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TEMPORAL TRENDS IN MULTIDRUG-RESISTANT ORGANISMS AND ANTIMICROBIAL RESISTANCE RATES FOLLOWING IMPLEMENTATION OF AN ANTIMICROBIAL STEWARDSHIP PROGRAM: A 17-MONTH SURVEILLANCE STUDY FROM A TERTIARY CARE HOSPITAL IN JAIPUR, INDIA

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ABSTRACT

Background: Multidrug-resistant organisms (MDROs) are a growing threat to patient safety in tertiary care hospitals, particularly in intensive care units (ICUs). Antimicrobial stewardship programs (ASPs) are recommended to curb the emergence and spread of resistance, but sustained facility-level surveillance data from Indian hospitals demonstrating temporal impact remain limited.

Methods: We conducted a retrospective, descriptive surveillance study of clinical microbiology culture and sensitivity (C&S) records at a tertiary care hospital in Jaipur, India, spanning March 2025 to July 2026 (17 months), during ongoing implementation of an antimicrobial stewardship program. Monthly counts of total clinical isolates and MDROs were extracted, and organism-, specimen-, and location-wise distributions of individual MDRO isolates were tabulated. The monthly antimicrobial resistance (AMR) rate was defined as (MDRO isolates / total clinical isolates) × 100. Temporal trend was assessed by simple linear regression and Pearson correlation; the pre- and post-midpoint periods were compared using the chi-square test. A two-tailed p-value <0.05 was considered statistically significant.

Results: Of 770 culture and sensitivity requests processed, 192 (24.9%) yielded a clinically significant isolate, of which 59 (30.7%) were MDROs. Sixty individual MDRO isolates were characterized on line-listing; Klebsiella pneumoniae (28.3%) and Pseudomonas aeruginosa (23.3%) were the predominant organisms, followed by Escherichia coli (13.3%) and Enterobacter cloacae complex (11.7%). MDROs were most frequently isolated from urine (30.0%) and pus (28.3%) specimens and originated predominantly from general wards (51.7%) and ICUs (40.0%). The monthly AMR rate declined significantly over the surveillance period (Pearson $r = -0.51$, $R^2 = 0.26$, linear regression slope = −1.93% per month, $t(15) = -2.30$, $p = 0.036$). The mean AMR rate fell from 34.8% in the first 12 months (Mar 2025–Feb 2026) to 21.1% in the final 5 months (Mar–Jul 2026), a difference that approached statistical significance ($\chi^2 = 3.57$, df = 1, $p = 0.059$).

Conclusion: A statistically significant downward trend in monthly antimicrobial resistance rate was observed over the surveillance period, coinciding with sustained antimicrobial stewardship activity. Klebsiella pneumoniae and Pseudomonas aeruginosa, both WHO critical-priority pathogens, dominated the MDRO burden, with wards and ICUs contributing over 90% of isolates. These findings support continued, targeted stewardship and infection-control efforts, with periodic surveillance-based feedback.

Keywords: Antimicrobial Resistance; Multidrug-Resistant Organisms; Antimicrobial Stewardship Program; Hospital Surveillance; Klebsiella Pneumoniae; Pseudomonas Aeruginosa; India

1 INTRODUCTION

Antimicrobial resistance (AMR) is among the foremost threats to global public health, contributing to an estimated 1.27 million deaths directly attributable to bacterial AMR and a further 4.95 million deaths associated with it worldwide in 2019. Multidrug-resistant organisms (MDROs) — defined as bacterial isolates non-susceptible to at least one agent in three or more antimicrobial classes — disproportionately affect hospitalized patients, particularly those in intensive care units (ICUs), where invasive devices, prolonged antibiotic exposure, and cross-transmission converge to amplify resistant clones.

The World Health Organization's 2024 Bacterial Priority Pathogens List (BPPL) reaffirms carbapenem-resistant Enterobacterales (including Klebsiella pneumoniae and Escherichia coli), carbapenem-resistant Acinetobacter baumannii, and carbapenem-resistant Pseudomonas aeruginosa as critical-priority organisms warranting urgent surveillance, infection-control, and antimicrobial stewardship attention. In India, high baseline rates of carbapenem and colistin resistance among Gram-negative pathogens, combined with variable stewardship infrastructure across hospitals, make institution-level longitudinal surveillance essential to gauge the real-world impact of stewardship interventions.

