



INFECTIOUS DISEASE

Assessment of Antimicrobial Consumption Patterns in Adult and Pediatric Patients in Intensive Care Units Using DDD, DOT, and WHO AWaRe Classification: A Point Prevalence Study from Central India

NEHA SUNIL BAWANKAR¹, SONAL PRAKASH CHAVAN¹, ARUNA R¹, SUNANDA SANJAY ZODPEY (SHRIKHANDE)¹, ATUL VIJAY RAJKONDAWAR², MANISH MAHADEO TIWARI³, BRAJESH BAIJNATH GUPTA⁴

¹ Department of Microbiology, Government Medical College; ² Department of Medicine, Government Medical College;

³ Department of Pediatrics, Government Medical College; ⁴ Department of Surgery, Government Medical College

Keywords

Antibiotic consumption • Central India • Intensive care units • Point prevalence survey • Stewardship

Summary

Introduction. *Inappropriate use of antimicrobials is the primary driver of antimicrobial resistance, which threatens modern medicine. Monitoring antimicrobial consumption is the initial step for planning and guiding antimicrobial stewardship initiatives. This pilot study aimed to evaluate antimicrobial consumption patterns among adult and pediatric patients and to identify factors influencing antimicrobial use in the intensive care units (ICUs) of a tertiary care hospital in Central India.*

Methods. *This hybrid point-prevalence survey was conducted across five ICUs of a tertiary care hospital in March 2025. The survey included all ICU-admitted patients on the day of the survey. Antimicrobial prescription data, laboratory investigations, and clinical-demographic data were retrieved from medical records. The WHO Anatomical Therapeutic Chemical and WHO-AWaRe classification systems were used to categorize the antimicrobials used. Antibiotic consumption was evaluated using the Defined Daily Dose methodology, and factors associated with*

antimicrobial use were analyzed using descriptive statistics and logistic regression.

Results. *Among 88 patients, 79 (89.77%) received at least one antimicrobial. Of 188 antimicrobials prescribed, antibacterials accounted for the highest consumption (96.3%). The most commonly prescribed antibiotics included cefotaxime, metronidazole, and meropenem. The highest (65%) consumption of antimicrobials was from the “Watch group”, with empirical therapy as the primary indication, accounting for 63.29% of prescriptions, of which 63.29% were appropriate. No significant differences were observed in consumption patterns between pediatric and adult patients.*

Conclusion. *The high consumption of antimicrobials in ICUs is predominantly from the Watch category, with higher use for empirical therapy, indicating an urgent need for robust antimicrobial and diagnostic stewardship.*

Introduction

Antibiotics are key players in fighting against infections. However, their injudicious use, particularly in critical care settings, has rapidly driven the selective pressure for antimicrobial resistance (AMR) [1]. AMR threatens modern medicine due to limited treatment options, resulting in increased mortality and morbidity, longer hospital stays, and increased medical expenses [1, 2]. Each year, over 700,000 deaths are linked to AMR, and if prompt action is not taken, it could result in 10 million fatalities and a potential cost to the global economy of up to \$100 trillion by 2050 [3]. Furthermore, AMR is expected to have a greater impact on low- and middle-income countries (LMICs) [2, 4].

Gathering information on current antibiotic consumption patterns in hospitals is crucial for developing effective antibiotic stewardship policies and strategies to guide and control antibiotic misuse, combat AMR, and identify areas for improvement [5,

6]. However, there are limited reports on rates and patterns of antibiotic consumption from LMICs. A point prevalence survey (PPS) is a practical tool for collecting data on antimicrobial use and identifying areas that need corrective action. Additionally, conducting repeated PPS is beneficial for evaluating the impact of the corrective actions implemented in identified problematic areas [7, 8].

In this study, we aimed to determine the characteristics of antimicrobial prescribing practices, including consumption rates, clinical appropriateness, the most prevalent antibiotic classes, and risk factors for increased antimicrobial use among adult and pediatric patients hospitalized in ICUs. This pilot study will provide a snapshot of antimicrobial use patterns in the Intensive Care Units (ICUs) at a tertiary care hospital in Central India, helping to identify areas for improvement, formulate robust antimicrobial stewardship initiatives, and inform the design of more extensive, definitive studies in the future.

Materials and Methods

STUDY DESIGN AND SETTING

This hybrid point-prevalence cohort study (cross-sectional enrolment with longitudinal follow-up) was conducted in the 143-bed ICUs of a tertiary care hospital in Central India in March 2025. The study was approved by the Institutional Ethics Committee (No. 3687 EC/Pharmac/GMC/NGP).

STUDY POPULATION AND DATA COLLECTION

All patients admitted to the Neonatal ICU (NICU), Pediatric ICU (PICU), Medicine ICU (MICU), Surgery ICU (SICU), and Plastic Surgery ICU (PI-SICU) before or on the day of the survey (March 25, 2025) were included in the study. Surgery ICU included post-LSCS patients, post-operative patients, and trauma/accident injury patients. The data of clinical and demographic details, invasive devices, comorbid conditions, relevant laboratory or microbiological reports, retrospective (from the day of admission to the day of survey) and prospective data (from the day of survey till discharge) on the antibiotic consumption (drug name, dosages, administration route, frequency, culture and antimicrobial sensitivity tests, duration of treatment, and total number of dosages till discharge) of the patients were collected from their records. The drugs classified as systemic antibiotics fall under the J01 category of the World Health Organization (WHO) Anatomical Therapeutic Chemical (ATC) classification system, which includes antibacterials for systemic use, excluding antimycobacterial drugs [9].

A set of quality indicators for initiating antimicrobial therapy was evaluated from patients' medical records, including documented reasons, whether the treatment was empirical or targeted, based on microbiological results from clinical specimens or other microbiological results, such as bacterial antigen or antibody testing or biomarker data, such as C-reactive protein (CRP) and procalcitonin levels, adherence to established Indian Council of Medical Research treatment guidelines, and documentation of review or cessation of antimicrobial therapy after culture report. Furthermore, if the choice of antimicrobial was based on a microbiological culture and susceptibility report, information on the targeted organisms was also gathered. For surgical prophylaxis, we recorded any single dose of an antimicrobial agent administered within 24 hours before 8:00 a.m. on the day of the survey. Clinical appropriateness was evaluated by two independent investigators based on these records and antimicrobial stewardship principles.

The following patients were excluded from this study: those treated in outpatient departments; patients who were discharged before 8:00 a.m. on the day of the survey but remained in the hospital awaiting transportation; patients undergoing treatment or surgery who were either discharged or expected to be discharged on the same day; individuals using topical or ophthalmic antibiotics; and patients whose treatment was discontinued before 8:00 a.m..

DATA ANALYSIS

Antimicrobial use was documented based on the number of patients receiving parenteral antimicrobials for either therapeutic or prophylactic purposes, as well as the total number of therapies or prophylactic measures administered. Descriptive statistics, including frequency, percentages, and means or ranges, were used to summarise the data. Furthermore, the number of antimicrobials designated for systemic use was classified according to the WHO ATC classification system [9].

