



ANTIMICROBIAL RESISTANCE PATTERNS AND CLINICAL DISTRIBUTION OF *PSEUDOMONAS AERUGINOSA* ISOLATES AT A TERTIARY CARE HOSPITAL IN CHANDIGARH, INDIA: A FIVE-YEAR RETROSPECTIVE LONGITUDINAL STUDY

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ABSTRACT

Background: *Pseudomonas aeruginosa* is a WHO critical-priority nosocomial pathogen having both intrinsic and acquired multidrug resistance determinants. Longitudinal surveillance data from public tertiary care hospitals in North India remain limited. This study characterizes antimicrobial resistance patterns, multidrug resistance (MDR) trends, seasonal variation, departmental distribution, and specimen-specific risk profiles over five years.. **Methods:** A retrospective observational study analysed 1,724 non-duplicate clinical isolates of *P. aeruginosa* recovered from pus/wound swabs (n = 1,532) and blood cultures (n = 192) at Government Medical College and Hospital (GMCH), Chandigarh, India, from January 2021 to May 2026. Antimicrobial susceptibility testing was performed by Kirby-Bauer disk diffusion; colistin MIC was determined by broth microdilution according to CLSI guidelines. MDR and XDR were defined per international consensus criteria. **Results:** Ciprofloxacin resistance was highest at 31.5%, followed by tobramycin (29.6%), gentamicin (26.3%), amikacin (22.4%), cefepime (21.4%), and ceftazidime (20.5%). Carbapenem resistance was 14.3% (imipenem) and 12.7% (meropenem). Piperacillin-tazobactam resistance declined markedly from 26.4% in 2021 to 2.5% in 2026. Colistin resistance was 0% across all 1,528 tested isolates. MDR prevalence was 21.1% (n = 364) and XDR was 10.3% (n = 177); no pandrug-resistant (PDR) isolates were identified. The Burns Unit exhibited the highest resistance burden (ciprofloxacin 74.1%, imipenem 63.0%, MDR 70.4%), followed by ENT (ciprofloxacin 65.9%, MDR 43.1%). Blood culture isolates showed higher amikacin resistance (29.5% vs. 21.5%, p = 0.012) than pus isolates. Monthly isolate burden peaked distinctly during the monsoon/post-monsoon months (July–October). **Conclusions:** *P. aeruginosa* demonstrates significant but evolving resistance patterns. Colistin remains fully active in vitro, and piperacillin-tazobactam exhibits favorable preservation. High departmental resistance in Burns and ENT units indicates an urgent need for ward-specific antibiograms and targeted stewardship interventions.

KEYWORDS :

INTRODUCTION

Pseudomonas aeruginosa is a ubiquitous, aerobic, Gram-negative, non-fermenting bacillus that ranks among the most clinically formidable opportunistic pathogens encountered in modern healthcare environments¹. Equipped with a large genome (~6.3 Mbp) encoding diverse virulence factors—including exotoxin A, type III secretion effector proteins, alkaline proteases, pyocyanin, and alginate polysaccharide—the organism is uniquely adapted to survive host immune responses and colonise damaged tissue². *P. aeruginosa* is implicated in a broad spectrum of severe healthcare-associated infections (HAIs), including ventilator-associated pneumonia (VAP), catheter-associated urinary tract infections (CAUTIs), surgical site and deep wound infections, catheter-related bloodstream infections (CRBSIs), and destructive burn wound sepsis, especially in immunocompromised, critical care, and paediatric populations.

The global burden of antimicrobial resistance (AMR) represents an escalating public health crisis. Landmark global systematic analyses from the Global Research on Antimicrobial Resistance (GRAM) study estimate that bacterial AMR was directly responsible for 1.27 million deaths worldwide in 2019 and contributed to nearly 4.95 million deaths, with Gram-negative pathogens accounting for the highest burden³. *P. aeruginosa* alone accounts for over 300,000 resistance-associated fatalities globally each year, and surveillance reports from the Centers for Disease Control and Prevention (CDC) document continued increase in hospital-acquired multidrug-resistant infections⁴.

Recognising this critical threat, the World Health Organization (WHO) continues to rank carbapenem-resistant *P. aeruginosa* (CRPA) in the "Critical Priority" tier of its Bacterial

Priority Pathogens List⁵, alongside carbapenem-resistant *Acinetobacter baumannii* and carbapenem-resistant Enterobacterales. As a member of the ESKAPE group (*Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Enterobacter species*), it has demonstrated a remarkable capacity to evade standard empirical antimicrobial regimens.

