Infection and Drug Resistance

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ORIGINAL RESEARCH

Prevalence and Determinants of Multi-Drug Resistance Bacterial Infection Among Burn Patients in a Tertiary Care Center in Nepal

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Purpose: The emergence of multidrug-resistant organisms (MDROs) in burn patients poses a significant threat to patient outcomes and healthcare systems, especially in resource-limited settings. Burn injuries compromise the skin barrier and often require invasive interventions, increasing the risk of infection and antimicrobial resistance. This study aimed to determine the prevalence of multi-drug resistance (MDR) and identify the associated risk factors.

Patient and Methods: A retrospective study was conducted among burn patients admitted to Nepal Cleft and Burn Center, Kathmandu, from January to December 2023. All culture-positive isolates were assessed to determine the prevalence of MDR and distribution of common pathogens. Sociodemographic and clinical data were evaluated using multivariate logistic regression to identify predictors of MDRO infection.

Results: Among 535 burn patients, 348 had positive cultures. The prevalence of resistant organisms was 56.82%, comprising MDR (n = 155), Extensively Drug-Resistant (XDR) (n = 147), and Pan-drug Resistant (PDR) (n = 2). The most common Gram-negative isolates were *Pseudomonas aeruginosa* (29.0%), *Klebsiella pneumoniae* (18.1%), *Citrobacter koseri* (17.5%), *Acinetobacter baumannii* (16.4%), and *Escherichia coli* (13.8%). Among Gram-positive organisms, Coagulase-negative *Staphylococci* (15.5%) and MRSA (13.2%) were identified. The use of catheters, nasogastric tubes, and ventilators was significantly higher in MDRO cases. Bloodstream (18.8%), urinary (12.8%), and catheter-related infections (11.2%) were also observed among patients. Intensive Care Unit (ICU) admission [Adjusted Odds Ratio (AOR): 3.047, 95% Confidence Interval (CI): 1.089–8.528; p = 0.034] and nasogastric tube use [AOR: 11.830, CI: 1.339–104.489; p = 0.026] were significant predictors of MDRO infection.

Conclusion: MDRO infections are highly prevalent (56.82%) in burn patients. ICU stay and use of invasive devices are key risk factors. These findings underscore the importance of antimicrobial stewardship, stringent infection control measures, and routine surveillance for antimicrobial resistance in burn units.

Keywords: antibiotic resistance, burn, prevalence, stewardship

Introduction

Burn injuries are among the most complex forms of trauma, leading to significant morbidity, prolonged disability, and high mortality worldwide.[1,2] The World Health Organization (WHO) estimates that approximately 11 million people suffer from burn injuries each year, with around 180,000 deaths, most of which occur in low- and middle-income countries (LMICs).[3] In Nepal, official data are limited due to the absence of a national burn registry, but the government suggests about 2100 deaths and 55,000 burn-related injuries annually. Experts believe these figures underestimate the actual burden, as burns account for roughly 5% of all disabilities across age groups in the country.[4]

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Burn injuries can result from exposure to flames, hot liquids, chemicals, electricity, or radiation, with thermal burns being the most common.[5,6] Based on the depth and extent of tissue damage, burns are classified as first-degree (superficial), second-degree (partial thickness), third-degree (full thickness), and occasionally, fourth-degree.[7] The loss of skin integrity compromises the body's primary defence against infection, making burn patients highly susceptible to microbial invasions. The wound environment, which is rich in necrotic tissue and lacks blood supply, provides an ideal setting for bacterial colonization and infection.[8–11]

Infections are a leading complication in burn patients, primarily when invasive medical devices such as catheters and ventilators are used.[12] Common pathogens in burn units include *Staphylococcus aureus (S. aureus), Acinetobacter baumannii (A. baumannii), and Pseudomonas aeruginosa (P. aeruginosa), which are* capable of forming biofilms that protect them from immune responses and antibiotics.[13–16] These infections impose a substantial clinical and public health burden, contributing to prolonged hospitalisation, increased treatment cost, and poorer health outcomes, particularly in resource-limited settings.[17] They are projected to cause global economic losses of US$1–3 trillion by 2030, potentially pushing up to 28 million people into extreme poverty and increasing medical treatment costs in low-income countries by about 25%, thereby threatening progress toward the Sustainable Development Goals 2030.[18]

One of the most alarming challenges in burn care is the emergence of antimicrobial resistance (AMR), particularly multidrug-resistant organisms (MDRO).[19] Multi-drug resistance (MDR) is typically defined as bacterial resistance to at least one agent in three or more antimicrobial categories. Even more concerning are Extensively Drug-Resistant (XDR) organisms, which are resistant to all but two or fewer antibiotic classes, and Pan-drug Resistant (PDR) organisms, which are resistant to all available antibiotics.[20] The overuse and inappropriate selection of broad-spectrum antibiotics in empirical therapy contribute to this growing threat.[21,22]

Globally, MDR infections are highly prevalent in burn units, especially in intensive care settings. In countries like Nepal, limited access to effective antibiotics, lack of functional antibiotic stewardship programs, and poor infection control practices exacerbate the prevalence of MDR in burn wound infections.[11,23,24] Studies conducted in Nepal have identified MDR strains such as *P. aeruginosa, Klebsiella pneumoniae (K. pneumoniae)*, and *A. baumannii* as predominant in burn wounds.[25–27] Treating these infections often necessitates the use of last-resort antibiotics such as colistin and carbapenems, which have serious side effects.[28–30]

Despite extensive global research on MDR infections in burn patients, there is limited data from South Asia and almost no comprehensive evidence from Nepal, highlighting the need for this study. This study addresses this gap by providing comprehensive, region-specific insights into MDR infections among burn patients and evaluating key risk factors. Unlike previous studies, which have only focused on mortality among burn patients,[23,31] this study addresses MDR infections, their prevalence, and associated risk factors. This study lays a foundation for future research and policy adaptations, guiding antimicrobial stewardship programs and improving clinical practices within Nepal's burn management framework.

Methodology

Study Design, Setting and Sample

The study adopted a retrospective, observational, and quantitative design. The study was conducted at the Department of Burns, Plastic and Reconstructive Surgery in Nepal Cleft and Burn Center, a tertiary care hospital specialising in burn treatment located in Kirtipur, Kathmandu, Nepal. All burn patients admitted to the hospital for treatment in 2023 who met the inclusion criteria were included in the study population, and their medical records were reviewed.