All statistical analyses were performed using Microsoft Excel 2024 and the Statistical software STATA version 14.0. Antibiotic consumption in adult patients was measured using the WHO Antimicrobial Consumption Tool and reported as Defined Daily Doses (DDDs) and days of therapy (DOTs). To calculate the total DDD consumed per pack, we used product and pack size data from prescriptions and the hospital pharmacy, along with DDD data for the corresponding formulations from the WHO ATC/DDD index [10]. In the <18-year age group (NICU and PICU), the DOT is used to measure antibiotic use because it is independent of weight- and age-related dose differences. The antibiotics were categorized according to the updated WHO 2025 list in compliance with the Access, Watch and Reserve (AWaRe) system [11], and we used data from the Central Drugs Standard Control Organization (CDSCO) to determine the approval status [12]. The McCabe score system is used to classify the severity of underlying medical conditions [13].

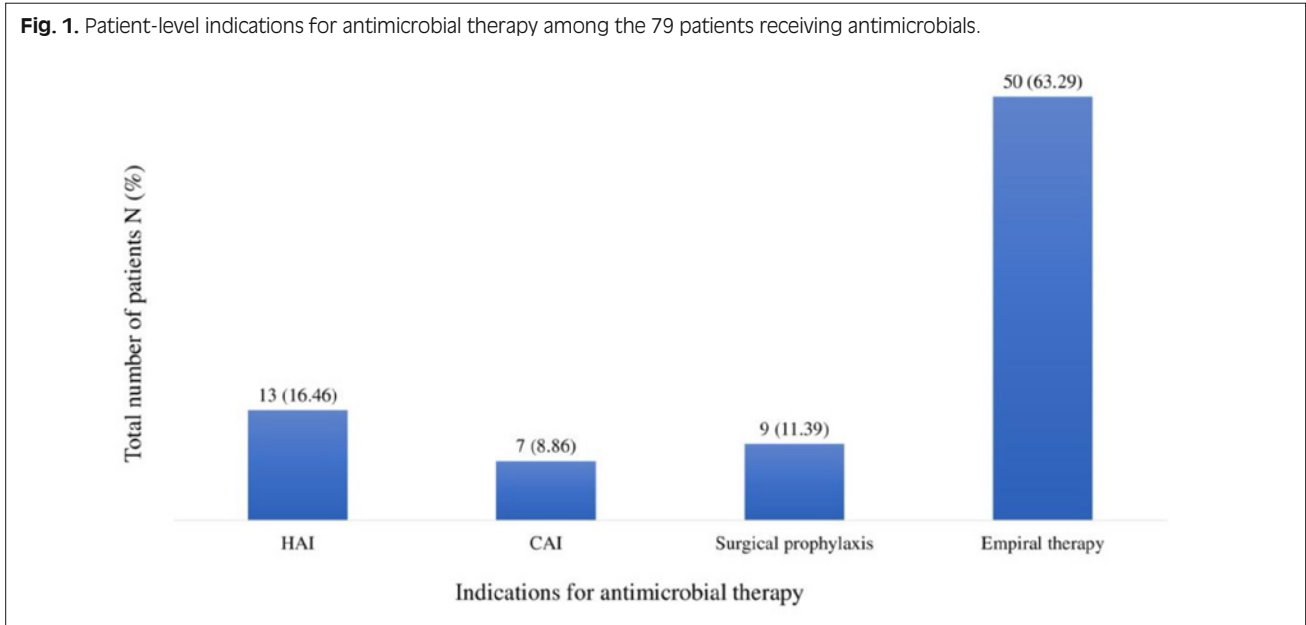
Using univariate analysis, the demographic and clinical characteristics of patients receiving antimicrobials were assessed for statistical significance using the chi-squared (χ^2) test. Antimicrobial DOT rates for individual antimicrobial agents were compared between pediatric and adult patients using Poisson regression and negative binomial regression. The Pearson chi-square test was applied to compare the clinical appropriateness of antimicrobials prescribed in adult and pediatric patients. A *p-value* of <0.05 was considered statistically significant. STATA version 14.0 software was used for statistical analysis.

Results

Of the 88 patients admitted to the five established ICUs, with 769 patient-days of hospitalization, 79 received one or more types of parenteral antimicrobial therapy on the day of the PPS.

Out of the total 188 antimicrobials prescribed, according to ATC classification, 181 (96.28%) were antibacterial (J01), 4 (2.13%) were antiviral (J05), and 3 (1.6%) were antifungal (J02) for systemic use. Most antimicrobials (123/188, 65%) were used for empirical therapy followed by therapeutic purposes (49/188, 26%) and surgical prophylaxis (16/188, 8.5%) (Tab. I). Of 79 prescriptions, the most common indications were empirical therapy (50/79, 63.29%), followed by hospital-associated infections (HAI) (13/79, 16.46%), with $\chi^2=27.61$ and

Fig. 1. Patient-level indications for antimicrobial therapy among the 79 patients receiving antimicrobials.



Tab. I. Prescription-level antimicrobial utilization according to indication and WHO AWaRe classification (N = 188 antimicrobial prescriptions).

WHO AWaRe Group; N (%)*	Antimicrobial agents	ATC Code	All indication N (%)	Therapeutic N (%)	Empirical Therapy N (%)	Surgical prophylaxis N (%)
Access; 63 (35)	Amoxicillin-clavulanate	J01CR02	4 (2.13)	2 (4.08)	2 (1.63)	0 (0)
	Amikacin	J01GB06	7 (3.72)	2 (4.08)	5 (4.07)	0 (0)
	Gentamicin	J01GB03	7 (3.72)	1 (2.04)	6 (4.88)	0 (0)
	Doxycycline	J01AA02	5 (2.67)	2 (4.08)	3 (2.44)	0 (0)
	Clindamycin	J01FF01	2 (1.10)	1 (2.04)	1 (0.81)	0 (0)
	Metronidazole	J01XD01	37 (19.68)	10 (20.41)	22	5 (31.25)
	Nitrofurantoin	J01XE01	1 (0.53)	1 (2.04)	0 (0)	0 (0)
Watch; 117 (65)	Piperacillin-tazobactam	J01CR05	25 (13.30)	5 (10.20)	17 (13.82)	3 (18.75)
	Cefotaxime	J01DD01	42 (22.34)	7 (14.29)	30 (24.39)	5 (31.25)
	Ceftriaxone	J01DD04	10 (5.32)	2 (4.08)	7 (5.69)	1 (6.25)
	Cefixime	J01DD08	1 (0.53)	0 (0)	1 (0.81)	0 (0)
	Azithromycin	J01FA10	3 (1.60)	0 (0)	3 (2.44)	0 (0)
	Ciprofloxacin	J01MA02	5 (2.66)	3 (6.12)	2 (1.63)	0 (0)
	Levofloxacin	J01MA12	5 (2.66)	2 (4.08)	2 (1.63)	1 (6.25)
	Meropenem	J01DH02	14 (7.45)	4 (8.16)	9 (7.32)	1 (6.25)
	Vancomycin	J01XA01	12 (6.38)	4 (8.16)	8 (6.50)	0 (0)
Reserve; 1 (0.6)	Colistin	J01XB01	1 (0.53)	0 (0)	1 (0.81)	0 (0)
NA	Fluconazole	J02	3 (1.60)	1 (2.04)	2 (1.63)	0 (0)
NA	Acyclovir	J05	4 (2.13)	2 (4.08)	2 (1.63)	0 (0)
	Total		188 (100)**	49 (100)	123 (100)	16 (100)

