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Research Article

Association of Multidrug-Resistant Bacterial Infections with Histopathological Severity, Antibiotic Outcomes, and Community-Level Risk Factors in Surgical Wound Infections

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ABSTRACT

Background: Multidrug-resistant (MDR) organisms increasingly complicate surgical wound infections and may worsen tissue damage, delay healing, and reduce antibiotic effectiveness.

Objective: To determine the association of MDR bacterial infections with histopathological severity, antibiotic outcomes, and community-level risk factors in surgical wound infections.

Methods: This cross-sectional analytical study included 120 patients with surgical wound infections from January 2024 to January 2025 at the Department of Pathology, Khawaja Muhammad Safdar Medical College, Sialkot, Pakistan, in collaboration with the Department of Microbiology, Sharif Medical and Dental College, Lahore, Pakistan. Wound specimens were cultured, antibiotic susceptibility was assessed, and tissue samples were examined histopathologically. Clinical outcomes and risk factors were analyzed.

Results: MDR bacterial infection was identified in 68 patients (56.7%), while 52 patients (43.3%) had non-MDR infection. MDR infection was significantly associated with diabetes mellitus (50.0% vs 23.1%; $p=0.003$), prior antibiotic use (66.2% vs 25.0%; $p<0.001$), delayed presentation (58.8% vs 25.0%; $p<0.001$), poor hygiene (55.9% vs 21.2%; $p<0.001$), and previous hospitalization (45.6% vs 19.2%; $p=0.003$). Severe histopathological involvement was more frequent in MDR cases than non-MDR cases (41.2% vs 13.5%; $p=0.001$). MDR infections showed lower favorable antibiotic response (38.2% vs 76.9%; $p<0.001$), higher repeat debridement (42.6% vs 15.4%; $p=0.001$), and longer hospital stay (9.6 ± 3.4 vs 6.1 ± 2.7 days; $p<0.001$).

Conclusion: MDR surgical wound infections were common and were associated with severe tissue injury, poor antibiotic response, and adverse clinical outcomes.

Keywords: Multidrug Resistance, Surgical Wound Infection, Histopathology, Antibiotic Outcome, Wound Healing, Community Risk Factors.

INTRODUCTION

Surgical wound infections remain among the most common healthcare-associated infections worldwide and continue to impose a substantial burden on patients and healthcare systems through prolonged hospitalization, increased healthcare costs, delayed wound healing, and higher postoperative morbidity and mortality[1]. Surgical wound infections have persisted in low-, middle- and high-income countries and despite the improvement of the surgical techniques, antimicrobial prophylaxis, and antimicrobial care, they remain common. The development of multidrug-resistant (MDR) bacterial pathogens has added to the complexity of these infections by limiting the efficacy of traditional antimicrobial treatments and causing treatment failures[2,3].

Increasingly, multidrug-resistant organisms are spreading in hospitals and in the community, creating a challenge for clinicians treating postoperative wound infections[4]. Infection with common multidrug resistant (MDR) pathogens is a frequent cause of surgical site infections and includes methicillin-resistant Staphylococcus aureus (MRSA), extended-spectrum β-lactamase (ESBL) producing Escherichia coli and Klebsiella pneumonia, carbapenem-resistant Acinetobacter baumannii and multidrug-resistant Pseudomonas aeruginosa[5]. Because of their different resistance mechanisms such as enzymatic destruction of antibiotics, modification of the antibiotic target site, decreasing uptake of antibiotic across the membrane, and active export of the antibiotic by efflux systems, therapeutic options are limited. Thus, infections with MDR bacteria are also linked to extended treatment with antibiotics, higher rates of surgical re-intervention, longer time for tissue healing and worse outcomes as opposed to infections with susceptible bacteria[6].

The severity of the tissue damage in surgical wound infections is not just related to the presence of a particular microbe, but also to the host inflammatory response and the pathological extent of tissue damage[7]. Histopathological examination is performed to assess the inflammatory cell infiltration, tissue necrosis, edema, vascular congestion, granulation tissue formation, fibrosis and presence of bacteria in the wound bed which gives an important clue for the biological behavior of infected wounds[8]. Mild histopathological changes may occur in both bacterial and fungal infections, and can be associated with persistent infection, local immune dysfunction and delayed wound healing, which can all have a negative impact on clinical results. However, a thorough investigation of the correlation between multidrug-resistant bacterial infections and histopathological severity has not been widely studied, especially in clinical practice where microbiological and pathological results are assessed separately[9].