Eligibility Criteria

Inclusion Criteria

The study included all the burn patients who received treatment at the hospital, regardless of age, gender, or any pre-existing health conditions. It encompassed burn injuries of all causes, such as flame, scald, chemical, electrical, or radiation burns, and of all degrees. Eligible patients had to have undergone culture and sensitivity testing during their

hospital stay and have received at least one course of antibiotic treatment. Those who tested positive for MDROs were categorized into the MDR group, while the rest were placed in the non-MDR group.

Exclusion Criteria

The study excluded burn in pregnant women, patients with incomplete or inadequate medical records, those who did not undergo microbiological investigations, or those admitted for less than 24 hours. Additionally, the analysis excluded patients with pre-existing infections unrelated to the burn and those with no signs of new or hospital-acquired infections after the burn.

Sample Size

The sample size depends on the availability of existing medical data in hospital records, making it a feasibility-based sample. A total of 790 burn patients were admitted from January to December 2023. Of these, 255 were excluded due to missing files (n = 6), pregnancy (n = 2), or the absence of culture testing (n = 247). The remaining 535 patients who underwent culture and sensitivity testing were included to assess the prevalence of MDR. Among them, 187 showed no bacterial growth and were excluded, leaving 348 culture-positive patients for the final analysis. These patients were categorized into MDR and non-MDR groups. The findings are interpreted with appropriate caution, considering the feasibility-based sampling and the exclusions applied [Figure 1].

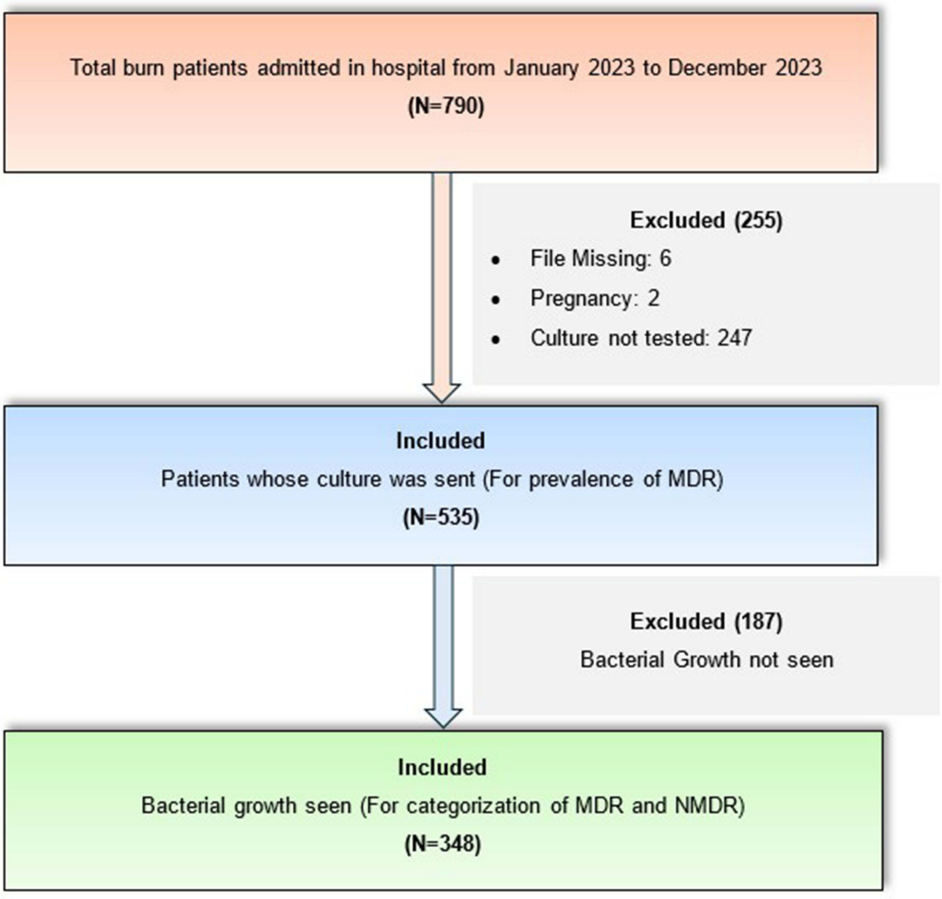

Figure 1 Sample size determination flowchart. Flow diagram illustrating patient selection from 790 admitted burn patients, with exclusions for missing files, pregnancy, or no culture. Of 535 cultured patients, 187 without bacterial growth were excluded, resulting in a final sample of 348 patients.

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Data Collection

The data collection for this study took place from March 2024 to June 2024 at the Nepal Cleft and Burn Centre in Kathmandu. Relevant information, including patient demographics, burn injury details, clinical data, antibiotic regimens, duration of therapy, length of hospital stay, and survival outcomes of burn patients, was extracted using a structured data collection tool. In addition, data on culture results, pathogen identification, and Antimicrobial Susceptibility Test (AST) were collected directly from laboratory records. Microbial identification and AST were performed in the hospital laboratory according to Clinical and Laboratory Standards Institute (CLSI) 2020 guidelines using the Kirby-Bauer disk diffusion method, and zones of inhibition were interpreted using CLSI breakpoints. MDR/XDR/PDR classification was done according to standard definitions (MDR: resistance to ≥1 drug in ≥3 antibiotic classes; XDR: resistance to all but ≤2 classes; PDR: resistance to all classes) based on AST records.[20] The antibiotics tested in susceptibility assays included commonly used agents representing multiple antimicrobial classes. These included aminoglycosides (amikacin, gentamicin), penicillins (amoxicillin, cloxacillin), and penicillin/β-lactamase inhibitor combinations (amoxicillin–clavulanic acid, piperacillin–tazobactam). Macrolides (erythromycin, azithromycin), cephalosporins (cefazolin, cephalexin, cefoxitin, cefixime, cefotaxime, cefpodoxime, ceftazidime, ceftriaxone, cefepime), and cephalosporin/β-lactamase inhibitor combinations (cefoperazone–sulbactam) Additional antibiotic classes tested were amphenicols (chloramphenicol), fluoroquinolones (ciprofloxacin, levofloxacin, norfloxacin, ofloxacin), lincosamides (clindamycin), sulfonamides (cotrimoxazole), tetracyclines (doxycycline, tetracycline), and glycylcyclines (tigecycline). Carbapenems (imipenem, meropenem), oxazolidinones (linezolid), nitrofurans (nitrofurantoin), polypeptides (colistin, polymyxin B), and glycopeptides (vancomycin, teicoplanin).