ATC: Anatomical Therapeutic Chemical; NA: Not available (Fluconazole and Acyclovir not yet included in AWaRe classification). *AWaRe classification is only applied for antibacterial drugs (Total=181); Green color-Access group antibacterial; Yellow color- Watch group antibacterial; Red color- Reserve group antibacterial. **Each antimicrobial prescription was considered a separate observation; therefore, the total number of prescriptions (N = 188) exceeds the number of patients receiving antimicrobials (N = 79), as individual patients could receive more than one antimicrobial agent.

p-value <0.001 (Fig. 1). In 13 HAI cases, the isolated organisms were *K. pneumoniae* (n=3), methicillin-resistant *Staphylococcus aureus* (MRSA) (n=3), *Acinetobacter baumannii* (n=3), *Enterococcus faecium* (n=2), *Pseudomonas aeruginosa* (n=2), *Escherichia coli* (n=1), and *Citrobacter koseri* (n=1). Among 7

community-associated infections, 4 were *Escherichia coli*, and 3 were *Staphylococcus aureus*. All the isolated organisms were multidrug-resistant (MDR).

The total antimicrobial consumption among adult ICU patients was 356.2 DDD over 281 patient-days, corresponding to 126.77 DDD per 100 patient-days

Tab. II. Antimicrobial consumption pattern in adults using the WHO-Defined Daily Dose method (N=43).

Antimicrobials	Route	No. of Treatment Days	No. of patients, N (%) (N=43) *	Total DDD for each antimicrobial	DDD/100 patient days
Piperacillin-tazobactam	IV	61	16 (37.21)	51.9	18.47
Cefotaxime	IV	99	25 (58.14)	51.9	18.47
Ceftriaxone	IV	1	1 (2.33)	1.1	0.39
Meropenem	IV	36	9 (20.93)	18.20	6.48
Azithromycin	IV	10	3 (6.98)	10	3.56
Ciprofloxacin	IV	15	4 (9.30)	11.5	4.09
Levofloxacin	IV	7	3 (6.98)	13.5	4.8
Doxycycline	IV	13	3 (6.98)	26	9.2
Metronidazole	IV	128	26 (60.47)	122	43.42
Amoxicillin-clavulanate	IV	19	3 (6.98)	8.98	3.19
Vancomycin	IV	22	4 (9.30)	21.5	7.65
Nitrofurantoin	Oral	7	1 (2.33)	7	2.49
Fluconazole	Oral	1	1 (2.33)	2	0.71
Acyclovir	IV	12	2 (4.65)	6.53	2.32
Total DDD/ 100 Patient Days= Total DDD of antimicrobial/ Total patient days x 100 = 356.2/281 x 100= 126.77					

The data are presented as a number (N); LD- Loading dose; *DDD is calculated only for adult patients aged >18 years. Pediatric patients were excluded from DDD analysis.

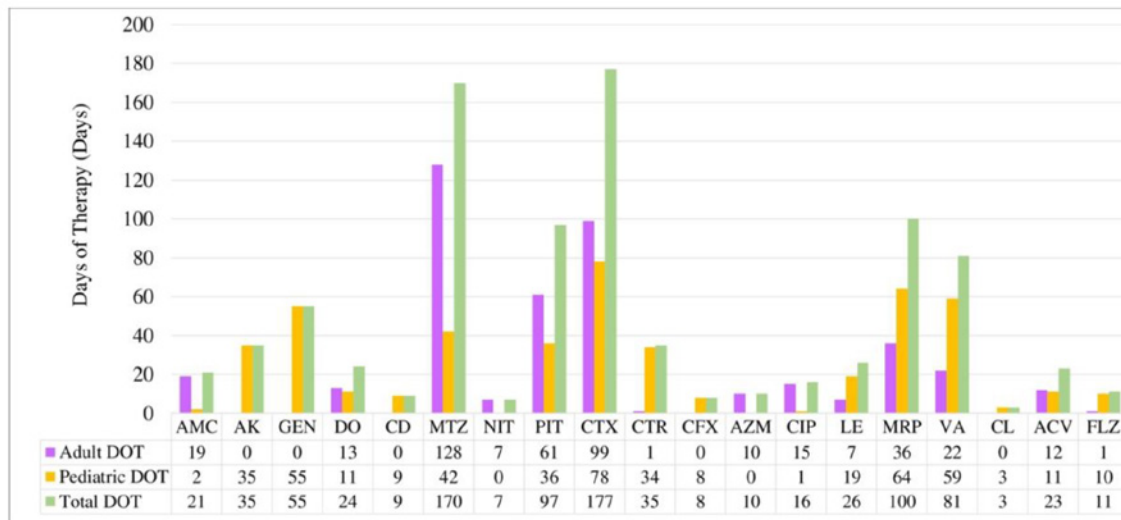
DDD-Daily Defined Dose; IV-Intravenous; TDS-Thrice a day; BD-Twice a day; OD-Once a day; QID- Quarter in Die.

(range: 0.39 to 43.42 DDD per 100 patient-days) (Tab. II). Overall, the “Watch group” of antibiotics comprised a significant (65%) proportion of antibiotic consumption (DDD: 0.39 to 19.93 DDD per 100 patient-days), followed by the “Access group” (35%) with a DDD range of 2.49 to 43.42 DDD/100 patient-days. Only 0.5% of consumption was from the “Reserve category” (Tabs. I, II). In terms of days of therapy (DOT), overall antimicrobial consumption was 1180.75 DOT/1000 patient-days, as 908 antimicrobial DOT were used over 769 patient-days. In Adult patients, 431 DOT were used over 281 patient-days, corresponding to 1533.81 DOT/1000 patient-days; while pediatric patients (NICU and PICU) accounted for 477 DOT over 488 patient-days, corresponding to 977.46 DOT/1000 patient-days. This indicates that, descriptively, antimicrobial consumption measured as DOT/1000 patient-days was 1.6 times higher in adult ICUs than in pediatric ICUs. For antimicrobial level analysis, we applied a Poisson regression model, in which substantial overdispersion (Pearson $\chi^2/df=25.32$) was observed. Therefore, we used a negative binomial regression model with log(patient-days) as an offset, which showed no statistically significant difference in DOT rates at the antimicrobial level between pediatric and adult ICUs. In adults, the most commonly prescribed antimicrobials were metronidazole (128 DOT), cefotaxime (99 DOT), piperacillin-tazobactam (61 DOT), and meropenem (36 DOT). However, in pediatric patients, the most frequently prescribed were cefotaxime (78 DOT), meropenem (64 DOT), vancomycin (59 DOT), and gentamicin (54 DOT), (Fig. 2). Thus, three out of the four most commonly used antimicrobials were from the “Watch group”.