The therapeutic challenge posed by *P. aeruginosa* stems from its combination of intrinsic and acquired resistance determinants⁶. Intrinsic mechanisms include low outer-membrane permeability (12- to 100-fold lower than that of *Escherichia coli*), inducible chromosomal AmpC cephalosporinases, and constitutively expressed multidrug resistance (MDR) efflux pump systems such as *MexAB-OprM* and *MexXY-OprM*⁷. Acquired resistance occurs via horizontal acquisition of mobile genetic elements encoding metallo-beta-lactamases (MBLs), extended-spectrum beta-lactamases (ESBLs), and aminoglycoside-modifying enzymes (AMEs), as well as chromosomal mutations in the *OprD* outer membrane porin and *gyrA/parC* topoisomerase genes⁸.

India faces a substantial burden of AMR driven by high antibiotic consumption, over-the-counter antimicrobial availability, and a heavy underlying burden of comorbidities⁹.

This study provides a five-year retrospective analysis of antimicrobial resistance patterns, multidrug resistance (MDR) and extensive drug resistance (XDR) prevalence, departmental and specimen-wise distributions, and seasonal variations among 1,724 clinical isolates of *P. aeruginosa*.

2. MATERIALS AND METHODS

2.1 Study Setting and Design

This retrospective, observational, laboratory-based surveillance study was carried out at the Department of Microbiology, Government Medical College and Hospital (GMCH), Chandigarh, India. The study analysed all consecutive, non-duplicate clinical isolates of *P. aeruginosa*.

2.2 Specimen Inclusion and Exclusion Criteria

During the study period, all consecutive clinical isolates of *P. aeruginosa* from blood cultures and pus/wound swabs were included in the analysis. To prevent duplication, only the first *P. aeruginosa* isolate from each patient during the study period was included. The accompanying antibiotic-specific analysis did not include isolates with incomplete or unavailable antimicrobial susceptibility findings.

2.3 Microbiological Isolation and Identification

Clinical specimens were processed according to standard microbiological procedures¹⁰. Pus and wound swabs were inoculated onto 5% Sheep Blood Agar and MacConkey Agar (HiMedia Laboratories, Mumbai, India) and incubated aerobically at 37°C for 24–48 hours. Blood cultures were monitored using continuous-monitoring automated blood culture systems; positive bottles were subcultured onto solid media. *P. aeruginosa* was identified based on characteristic colony morphology, Gram staining, oxidase reaction, and standard biochemical tests.

2.4 Antimicrobial Susceptibility Testing (AST)

Antimicrobial susceptibility testing was performed on Mueller-Hinton Agar (MHA) plates using the Kirby-Bauer disk diffusion technique in accordance with Clinical and Laboratory Standards Institute (CLSI) M100 guidelines¹¹. Standardised antibiotic discs included: ciprofloxacin (5 µg), amikacin (30 µg), gentamicin (10 µg), tobramycin (10 µg), ceftazidime (30 µg), cefepime (30 µg), aztreonam (30 µg), piperacillin-tazobactam (100/10 µg), imipenem (10 µg), and meropenem (10 µg). Colistin susceptibility was determined by broth microdilution (BMD) using cation-adjusted Mueller-Hinton broth (CAMHB) to establish minimum inhibitory concentrations (MICs; Intermediate ≤ 2 µg/mL; Resistant ≥ 4 µg/mL). Quality control was maintained using the reference strain *Pseudomonas aeruginosa* ATCC 27853.

2.5 MDR, XDR, and PDR Definitions

Isolates were categorised using consensus criteria established by ECDC and CDC (Magiorakos et al.)¹². An isolate was defined as MDR if it showed non-susceptibility to at least one antimicrobial agent in three or more antimicrobial categories; labelled as XDR when it showed non-susceptibility to at least one agent in all but two or fewer antimicrobial categories, and PDR as non-susceptibility to all agents in all antimicrobial categories.