Data Management

Data were initially recorded using a structured proforma and subsequently transferred to an Excel spreadsheet. All physical forms were securely stored in a locked facility, and patient confidentiality was safeguarded through anonymization and de-identification procedures. To prevent data loss, regular backups were stored on Google Drive. The dataset was cleaned and coded for consistency and accuracy. All digital files were password-protected to maintain data security.

Data Analysis

The raw data were cleaned and coded before analysis using Microsoft Excel 2016 and SPSS version 26. Descriptive statistics summarised the demographic details of burn patients and MDR prevalence, presenting the data as frequencies and percentages. The normality of the continuous data was assessed using the Shapiro–Wilk test. Since the data were non-normally distributed, non-parametric tests were applied. Categorical variables were analysed using Pearson's Chi-square test or Fisher's exact test, while continuous variables were compared using the Wilcoxon-Mann–Whitney *U*-test between MDR and Non-MDR groups and presented as medians with interquartile ranges. Binary logistic regression (univariate and multivariate) analysis was conducted to identify independent predictors of MDR. Variables with a p-value less than 0.25 in univariate analysis were selected for multivariate analysis to adjust for potential confounders.[32,33] Results were reported as odds ratios with 95% confidence intervals (CI), and p-values less than 0.05 were considered statistically significant.

Results

Baseline Characteristics of Burn Patients

Among 348 culture-positive burn patients, children and young adults were most commonly affected, with a median age of 30 years [Interquartile Range (IQR):15.00–52.00]. The median TBSA burned was 20.00% (IQR: 12.00–35.00). Flame burns were the most common cause (60.9%), and second-degree burns were the most prevalent (80.7%). A significant proportion of patients required Intensive Care Unit (ICU) care (54.6%) and presented within 3 days of injury (69.5%). Sepsis (13.8%) and respiratory complications (18.4%) were the leading complications. Common comorbidities included hypertension (9.5%) and diabetes (6.6%). Third-generation cephalosporins (44.5%), polymyxins (34.2%), and glycopeptides (26.7%) were the most commonly used antibiotics. The overall mortality rate was 22.1%, while 11.5% of patients went into Discharge on Patient Request (DOPR) and 2.6% left against medical advice [Table 1].

Table 1 Baseline Characteristics of Burn Patients (N=348)

Variables	N (%)
Age (Years), Median (IQR)	30 (15.00–52.00)
Age Group (Years)	
0-10	79 (22.7%)
11-20	35 (10.1%)
21-30	61 (17.5%)
31-40	42 (12.1%)
41-50	35 (10.1%)
51-60	43 (12.4%)
61-70	26 (7.5%)
>70	27 (7.8%)
Gender	
Female	187 (53.7%)
Male	161 (46.3%)
Presentation Time to Hospital after Injury (Days)	
0-3	242 (69.5%)
4-15	80 (23.0%)
16-30	16 (4.6%)
>30	10 (2.9%)
Length of Stay (Days)	
0-7	59 (17.0%)
8-14	104 (29.9%)
15-30	125 (35.9%)
31-60	46 (13.2%)
61-90	8 (2.3%)
>90	6 (1.7%)
Alleged Intent of Injury	
Accidental	343 (98.6%)
Self-Inflicted	5 (1.4%)
Cause of Burn Injury	
Chemical	2 (0.6%)
Contact	5 (1.4%)
Electric	41 (11.8%)
Flame	212 (60.9%)
Lightening	4 (1.1%)
LPG explosion	8 (2.3%)
Scald	76 (21.8%)
TBSA %, Median (IQR)	20.00 (12.00–35.00)
TBSA %	
0-10	83 (23.9%)
11-20	95 (27.3%)
21-30	74 (21.3%)
31-40	49 (14.1%)
41-50	28 (8.0%)
>50	19 (5.5%)
Burn Degree	
1st	4 (1.1%)
2nd	281 (80.7%)
3rd	29 (8.3%)
4th	7 (2.0%)
Mixed	27 (7.8%)

(*Continued*)

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Table 1 (Continued).

Variables	N (%)
Old Infected	43 (12.4%)
Inhalation Injury	59 (17.0%)
ICU Admission	190 (54.6%)
Treatment Approach	
Antibiotic Therapy	57 (16.4%)
Operation + Antibiotics	291 (83.6%)
Comorbidities	
Hypertension	33 (9.5%)
Diabetes	23 (6.6%)
Thyroid	8 (2.3%)
COPD	10 (2.9%)
Chronic Alcoholism	3 (0.9%)
Cardiac Disease	6 (1.7%)
Mental Disease	7 (2.0%)
Seizure Disorder	20 (5.7%)
Other Comorbidities	10 (2.9%)
Complications	
AKI	13 (3.7%)
Sepsis	48 (13.8%)
Multiple Organ Dysfunction	7 (2.0%)
Respiratory Complications	64 (18.4%)
Cardiovascular Complications	2 (0.6%)
Other Complications	14 (4.0%)
Antibiotics	
Aminoglycosides	27 (7.8%)
Penicillins	20 (5.7%)
Penicillin+Betalactam	154 (44.3%)
Macrolides	9 (2.6%)
Cephalosporin (1st Gen)	35 (10.1%)
Cephalosporin (2nd Gen)	3 (0.9%)
Cephalosporin (3rd Gen)	155 (44.5%)
Cephalosporin (4th Gen)	29 (8.3%)
Fluoroquinolones	40 (11.5%)
Lincosamide	3 (0.9%)
Sulfonamide	14 (4.0%)
Tetracycline	32 (9.2%)
Glycylcycline	2 (0.6%)
Carbapenem	70 (20.1%)
Oxazolidinones	35 (10.1%)
Polymyxins	119 (34.2%)
Glycopeptides	93 (26.7%)
Other Antibiotics	48 (13.8%)
Health Outcome	
Death	77 (22.1%)
DOPR	40 (11.5%)
LAMA	9 (2.6%)
Survived	222 (63.8%)

Abbreviations: IQR, Inter-Quartile Range; LPG, Liquefied Petroleum Gas; TBSA, Total Body Surface Area; ICU, Intensive Care Unit; COPD, Chronic Obstructive Pulmonary Disease; AKI, Acute Kidney Injury; DOPR, Discharge on Patient Request; LAMA, Leave Against Medical Advice.