Antimicrobial prescriptions were evaluated for clinical appropriateness, of which 63.29% were appropriate, 25.32% were potential overuse, and 11.39% were

inappropriate, with no significant difference observed between pediatric and adult patients (*p-value*: 0.45) (Tab. III). Among 79 patients on antimicrobials, 22 (27.85%) received a single antimicrobial, 30 (37.97%) received two, 14 (17.72%) received three, and 13 (16.46%) received more than three antimicrobials. Based on the McCabe score, 11 patients (12.5%) had a rapidly fatal disease, 16 patients (18.18%) had an ultimately fatal disease, 50 patients (56.82%) had a non-fatal disease, and 11(12.5%) patients had an unknown status. All patients with rapidly fatal disease, as well as most patients with ultimately fatal disease, were receiving empirical antimicrobial therapy (Tab. IV). Potential overuse was observed in most patients with rapidly fatal disease, ultimately fatal disease, and surgical prophylaxis in craniotomy patients. Based on the microbiological culture report and biomarker assay, empirical therapy was modified in 86% (43/50) of patients. In the remaining 7 (14%) patients, the empirical regimen was continued without change following clinical review because it was considered appropriate in 5 patients according to culture and antimicrobial susceptibility test report, while in two patients with ultimately fatal illness, broad-spectrum therapy was continued despite negative culture and biomarker results (Fig. 3).

The demographic and clinical characteristics of patients who received antimicrobial therapy are presented in Table IV. Univariate analysis revealed that antimicrobial consumption was significantly higher among patients older than one year and adults. Increased usage was observed in the MICU, followed by the SICU and PICU, and among patients with urinary and central venous catheters (CVCs). It was also observed in those with two or more invasive devices and in those with ICU stays longer than 7 days (Range: 7-33 days). However, the lowest antimicrobial consumption was observed in

Fig. 2. Adult versus pediatric antimicrobial utilization based on Days of Therapy (DOT).

Negative Binomial Regression (Pediatric v/s adult)

Incidence Rate Ratio: 1.14

95% Confidence Interval: 0.81-1.61

P-value: 0.445

AMC; Amoxicillin-clavulanate; AK-Amikacin; GEN; Gentamicin; DO; Doxycycline; CD; Clindamycin; MTZ; Metronidazole; NIT; Nitrofurantoin; PIT; Piperacillin-tazobactam; CTX; Cefotaxime; CTR; Ceftriaxone; CFX; Cefixime; AZM; Azithromycin; CIP; Ciprofloxacin; LE-Levofloxacin; MRP; meropenem; VA; Vancomycin; CL-Colistin; ACV; Acyclovir; FLZ; Fluconazole.

Tab. III. Categorization of Antimicrobial Prescriptions Based on Clinical Appropriateness.

Category	Criteria	Adult (>18 years) N (%)	Paediatric (<18 years) N (%)	Total N (%)	χ^2 : 0.92, p-value: 0.63
Appropriate	Empiric therapy with appropriate indication, dose, route, frequency, and duration according to ICMR treatment guidelines, combination justified, targeted therapy based on culture-sensitivity report, PK-PD parameters considered, biomarkers (CRP, procalcitonin) suggestive of infection	22 (57.89)	28 (68.29)	50 (63.29)	
Potential overuse	Too many broad-spectrum agents used together, unnecessary duplication, or very broad combinations in mild/moderate illness, surgical prophylaxis >24hr	11 (28.95)	9 (21.95)	20 (25.32)	
Inappropriate use	No indication for antibiotics/ treating non-infectious causes with antibiotics (e.g., viral illness), or wrong antibiotic class (e.g., dual β -lactams), unsuitable routes or dosing intervals.	5 (13.16)	4 (9.76)	9 (11.39)	
Total		38 (100.0)	41 (100.0)	79 (100.0)	

Note: Data are presented as n (%). The Pearson chi-square test is used to compare adult and pediatric patients. A *p*-value of <0.05 was considered statistically significant.

PK-PD: Pharmacokinetic-Pharmacodynamic

the ≤ 1 -year age group, in the NICU, and among those with ICU stays of less than 4 days. Multivariable logistic regression was not applied because very few patients did not receive antimicrobials, preventing a stable estimation of the model.

Discussion

AMR is a complex issue influenced by various interconnected factors. The inappropriate and overuse of antimicrobials are major contributors to AMR [2].

Research indicates a strong correlation between antibiotic consumption and the rise of resistant pathogens [14, 15]. To tackle this challenge, the World Health Organization (WHO) has established a Global Action Plan that includes a standardized methodology for PPS to optimize antimicrobial use and combat AMR [16]. Notably, India is the world's leading consumer of antibiotics. Evaluating antimicrobial usage patterns in a hospital setting is crucial for effectively managing and mitigating antibiotic overuse, thereby tackling AMR [6]. This research provides critical insights into patterns of antimicrobial consumption in pediatric and adult

Tab. IV. Univariate analysis for the association of various risk factors with the consumption of antibiotics.

Variables	Total Surveyed Patients, N (%) (N=88)	Patients Receiving Antibiotics, N (%) (N=79)	p-value
Age group			
≤1 years	27 (30.68)	19 (70.37)	0.0058
2-18 years	18 (20.45)	17 (94.44)	
19-25 years	2 (2.27)	2 (100)	
26-54 years	22 (25)	22 (100)	
55-64 years	4 (4.55)	4 (100)	
≥65 years	15 (17.05)	15 (100)	
Gender			
Female	35 (39.77)	33 (94.29)	0.2562
Male	53 (60.23)	46 (86.79)	
ICU Type			
Medicine ICU	26 (29.55)	26 (100)	0.0007
Neonatal ICU	25 (28.41)	17 (68)	
Paediatric ICU	13 (14.77)	13 (100)	
Surgery ICU	16 (18.18)	16 (100)	
Plastic Surgery ICU	8 (9.09)	7 (87.5)	
McCabe Score			
Rapidly fatal	11 (12.5)	11 (100)	0.2038
Ultimately fatal	16 (18.18)	15 (93.75)	
Non-fatal	50 (56.82)	42 (84)	
Unknown	11 (12.5)	11 (100)	
Central vascular catheter			
Yes	29 (32.95)	29 (100)	0.0264
No	59 (67.05)	50 (84.75)	
Urinary catheter			
Yes	37 (42.05)	37 (100)	0.007
No	51 (57.95)	42 (82.35)	
Mechanical Ventilation			
Yes	33 (37.5)	32 (96.97)	0.0844
No	55 (62.5)	47 (85.45)	
No. of devices			
1	22 (25)	21 (95)	0.0319
2	9 (10.23)	9 (100)	
>2	19 (21.59)	19 (100)	
None	38 (43.18)	30 (78)	
Outcome			
Death	30 (34.1)	30 (100)	0.0228
Transfer out/ Discharged	58 (61.36)	49 (83.33)	
ICU stay (days)			
<4	16 (18.18)	13 (81.25)	0.1376
4-7	36 (40.90)	31 (86.11)	
>7	36 (40.90)	35 (97.22)	

Note: Data are presented as number (n) and percentage (%). Percentages were calculated row-wise using the total number of patients in each sub-group as the denominator. A p-value of <0.05 was considered statistically significant.

patients admitted to ICUs of a tertiary care teaching hospital, using a PPS methodology.