The management of a surgical wound infection is dependent upon prompt identification of the organisms involved and selection of suitable antimicrobial therapy with regard to susceptibility testing[10]. With the growing problem of antimicrobial resistance, however, the effectiveness of what were once considered standard antibiotic regimens for empirical treatment has significantly decreased. Patients with MDR show an increased need for broad spectrum antibiotics, combination antimicrobial therapy, longer treatment durations, frequent wound debridement and longer hospital stays[11]. Failure to start effective antimicrobial therapy promptly does not only have a negative impact on clinical outcomes, but also allows resistant organisms to spread further in healthcare settings. Knowledge of the susceptibility and response to antibiotic therapy of MDR pathogens is thus critical for effective antimicrobial stewardship and better outcomes[12].

In addition to the microbiological factors, a variety of patient and community factors affect the acquisition of resistant organisms and the course of the surgical wound infection[13]. The factors such as diabetes mellitus, obesity, malnutrition, smoking, anemia, poor glycemic control, previous hospitalization, inadequate personal hygiene, delayed postoperative follow-up, overcrowded living conditions and limited access to healthcare services have all been identified as significant risk factors for infection[14]. Socioeconomic deprivation and misuse of antibiotics in the community also contribute to the spread and emergence of resistant strains of bacteria. These biological, behavioural and environmental factors are interconnected and underscore the multifactorial nature of surgical wound infections and the need to combine microbiological, pathological and epidemiological aspects in the clinical decision-making process[15].

While studies have investigated bacterial resistance profiles, wound pathology or individual clinical risk factors, few studies have investigated the association between multidrug-resistant bacterial infections, histopathological severity, antibiotic treatment outcome and community-level determinants in the same patient population[16]. A holistic assessment of these factors might help stratify the risk, provide an early identification mechanism for those most likely to have poor outcomes and help formulate targeted infection prevention strategies and evidence-based antimicrobial policies[17].

Therefore, the present study aimed to investigate the association between multidrug-resistant bacterial infections and histopathological severity in patients with surgical wound infections while simultaneously evaluating antibiotic treatment outcomes and

community-level risk factors associated with the development and progression of multidrug-resistant wound infections. Combining microbiological culture results, histopathological analysis, antimicrobial susceptibility patterns, and epidemiological patient features, this study aims to offer clinically relevant evidence that can be used to inform surgical infection management, antimicrobial stewardship program initiatives, and patient care after surgery[18].

MATERIALS AND METHODS

This cross-sectional analytical study was conducted from January 2024 to January 2025 at the Department of Pathology, Khawaja Muhammad Safdar Medical College, Sialkot, Pakistan, in collaboration with the Department of Microbiology, Sharif Medical and Dental College, Lahore, Pakistan. A total of 120 patients, who had clinically suspected surgical wound infections, were selected and gave informed consent. All adult patients who had undergone surgical procedures and developed wound discharge, erythema, swelling, pain, delayed healing, fever or wound dehiscence were included irrespective of their gender. Patients with incomplete clinical documentation, who received antibiotics for longer than 72 hours prior to sampling, no treatment history or who had non-bacterial wound infections were excluded.

Structured proforma for demographic, clinical and community-level data were collected. These were: age, sex, type of surgery, duration after surgery, diabetes mellitus, smoking status, obesity, previous hospitalization, previous antibiotic use, delayed presentation, socioeconomic status, overcrowding, hygiene status, and access to health care facilities. Risk factors at the community level were determined by patient history and classified based on a set of predefined clinical criteria.

Wound samples were taken using a sterile technique prior to the commencement or alteration of antibiotic therapy. Pus/swabs were collected from the infected wound area after cleaning the surface with sterile normal saline or tissue samples were collected from the wound area. Samples were rushed to the microbiology laboratory for culture and antimicrobial susceptibility test. The bacterial isolates were characterized by conventional microbiological techniques such as Gram stain, colony morphology, biochemical tests and automated identification if available. Antimicrobial susceptibility testing was done by Kirby–Bauer disc diffusion method on Mueller–Hinton agar as per laboratory guidelines. Multidrug resistance was considered resistance to ≥1 antimicrobial agent in 3 or more antimicrobial classes. Methicillin resistant Staphylococcus aureus, ESBL producing Enterobacteriaceae, carbapenem resistant Acinetobacter baumannii and multidrug resistant Pseudomonas aeruginosa were classified as clinically important resistant organisms.