2.6 Statistical Analysis & Ethical Considerations

The presentation of the Categorical variables was done in the form of numbers and percentages (%). Antimicrobial resistance rates were calculated as the proportion of non-susceptible isolates among isolates tested for each antimicrobial agent. Trends in antimicrobial resistance and MDR/XDR prevalence over the study period were assessed by comparing annual proportions. Differences in antimicrobial resistance between pus/wound and blood culture isolates and among clinical departments were assessed using the chi-square test or Fisher's exact test, as appropriate. Statistical significance was defined as a two-sided p-value <0.05. Seasonal variation was assessed by comparing the monthly distribution of *P. aeruginosa* isolates across the study period. The data entry was done in the Microsoft EXCEL spreadsheet and the final analysis was done with the use of Statistical Package for Social Sciences (SPSS) software, IBM manufacturer, Chicago, USA, ver 26.0. For statistical significance, p value of less than 0.05 was considered statistically significant.

3. RESULTS

3.1 Annual Distribution and Demographic Characteristics

A total of 1,724 non-duplicate clinical isolates of *Pseudomonas aeruginosa* were isolated during the study period from January 2021 to May 2026. The annual number of isolates increased from 216 in 2021 to 399 in 2025, accounting for an 84.7% increase in isolate burden. A total of 119 isolates were recovered during January to May 2026 and were analysed separately because the isolated from not taken from a complete year. (Figure 1)

Pus and wound specimens constituted the predominant source of isolates, accounting for 1,532/1,724 (88.9%), whereas 192 (11.1%) were recovered from blood cultures. Male patients remained consistently predominant with 1,175 (68.2%) isolates obtained from male and 549 (31.8%) from female patients. Considering the age distribution, young adults (18–40 years) remained the predominant group with 600 (34.8%) patients trailed by middle-aged adults (41–60 years) comprising 596 (34.6%) patients followed by elderly (>60 years) contributing 364 (21.1%) patients whereas paediatric patients were 132 (7.7%). (Table 1)

The age-stratified analysis demonstrated an inverse relation between the age groups and MDR burden. Paediatric group showed the highest proportional of MDR (30.3%) trailed by young adults (23.7%). (Figure 2)

3.2 Departmental Distribution

With 649 (37.6%) isolates, General Surgery contributed the highest percentage of *P. aeruginosa* isolates, followed by ENT with 290 (16.8%), Internal Medicine with 237 (13.7%), and Orthopedics with 156 (9.0%). Eighty (4.6%) isolates were from dermatology, followed by other departments. (Table 2)

Significant disparities in antibiotic resistance were noted between clinical departments. The Burns Unit had the greatest resistance burden, with ciprofloxacin resistance at 74.1%, imipenem resistance at 63.0%, MDR prevalence of 70.4%, and XDR prevalence of 40.7%. ENT exhibited a significant resistance burden, with ciprofloxacin resistance at 65.9%, MDR prevalence at 43.1%, and XDR prevalence at 20.0%. (Table 3)

3.3 Overall Antimicrobial Susceptibility Profile

Ciprofloxacin exhibited the highest cumulative resistance, with 542 of 1,721 (31.5%) isolates being resistant. Trained by tobramycin at 29.6%, gentamicin at 26.3%, amikacin at 22.4%, cefepime at 21.4%, and ceftazidime at 20.5%. The prevalence of aztreonam resistance stood at 16.2%.

The prevalence of carbapenem resistance was notably lower, with 247 of 1,723 (14.3%) isolates being resistant and meropenem resistance was noted in 140 of 1,101 (12.7%) isolates. The resistance rate for piperacillin-tazobactam was recorded at 10.3%, whereas 83.6% of isolates were susceptible and 6.0% were deemed intermediate. Colistin revealed full in-vitro effectiveness among the 1,528 isolates assessed via broth microdilution, with a 100% susceptibility rate. (Table 4)

3.4 Longitudinal Antimicrobial Resistance Trend

Significant fluctuations in antibiotic resistance were noted during the study period. Ciprofloxacin resistance persistently persisted at elevated levels, fluctuating from 26.4% in 2024 to 34.3% in 2022, and recorded at 27.7% between January and May 2026. Conversely, resistance to several other agents shown a general decline. Amikacin resistance decreased from 25.9% in 2021 to 13.8% in 2024, 20.1% in 2025, and 11.8% from January to May 2026. Ceftazidime resistance diminished from 25.6% in 2021 to 7.6% in 2026.