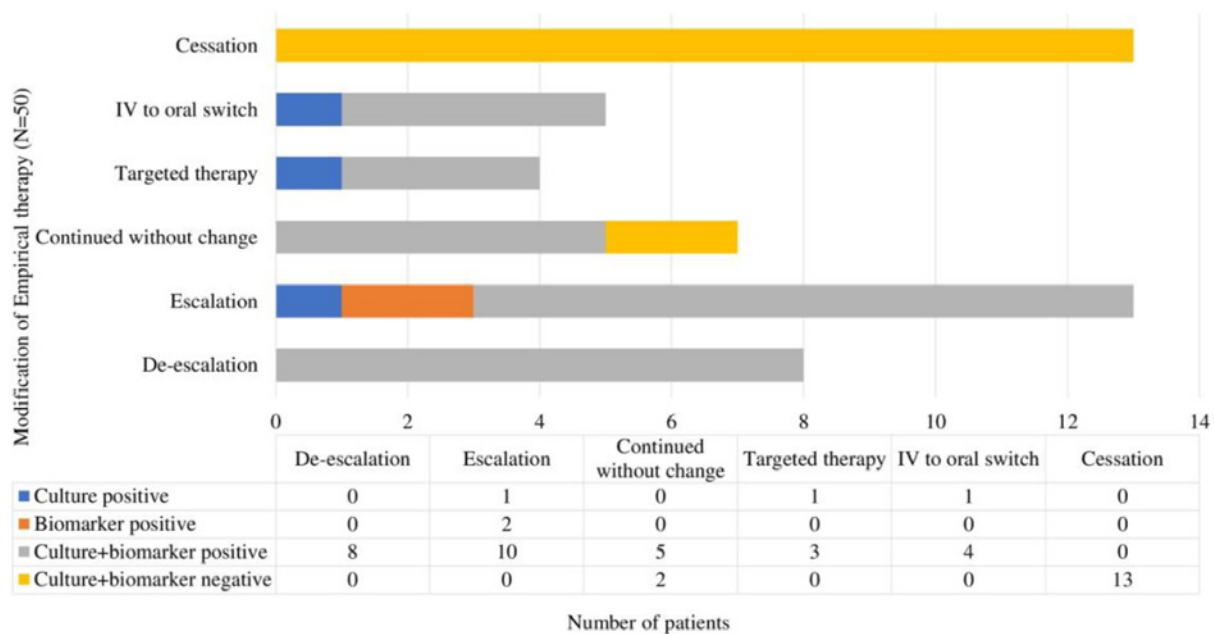
This study revealed a high prevalence of antimicrobial consumption in ICUs, with 79 of 88 cases (89.77%). A high prevalence of antimicrobial use in ICUs was also

reported in other PPS studies [17, 18]. A comparatively low prevalence (47.3-77.6%) was observed in similar hospital-based studies (which included both ICUs and wards) across different regions [19-23]. Our institute is a tertiary-care referral hospital in this area, with most referred patients being critically ill, having invasive devices, and several comorbidities; most admitted patients had rapidly progressive or ultimately fatal disease, and post-operative patients with suspected sepsis requiring empirical broad-spectrum antimicrobials. However, these consistently increasing rates of antimicrobial consumption highlight the critical need for effective stewardship interventions in high-dependency areas, such as ICUs.

In our cohort, the majority of prescribed agents for systemic use were antibacterials, with a small percentage of antivirals and antifungals (Tab. I). This aligns with findings from a PPS conducted by Porto et al., which reported that antibacterials accounted for over 89.9% of all antimicrobials used [22]. The most commonly prescribed antibiotics in our ICUs included cefotaxime, metronidazole, meropenem, piperacillin-tazobactam, and vancomycin (Tab. I, Fig. 3). This pattern is consistent with the studies from other countries, which reported that third-generation cephalosporins, β -lactam/ β -lactamase inhibitor combinations, and carbapenems were the predominant agents used [22, 24-26]. Cephalosporins are commonly prescribed for ICU patients because of their broad-spectrum activity against a wide range of pathogens and their well-tolerated nature, with a lower risk of adverse effects compared to other antibiotic classes. Additionally, piperacillin-tazobactam has favorable pharmacokinetic properties, including good tissue penetration and a prolonged half-life [27]. This makes them suitable choices for treating severe infections in critically ill patients, where achieving adequate drug concentrations is crucial for successful treatment. Furthermore, the use of broad-spectrum β -lactams or their combination aligns with the high rates of MDR Enterobacterales infections and the need for empirical treatment of sepsis in our patient cohort. Due to the high prevalence of MRSA in our institute, vancomycin is the preferred choice for gram-positive coverage in empirical therapy. Higher use of metronidazole was observed in our ICUs, mainly for gastrointestinal infections, aspiration pneumonia, and intra-abdominal surgeries. However, it was also found to be potentially overused in combination with β -lactam/ β -lactamase inhibitor combinations and/or carbapenems, reflecting unnecessary duplication of anaerobic coverage, which does not add value to therapeutic outcomes. It underscores a significant area for improvement in clinical practice, emphasizing the need for more judicious use of these medications to avoid unnecessary complexity in treatment regimens and potential adverse effects.

The increased usage of broad-spectrum “Watch” group antibiotics in this study (117/181, 65%) raises significant concerns, especially considering the WHO’s recommendations to limit their use to combat the emergence of AMR. A similar high prevalence (37.4%-

Fig. 3. Modifications of Empirical Antimicrobial Therapy Following Microbiological and Biomarker-Guided Assessment (N=50).



"continued without change" represents an active, guideline-concordant clinical decision following antimicrobial susceptibility test report review, rather than an absence of review or stewardship intervention.).

71.7%) of Watch antibiotics has been observed in hospital settings across other low- and middle-income countries (LMICs) [24, 28-32]. A multicenter review of AWARe surveillance in LMICs analyzed that the higher proportions of Watch antibiotics in tertiary and teaching hospitals are often attributed to common practices in empiric treatment and to limitations in rapid diagnostic capabilities [32]. Analysis of the high use of Watch antimicrobial agents in our ICUs revealed concerns about treatment failures with Access antibiotics, availability and prescriber familiarity with Watch antibiotics, and the high prevalence of MDR organisms (MDROs) in ICUs. Similar contributing factors were also reported in a multicentric study in India [33].