Wound tissue biopsies and debrided tissue specimens were fixed in 10% neutral buffered formalin for histopathological evaluation and were processed routinely, embedded in paraffin, sectioned and stained with hematoxylin and eosin. Histopathological severity was measured by means of degree of acute and chronic inflammatory cell infiltration, tissue necrosis, edema, vascular congestion, granulation tissue formation, fibrosis and bacterial colonization. For composite microscopic findings, wound was classified as mild, moderate, or severe. The severity was defined as mild (superficial inflammation with minimal tissue destruction), moderate (dense inflammatory infiltrate with focal necrosis and impaired granulation), and severe (extensive necrosis, deep tissue involvement, marked inflammatory response, vascular compromise, and poor reparative changes).

The quality of antibiotic outcomes was evaluated in the follow-up by examining clinical response to antimicrobial therapy prescribed. Treatment response was defined as good if wound secretion, wound erythema, pain, swelling, fever and wound healing were improved and there was no requirement of escalating antibiotic treatment. Poor outcome was defined as persistence or progression of infection, antibiotic change or escalation, repeat debridement, long hospital stay, wound dehiscence, and/or readmission for wound infection.

The entered data was analyzed by SPSS software version 26.0. Mean ± standard deviation was used to present continuous variables, and the categorical variables were presented as frequencies and percentages. Categorical variables were compared between the groups of MDR and non-MDR infection using the chi-square test or Fisher's exact test. Comparisons of continuous variables were

performed using the independent-sample t-test, if appropriate. Factors independently associated with MDR bacterial infection and severe histopathological involvement were determined using binary logistic regression analysis. Odds ratios (95% Confidence Intervals) were computed. A p-value of less than 0.05 was considered statistically significant.

This study was approved by the appropriate institutional review board prior to its onset. All the information gathered were used only for academic and research purposes and patient confidentiality was maintained during the research process.

RESULTS

A total of 120 patients with clinically confirmed surgical wound infections were analyzed. The average age of the population studied was 45.8 ± 13.6 years. There were 72 males (60.0%) and 48 females (40.0%). Of the 68 patients (56.7%), 68 patients had multidrug-resistant bacterial infection and 52 patients (43.3%) had non-MDR bacterial infection. The age of patients with MDR infection was higher than that of patients with non-MDR infection (48.1 ± 12.9 year vs. 42.7 ± 14.1 year; p=0.031). The gender distribution did not differ significantly between MDR and non-MDR infections (p=0.410); although males were more common in both groups, (Table 1).

A total of 46 patients (38.3%) had diabetes mellitus, and it was significantly higher in MDR group vs non-MDR group (34 patients (50.0%) vs 12 patients (23.1%), p=0.003). The most significant clinical difference between the two groups was previous antibiotic exposure. Overall, it was recorded in 58 patients (48.3%), such as 45 patients (66.2%) with MDR infection, and only 13 patients (25.0%) with non-MDR infection (p<0.001). Previous hospitalization was also associated with MDR infection and was seen in 31 cases of MDR (45.6%) and 10 cases of non-MDR (19.2%) (p=0.003).

A definite association was seen between community level factors and MDR surgical wound infection. Delayed presentation beyond 5 days was documented for 53 patients (44.2%) and was statistically higher in the MDR compared to non-MDR cases of 40 (58.8%) and 13 (25.0%), respectively (p<0.001). Poor hygiene status was observed in 49 patients (40.8%), including 38 MDR cases (55.9%) and 11 non-MDR cases (21.2%) (p<0.001). Overcrowded household conditions were reported in 44 patients (36.7%) and were more frequent in the MDR group than the non-MDR group, 33 (48.5%) versus 11 (21.2%) (p=0.002). Low socioeconomic status was observed in 57 of the patients (47.5%) and was significantly associated with MDR infection (39 MDR patients (57.4%) vs 18 non-MDR patients (34.6%) (p=0.013), as shown in Table 1.