Prevalence of MDR in Burn Patients

The overall prevalence of antimicrobial resistance, including MDR, XDR, and PDR, among culture-tested burn patients was 56.82%. MDR cases accounted for 28.92% (87 females and 68 males), while XDR cases represented 27.48% (78 females and 69 males), and PDR cases were scarce, comprising only 0.37% (1 female and 1 male). Overall resistance was found to be higher among females (31.03%) compared with males (25.79%) [Figure 2].

Factors Associated with MDR Among Burn Patients

Logistic regression analysis identified key risk factors associated with MDR in burn patients. ICU admission was a significant independent predictor, increasing the odds of MDR by threefold [Adjusted Odds Ratio (AOR): 3.047, CI: 1.089–8.528, $p = 0.034$]. The most notable risk factor was the use of a nasogastric (NG) tube, which was associated with a 12-fold higher risk of MDR [AOR: 11.830, CI: 1.339–104.489, $p = 0.026$]. Although bloodstream infections and sepsis showed a strong association in the Crude Odds Ratio (COR), this association lost statistical significance after adjusting for confounders. Factors such as burn size (Total Body Surface Area [TBSA] > 20%), comorbidities, and prolonged hospital stays (> 15 days) were not independently associated with MDR, suggesting that ICU care and invasive devices play a more direct role in the development of MDR. Notably, in the unadjusted analysis, delayed presentation (>3 days) appeared to be associated with decreased odds; however, this association lost significance after adjusting for other variables [Table 2].

Common Pathogens Isolated

Table 3 illustrates the distribution of microorganisms isolated in MDR and Non-MDR (NMDR) patients, which emphasizes the higher prevalence of Gram-negative bacterial infections in MDR patients compared to NMDR patients, with *P. aeruginosa* (31.6%), *K. pneumoniae* (19.7%), and *A. baumannii* (18.4%) being the most common isolates. In contrast, NMDR patients had

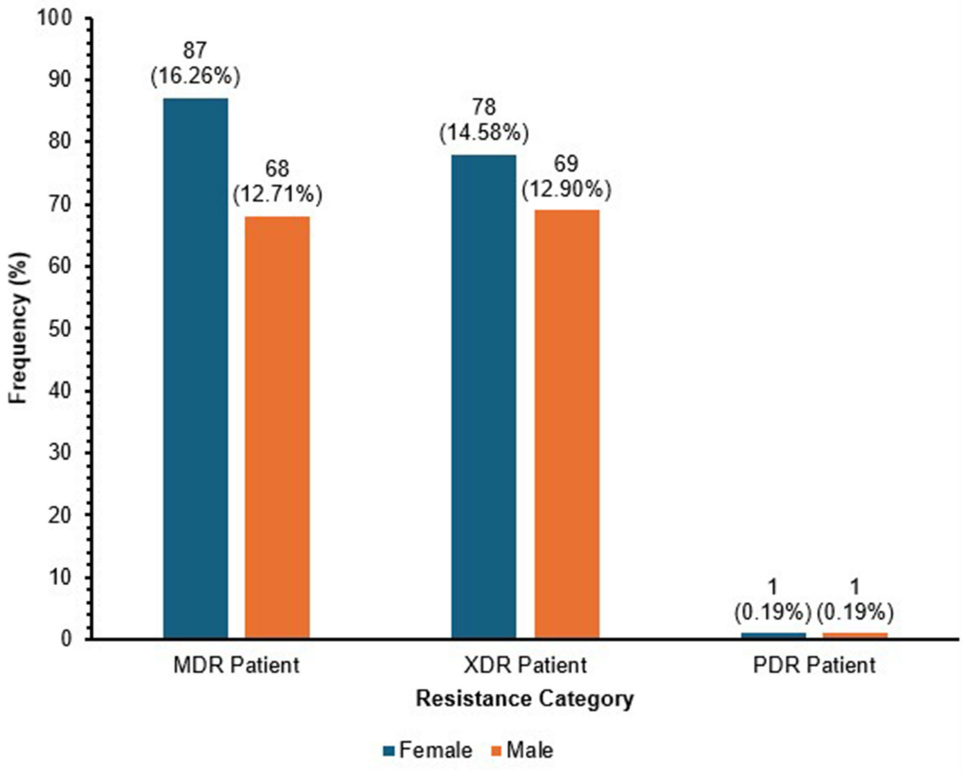

Figure 2 Prevalence of resistance levels among culture-tested burn patients (N = 535). This bar graph illustrates the distribution of MDR, XDR, and PDR bacterial infections among male and female burn patients. The y-axis represents frequency (%), and the x-axis displays resistance categories.

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Table 2 Factors Associated with MDR Among Burn Patients

Variables	COR (95% CI)	p-value	AOR (95% CI)	p-value
Age in Years	1.004 (0.991–1.018)	0.533	-	-
Gender				
Female (Reference)				
Male	0.759 (0.403–1.430)	0.393	-	-
ICU Admission				
No (Reference)				
Yes	6.713 (3.017–14.935)	<0.0001*	3.047 (1.089–8.528)	0.034*
Alleged Intent of Injury				
Accidental (Reference)				
Self-Inflicted	0.573 (0.063–5.250)	0.622	-	-
Cause				
Electric (Reference)		0.738	-	-
Flame	1.226 (0.470–3.198)	0.676	-	-
Scald	1.013 (0.345–2.972)	0.981	-	-
Others	3.086 (0.345–27.627)	0.314	-	-
Old Infected				
No (Reference)				
Yes	0.226 (0.108–0.474)	<0.0001*	0.402 (0.160–1.012)	0.053
Inhalation Injury				
No (Reference)				
Yes	4.846 (1.140–20.607)	0.033*	0.908 (0.174–4.745)	0.909
Degree				
1st (Reference)				
2nd	0.000 (0.000–0.000)	0.999	-	-
3rd	0.000 (0.000–0.000)	0.999	-	-
4th	1.000 (0.000–0.000)	1.000	-	-
Mixed	0.000 (0.000–0.000)	0.999	-	-
Comorbidities				
No (Reference)				
Yes	1.607 (0.717–3.604)	0.249	1.716 (0.709–4.150)	0.231
Invasive Device				
No Catheter (Reference)				
Catheter	3.164 (1.657–6.043)	<0.0001*	1.232 (0.555–2.735)	0.607
No NG tube (Reference)				
NG tube	24.731 (3.359–182.065)	0.002*	11.830 (1.339–104.489)	0.026*
No Ventilation (Reference)				
Ventilator	2.557 (0.592–11.053)	0.209	0.156 (0.020–1.191)	0.073
Surgery				
No (Reference)				
Yes	0.783 (0.315–1.950)	0.600	-	-
Site of Infection				
Skin - No (Reference)				
Skin - Yes	0.191 (0.025–1.433)	0.107	0.540 (0.058–5.048)	0.589
Blood - No (Reference)				
Blood - Yes	9.923 (1.338–73.574)	0.025*	1.759 (0.163–18.962)	0.642
Complications				
Sepsis with Septic Shock - No (Reference)				
Sepsis with Septic Shock - Yes	7.864 (1.057–58.506)	0.044*	4.889 (0.507–47.109)	0.170

(*Continued*)

Table 2 (Continued).