Imipenem resistance diminished from 24.1% in 2021 to 5.0% between January and May 2026. In 2023, the resistance to

meropenem was 15.0%, which declined to 10.2% in 2024, rose somewhat to 14.1% in 2025, and reached 9.2% in 2026. Piperacillin-tazobactam exhibited the most significant decline, decreasing from 26.4% resistance in 2021 to 8.3% in 2022, remaining under 11% subsequently and achieving 2.5% in 2026. Colistin resistance persisted at 0% for the entire surveillance duration. (Table 5)

3.5 Comparison of Pus/Wound and Blood Culture Isolates

Resistance profiles varied across isolates obtained from pus or wound specimens and those derived from blood cultures. Ciprofloxacin resistance was markedly elevated in pus/wound isolates compared to blood culture isolates (32.9% versus 20.3%; $p < 0.001$). Conversely, the resistance to amikacin was markedly elevated in blood culture isolates (29.5% compared to 21.5%; $p = 0.012$). Gentamicin resistance shown comparable rates in both cohorts (26.2% versus 27.5%; $p = 0.698$). Imipenem resistance (13.9% compared to 17.7%; $p = 0.147$) and meropenem resistance (13.0% against 10.5%; $p = 0.443$) exhibited no significant differences between pus/wound and blood isolates. Colistin susceptibility remained same in both cohorts, with no resistance seen.

The general incidence of multidrug-resistant organisms was markedly greater in pus/wound isolates compared to blood culture isolates (22.1% versus 13.0%; $p = 0.004$). The occurrence of XDR was not statistically different across the two specimen groups (10.6% compared to 7.8%; $p = 0.231$). (Table 6)

3.6 Seasonal Distribution

The monthly distribution exhibited a notable rise in the load of *P. aeruginosa* isolates during the monsoon and post-monsoon phases, especially from July to October. This seasonal aggregation was noted throughout the monitoring duration and signifies a crucial epidemiological characteristic of the institutional isolate distribution.

3.7 MDR, XDR and PDR

Overall, 364/1,724 (21.1%) isolates fulfilled the criteria for MDR and 177 (10.3%) were classified as XDR. No PDR isolates were identified during the surveillance period. The annual analysis demonstrated variation in MDR and XDR prevalence over time, while the department-stratified analysis showed substantial heterogeneity, with the highest burden observed in the Burns Unit. (Figure 3)

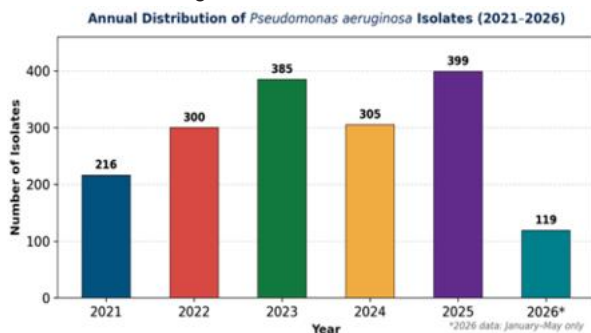


Figure 1: Annual distribution of *Pseudomonas aeruginosa* isolates at GMCH Chandigarh (January 2021 – May 2026). A progressive 84.7% increase in annual isolate burden is documented between 2021 and 2025. (*2026 reflects January–May data only).

Table 1: Annual Isolate Distribution, Specimen Type, Sex, and Age Demographics

Parameter	2021	2022	2023	2024	2025	2026*	Total
Total Isolates (n)	216	300	385	305	399	119	1,724
Pus / Wound Swabs n (%)	193 (89.4)	265 (88.3)	341 (88.6)	271 (88.9)	349 (87.5)	113 (95.0)	1,532 (88.9)
Blood Cultures n (%)	23 (10.6)	35 (11.7)	44 (11.4)	34 (11.1)	50 (12.5)	6 (5.0)	192 (11.1)

Male Patients n (%)	148 (68.5)	208 (69.3)	262 (68.1)	207 (67.9)	269 (67.4)	81 (68.1)	1,175 (68.2)
Female Patients n (%)	68 (31.5)	92 (30.7)	123 (31.9)	98 (32.1)	130 (32.6)	38 (31.9)	549 (31.8)
Paediatric (<18 yrs) n (%)	—	—	—	—	—	—	132 (7.7)
Young Adult (18-40 yrs) n (%)	—	—	—	—	—	—	600 (34.8)
Middle-Aged (41-60 yrs) n (%)	—	—	—	—	—	—	596 (34.6)
Elderly (>60 yrs) n (%)	—	—	—	—	—	—	364 (21.1)