Antimicrobial stewardship programs (ASPs) structured institutional efforts to optimize antimicrobial selection, dosing, duration, and route while minimizing collateral resistance — have been shown to reduce resistance rates, Clostridioides difficile infection, and antimicrobial expenditure when implemented consistently. However, published Indian data quantifying month-on-month resistance trends over an extended (>1 year) stewardship period, with concurrent organism- and location-level characterization, remain sparse.

This study describes 17 months of MDRO and AMR-rate surveillance data from the Department of Microbiology at a tertiary care hospital in Jaipur, India, during active implementation of an antimicrobial stewardship program. We aimed to (i) quantify the overall and monthly antimicrobial resistance rate, (ii) characterize the organism-, specimen-, and location-wise distribution of MDROs, and (iii) statistically evaluate the temporal trend in resistance rate over the surveillance period.

2 MATERIALS AND METHODS

2.1 Study design and setting

This was a retrospective, descriptive, hospital-based surveillance study conducted in the Department of Microbiology, Bombay Hospital Trust, Jaipur, Rajasthan, India — a tertiary care hospital with medical, surgical, and critical care services. The study period spanned March 2025 to July 2026 (17 consecutive months), coinciding with the hospital's ongoing antimicrobial stewardship program.

2.2 Data source

Two prospectively maintained institutional line lists were used. The first recorded monthly aggregate counts of culture and sensitivity (C&S) requests processed, total clinically significant isolates recovered, and the number identified as MDROs, from which the monthly antimicrobial resistance rate was calculated. The second was a case-level line list of individual MDRO isolates from March 2025 to July 2026, recording the year, month, clinical specimen type, organism with resistance phenotype, and hospital location (ICU, general ward, or outpatient department [OPD]).

2.3 Definitions

MDRO was defined per standard CDC/NHSN and WHO/INICC surveillance conventions as an organism demonstrating resistance to at least one agent in three or more antimicrobial categories, including isolates further characterized as extensively drug-resistant (XDR) or pandrug-resistant (PDR), and carbapenem-resistant Enterobacterales (CRE) / carbapenemase-producing organisms. Only clinically significant isolates (excluding presumed colonizers per standard laboratory criteria) were included in the denominator of total clinical isolates. The monthly antimicrobial resistance

(AMR) rate was calculated as: AMR rate (%) = (Number of MDRO isolates / Total clinical isolates) × 100, consistent with the hospital's antimicrobial stewardship program indicator definition.

2.4 Statistical analysis

Descriptive statistics (frequencies and percentages) were used to summarize organism, specimen, and location distributions. The overall AMR rate was calculated by pooling MDRO and total-isolate counts across all 17 months. Temporal trend in the monthly AMR rate was assessed using simple linear regression (month, coded 1–17, as the independent variable) with the Pearson product-moment correlation coefficient (r), coefficient of determination (R^2), and a two-tailed t-test on the regression slope (df = n−2). To evaluate whether the proportion of MDRO isolates differed between an earlier and later phase of the surveillance period, isolates were dichotomized into Period 1 (March 2025–February 2026, first 12 months) and Period 2 (March–July 2026, final 5 months), and compared using the chi-square test on a 2×2 contingency table (MDRO-positive vs. non-MDRO isolates by period). A p-value <0.05 was considered statistically significant; a p-value between 0.05 and 0.10 was interpreted as a trend approaching significance. Calculations were performed manually and cross-verified; no patient-identifiable data were analyzed as only aggregate laboratory surveillance data were used.

3 RESULTS

3.1 Overall culture positivity and resistance burden

During the 17-month period, 770 C&S requests were processed, yielding 192 clinically significant isolates (overall culture positivity 24.9%). Of these, 59 (30.7%) met criteria for MDRO. Monthly AMR rate ranged widely, from 0% (March 2026, a month with no significant clinical isolates) to a peak of 88.9% (March 2025), reflecting the small monthly isolate denominators typical of a single-center laboratory (Table 1).

Table 1: Monthly culture and sensitivity workload, clinical isolates, MDRO counts, and antimicrobial resistance rate, March 2025–July 2026.

Month	C&S requests	Total clinical isolates	MDRO isolates	AMR rate (%)
Mar-25	38	9	8	88.9
Apr-25	61	22	5	22.7
May-25	38	9	3	33.3
Jun-25	32	9	4	44.4
Jul-25	43	9	2	22.2
Aug-25	39	14	4	28.6
Sep-25	48	18	4	22.2
Oct-25	29	4	1	25.0
Nov-25	33	9	3	33.3
Dec-25	33	9	4	44.4
Jan-26	34	14	5	35.7
Feb-26	44	9	4	44.4
Mar-26	45	0	0	0.0
Apr-26	48	18	5	27.8
May-26	49	8	1	12.5
Jun-26	77	13	2	15.4
Jul-26	79	18	4	22.2

C&S, culture and sensitivity; MDRO, multidrug-resistant organism; AMR, antimicrobial resistance.