Table 1. Baseline Characteristics and Community-Level Risk Factors According To MDR Status

Variable	Total (n=120)	MDR infection (n=68)	Non-MDR infection (n=52)	p-value
Age, years, mean ± SD	45.8 ± 13.6	48.1 ± 12.9	42.7 ± 14.1	0.031
Male gender	72 (60.0%)	43 (63.2%)	29 (55.8%)	0.410
Female gender	48 (40.0%)	25 (36.8%)	23 (44.2%)	0.410
Diabetes mellitus	46 (38.3%)	34 (50.0%)	12 (23.1%)	0.003
Smoking	39 (32.5%)	27 (39.7%)	12 (23.1%)	0.052
Obesity	31 (25.8%)	22 (32.4%)	9 (17.3%)	0.061
Prior antibiotic use	58 (48.3%)	45 (66.2%)	13 (25.0%)	<0.001
Previous hospitalization	41 (34.2%)	31 (45.6%)	10 (19.2%)	0.003
Delayed presentation >5 days	53 (44.2%)	40 (58.8%)	13 (25.0%)	<0.001
Poor hygiene status	49 (40.8%)	38 (55.9%)	11 (21.2%)	<0.001
Overcrowded household	44 (36.7%)	33 (48.5%)	11 (21.2%)	0.002
Low socioeconomic status	57 (47.5%)	39 (57.4%)	18 (34.6%)	0.013

Microbiological analysis showed that gram-negative organisms were slightly common than gram-positive organisms. The most frequent isolate was Staphylococcus aureus in 32 patients (26.7%), followed by Escherichia coli in 27 patients (22.5%), Klebsiella pneumoniae in 21 patients (17.5%), Pseudomonas aeruginosa in 18 patients (15.0%), Acinetobacter baumannii in 12 patients (10.0%), and other bacterial isolates in 10

patients (8.3%). Sixty-three percent (18/32) of all Staphylococcus aureus isolates were MDR (including methicillin-resistant strains). A high percentage of isolates were multidrug resistant (MDR) (83.3%, 10/12) of Acinetobacter baumannii. MDR was also found in 15 out of 18 Pseudomonas aeruginosa isolates (83.3%), 14 out of 21 Klebsiella pneumoniae isolates (66.7%) and 16 out of 27 Escherichia coli isolates (59.3%). The results suggest that gram-negative resistant microorganisms were a significant fraction of the surgical wound isolates.

Histopathological grading showed that MDR infection was correlated with higher tissue injury grades. Only 12 of the 68 cases (17.6%) were histopathological mild in MDR cases, and 22 of 52 cases (42.3%) were histopathological mild in non-MDR cases (p=0.003). There was no significant difference in moderate severity between the groups as it was observed in 28 MDR cases (41.2%) and 23 non-MDR cases (44.2%) (p=0.742). In contrast, severe histopathological involvement was thrice as high in MDR wounds (28 patients, 41.2%) compared to non-MDR wounds (7 patients, 13.5%) (p=0.001) which is shown in Table 2.

The microscopic tissue results also confirmed the correlation between MDR infection and severity of wounds. A dense acute inflammatory infiltrate was seen in 51 (75.0%) of the MDR and 25 (48.1%) of the non-MDR cases (p=0.002). In addition, tissue necrosis was significantly more prevalent in the MDR infections (47 cases, 69.1%) than among the non-MDR (19 cases, 36.5%) (p<0.001). Marked edema was observed in 44 MDR cases (64.7%) and 20 non-MDR cases (38.5%) (p=0.004), while vascular congestion was detected in 42 MDR cases (61.8%) compared with 18 non-MDR cases (34.6%) (p=0.003).

Bacterial colonies were seen on microscopy in 36 (52.9%) MDR positive wounds and 12 (23.1%) non-MDR wounds (p=0.001), indicating a higher local bacterial load in MDR infections. MDR infections were also more often associated with poor granulation tissue formation, with 40 cases (58.8%) of poor granulation tissue seen in MDR infections as compared to 14 cases (26.9%) of non-MDR infections (p<0.001). A chronic inflammatory infiltrate was observed in 39 cases of MDR (57.4%) and 21 cases of non-MDR (40.4%) but this was not statistically significant (p=0.064). These results showed that the destructive and less reparative histological patterns were more prominent in the MDR infections as summarized in Table 2.