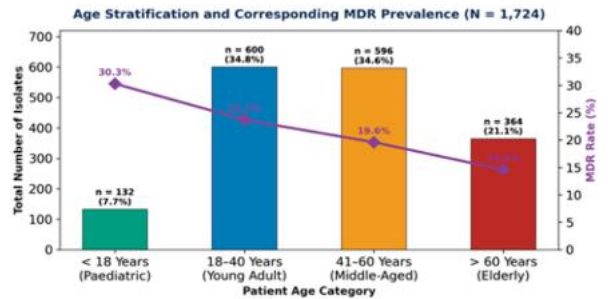


Figure 2: Patient age stratification and corresponding Multidrug Resistance (MDR) rates. The paediatric population (<18 years) exhibited the highest proportional MDR prevalence (30.3%), followed by young adults (23.7%).

3.2 Departmental Distribution and Resistance Hotspots

Table 2: Clinical Departmental Distribution of *P. aeruginosa* Isolates (2021-2026)

Clinical Department / Specialty	Absolute Isolate Count (n)	Proportional Share (%)
General Surgery	649	37.6%
Otorhinolaryngology (ENT)	290	16.8%
Internal Medicine	237	13.7%
Orthopaedics	156	9.0%
Dermatology	80	4.6%
Paediatrics	45	2.6%
Pulmonology / Respiratory Medicine	35	2.0%
Obstetrics & Gynaecology	33	1.9%
Burns Unit	27	1.6%
Intensive Care Unit (ICU)	21	1.2%
Cardiology	17	1.0%
Neurology	17	1.0%
Other Specialty Services	117	6.8%
Total	1,724	100.0%

Table 3: Department-Stratified Resistance Rates and MDR/XDR Prevalence

Department	Isolates (n)	Ciprofloxacin R%	Imipenem R%	MDR Rate (%)	XDR Rate (%)
General Surgery	649	27.6%	14.9%	17.6%	8.9%
ENT	290	65.9%	12.1%	43.1%	20.0%
Internal Medicine	237	27.0%	15.2%	17.3%	8.4%
Orthopaedics	156	14.2%	5.8%	9.0%	3.2%
Burns Unit	27	74.1%	63.0%	70.4%	40.7%
Intensive Care Unit (ICU)	21	28.6%	23.8%	28.6%	14.3%

3.4 Overall Antimicrobial Susceptibility Profile

Table 4: Cumulative Antimicrobial Susceptibility Profile of *P. aeruginosa* Isolates (2021-2026)

Antimicrobial Agent	Class	Tested (n)	Sensitive (%)	Intermediate (%)	Resistant (%)	Resistance Rate (%)
Ciprofloxacin (5 µg)	Fluoro-quinolone	1,721	1,126 (65.4)	53 (3.1)	542 (31.5)	31.5%

Tobramycin (10 µg)	Amino-glycoside	331	231 (69.8)	2 (0.6)	98 (29.6)	29.6%
Gentamicin (10 µg)	Amino-glycoside	1,649	1,192 (72.3)	23 (1.4)	434 (26.3)	26.3%
Amikacin (30 µg)	Amino-glycoside	1,706	1,282 (75.1)	42 (2.5)	382 (22.4)	22.4%
Cefepime (30 µg)	4th Gen Cephalosporin	313	233 (74.4)	13 (4.2)	67 (21.4)	21.4%
Ceftazidime (30 µg)	3rd Gen Cephalosporin	1,721	1,307 (75.9)	62 (3.6)	352 (20.5)	20.5%
Aztreonam (30 µg)	Mono-bactam	1,712	1,169 (68.3)	265 (15.5)	278 (16.2)	16.2%
Imipenem (10 µg)	Carbapenem	1,723	1,361 (79.0)	115 (6.7)	247 (14.3)	14.3%
Meropenem (10 µg)	Carbapenem	1,101	920 (83.6)	41 (3.7)	140 (12.7)	12.7%
Piperacillin-Tazobactam	BLI Combination	1,721	1,439 (83.6)	104 (6.0)	178 (10.3)	10.3%
Colistin (BMD MIC)	Polymyxin	1,528	1,528 (100.0)	0 (0.0)	0 (0.0)	0.0%

3.5 Longitudinal Trends in Antimicrobial Resistance

Table 5: Year-Wise Antimicrobial Resistance Trajectory (%) (2021–2026)