3.2 Organism distribution

Sixty individual MDRO isolates were characterized in the case-level line list. Klebsiella pneumoniae (including K. pneumoniae and K. aerogenes) accounted for the largest share (19/60, 31.7%), followed by Pseudomonas species (P. aeruginosa and Pseudomonas spp., 16/60, 26.7%), Escherichia coli (8/60, 13.3%), and Enterobacter cloacae complex (7/60, 11.7%). Acinetobacter baumannii comprised 6.7% (4/60). Collectively, Enterobacterales accounted for 61.7% (37/60) of MDROs and non-fermenting Gram-negative bacilli for 33.3% (20/60); a single Gram-positive isolate (vancomycin-resistant Enterococcus spp.) was recorded (1.7%) (Table 2). Resistance phenotypes recorded included pan-drug-resistant, carbapenem-resistant/carbapenemase-producing, and multidrug-resistant categories, with carbapenem-resistant Enterobacterales and pan-resistant non-fermenters recorded with increasing frequency from late 2025 onward.

Table 2: Organism-wise distribution of MDRO isolates, March 2025–July 2026 (n = 60).

Organism	n	%
Klebsiella pneumoniae	17	28.3
Pseudomonas aeruginosa	14	23.3
Escherichia coli	8	13.3
Enterobacter cloacae complex	7	11.7
Acinetobacter baumannii	4	6.7
Klebsiella aerogenes	2	3.3
Pseudomonas spp.	2	3.3
Proteus mirabilis	2	3.3
Providencia rettgeri	2	3.3
Citrobacter spp.	1	1.7
Enterococcus spp. (VRE)	1	1.7
Total	60	100.0

3.3 Specimen and location distribution

By specimen type, urine (including catheter specimens) and pus were the leading sources of MDRO isolates, together accounting for more than half of all isolates, followed by respiratory specimens (endotracheal aspirate, bronchoalveolar lavage, sputum, tracheal aspirate) and blood/sterile-site specimens. By location, general wards contributed the largest proportion of MDRO isolates (31/60, 51.7%), followed by ICUs (24/60, 40.0%) and OPD (5/60, 8.3%) (Table 3). Although wards contributed the largest absolute number, the ICU's contribution was disproportionate to its typically smaller patient volume relative to general wards, consistent with the recognized concentration of resistant organisms in critical care areas.

Table 3: Location-wise distribution of MDRO isolates (n = 60).

Location	n	%
Intensive Care Unit	24	40.0
General Ward	31	51.7
Outpatient Department	5	8.3
Total	60	100.0

3.4 Temporal trend in antimicrobial resistance rate

Simple linear regression of monthly AMR rate (%) against month number (1–17) demonstrated a statistically significant declining trend: slope = −1.93% per month (95% direction consistent with declining resistance), Pearson r = −0.51, R^2 = 0.26, t(15) = −2.30, p = 0.036. This indicates that approximately 26% of month-to-month variability in AMR rate was explained by linear time trend, with resistance rate declining by approximately 1.9 percentage points, on average, for each successive month of the surveillance period.

When isolates were grouped into an earlier period (March 2025–February 2026, 135 total isolates, 47 MDRO) and a later period (March–July 2026, 57 total isolates, 12 MDRO), the AMR rate fell from 34.8% to 21.1% (Table 4). This difference approached but did not reach conventional statistical significance on chi-square testing ($\chi^2 = 3.57$, df = 1, p = 0.059), consistent with a genuine downward trend that the study may have been underpowered to confirm categorically given the modest monthly isolate numbers characteristic of single-center data.

Table 4: Comparison of antimicrobial resistance rate between early and late surveillance periods.

Period	Total isolates	MDRO isolates	AMR rate (%)
Period 1 (Mar 2025–Feb 2026, 12 mo)	135	47	34.8
Period 2 (Mar–Jul 2026, 5 mo)	57	12	21.1

$\chi^2 = 3.57$, df = 1, p = 0.059 (two-tailed, uncorrected); linear regression across all 17 months: r = −0.51, $R^2 = 0.26$, p = 0.036.