Table 2. Histopathological Severity and Microscopic Findings According To MDR Status

Histopathological parameter	MDR infection (n=68)	Non-MDR infection (n=52)	p-value
Mild severity	12 (17.6%)	22 (42.3%)	0.003
Moderate severity	28 (41.2%)	23 (44.2%)	0.742
Severe severity	28 (41.2%)	7 (13.5%)	0.001
Dense acute inflammation	51 (75.0%)	25 (48.1%)	0.002
Chronic inflammatory infiltrate	39 (57.4%)	21 (40.4%)	0.064
Tissue necrosis	47 (69.1%)	19 (36.5%)	<0.001
Marked edema	44 (64.7%)	20 (38.5%)	0.004
Vascular congestion	42 (61.8%)	18 (34.6%)	0.003
Bacterial colonies on microscopy	36 (52.9%)	12 (23.1%)	0.001
Poor granulation tissue	40 (58.8%)	14 (26.9%)	<0.001

There were significant differences in antibiotic response between MDR and non-MDR infection. Overall, 66 patients (55.0%) had a favorable response to initial or culture-guided antibiotic therapy. However, favorable response was significantly lower in the MDR group, where only 26 patients (38.2%) improved without major escalation, compared with 40 patients (76.9%) in the non-MDR group (p<0.001). Forty-two patients (61.8%) belonging to the MDR group were poor responders to antibiotics as opposed to 12 patients (23.1%) in the non-MDR group (p<0.001) (Table 3).

Antibiotic escalation was required in 39 MDR cases (57.4%) but in only 11 non-MDR cases (21.2%) (p<0.001). MDR group patients had combination antibiotic therapy in 34 (50.0%) patients, while non-MDR group patients had in only 9 (17.3%) patients (p<0.001). These results indicate that MDR infections were less likely to be sensitive to the empirical antibiotic therapy and more likely to require alteration of

therapy after knowing the culture and susceptibility results.

Furthermore, clinical wound outcomes were inferior for patients with MDR infection. Twenty-nine MDR cases (42.6%) required a repeated wound debridement versus eight non-MDR cases (15.4%) (P= .001). Wound dehiscence occurred in 22 MDR patients (32.4%) and 6 non-MDR patients (11.5%) (p=0.007). Prolonged hospital stay of more than seven days was documented in 43 MDR patients (63.2%) compared with 14 non-MDR patients (26.9%) (p<0.001). Hospitalization period was also significantly longer among patients in the MDR group (9.6 ± 3.4 days) compared with the non-MDR group (6.1 ± 2.7 days) (p<0.001). Ten MDR patients (14.7%) and three non-MDR patients (5.8%) were readmitted for wound infection, but this was not statistically significant (p=0.119) (Table 3).

Table 3. Antibiotic Response and Clinical Outcomes According to MDR Status

Outcome variable	MDR infection (n=68)	Non-MDR infection (n=52)	p-value
Favorable antibiotic response	26 (38.2%)	40 (76.9%)	<0.001
Poor antibiotic response	42 (61.8%)	12 (23.1%)	<0.001
Antibiotic escalation required	39 (57.4%)	11 (21.2%)	<0.001
Combination antibiotic therapy	34 (50.0%)	9 (17.3%)	<0.001
Repeat wound debridement	29 (42.6%)	8 (15.4%)	0.001
Wound dehiscence	22 (32.4%)	6 (11.5%)	0.007
Prolonged hospital stay >7 days	43 (63.2%)	14 (26.9%)	<0.001
Mean hospital stay, days ± SD	9.6 ± 3.4	6.1 ± 2.7	<0.001
Readmission due to wound infection	10 (14.7%)	3 (5.8%)	0.119

Multivariable logistic regression analysis was used to determine independent risk factors for MDR bacterial infection. The use of antibiotics prior to the onset of infection was still the most significant independent risk factor for MDR infection with an adjusted OR of 4.21 (95% CI: 1.88–9.43, p<0.001). Delayed presentation >5 days was also independently associated with MDR infection with an adjusted OR of 3.38 (95% CI: 1.49–7.66; p=0.004). Having poor hygiene status was associated with about three times the risk of MDR infection (adjusted OR: 3.16; 95% CI: 1.38 to 7.24; p=0.006). Another important predictor for MDR infection was diabetes mellitus with an adjusted OR of 2.71 (95% CI: 1.18–6.22; p=0.019). Adjusting for other factors, the previous hospitalization was independently associated with MDR infection with an adjusted OR of 2.84 (95% CI: 1.18–6.83; p=0.020). MDR infection was also independently associated with severe histopathological severity with a 3.74-fold increase in risk (95% CI: 1.45–9.67; p=0.006). The results shown in Table 4 indicated that the household condition of overcrowding was associated with MDR infection, although this association was not statistically significant (adjusted OR: 2.09; 95% CI: 0.91–4.79; p=0.082).