Antimicrobial Agent	2021	2022	2023	2024	2025	2026*
Ciprofloxacin	31.5%	34.3%	33.5%	26.4%	32.4%	27.7%
Gentamicin	27.3%	33.3%	27.0%	20.4%	26.1%	21.0%
Amikacin	25.9%	31.3%	26.0%	13.8%	20.1%	11.8%
Ceftazidime	25.6%	26.7%	23.1%	14.5%	18.8%	7.6%
Aztreonam	23.7%	21.7%	13.7%	12.5%	14.6%	12.6%
Imipenem	24.1%	16.0%	13.5%	10.2%	14.5%	5.0%
Meropenem	N/A	N/A	15.0%	10.2%	14.1%	9.2%
Piperacillin-Tazobactam	26.4%	8.3%	10.1%	6.3%	8.8%	2.5%
Colistin	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 6: Comparison of Resistance Profiles Between Pus/Wound and Blood Isolates

Antimicrobial / Category	Pus/Wound Swabs (n=1,532)	Blood Cultures (n=192)	p-value	Statistical Significance
Ciprofloxacin Resistance	32.9% (n=503)	20.3% (n=39)	< 0.001	Significant (p < 0.01)
Gentamicin Resistance	26.2% (n=383)	27.5% (n=51)	0.698	Not Significant
Amikacin Resistance	21.5% (n=326)	29.5% (n=56)	0.012	Significant (p < 0.05)
Imipenem Resistance	13.9% (n=213)	17.7% (n=34)	0.147	Not Significant
Meropenem Resistance	13.0% (n=127)	10.5% (n=13)	0.443	Not Significant
Colistin Resistance	0.0% (n=0)	0.0% (n=0)	> 0.999	Identical (100% S)
MDR Rate (>= 3 classes)	22.1% (n=339)	13.0% (n=25)	0.004	Significant (p < 0.01)
XDR Rate (>= 4 classes)	10.6% (n=162)	7.8% (n=15)	0.231	Not Significant

3.7 Multidrug Resistance (MDR) and Extensive Drug Resistance (XDR)

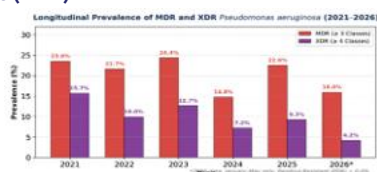


Figure 3: Annual prevalence (%) of Multidrug-Resistant

(MDR; ≥ 3 antibiotic classes) and Extensively Drug-Resistant (XDR; ≥ 4 classes) *Pseudomonas aeruginosa*. Zero pandrug-resistant (PDR) isolates were detected throughout the 5-year surveillance window.

4. DISCUSSION

This five-year surveillance study of 1,724 *P. aeruginosa* isolates provides longitudinal resistance data from a tertiary medical institution in North India. Several key clinical observations emerge:

4.1 Fluoroquinolone Resistance and Departmental Pressures

Ciprofloxacin showed the highest overall resistance in our study (31.5%), with resistance levels remaining consistently high during the monitoring period. This finding is significant because fluoroquinolones have traditionally been extensively used to treat *P. aeruginosa*, especially in urinary, respiratory, and ear infections. In Northern India, outpatient and specialty ENT clinics frequently encounter chronic suppurative otitis media (CSOM), where topical and systemic ciprofloxacin are widely used as first-line empirical treatments^{13, 14}. Chronic topical fluoroquinolone exposure exerts selective pressure in the external auditory canal and middle ear, selecting for point mutations within the bacterial quinolone resistance-determining regions (QRDR) of *gyrA* (e.g., Thr83Ile) and *parC* (e.g., Ser87Leu), as well as triggering the overexpression of RND efflux pumps such as *MexAB-OprM* and *MexCD-OprJ*. In line with nationwide surveillance reports from the Indian Council of Medical Research (ICMR) Antimicrobial Resistance Surveillance Network¹⁵.

4.2 Hyper-Resistance and Infection Dynamics in the Burns Unit

Isolates from the Burns Unit demonstrated the highest resistance burden across all clinical departments, exhibiting 74.1% resistance to ciprofloxacin, 63.0% to imipenem, and an overall MDR prevalence of 70.4% (with 40.7% classified as XDR). Patients with extensive thermal injury represent a highly susceptible population due to loss of the physical cutaneous barrier, systemic thermal shock-induced immunosuppression, hypermetabolic physiology, and the necessity of prolonged intravenous access and urinary catheterisation^{16,17}.