In this PPS, DDD consumption in ICUs ranges from 0.39 to 43.42 DDD/100 patient-days, with varying levels of consumption observed for each antimicrobial. The highest DDDs were for metronidazole 500 mg (DDD=110), cefotaxime 1 g (DDD=41), and piperacillin-tazobactam 4.5 g (DDD=41.1), which are comparable to Wahlang et al.'s study, which reported high DDD consumption for these three antimicrobials [24]. Coenen et al. reported European surveillance data, in which DDD consumption ranged from 1.8 to 12.4 DDD/100 bed-days [34]. Mittal et al.'s study from North India reported that total antibiotic consumption in inpatient departments ranged from 60.22 to 102.42 DDD per 100 bed-days during 2017-2023 [6]. In terms of DOT/patient-days, antimicrobial utilization in pediatric patients was 0.98 DOT/patient-days, comparable to antimicrobial consumption in pediatric populations reported in other studies [35-37]. In adults, high antimicrobial DOTs were

for metronidazole, cefotaxime, piperacillin-tazobactam, and meropenem. However, in pediatric patients, cefotaxime, meropenem, vancomycin, and gentamicin were used. Similar patterns were reported in global-PPS conducted in Canadian hospitals [23].

The empirical antimicrobial therapy prescribed in our ICUs was significantly higher (n=50, 63.29%), comparable to other LMICs [2, 15] but higher than rates reported in higher-income countries [38, 39]. Most (52%, 26/50) patients receiving empirical therapy were classified as rapidly fatal and ultimately fatal disease based on the McCabe Score, influencing clinicians to initiate empirical therapy (Tab. IV). However, empirical treatments were reviewed based on biomarker and microbiological culture-susceptibility reports, except in two patients with ultimately fatal disease (Fig. 3). Moreover, in the potentially overused category, most of the prescriptions contained multiple therapies (n=13), overlapping β -lactam (n=5) and anaerobic coverage (n=5), and prolonged surgical prophylaxis (n=4). Only 20/79 (25.32%) of prescriptions were intended to treat HAIs and community-acquired infections, which are predominantly caused by MDROs. The prevalence of these MDROs further supports the observed tendency for empirical treatment escalation (26%, 13/50) in our ICUs. Prolonged surgical prophylaxis (>24 hours) and the use of multiple antimicrobials in craniotomy patients were contrary to current guideline recommendations [40]. This overuse of empirical antimicrobials and prolonged surgical prophylaxis creates unnecessary selective pressure, highlighting the urgent need to strengthen diagnostic stewardship and local prophylaxis guidelines.

Therefore, implementing continuous audit and feedback mechanisms may help to optimize prescribing behavior. In univariate regression analysis, antimicrobial use was significantly associated with age group, ICU type, presence of urinary and central venous catheters (CVCs), number of invasive devices, and patient outcome (Tab. IV). Similar drivers were also reported by Barbadoro et al. [20]. Higher antimicrobial use in patients with invasive devices and certain ICUs likely reflects more severe illness and a higher risk of HAIs.

During this study, we analyzed several key areas to improve antimicrobial stewardship and patient outcomes in our setup: establish protocols to limit the overuse of 3rd-generation cephalosporins, revise perioperative guidelines to avoid unnecessary long-term prophylaxis, and increase targeted therapy based on cultures. Enhancing medical documentation of antimicrobial changes will support better decision-making, while ongoing education and training for junior physicians, along with monitoring, will ensure compliance. Promoting collaboration among healthcare teams will provide comprehensive care and optimize antibiotic use, ultimately improving patient safety and combating antibiotic resistance. The findings call for stringent compliance with the WHO AWaRe classification framework, adoption of restrictive antibiotic policy, implementation of regular PPS, and enhanced diagnostic stewardship to facilitate appropriate de-escalation and cessation practices.

The study's limitations include its hybrid PPS, single-center design, small sample size, and reliance on a single-day PPS, which limit its ability to capture temporal fluctuations or variations in antibiotic duration. Although patients were enrolled using a PPS approach, antimicrobial consumption data were collected both retrospectively and prospectively to calculate DDDs and DOTs and to assess treatment modifications. This hybrid design differs from a traditional single-day PPS, which may limit the direct comparison of antimicrobial consumption metrics with other PPS studies. DDDs calculated in this study used patient-days as the denominator; therefore, they cannot be compared with those from other studies using bed-days as the denominator. Due to the small sample size and a high prevalence of antimicrobial use, findings of univariate analysis should be interpreted cautiously. This analysis was intended to identify potential factors associated with antimicrobial prescribing rather than establish independent predictors. Larger multicentric studies employing multivariable regression analyses are warranted to validate these observations and identify independent risk factors of antimicrobial use in ICUs. Despite these constraints, this is the first PPS study of antimicrobial consumption and prescribing patterns in this part of India, and it offers an essential baseline for developing antimicrobial stewardship initiatives within the institution and will assist in planning future adequately powered multicentre studies, including sample size estimation and refinement of the study methodology.

Conclusion

The high consumption of antimicrobials in ICUs is predominantly from the Watch category, with higher use for empirical therapy, indicating an urgent need for robust antimicrobial and diagnostic stewardship. The use of CVCs and ICU admissions >7 days were identified as key drivers of increased antimicrobial use in our ICUs. Implementing regular PPS, followed by an audit and comprehensive awareness training for clinicians, is imperative to address this issue. Future studies with large sample sizes are needed for more robust comparison between adult and pediatric antimicrobial consumption.

Acknowledgment

We sincerely acknowledge S. M. More, Statistician, Govt. Medical College, Nagpur, for his assistance with statistical analysis.

Funding

None.

Conflict of interest statement

None to declare.

Authors' contributions

All authors contributed to the study conception and design. All authors read and approved the final manuscript. NSB wrote the first draft of the manuscript, and all authors commented on previous versions of the manuscript. NSB: Conceptualization, Data acquisition, Methodology, Investigation, Formal analysis, Writing and editing of the original draft. SPC: Supervision, Project Administration, Review of the original draft. AR: Data acquisition. SSZ: Conceptualization, Resources, Project Administration, Supervision, Review of the original draft. AVR: Resources, Project Administration, Supervision, Review of the original draft. MMT: Resources, Project Administration, Supervision, Review of the original draft. BBG: Resources, Project Administration, Supervision, Review of the original draft.