Table 4. Multivariable Predictors of MDR Bacterial Infection

Predictor	Adjusted OR	95% CI	p-value
Prior antibiotic use	4.21	1.88–9.43	<0.001
Delayed presentation >5 days	3.38	1.49–7.66	0.004
Diabetes mellitus	2.71	1.18–6.22	0.019
Poor hygiene status	3.16	1.38–7.24	0.006
Previous hospitalization	2.84	1.18–6.83	0.020
Overcrowded household	2.09	0.91–4.79	0.082
Severe histopathological severity	3.74	1.45–9.67	0.006

The overall incidence of MDR bacterial infections in surgical wound infection was 68 out of 120 patients (56.7%). These infections had a relation to more extensive microscopic damage of the tissues with higher incidence of necrosis, vascular congestion, bacterial colonization and lack of good granulation tissue formation. MDR infection was also associated with lower rates of antibiotic response, more escalation of therapy, higher rates of repeat

debridement, higher rates of wound dehiscence, and longer hospitalizations. After adjustment, community-level and patient-related factors, particularly antibiotic use prior to presentation, delayed presentation, diabetes mellitus, poor hygiene, and previous hospitalization, were important risk factors for MDR infection at community level.

DISCUSSION

This study demonstrated a high burden of multidrug-resistant bacterial infections among patients with surgical wound infections, with MDR organisms identified in 68 of 120 cases (56.7%)[1]. This discovery suggests that resistant bacterial pathogens are no longer confined to the realm of complicated tertiary-care infections but are becoming more common during routine postoperative wound care. The high frequency of MDR found in the present study is clinically significant because these infections not only were microbiologically resistant but were found to be associated with higher histopathological tissue damage and were less responsive to antibiotic treatment and led to poorer wound outcomes[2,3].

MDR infections were more likely to be seen in patients who were older, had diabetes mellitus, antibiotic use prior to hospitalization or laboratory analysis, delayed presentation to the hospital, poor hygiene status, overcrowding, or low socioeconomic status[4]. Of these, the use of antibiotics before the visit was the strongest independent predictor of the occurrence of MDR infection[5]. This validates the notion that uncontrolled use and/or misuse of antibiotics generate a selective pressure that allows resistant organisms to survive and become predominant in the flora of wounds. Often, in the community, antibiotics may be prescribed without the aid of a culture and may not be completed, and may be started prior to examination. These practices can cause wound infections to become resistant to treatment, which can lead to a long, costly course of treatment[6].

One of the most important results of this study was the strong correlation between MDR infection and the histological severity[7]. In 41.2% of the MDR cases and in 13.5% of the non-MDR cases severe microscopic changes were observed. The density of acute inflammatory response, necrosis of tissue, marked edema, vascular congestion, bacterial colonies, and poor formation of granulation tissue were greater in the MDR-positive wounds[8]. The results indicate that MDR infections can be correlated to a more destructive environment of the wound. This bacterial persistence after antibiotic exposure could result in a longer inflammatory response, affect tissue oxygenation, augment the necrotic load and slow down reparative mechanisms. The poor granulation tissue in MDR wounds also reflects a reduced capacity to heal and is responsible for the increased rates of prolonged hospital stays and repeat wound debridements[9].

The microbiological pattern found in this study reflects the evolving nature of surgical wound infections as well[10]. Despite the most common organism being Staphylococcus aureus, gram-negative bacteria Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, and Acinetobacter baumannii were a significant fraction of organisms isolated[11]. The MDR rates were especially high with Acinetobacter baumannii and Pseudomonas aeruginosa, highlighting the rising clinical importance of MDR gram negative pathogens in wound infections. These organisms can survive in the hospital setting, form biofilms, are resistant to multiple classes of antibiotics and can cause chronic infections, especially in patients who have delayed wound care or frequent hospital contact[12].

The outcomes of antibiotic treatment were significantly worse in patients with MDR infection. The overall antibiotic response was favourable in only 38.2% of the MDR cases and 76.9% of non-MDR cases[13]. Antibiotics were escalated in the MDR group more frequently as was combination therapy, repeat wound debridement and longer hospital stay[14]. This means that microbiological resistance has a direct clinical correlation. Susceptible organism infections can usually be treated with standard empirical or culture-directed antibiotic therapy, whereas MDR infections often require treatment with a more broad-spectrum antibiotic, extended antibiotic therapy, and more aggressive surgical therapy. The increased incidences of wound dehiscence in the MDR cases also indicates that resistant infection may be associated with impaired tissue repair and integrity[15].