4 DISCUSSION

This 17-month surveillance study demonstrates a statistically significant declining trend in the monthly antimicrobial resistance rate at a tertiary care hospital in Jaipur during a period of sustained antimicrobial stewardship activity, with the mean rate falling from approximately 35% in the first year to approximately 21% in the final five months. While the observational, non-controlled design precludes a causal claim, this temporal pattern is consistent with reports from other Indian and international centers describing measurable reductions in MDRO burden following structured stewardship interventions, including prospective audit and feedback, restricted antibiotic policies, and infection-control bundling.

The predominance of Klebsiella pneumoniae and Pseudomonas aeruginosa in this cohort mirrors regional and national AMR surveillance data and aligns with their designation as critical-priority pathogens in the WHO 2024 Bacterial Priority Pathogens List, reflecting both their intrinsic propensity for acquiring resistance determinants (including carbapenemases) and their capacity for nosocomial transmission via contaminated hands, devices, and the hospital environment. The substantial contribution of urinary and wound/pus specimens is consistent with the recognized role of indwelling urinary catheters and surgical/traumatic wounds as reservoirs for resistant Gram-negative organisms, while the concentration of isolates in ICUs relative to their bed strength underscores the importance of ICU-focused stewardship, hand hygiene, and device-care bundles.

The finding that general wards contributed a larger absolute share of MDROs than ICUs, despite the latter's traditionally higher resistance burden per admission, may reflect referral patterns, a larger overall ward bed base, and possible endemic transmission outside critical care areas — a pattern that merits targeted ward-level infection-control review, including hand hygiene audits, environmental cleaning verification, and antimicrobial order review outside the ICU setting.

The month with zero MDROs (March 2026) and the wide month-to-month fluctuation in AMR rate highlight a key limitation of small-denominator, single-center surveillance: monthly rates calculated from fewer than 20 isolates are highly sensitive to chance variation, and short-term rate changes should be interpreted cautiously. The linear regression and period-comparison analyses, which pool data across the whole surveillance window, are therefore more robust indicators of the underlying trend than any single month's figure, and both point in the same directional conclusion — a genuine decline in resistance proportion over the study period.

4.1 Limitations

This study has several limitations. First, it is a single-center, retrospective, descriptive analysis without a contemporaneous non-stewardship comparator, so causal attribution of the observed decline to the stewardship program cannot be established; secular trends, changes in case-mix, testing volume, or specimen-collection practices may have contributed. Second, monthly isolate numbers were small (range 0–22), limiting the precision and power of month-level statistical comparisons, as reflected in the borderline chi-square result. Third, minor discrepancies (approximately 1–2%) between the aggregate monthly stewardship log and the case-level MDRO line list — a recognized feature of parallel manual surveillance registers — were noted and are unlikely to materially affect the conclusions but warrant future data-system reconciliation. Fourth, antibiotic consumption data, device-utilization ratios, and patient-level outcomes (mortality, length of stay) were not available for correlation with the observed resistance trend, and organism-specific antibiogram detail (individual agent susceptibility) was not analyzed in this dataset. Finally, the fixed split between Period 1 and Period 2 for chi-square comparison, while a priori and time-based, is one of several possible ways to dichotomize the trend and should be interpreted alongside, rather than instead of, the continuous regression analysis.

Abbreviations

- MDROs- Multidrug-resistant organisms
- ICUs- Intensive care units
- ASP- Antimicrobial Stewardship Programs
- C&S- Culture and sensitivity
- AMR- Antimicrobial resistance

5 CONCLUSION

Over a 17-month period of antimicrobial stewardship implementation at a tertiary care hospital in Jaipur, the monthly antimicrobial resistance rate among clinical isolates declined significantly ($p = 0.036$ by linear regression), from a mean of 34.8% in the first year to 21.1% in the final five months. Klebsiella pneumoniae and Pseudomonas aeruginosa, both WHO critical-priority pathogens, were the leading MDROs, predominantly isolated from urine and pus specimens in general wards and ICUs. These findings support the continued value of structured, longitudinal AMR surveillance as both an outcome indicator and a driver for sustained antimicrobial stewardship and infection-control activity, and highlight the need for larger, multicentric, and ideally controlled studies to more definitively establish the impact of stewardship interventions on institutional resistance trends.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The author declares no conflicts of interest.

Statement of informed consent

This retrospective, record-based study involved no direct patient contact or intervention; formal ethics committee approval was not obtained due to unavailability of the institutional ethics committee, and patient data was anonymized to maintain confidentiality.

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