Burn wounds provide a protein-rich, avascular eschar environment that promotes rapid pseudomonal colonisation and dense biofilm formation, which significantly impairs antibiotic penetration^{17, 18}. Furthermore, routine systemic antimicrobial prophylaxis, repeated wound debridements, and prolonged hospitalisation select for multidrug-resistant, high-risk international pseudomonal clones (such as ST235 and ST111) that frequently harbor metallo-beta-lactamases and aminoglycoside-modifying enzymes^{18,19}.

4.3 Carbapenem Trajectories and Molecular Epidemiology

Carbapenem resistance among our isolates was documented at 14.3% for imipenem and 12.7% for meropenem. These resistance frequencies are lower than those reported from several other tertiary public hospitals in India, where carbapenem resistance in *P. aeruginosa* has ranged from 25% to 50%^{20,21}, as well as international longitudinal series²².

In *P. aeruginosa*, carbapenem resistance typically arises through non-carbapenemase mechanisms—primarily mutational inactivation or transcriptional downregulation of the *OprD* outer membrane porin, frequently coupled with baseline AmpC derepression and *MexAB-OprM* efflux pump upregulation^{19, 20}. However, the dissemination of transferable carbapenemases (including class B metallo-beta-lactamases such as NDM, VIM, and IMP) represents an emerging clinical challenge in South Asian healthcare environments²¹.

4.4 Piperacillin-Tazobactam as a Carbapenem-Sparing Alternative

Piperacillin-tazobactam exhibited a total resistance rate of 10.3%, with a significant decrease from 26.4% in 2021 to 2.5% in 2026. This signifies one of the most favourable longitudinal trend observed in our study. This decline may be associated with antimicrobial stewardship initiatives implemented at GMCH Chandigarh, which emphasised targeted empiric selection and restricted indiscriminate carbapenem use. By preserving susceptibility to piperacillin-tazobactam, clinicians have access to an effective beta-lactam agent for empirical and directed antipseudomonal therapy, facilitating carbapenem-sparing regimens in hemodynamically stable patients per international guidelines^{23,24}.

4.5 Complete Preservation of Colistin Efficacy

While reports from several international centres have documented the emergence of plasmid-mediated colistin resistance (*mcr* genes) and difficult-to-treat (DTR) Gram-negative phenotypes^{25, 26}, colistin remains fully active at our institution. This preserved efficacy likely reflects institutional policies that restrict parenteral polymyxin use strictly to laboratory-confirmed XDR or carbapenem-resistant infections where all conventional beta-lactams and aminoglycosides have failed²⁷.

4.6 MDR and XDR Burden

In all, 21.1% of the isolates were MDR and 10.3% were XDR, with no PDR isolates identified. The burden of multidrug-resistant organisms was much greater in the Burns Unit and ENT compared to the primary general clinical departments.

The general incidence of MDR aligns with the range documented in extensive surveillance studies. In the 20-year SENTRY study, the prevalence of MDR was 24.9% overall, declining from 27.5% between 2005 and 2008 to 21.8% from 2013 to 2016. The associated XDR prevalence diminished from 20.2% to 15.2%²⁸.

4.6 Seasonal Patterns and Infection Control Implications

An important epidemiological observation is the marked seasonal increase in *P. aeruginosa*. A notable rise in the load of *P. aeruginosa* isolates was detected from July to October, aligning generally with the monsoon and post-monsoon seasons.

For *P. aeruginosa*, factors such as environmental durability, moisture levels, water contact, healthcare usage, wound severity, and alterations in patient demographics may hypothetically influence seasonal fluctuations²⁹.

5. CONCLUSIONS

This five-year surveillance study documents the evolving antimicrobial resistance dynamics of *Pseudomonas aeruginosa*. The major findings were persistent resistance to ciprofloxacin, significant resistance to aminoglycosides, and pronounced clustering of MDR/XDR in Burns and ENT. Conversely, diminishing resistance to piperacillin-tazobactam, amikacin, and carbapenems, along with total in-vitro susceptibility to colistin in the isolates, signifies positive outcomes.

The evidence endorses ongoing longitudinal laboratory monitoring alongside department-specific antibiograms, tracking of antibiotic usage, infection control measures, and molecular analysis of high-risk resistant strains. The significant disparities among clinical services suggest that antimicrobial stewardship approaches ought to be customized to local contexts rather than relying exclusively on hospital-wide resistance data.

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