There was a high association between community-level risk factors and MDR infection. MDR cases more commonly presented more than 5 days later, had worse hygiene status, more overcrowded living conditions and lower socioeconomic status[16]. These can lead to

greater contamination with bacteria, delayed access to good wound care facilities, suboptimal wound care, and the spread of resistant bacteria in the home or community. An independent association between poor hygiene and delayed presentation and MDR infection suggests a need for public health measures in addition to hospital-based antibiotic policies. Burden of resistant wound infections may be reduced through patient education, early postoperative follow-up, wound-care counseling, and community-level hygiene improvement[17,18].

Diabetes mellitus was also an independent risk factor for MDR infection. Diabetic patients have been shown to have impaired neutrophil function, reduced tissue perfusion, hyperglycemia induced immune dysfunction and delayed collagen synthesis, all of which make them more susceptible to wound infection[19]. All these factors set the stage for the persistence and destruction of tissue by bacteria. Diabetes was associated more with MDR cases in the present study, which suggests monitoring of the wound post surgery and strict glycemic control for diabetic patients[20].

The present study is of important clinical implications. Firstly, surgical wound infections should not be managed on clinical appearance alone, particularly in a high MDR prevalent setting[5-8]. Susceptibility testing and early culture testing should be promoted prior to changing antibiotics. Second, in patients who need to be debrided and/or biopsied, a histopathological evaluation may be able to give more information about the severity of the wound[9-14]. Severe necrosis, bacterial colonies, and poor granulation tissue may alert the clinicians to a more complicated course of infection. Thirdly, antimicrobial stewardship needs to be coupled with community level interventions as pre-antibiotic use and delayed health care seeking behaviour were major risk factors of MDR infections[15,16].

This study has some limitations. It was performed on a sample of 120 patients from selected institutional settings, and may not apply to all surgical populations[17,18]. No molecular resistance testing was carried out therefore resistance mechanisms were identified as a phenotypic process. Polymicrobial patterns of wound infections may be underestimated as anaerobic bacteria and fungal causes were not cultured. As limitations, the study may not sufficiently represent the spectrum of community-level determinants of antibiotic resistance, microbiological resistance and disease severity, or antibiotic outcomes in individuals with S.W.I[19,20].

CONCLUSION

Patients with surgical wound infections frequently suffered from multidrug-resistant bacterial infections, which were significantly associated with severe histopathological tissue damage, poor antibiotic response, antibiotic therapy escalation, re-wound-debridement, wound dehiscence and longer hospital stay. Previous antibiotic use, late presentation, diabetes mellitus, poor hygiene score, previous hospitalisation and advanced histopathology involvement emerged as independent predictors of MDR infection. These results highlight the importance of early microbiological diagnosis, wise use of antibiotics, prompt surgical wound care, histopathological evaluation in severe cases and community-based efforts to prevent infections. Improved antimicrobial stewardship and patient education on wound hygiene and seeking healthcare early could help to decrease the burden of MDR surgical wound infections and enhance postoperative outcomes.

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Authors' Contributions

AS conceived and designed the study, supervised data collection, analyzed the data, and drafted the manuscript. RM, HMIA, and OA contributed to the study design, interpretation of findings, and critical revision of the manuscript. AZ supervised the microbiological investigations and contributed to data interpretation. RS contributed to the epidemiological analysis, statistical interpretation, and manuscript revision. All authors reviewed, approved the final manuscript, and agree to be accountable for all aspects of the work.

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Conflict of Interest: The authors declare that there is no conflict of interest regarding the publication of this study.