References

- [1] Ferrara F, Castagna T, Pantolini B, Campanardi MC, Roperti M, Grotto A, Fattori M, Dal Maso L, Carrara F, Zambbarbieri G, Zovi A, Capuozzo M, Langella R. The challenge of antimicrobial resistance (AMR): current status and future prospects. *Naunyn Schmiedeberg's Arch Pharmacol* 2024;397:9603-15. <https://doi.org/10.1007/s00210-024-03318-x>.
- [2] Fentie AM, Degefaw Y, Asfaw G, Shewarega W, Woldearegay M, Abebe E, Gebretekale GB. Multicentre point-prevalence sur-

- vey of antibiotic use and healthcare-associated infections in Ethiopian hospitals. *BMJ Open* 2022;12:e054541. <https://doi.org/10.1136/bmjopen-2021-054541>.
- [3] O'Neill J. Antimicrobial Resistance: Tackling a crisis for the health and wealth of nations, 2016. Available at: <https://wellcomecollection.org/works/rdpck35v>. Accessed on 02/08/2026.
- [4] Tang KWK, Millar BC, Moore JE. Antimicrobial Resistance (AMR). *Br J Biomed Sci* 2023;80:11387. <https://doi.org/10.3389/bjbs.2023.11387>.
- [5] World Health Organisation. WHO methodology for point prevalence survey on antibiotics use in hospitals, 2018. Available at: <https://apps.who.int/iris/handle/10665/280063>. Accessed on: 20/03/2025.
- [6] Mittal N, Tayal A, Kumar S, Dhawan R, Goel N, Mittal R. Longitudinal Trends in In-Patient Antibiotic Consumption According to the WHO Access, Watch, Reserve (AWaRe) Antibiotic Groups and Cost: An Analysis of Data at a National Antimicrobial Consumption Network (NAC-NET) Site in North India over 7 Years (2017-2023). *Antibiotics (Basel)* 2024;13:673. <https://doi.org/10.3390/antibiotics13070673>.
- [7] Xie DS, Xiang LL, Li R, Hu Q, Luo QQ, Xiong W. A multi-center point-prevalence survey of antibiotic use in 13 Chinese hospitals. *J Infect Public Health* 2015;8:55-61. <https://doi.org/10.1016/j.jiph.2014.07.001>.
- [8] Guclu E, Ogutlu A, Karabay O, Demirdal T, Erayman I, Hosoglu S, Turhan V, Erol S, Oztoprak N, Batirel A, Altay FA, Kaya G, Karahocagil M, Sozen H, Yildirim M, Kocak F, Teker B. Antibiotic consumption in Turkish hospitals: a multi-centre point prevalence study. *J Chemother* 2017;29:19-24. <https://doi.org/10.1080/1120009x.2016.1156893>.
- [9] WHO. Anatomical Therapeutic Chemical (ATC) Classification [Internet]. www.who.int. 2024. Available at: <https://www.who.int/tools/atc-ddd-toolkit/atc-classification>. Accessed on: 20/03/2025.
- [10] ATC-DDD Toolkit. www.who.int. Available at: <https://www.who.int/tools/atc-ddd-toolkit/about-ddd>. Accessed on: 20/03/2025.
- [11] WHO. AWaRe classification of antibiotics for evaluation and monitoring of use, 2023. www.who.int. 2023. Available at: <https://www.who.int/publications/i/item/WHO-MHP-HPS-EML-2023.04>. Accessed on: 20/03/2025.
- [12] Central Drugs Standard Control Organisation. Directorate General Of Health Services, Ministry of Health & Family Welfare, Government of India. cdsco.gov.in. Available at: <https://cdsco.gov.in/opencms/opencms/en/Home>. Accessed on: 20/03/2025.
- [13] McCabe WR, Jackson GG. Gram-negative bacteremia: I. Etiology and ecology. *Arch Intern Med* 1962;110:847-53. <https://doi.org/10.1001/archinte.1962.03620240029006>.
- [14] Centers for Disease Control and Prevention. Antibiotic use in the United States, 2023 update: Progress and opportunities. Antibiotic Prescribing and Use. 2024. Available at: <https://www.cdc.gov/antibiotic-use/hcp/data-research/stewardship-report.html>. Accessed on: 20/03/2025.
- [15] Abubakar U. Point-prevalence survey of hospital acquired infections in three acute care hospitals in Northern Nigeria. *Antimicrob Resist Infect Control* 2020;9:63. <https://doi.org/10.1186/s13756-020-00722-9>.
- [16] World Health Organization. Global action plan on antimicrobial resistance. *Microbe Mag* 2015;10:354-5. Available at: <https://www.who.int/publications/i/item/9789241509763>. Accessed on: 20/03/2025.
- [17] Black E, Neville H, Losier M, Harrison M, Abbass K, Slayter K, Johnston L, Sketris I. Antimicrobial Use at Acute Care Hospitals in Nova Scotia: A Point Prevalence Survey. *Can J Hosp Pharm* 2018;71:234-42. <https://pubmed.ncbi.nlm.nih.gov/articles/PMC6118829/>.
- [18] Sinatra I, Carubia L, Marchese V, Aprea L, D'Alessandro N, Mammina C, Torregrossa MV. Prevalence survey of healthcare-associated infections and antimicrobial use at the University Hospital "Paolo Giaccone", Palermo, Italy. *J Prev Med Hyg* 2013;54:200-4. <https://pubmed.ncbi.nlm.nih.gov/articles/PMC4718321/>.
- [19] Oo WT, Carr SD, Marchello CS, San MM, Oo AT, Oo KM, Lwin KT, Win HH, Crump JA. Point-prevalence surveys of antimicrobial consumption and resistance at a paediatric and an adult tertiary referral hospital in Yangon, Myanmar. *Infect Prev Pract* 2021;4(1):100197. <https://doi.org/10.1016/j.infpip.2021.100197>.
- [20] Barbadoro P, Dolcini J, Fortunato C, Mengarelli Detto Rinaldini D, Martini E, Gioia MG, Mengoni D, D'Errico MM; Marche's ICA-Net Working Collaborative Group. Point prevalence survey of antibiotic use and healthcare-associated infections in acute care hospitals: a comprehensive report from the Marche Region of Italy. *J Hosp Infect* 2023;141:80-7. <https://doi.org/10.1016/j.jhin.2023.07.025>.
- [21] Saleem Z, Hassali MA, Versporten A, Godman B, Hashmi FK, Goossens H, Saleem F. A multicenter point prevalence survey of antibiotic use in Punjab, Pakistan: findings and implications. *Expert Rev Anti Infect Ther* 2019;17:285-93. <https://doi.org/10.1080/14787210.2019.1581063>.
- [22] Porto APM, Goossens H, Versporten A, Costa SF; Brazilian Global-PPS Working Group. Global point prevalence survey of antimicrobial consumption in Brazilian hospitals. *J Hosp Infect* 2020;104:165-71. <https://doi.org/10.1016/j.jhin.2019.10.016>.
- [23] Frenette C, Sperlea D, German GJ, Afra K, Boswell J, Chang S, Goossens H, Grant J, Lefebvre MA, McGeer A, Mertz D, Science M, Versporten A, Thirion DJG. The 2017 global point prevalence survey of antimicrobial consumption and resistance in Canadian hospitals. *Antimicrob Resist Infect Control* 2020;9:104. <https://doi.org/10.1186/s13756-020-00758-x>.
- [24] Birdie Wahlang J, Syiem RP, Sarkar C, Lyngdoh NM, Tiewsoh I, Brahma DK, Surong A, Langstieh AJ. Evaluation of antibiotic consumption using WHO – antimicrobial consumption tool and AWaRe classification. *J Family Med Prim Care* 2024;13:5805-11. https://doi.org/10.4103/jfmpe.jfmpe_952_24.
- [25] Rachina S, Belkova Y, Kozlov R, Versporten A, Pauwels I, Goossens H, Bochanova E, Domanskaya O, Elokchina E, Ezhova L, Mishchenko V, Ni O, Popov D, Portnjagina U, Shchetinin E, Shegimova V, Strezh Y, Vityazeva V, Zubareva N, Russian Global-Pps Project Study Group. Longitudinal Point Prevalence Survey of Antimicrobial Consumption in Russian Hospitals: Results of the Global-PPS Project. *Antibiotics (Basel)* 2020;9:446. <https://doi.org/10.3390/antibiotics9080446>.
- [26] Tsegay HY, Hailu BY, Tafere GG, Demoz FB, Sisay TY, Sahle MG, Tuem KB. Antibiotic prescribing patterns and consumption at a comprehensive specialized hospital in northern Ethiopia: a prospective cross-sectional study underscoring the need for antimicrobial stewardship. *BMC Infect Dis* 2026;26(1):962. <https://doi.org/10.1186/s12879-026-13254-1>.
- [27] Alikhani MS, Nazari M, Hatamkhani S. Enhancing antibiotic therapy through comprehensive pharmacokinetic/pharmacodynamic principles. *Front Cell Infect Microbiol* 2025;15:1521091. <https://doi.org/10.3389/fcimb.2025.1521091>.
- [28] Mugada V, Mahato V, Andhavaram D, Vajhala SM. Evaluation of Prescribing Patterns of Antibiotics Using Selected Indicators for Antimicrobial Use in Hospitals and the Access, Watch, Reserve (AWaRe) Classification by the World Health Organization. *Turk J Pharm Sci* 2021;18:282-8. <https://doi.org/10.4274/tjps.galenos.2020.11456>.
- [29] Sajjad U, Afzal N, Asif M, Rehman MB, Afridi AU, Kazmi T. Evaluation of antibiotic prescription patterns using WHO AWaRe classification. *East Mediterr Health J* 2024;30:156-62. <https://doi.org/10.26719/emhj.24.031>.
- [30] Nsojo A, George L, Mwasomola D, Tawete J, Mbotwa CH, Mwewa CN, Mwakyula I. Prescribing patterns of antimicrobials according to the WHO AWaRe classification at a tertiary referral