Variables	COR (95% CI)	p-value	AOR (95% CI)	p-value
TBSA%				
≤20% (Reference)				
>20%	4.378 (2.035–9.422)	<0.0001*	1.181 (0.438–3.186)	0.742
Presentation Time				
≤3 days (Reference)				
>3 days	0.343 (0.180–0.652)	0.001*	0.879 (0.386–2.002)	0.758
Length of Stay				
≤15 days (Reference)				
>15 days	1.696 (0.888–3.240)	0.110	0.913 (0.432–1.929)	0.812

Notes: (*) Indicates crude odds ratio and adjusted odds ratio with 95% confidence interval is significant at $p<0.05$.
Abbreviations: COR, Crude Odds Ratio; AOR, Adjusted Odds Ratio; ICU, Intensive Care Unit; NG, Nasogastric; TBSA, Total Body Surface Area.

Table 3 Mostly Cultured Organism in Burn Patients

Organism Isolated	MDR (n=304)	NMDR (n=44)	Total (N=348)
Gram Negative Bacteria			
A. baumanii	56 (18.4%)	1 (2.3%)	57 (16.4%)
Acinetobacter lwoffi (A. lwoffi)	25 (8.2%)	1 (2.3%)	26 (7.5%)
P. aeruginosa	96 (31.6%)	5 (11.4%)	101 (29.0%)
Citrobacter koseri (C. koseri)	54 (17.8%)	7 (15.9%)	61 (17.5%)
Enterobacter aerogens (E. aerogens)	8 (2.6%)	4 (9.1%)	12 (3.4%)
Enterobacter cloacae (E. cloacae)	5 (1.6%)	2 (4.5%)	7 (2.0%)
E. coli	43 (14.1%)	5 (11.4%)	48 (13.8%)
Klebsiella oxytoca (K. oxytoca)	1 (0.3%)	1 (2.3%)	2 (0.6%)
K. pneumoniae	60 (19.7%)	3 (6.8%)	63 (18.1%)
Proteus mirabilis (P. mirabilis)	12 (3.9%)	0 (0.0%)	12 (3.4%)
Proteus vulgaris (P. vulgaris)	4 (1.3%)	2 (4.5%)	6 (1.7%)
Gram Positive Bacteria			
CoNS	49 (16.1%)	5 (11.4%)	54 (15.5%)
MRSA	46 (15.1%)	0 (0.0%)	46 (13.2%)
S. aureus	19 (6.3%)	4 (9.1%)	23 (6.6%)
Staphylococcus saprophyticus (S. saprophyticus)	1 (0.3%)	0 (0.0%)	1 (0.3%)
Enterococcus faecalis (E. faecalis)	7 (2.3%)	4 (9.1%)	11 (3.2%)

Abbreviations: MDR, Multidrug Resistant; NMDR, Non-Multidrug Resistant; CoNS, Coagulase Negative Staphylococci; MRSA, Methicillin Resistance Staphylococcus aureus.

lower infection rates, with *P. aeruginosa* (11.4%) and *Citrobacter koseri (C. koseri)* (15.9%) being the most frequently isolated organisms. Among Gram-positive bacteria (GPB), Methicillin-resistant *Staphylococcus aereus* (MRSA) was found only in MDR patients (15.1%), while Coagulase-negative *Staphylococci* (CoNS) (16.1%) were more common in MDR cases than NMDR cases (11.4%). *Enterococcus faecalis* was more prevalent in NMDR cases (9.1%) compared to MDR cases (2.3%).

The overall prevalence of the most common Gram-Negative Bacteria (GNB) isolates among burn patients was found to be *P. aeruginosa* (29.0%), *K. pneumonia* (18.1%), *C. koseri* (17.5%), *A. baumannii* (16.4%), and *Escherichia coli (E. coli)* (13.8%). Among GPB, CoNS (15.5%), and MRSA (13.2%) were identified as common isolates in burn patients. Resistance to widely used antibiotics, including gentamicin, amikacin, ceftazidime, ciprofloxacin, amoxicillin, erythromycin, and cephalexin, was widespread in both gram-negative and gram-positive isolates. Despite this, GNB remained highly susceptible to polymyxins. At the same time, gram-positive organisms remained sensitive primarily to linezolid, vancomycin, and tigecycline.

Incidence and Use of Invasive Devices

Table 4 compares the use of invasive devices between MDR and NMDR patients. Catheters were the most frequently used devices, with 76% of MDR patients requiring them compared to 50% of NMDR patients. Nasogastric (NG) tubes were used exclusively in MDR patients (36.5%), followed by CVP lines (20.4%). Romovac drains were used only in MDR patients (2.0%), though in a smaller proportion. Additionally, ventilator use was higher in MDR patients (10.9%) compared to NMDR patients (4.5%).

Incidence and Site of Infection

Table 5 highlights the comparison of infection sites between MDR and NMDR patients, which shows that skin infections were the most common in both MDR (89.1%) and NMDR (97.7%) patients. However, bloodstream infections were significantly more frequent in the MDR group (18.8%) compared to NMDR patients (2.3%). Similarly, Urinary tract infections, lung infections, and catheter-related infections were observed in 12.8%, 4.3% and 11.2% of MDR patients, respectively, while none were reported in NMDR cases.

MDRO and Their Site of Infections

Table 6 illustrates the distribution of common organisms isolated in various sites of infection. Gram-negative bacteria were the predominant pathogens across most infection sites, accounting for 100% of urine infections, 98.7% of blood infections, and 71.1% of skin infections. Key GNB included *A. baumanii*, frequently isolated from blood (32.0%) and lungs (25.0%); *P. aeruginosa*, common in blood (23.1%), lungs (33.3%), skin (24.5%), and urine (23.8%); and *K. pneumoniae*, notably found in urine (23.8%) and blood (21.8%). Gram-positive bacteria were primarily found in skin (28.9%) and catheter infections (18.6%), with MRSA being significant in skin infections (13.0%) and CoNS in catheter infections (11.8%).