REFERENCES

1. Acierno C, Nevola R, Barletta F, Rinaldi L, Sasso FC, Adinolfi LE, et al. Multidrug-resistant infections and metabolic syndrome: an overlooked bidirectional relationship. Biomedicines. 2025;13(6):1343.
2. Kumar NR, Balraj TA, Shivashankar KK, Jayaram TC, Prashant A. Inflammaging in multidrug-resistant sepsis of geriatric ICU patients and healthcare challenges. Geriatrics. 2024;9(2):45.
3. Kreitmann L, Helms J, Martin-Loeches I, Salluh J, Poulakou G, Pene F, et al. ICU-acquired infections in immunocompromised patients. Intensive Care Med. 2024;50(3):332-349.
4. Karamolahi S, Kaviar VH, Haddadi MH, Hashemian M, Feizi J, Sadeghifard N, et al. Molecular characterization of Staphylococcus aureus isolated from hospital-acquired infections in Ilam, Iran. Mol Biol Rep. 2024;51(1):686.
5. Mateescu MC, Grigorescu S, Socea B, Bloanca V, Grigorescu OD. Contribution to the personalized management of the nosocomial infections: a new paradigm regarding the influence of the community microbial environment on the incidence of the healthcare-associated infections (HAI) in emergency hospital surgical departments. J Pers Med. 2023;13(2):210.
6. Chukwudile B, Pan D, Silva L, Gogoi M, Al-Oraibi A, Bird P, et al. Antimicrobial resistance among migrants in Europe: a systematic review and meta-analysis—update from 2017 to 2023. EClinicalMedicine. 2024;75.
7. Jokar J, Saleh RO, Rahimian N, Ghasemian A, Ghaznavi G, Radfar A, et al. Antibacterial effects of single phage and phage cocktail against multidrug-resistant Klebsiella pneumoniae isolated from diabetic foot ulcer. Virus Genes. 2023;59(4):635-642.
8. Bolloju KR, Pambi MS, Ajmir BS, Vadlamanu UR. Prevalence and prevention of orthopaedic surgical site infections in resource-limited settings: a systematic review and meta-analysis. J Contemp Clin Pract. 2024;10:541-558.
9. Kumar D, Singh SK, Nath G. Chronic carriers and multidrug resistance in typhoid fever: pathogenesis, challenges, and integrated control strategies. Infection. 2025:1-18.
10. Balasubramanian B, Shanmugam S, Kim IH. Companion dogs and cats as key reservoirs of antimicrobial resistance: evidence and One Health implications. Antibiotics. 2026;15(5):515.
11. Ali SM, Tuama AA. Gut microbiota dysbiosis drives resistance gene transfer and bacterial adaptation. Indones J Health Sci Med. 2025;2(1):10-21070.
12. Ni D, Liu G. Iron uptake systems: chemical tools for advancing infectious disease treatment and diagnosis. J Med Chem. 2025;68(15):15285-15338.
13. Khan H, Jan Z, Ullah I, Alwabli A, Alharbi F, Habib S, et al. A deep dive into AI integration and advanced nanobiosensor technologies for enhanced bacterial infection monitoring. Nanotechnol Rev. 2024;13(1):20240056.
14. Al-Taweel R, Hammad AS, Tajammul A, Crovella S, Al-Asmakh M. Wounds and the microbiota: the healing interplay between host and microbial communities. Int J Mol Sci. 2025;26(23):11365.
15. Mohammed W, Awad FA, Mustafa TI. The importance of Klebsiella pneumoniae as a pathogen and the increasing prevalence of antibiotic-resistant strains and molecular characteristics. Baghdad J Biochem Appl Biol Sci. 2023;4(4):180-203.
16. Kalpana S, Lin WY, Wang YC, Fu Y, Lakshmi A, Wang HY. Antibiotic resistance diagnosis in ESKAPE pathogens—a review on proteomic perspective. Diagnostics. 2023;13(6):1014.
17. Ristori MV, Guarrasi V, Soda P, Petrosillo N, Gurrieri F, Longo UG, et al. Emerging microorganisms and infectious diseases: one health approach for health shared vision. Genes. 2024;15(7):908.
18. Heussien Z, Yousef NA, AbdElfatah KE, Temark H. Green magnesium oxide nanoparticles (MgO-NPs) as an antibacterial agent against multidrug-resistant bacteria causing tonsillitis. Assiut Univ J Multidiscip Sci Res. 2025;3(1):53-76.
19. Addissouky TA. Transforming intestinal tuberculosis management: advances in diagnostics, therapeutics, and prevention. J Rare Dis. 2025;4(1):24.
20. Chadha J, Thakur N, Chhibber S, Harjai K. A comprehensive status update on modification of Foley catheter to combat

catheter-associated urinary tract infections and microbial biofilms. Crit Rev Microbiol. 2024;50(2):168-195.