Effect of sub MIC for Imipenem, Amikacin and Cefixime on Growth and Swarming of *Proteus mirabilis. J Pure Appl Microbiol, 12,* 2241-2244.
15. Jubeh, B., Breijyeh, Z., & Karaman, R. (2020). Resistance of gram-positive bacteria to current antibacterial agents and overcoming approaches. *Molecules*, *25*(12), 2888-2889.
16. Jamil, R. T., Foris, L. A., & Snowden, J. (2017). *Proteus mirabilis* infections. *StatPearls, 20,* 20-25.
17. Khandekar, S., Liebens, V., Fauvart, M., Tulkens, P. M., Michiels, J., & Van Bambeke, F. (2018). The putative de-N-acetylase DnpA contributes to intracellular and biofilm-associated persistence of *Pseudomonas aeruginosa* exposed to fluoroquinolones. *Frontiers in microbiology*, *9*, 378-382.
18. Karaman,Y., Abud, B., &Tekgul, Z.T., Cakmak, M., Yildiz, M., Gonullu, M. (2015). Effects of dexmedetomidine and propofol on sedation in patients after coronary artery bypass graft surgery in a fast-track recovery room setting. *National Center for Biotechnology Information, 4,* 522-528.
19. Kelly, E. J., Oliver, M. A., Carney, B. C., & Shupp, J. W. (2022). Infection and burn injury. *European Burn Journal*, *3*(1), 165-179.
20. Karakonstantis, S., Kritsotakis, E. I., & Gikas, A. (2020). Treatment options for *K. pneumoniae, P. aeruginosa* and *A. baumannii* co-resistant to carbapenems, aminoglycosides, polymyxins and tigecycline: an approach based on the

mechanisms of resistance to carbapenems. *Infection*, *48*(6), 835-851.
21. Muchesa, P. (2017). Occurrence of free-living amoebae and amoeba resistant bacteria in water distribution systems of health care institutions in Johannesburg, South Africa. University of Johannesburg (South Africa). *ProQuest, 6,* 51-52.
22. Malik, A., & Garg, V. K. (2024). Bioremediation for Sustainable Environmental Cleanup. *CRC Press, 9,* 90-99.
23. Padda, I.S., Nagalli, S. (2023). Cefotaxime. *National Center for Biotechnology Information, 10,* 15-16.
24. Pandey, R., Gupta, S., Upadhyay, A., Gupta, R.P., Shukla, M., Mishra, R. C., & Arya, Y.K., Singh, T., Niraula, S., Lau, J.Y., Kumari, V. (2020). Childhood maltreatment and its mental health consequences among Indian adolescents with a history of child work. *National Center for Biotechnology Information, 10,* 88-89.
25. Patel, K. B., Parmar, B., Ravi, K., Patidar, R., Chaudhari, J. C., Srivastava, D. N., & Bhadu, G. R. (2023). Metal-organic framework derived core-shell nanoparticles as high performance bifunctional electrocatalysts for HER and OER. *Applied Surface Science*, *616*, 156-499.
26. Pruitt, B. A., Wolf, S. E., & Mason, A. D. (2012). Epidemiological, demographic, and outcome characteristics of burn injury. *Total burn care*, *4*, 15-45.
27. Ruiz, P., Rodriguez-Cano, F., Zerolo, F. J., & Casal, M. J. M. D. R. (2002). Investigation of the in vitro activity of streptomycin against *Mycobacterium tuberculosis. Microbial Drug Resistance*, *8*(2), 147-149.
28. Rani, V., Aye, N. K., Saksena, R., Dabi, K. C., Mannan, M. A. U., & Gaind, R. (2024). Risk factors and outcome associated with the acquisition of MDR linezolid-resistant *Enterococcus faecium* a report from tertiary care centre. *European Journal of Clinical Microbiology & Infectious Diseases*, 7, 1-9.
29. Singh, Harpreet, Bandana Thakur, Sanjeev K. Bhardwaj, Madhu Khatri, Ki-Hyun Kim, & Neha Bhardwaj. (2023). "Nanomaterial-based fluorescent biosensors for the detection of antibiotics in foodstuffs: A review." *Food Chemistry*, *8*, 136657-136659.
30. Terreni, M., Taccani, M., & Pregnolato, M. (2021). New antibiotics for multidrug-resistant bacterial strains: latest research developments and future perspectives. *Molecules*, *26*(9), 2671-2672.
31. Tanwar, J., Das, S., Fatima, Z., & Hameed, S. (2014). Multidrug Resistance: An Emerging Crisis. *National Library of Medicine, 8,* 1-7.
32. Uluseker, Cansu, Krista Michelle Kaster, Kristian Thorsen, Daniel Basiry, Sutha Shobana, Monika Jain, Gopalakrishnan Kumar, Roald Kommedal, & Ilke Pala-Ozkok. (2021)."A review on occurrence and spread of antibiotic resistance in wastewaters and in wastewater treatment plants: mechanisms and perspectives." *Frontiers in microbiology, 12*, 717-718.
33. Vanamala, K., Tatiparti, K., Bhise, K., Sau, S., Scheetz, M. H., Rybak, M. J., Andes, D., & Iyer, A. K. (2021). Novel approaches for the treatment of *methicillin-resistant Staphylococcus aureus:* Using nanoparticles to overcome multidrug resistance. *Drug discovery today*, *26*(1), 31-43.
34. Wood, S. J., Kuzel, T. M., & Shafikhani, S. H. (2023). *Pseudomonas aeruginosa*:

infections, animal modeling, and therapeutics. *Cells*, *12*, 199-195.

35. Wellington, K., & Goa, K. L. (2003). Measles, mumps, rubella vaccine (Priorix™ GSK-MMR) a review of its use in the prevention of measles, mumps and rubella. *Drugs*, *63*, 2107-2126.