Table 4 Use of Invasive Devices Among MDR and NMDR Patients

Invasive Devices	MDR (n=304)	NMDR (n=44)
Catheter	231 (76.0%)	22 (50.0%)
CVP Lines	62 (20.4%)	0 (0.0%)
NG Tube	111 (36.5%)	1 (2.3%)
Romovac	6 (2.0%)	0 (0.0%)
Ventilator	33 (10.9%)	2 (4.5%)

Abbreviations: MDR, Multidrug Resistant; NMDR, Non-Multidrug Resistant; CVP, Central Venous Pressure; NG, Nasogastric.

Table 5 Site of Infection in MDR and NMDR Patients

Site of Infection	MDR (n=304)	NMDR (n=44)
Skin	271 (89.1%)	43 (97.7%)
Blood	57 (18.8%)	1 (2.3%)
Urine	39 (12.8%)	0 (0.0%)
Lungs	13 (4.3%)	0 (0.0%)
Catheter	34 (11.2%)	0 (0.0%)

Abbreviations: *MDR, Multidrug Resistant; NMDR, Non-Multidrug Resistant.*

Table 6 Mostly Cultured MDROs and Their Location in Burn Patients

Isolated Organisms	Site of Infection				
	Blood (n=78)	Catheter (n=59)	Lungs (n=12)	Skin (n=384)	Urine (n=42)
Gram Negative Bacteria					
A. baumanii	25 (32.0%)	11 (18.6%)	3 (25.0%)	36 (9.4%)	0 (0.0%)
A. lwoffi	6 (7.7%)	3 (5.1%)	0 (0.0%)	20 (5.2%)	0 (0.0%)
C. koseri	6 (7.7%)	10 (16.9%)	1 (8.3%)	38 (9.9%)	8 (19.0%)
E. aerogens	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (1.6%)	2 (4.8%)
E. cloacae	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (1.3%)	0 (0.0%)
E. coli	2 (2.6%)	4 (6.8%)	1 (8.3%)	30 (7.8%)	9 (21.4%)
K. oxytoca	1 (1.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
K. pneumoniae	17 (21.8%)	9 (15.3%)	3 (25.0%)	38 (9.9%)	10 (23.8%)
P. mirabilis	2 (2.6%)	5 (8.5%)	0 (0.0%)	4 (1.0%)	3 (7.2%)
P. vulgaris	0 (0.0%)	2 (3.4%)	0 (0.0%)	2 (0.5%)	0 (0.0%)
P. aeruginosa	18 (23.1%)	4 (6.8%)	4 (33.3%)	94 (24.5%)	10 (23.8%)
Total GNB	77 (98.7%)	48 (81.4%)	12 (100.0%)	273 (71.1%)	42 (100.0%)
Gram Positive Bacteria					
MRSA	0 (0.0%)	2 (3.4%)	0 (0.0%)	50 (13.0%)	0 (0.0%)
S. aureus	1 (1.3%)	0 (0.0%)	0 (0.0%)	14 (3.7%)	0 (0.0%)
E. faecalis	0 (0.0%)	2 (3.4%)	0 (0.0%)	5 (1.3%)	0 (0.0%)
CoNS	0 (0.0%)	7 (11.8%)	0 (0.0%)	42 (10.9%)	0 (0.0%)
Total GPB	1 (1.3%)	11 (18.6%)	0 (0.0%)	111 (28.9%)	0 (0.0%)

Abbreviations: CoNS, Coagulase Negative Staphylococci; MRSA, Methicillin Resistance Staphylococcus aureus; GNB, Gram Negative Bacteria; GPB, Gram Positive Bacteria.

Discussion

Burn patients are highly vulnerable to infections due to extensive tissue damage, loss of protective skin barrier, and compromised immune defences, which results in the requirement of prompt and specialized medical attention to reduce the risk of complications and death.[34] The increasing burden of antimicrobial resistance in such patients poses a significant challenge, particularly in resource-limited settings like Nepal.[35] This study evaluated the prevalence of MDR infections among hospitalized burn patients and identified associated risk factors and common resistant organisms.

Our findings are consistent with the local and international literature, which highlights antimicrobial resistance as a critical threat among burn patients. However, in the context of Nepal, data on the prevalence of MDR and its determinants among burn patients are limited.

Sociodemographic Characteristics

Burn injuries were most commonly observed in the young age group, with the highest proportions in children aged 0–10 years (22.7%) and young adults aged 21–30 years (17.5%). Similar age distributions have been reported by Karki et al,[36] Elsous et al,[37] and Odondi et al,[38] highlighting increased vulnerability among younger populations to accidental household burns and the risk among working-age adults due to occupational exposure. The slightly higher proportion of females (53.7%) compared to males (46.3%) aligns with several studies from South Asia that report a female predominance.[25,39–42] This could be due to increased engagement of females in household activities, loose clothing (like saris), and domestic violence.[1,43] However, other studies, such as those by Burton et al[44] and Dhakal,[45] reported higher burn rates among males, attributed to occupational and outdoor activities.

Burn Characteristics

Most patients (over 70%) had mild to moderate burns (≤30% TBSA), which is in agreement with previous studies conducted in Nepal.[36,45–47] Early intervention and improved safety awareness may have contributed to these lower TBSA values.[48] Flame burns were reportedly the most common cause, followed by scalds and electrical burns, while other

causes accounted for a smaller proportion. This result is in alignment with the studies conducted by Tripathee et al, Dhakal, and Othman et al and Khongwar et al[4,39,45,49,50] where similar predominance of flame burns was reported. This could be due to open flames, unsafe cooking practices, and fire hazards in remote areas.[43] Scald injuries, often associated with hot liquids, are more frequent among children and in domestic settings, probably due to their growing phase, restricted mobility, and interest in exploring.[48] While less common, electrical burns pose significant risks, especially in occupational environments or while working at home or with office appliances or circuits.[51] However, Ramirez-Blanco et al,[52] in contradiction to our findings, reported scald burn to be the leading cause of burn. Most patients in the study sustained second-degree burns (80.7%), as also reported by Eser et al and Ringo et al, who similarly observed a predominance of second-degree injuries among burn cases.[53,54] The cause of the burn may influence variation in burn depth. For instance, flame and scald injuries, the most common causes observed in our study, are more likely to result in second-degree burns, often necessitating hospitalization.[1]

Prevalence of MDR in Burn Patients

A substantial burden of antimicrobial resistance was observed in our study, with more than 50% of burn patients infected by multidrug- or extensively drug-resistant organisms.