- hospital in the southern highlands of Tanzania. *Infect Prev Pract* 2024;6:100347. <https://doi.org/10.1016/j.infpip.2024.100347>.
- [31] Sulaiman L, Cee W, Jbw SS, Sk R, Js C. Antibiotic use and consumption among medical patients of two hospitals in Sierra Leone: a descriptive report. *BMC Infect Dis* 2023;23:737. <https://doi.org/10.1186/s12879-023-08517-0>.
- [32] Saleem Z, Sheikh S, Godman B, Haseeb A, Afzal S, Qamar MU, Imam MT, Abuhussain SSA, Sharland M. Increasing the use of the WHO AWaRe system in antibiotic surveillance and stewardship programmes in low- and middle-income countries. *JAC Antimicrob Resist* 2025;7:dlaf031. <https://doi.org/10.1093/jacamr/dlaf031>.
- [33] Gandra S, Kotwani A. Need to improve availability of “access” group antibiotics and reduce the use of “watch” group antibiotics in India for optimum use of antibiotics to contain antimicrobial resistance. *J Pharm Policy Pract* 2019;12:20.
- [34] Coenen S, Ferech M, Haaijer-Ruskamp FM, Butler CC, Van der Stichele RH, Verheij TJ, Monnet DL, Little P, Goossens H; ESAC Project Group. European Surveillance of Antimicrobial Consumption (ESAC): quality indicators for outpatient antibiotic use in Europe. *Qual Saf Health Care* 2007;16:440-5. <https://doi.org/10.1136/qshc.2006.021121>.
- [35] Thampi N, Shah PS, Nelson S, Agarwal A, Steinberg M, Diam-bomba Y, Morris AM. Prospective audit and feedback on antibiotic use in neonatal intensive care: a retrospective cohort study. *BMC Pediatr* 2019;19:105. <https://doi.org/10.1186/s12887-019-1481-z>.
- [36] Begnaud CM Jr, Lemoine J, Broussard L, Rhodon R, Doshi H. A Quality Improvement Project to Reduce Antibiotic Utilization and Ancillary Laboratory Tests in the Appraisal of Early-Onset Sepsis in the NICU. *J Pediatr Nurs* 2021;60:215-22. <https://doi.org/10.1016/j.pedn.2021.06.012>.
- [37] McCarthy KN, Hawke A, Dempsey EM. Antimicrobial stewardship in the neonatal unit reduces antibiotic exposure. *Acta Paediatr* 2018;107:1716-21. <https://doi.org/10.1111/apa.14337>.
- [38] Vandael E, Latour K, Goossens H, Magerman K, Drapier N, Catry B, Versporten A; Belgian Point Prevalence Survey Study Group. Point prevalence survey of antimicrobial use and health-care-associated infections in Belgian acute care hospitals: results of the Global-PPS and ECDC-PPS 2017. *Antimicrob Resist Infect Control* 2020;9:13. <https://doi.org/10.1186/s13756-019-0663-7>.
- [39] Ciofi Degli Atti ML, D’Amore C, Ceradini J, Paolini V, Ciliento G, Chessa G, Raponi M. Prevalence of antibiotic use in a tertiary care hospital in Italy, 2008-2016. *Ital J Pediatr* 2019;45:63. <https://doi.org/10.1186/s13052-019-0645-7>.
- [40] Guidelines for Antimicrobial Use. *Icmr.org.in*. 2026. Available at: <https://amrtg.icmr.org.in/chapter10-ssi.html>. Accessed on: 03/08/2026.

Received on July 4, 2026. Accepted on August 24, 2026.

Correspondence: Neha Sunil Bawankar, Department of Microbiology, Government Medical College, Nagpur, 440003. E-mail: shivbkgouri@gmail.com.

How to cite this article: Bawankar NS, Chavan SP, Aruna R, Zodpey (Shrikhande) SS, Rajkondawar AV, Tiwari MM, Gupta BB. Assessment of Antimicrobial Consumption Patterns in Adult and Pediatric Patients in Intensive Care Units Using DDD, DOT, and WHO AWaRe Classification: A Point Prevalence Study from Central India. *J Prev Med Hyg* 2026;67:E335-E344. <https://doi.org/10.82082/2421-4248/jpmh2026.67.3.4040>

© Copyright by Pacini Editore Srl, Pisa, Italy

This is an open access article distributed in accordance with the CC-BY-NC-ND (Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International) license. The article can be used by giving appropriate credit and mentioning the license, but only for non-commercial purposes and only in the original version. For further information: <https://creativecommons.org/licenses/by-nc-nd/4.0/deed.en>