A globally varied yet elevated MDR rate has been reported in burn settings.[55] For instance, Anjum et al[56] in Bangladesh reported 85% of *P. aeruginosa* isolates from burn wounds were MDR, and 12% were XDR without any identified cases of PDR. Similarly, Naz et al[57] found that 55% of *Proteus* species and 53.3% of *Providencia* species were MDR, with XDR rates of 39.4% and 46.6%, respectively, and no PDR isolates were obtained from burn wound cultures. More than 50% of the MDR or XDR were found across diverse clinical isolates, including burn and wound infections in the studies conducted in Saudi Arabia and Iran (MDR, 95.8%; XDR, 87.5%) and (MDR, 84%; XDR, 10%),[58,59] respectively, with only 6% cases of PDR.[59] Although this Saudi study showed a higher total resistance burden, the relative proportions (especially MDR $\gg$ XDR > PDR) differ from our findings, where MDR and XDR were nearly equivalent. A prevalence of over 20% MDR or XDR and a lesser prevalence of PDR as reported in our study, was found in research conducted by Rajbhandari et al[60] and Alnour et al[61] (MDR MDR GNB 22.3%, XDR 9.41%, PDR 0%) and (MDR, 29.3%; XDR 33.4%; PDR 12.4%) respectively.

These statistics indicate the concerning rise of MDR across the globe, limiting the effective antibiotic treatment among burn patients. The high burden of resistance observed may be attributable to the empirical use of broad-spectrum antibiotics, limited local antibiotic stewardship programs, prolonged hospitalization, invasive procedures, and ineffective infection control practices commonly seen in burn units.[62,63]

Risk Factors Contributing to MDR

This study identified ICU admission and the use of an NG tube as independent risk factors significantly associated with the development of MDR infections in burn patients. ICU environments harbor higher concentrations of resistant organisms due to frequent use of broad-spectrum antibiotics, high patient turnover, and the necessity of invasive procedures.[64] This finding is consistent with previous studies that reported ICU admission as a key determinant of MDR acquisition in critically ill or burn patients.[65]

Similarly, Prolonged use of NG tubes facilitates microbial colonization and serves as a potential entry route for pathogens, reflecting both the severity of illness and increased exposure to nosocomial flora.[66] Although other factors, such as TBSA > 20%, invasive catheters, sepsis, and bloodstream infections, were significant in univariate analysis, they did not retain significance in the multivariate model. This suggests that these factors may have acted as confounders and that sample size variation across subgroups might have limited statistical power for multivariate analysis. Nonetheless, patients with larger TBSA burns and those requiring invasive devices demonstrated a higher, though not statistically significant risk of MDR infection.[21,67] These findings underscore the importance of stringent infection prevention practices in burn units. Early wound excision and coverage, meticulous wound care, and adherence to aseptic techniques during device insertion and handling are critical to minimizing the risk of nosocomial infections.[68,69]

Common MDR Isolates

The study revealed that *P. aeruginosa, K. pneumoniae,* and *A. baumannii*, were common isolates among GNB, while CoNS and MRSA were common isolates among GPB in burn units. This distribution mirrors the patterns reported in multiple studies conducted in burn units worldwide, where GNB predominate among MDR pathogens.[70–72] *P. aeruginosa* is well-recognized for its intrinsic resistance mechanisms, including efflux pumps, reduced permeability, and the production of β-lactamases such as extended-spectrum β-lactamases (ESBLs) and metallo-β-lactamases, which significantly limit the available treatment options[73,74] and often display resistance to multiple antibiotic classes, including aminoglycosides, fluoroquinolones, cephalosporins, and carbapenems.[75] Similarly, Upreti et al concluded 80% of *E. coli*, 80% of *P. aeruginosa*, and 68.2% of *S. aureus* in their study were MDR strains.[76] Likewise, Van Langeveld et al[77] also found *P. aeruginosa* and *S. aureus* as the most common GNP and GPB cultured in MDR patients.

A. baumannii is equally concerning due to its environmental persistence and its remarkable genetic adaptability to acquiring resistance to almost all classes of antibiotics.[78] Studies have reported MDR *A. baumannii* rates exceeding 80% in burn units, with high resistance to carbapenems, fluoroquinolones, and aminoglycosides.[79] ALfadli et al[80] also indicated *A. baumannii* as the most common isolated organism, followed by *K. pneumonia*.

Similarly, *K. pneumoniae* has emerged as a critical MDR pathogen in burn patients, mainly due to ESBL and carbapenem production, including New Delhi Metallo-β-lactamase-1.[81] Increased resistance to macrolides, chloramphenicol, quinolones, as well as β-lactam drugs was observed in MDR *K. pneumoniae* due to mechanisms such as efflux pumps.[82]

On the other hand, studies conducted in India, Brazil, and Pakistan showed a prevalence of MDR *P. aeruginosa* of 15.2%, 23.1%, and 19%, respectively, which is lower compared to our findings.[83] These variations likely reflect heterogeneity in infection control measures, antibiotic stewardship and usage policies, surveillance capacity, access to newer antimicrobials, and infection prevention infrastructure across LMICs.

Implications for Clinical Practice and Policies

The findings from this study have several important clinical and policy-level implications. The high prevalence of MDR and XDR infections in burn patients underscores the urgent need for robust infection prevention and control measures, including adequate staffing, routine surveillance cultures, effective environmental hygiene, isolation protocols, and the appropriate use of personal protective equipment, especially in critical care settings.

Identifying ICU stays and NG tube use as modifiable risk factors highlights the importance of judicious use of invasive devices and enhanced aseptic practices. Regular reassessment of the need for invasive devices and their timely removal when clinically appropriate can further reduce infection burden.[84] Implementing standardized care bundles for invasive devices and conducting ongoing staff training are key components for effective Infection Prevention and Control.[85]

Diagnostic delays and empirical antibiotic overuse in LMICs contribute to high resistance rates.[86] Given these resistance patterns, empirical antibiotic regimens in burn units should be regularly revised and guided by up-to-date local antibiograms to ensure appropriate initial coverage while minimising unnecessary broad-spectrum antibiotics. Overuse of broad-spectrum antibiotics risks amplifying resistance and limiting future treatment options.[87] Our findings underscore the need for tailored antimicrobial stewardship programs that cater to resource-limited environments, with a focus on rational antibiotic prescribing, ongoing education for healthcare workers, and regular antimicrobial audits. Policy-level interventions, including enhanced laboratory funding, regulation of over-the-counter antibiotics, and national AMR action plans, are also essential. Burn units in LMICs must be prioritized due to their vulnerability to rapid transmission and colonization by resistant pathogens. Furthermore, adopting a "One Health" approach, which recognises the interconnectedness of human, animal, and environmental health, can enhance the control of antimicrobial resistance.[88] However, many medical professionals are still unaware of this approach, reducing its practical impact.[89] Raising awareness and training among healthcare professionals about this integrated approach is essential for sustainable stewardship and improved patient outcomes.

Strengths and Limitations of the Study

Strengths

This study provides valuable local evidence on the prevalence of MDR, XDR, and PDR infections among burn patients in a low-resource setting. It offers important insights that can support empirical antibiotic selection and guide targeted infection control strategies. By identifying independent risk factors associated with MDR infections, the study presents clinically relevant findings that can inform patient management. It also contributes to the limited body of research on AMR in burn patients, particularly in LMICs, where such data remain scarce. These findings can help shape antimicrobial stewardship efforts within institutions and inform broader infection prevention policies. Overall, the study addresses a significant knowledge gap and supports evidence-based improvements in treatment protocols for burn patients in LMICs.

Limitations

Despite its contribution, this study has some limitations that should be acknowledged. First, the single-center design may limit the applicability of the findings to other settings with different patient populations, microbial patterns, or infection control practices. Second, the retrospective design introduces the possibility of selection bias and limits the ability to infer causality between identified risk factors and clinical outcomes. The associations described should therefore be interpreted with caution. This study recognized positive culture growth as the sole tool to identify infection, which might not be a true representation. The study was also limited by the absence of data on prior antibiotic use and adherence to treatment protocols, both of which could influence resistance patterns. Only phenotypic antimicrobial susceptibility testing was performed; genetic characterisation and molecular typing were not included, which limits insight into specific resistance mechanisms and strain distribution. Additionally, the lack of follow-up beyond hospitalisation limits the assessment of long-term outcomes or recurrence of infections. Finally, reliance on existing hospital records may have introduced issues related to data completeness and accuracy, which could affect the strength of the conclusions.

Conclusion

This study highlights a substantial burden of antibiotic resistance among burn patients, with nearly half of the culture-positive cases MDR, XDR, and PDR organisms indicating an alarming trend, particularly in low-resource settings. Gram-negative bacteria, especially *P. aeruginosa, A. baumannii*, and *K. pneumoniae*, were the most commonly isolated MDR pathogens across various infection sites. The identification of modifiable risk factors, such as ICU admission and the use of a nasogastric tube, provides actionable targets for prevention strategies. Strengthening infection control protocols, optimizing antibiotic stewardship, and implementing regular resistance surveillance can significantly mitigate the emergence and spread of these resistant organisms. These findings contribute valuable evidence to guide targeted interventions and policy decisions in burn care and infection management.

Recommendations

To address the growing concern of antibiotic resistance in burn patients, it is recommended that hospitals implement regular surveillance for monitoring of microbial resistance patterns, specifically focusing on MDROs commonly isolated from burn wounds. Local antibiogram data should be regularly updated and used to guide empirical antibiotic therapy. Antimicrobial stewardship programs must be strengthened to ensure the judicious use of antibiotics through education, prescription audits, and multidisciplinary collaboration. Additionally, infection control measures, particularly those related to the use of invasive devices, should be rigorously enforced to minimize the risk of nosocomial infections. Strengthening microbiology laboratory capacity is crucial for ensuring the timely and accurate identification of resistant pathogens, thereby, enabling informed and evidence-based treatment decisions. Additionally, routine burn unit surveillance should be institutionalised to track local resistance trends and assess the effectiveness of infection control interventions over time.

Future research should focus on assessing the impact of prior antibiotic exposure, evaluating targeted treatment protocols, and conducting longitudinal studies to monitor changes in resistance patterns and the long-term outcomes of stewardship efforts in the burn care setting.

Abbreviations

AKI, Acute Kidney Injury; AMR, Antimicrobial Resistance; AOR, Adjusted Odds Ratio; CI, Confidence Interval; CoNS, *Coagulase Negative Staphylococci*; COPD, Chronic Obstructive Pulmonary Disease; COR, Crude Odds Ratio; CVP, Central Venous Pressure; DOPR, Discharge On Patient Request; ESBLs, Extended Spectrum Beta Lactamases; GNB, Gram Negative Bacteria; GPB, Gram Positive Bacteria; ICU, Intensive Care Unit; IQR, Inter-Quartile Range; IRC, Institutional Research Committee; LAMA, Leave Against Medical Advice; LOS, Length of Stay; LMICs, Low-Middle Income Countries; LPG, Liquefied Petroleum Gas; MDR, Multi-drug Resistant; MDRO, Multi-drug Resistant Organism; MRSA, Methicillin-resistant *Staphylococcus aureus*; NG, Nasogastric; NMDR, Non- Multi-drug Resistant; OR, Odds Ratio; PDR, Pan-Drug Resistant; PHECT, Public Health Concern Trust; SPSS, Statistical Package for Social Sciences; TBSA, Total Body Surface Area; WHO, World Health Organization; XDR, Extensively-Drug Resistant.

Data Sharing Statement

The datasets generated and/or analyzed during the current study are not publicly available due to institutional policy and patient confidentiality restrictions, but are available from the corresponding author on reasonable request.

Ethical Approval and Informed Consent

The study received ethical clearance from the Institutional Review Committee (IRC) of Public Health Concern Trust, Nepal (phect-NEPAL), under IRC application number 141-2024. As the study was a retrospective review of patient medical records, the ethics committee waived the requirement for informed consent. Patient confidentiality was strictly maintained throughout the study.

Consent for Publication

No identifiable personal data, images, or videos are included in this manuscript. Therefore, consent for publication was not required.

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Author Contributions

All authors made a significant contribution to the work reported, including aspects such as conception, study design, data collection, analysis, interpretation, or overall project execution. Each author was involved in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; agreed on the journal to which the article had been submitted; and agreed to be accountable for all aspects of the work. The specific contributions are as follows: Conceptualization: SM, SS, UA, KKN, SMS, NM, SS. Supervision: SS, UA, KKN. Data collection, analysis, and writing of the original draft: SM, NM. Data analysis and interpretation: SM, SMS. Critical revision with intellectual contribution: SM, SS, UA, KKN, SMS, NM, SS.

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