Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol.6 No. 12 (2025): December 2025 Issue
https://doi.org/10.51168/sjhrafrica.v6i12.2338
Original Article

Antibiogram profiles of bacteria isolated from different clinical samples among patients admitted to a teaching hospital in Andhra Pradesh: A cross-sectional study.

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Abstract

Background:

This study evaluated the cumulative antibiogram profiles of bacterial isolates recovered from diverse clinical specimens among hospitalized patients at a tertiary-care teaching hospital in Andhra Pradesh, India.

Methods:

A cross-sectional, laboratory-based study was conducted from January 2024 to September 2024 in the Department of Pharmacology, in collaboration with the Department of Microbiology, Konaseema Institute of Medical Sciences and Research Foundation (KIMS & RF), Amalapuram. A total of 5,747 clinical specimens, including blood, urine, respiratory samples, pus, and body fluids, were processed. Significant bacterial growth was observed in 2,170 samples (37.7%). Isolates were identified using standard biochemical methods and confirmed with an automated system (VITEK-2). Antimicrobial susceptibility testing was performed using the Kirby–Bauer disk diffusion technique and interpreted according to CLSI M100 (2024) guidelines. Cumulative antibiograms were prepared in accordance with CLSI M39 recommendations.

Results:

Gram-negative bacilli constituted 72% of isolates, with *Escherichia coli* and *Klebsiella pneumoniae* being predominant. Non-fermenting Gram-negative organisms, notably *Pseudomonas aeruginosa* and *Acinetobacter baumannii*, were frequently isolated. Gram-positive cocci accounted for 28%, mainly *Staphylococcus aureus* and *Enterococcus* species. Among Gram-negative isolates, carbapenems (75–85%), piperacillin–tazobactam (60–70%), and amikacin (≈70%) demonstrated the highest susceptibility. Methicillin-resistant *Staphylococcus aureus* prevalence was 40%. All Gram-positive isolates remained uniformly susceptible to vancomycin (100%) and highly susceptible to linezolid (98%). Multidrug resistance was observed in approximately 35–45% of isolates.

Conclusion:

The findings reveal a predominance of Gram-negative pathogens with a considerable burden of multidrug resistance among inpatients. While carbapenems, β-lactam/β-lactamase inhibitor combinations, and amikacin remain effective against Gram-negative organisms, glycopeptides and oxazolidinones continue to be reliable options for Gram-positive infections.

Recommendations:

Regular updating of hospital antibiograms, strict adherence to antimicrobial stewardship principles, reinforcement of infection prevention and control practices, and judicious use of reserve antibiotics are strongly recommended to limit resistance progression and improve clinical outcomes.

Keywords: *Antibiogram; Antimicrobial resistance; Empirical therapy; Gram-negative bacilli; Multidrug resistance.*
Submitted: *June 22, 2025* ***Accepted:*** *October 28, 2025* ***Published:*** *December 31, 2025*
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Introduction

Antimicrobial resistance (AMR) has emerged as one of the gravest challenges confronting modern medicine, progressively eroding the effectiveness of standard therapies for common bacterial infections and contributing to rising morbidity, mortality, and health-care expenditure worldwide. Recent global estimates indicate that several million deaths are linked to bacterial infections annually, with a substantial proportion attributable to drug-resistant pathogens. The burden is

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disproportionately higher in low- and middle-income countries, where health systems face persistent constraints in infection prevention, diagnostics, and antimicrobial regulation [1].

India carries a particularly high share of the global AMR burden. This is driven by a combination of factors, including a high prevalence of infectious diseases, easy access to antibiotics without prescriptions, inappropriate or prolonged antibiotic use, inconsistent infection-control practices, and complex One-Health interactions involving humans, animals, and the environment. National surveys and regional investigations consistently report gaps in antimicrobial stewardship, variable prescribing behaviors, and inadequate surveillance mechanisms, resulting in marked inter-state and inter-hospital differences in resistance patterns [2,3].

Hospitalized patients are especially vulnerable to infections caused by resistant organisms. Both health-care–associated and community-acquired infections frequently involve pathogens such as *Escherichia coli*, *Klebsiella pneumoniae*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Acinetobacter baumannii*. Many of these organisms have demonstrated declining susceptibility to commonly used first- and second-line agents, including β-lactams, fluoroquinolones, and, in some settings, carbapenems. Continuous surveillance of isolates from blood, urine, respiratory samples, and wound specimens is therefore critical to guide timely empirical therapy and to mitigate adverse clinical outcomes [4,5].

An antibiogram, which summarizes local antimicrobial susceptibility data, is a cornerstone of antimicrobial stewardship. It supports rational empirical prescribing, facilitates early detection of emerging resistance trends, and informs infection-control strategies. International guidelines, particularly CLSI M100 and CLSI M39, outline standardized methods for antimicrobial susceptibility testing, cumulative data analysis, and presentation, emphasizing the use of institution-specific data and first isolates per patient to maintain clinical relevance. Regular dissemination of antibiogram reports has been shown to improve antibiotic selection and reduce unnecessary broad-spectrum antibiotic use [6–8].

More recent stewardship frameworks advocate the use of stratified antibiograms—organized by specimen type, inpatient location, or patient population—rather than single pooled summaries. Such stratification better captures heterogeneity in resistance patterns across wards and clinical syndromes, providing more precise guidance for empirical therapy. This approach is particularly valuable in tertiary-care teaching hospitals that manage diverse patient populations and complex infections [9,10].

Within India, and specifically in Andhra Pradesh, published microbiological studies from tertiary centres report pathogen distributions broadly similar to national trends, but with notable local variations in resistance rates. These include a high prevalence of extended-spectrum β-lactamase–producing Enterobacterales, methicillin-resistant *Staphylococcus aureus* (MRSA), and other multidrug-resistant organisms. Both earlier and more recent hospital-based reports from the region underscore the necessity of continuous, institution-specific antibiogram surveillance to capture temporal changes and guide empiric therapy appropriately [11–13].

Environmental and One-Health factors further shape the regional AMR landscape. The presence of antibiotic residues in water systems, agricultural use of antimicrobials, and bidirectional transmission between humans, animals, and the environment contribute to the persistence and spread of resistance. These factors reinforce the need to integrate clinical antibiogram data with broader surveillance efforts at the community and environmental levels [14,15].

The clinical and economic consequences of AMR are substantial. Resistant infections are associated with prolonged hospital stays, increased treatment costs, greater use of last-resort antibiotics, and higher mortality rates. Facility-level antibiogram data can help reduce these burdens by enabling earlier initiation of effective therapy and supporting stewardship interventions that decrease selective pressure for resistant strains [16].

Despite these well-recognized benefits, routine generation and clinical integration of well-stratified antibiograms remain inconsistent across many Indian hospitals. Global and national initiatives, including the WHO Global Antimicrobial Resistance Surveillance System (GLASS) and India's antimicrobial stewardship programs, emphasize strengthening laboratory capacity, standardizing antibiogram methodologies, and ensuring regular reporting as key components of the AMR response. Robust local antibiogram data are therefore indispensable for developing context-specific empirical guidelines, monitoring resistance trends over time, and prioritizing infection-control and stewardship resources in teaching hospitals [17-19].

Against this background, the present study analyzes the antibiogram profiles of bacterial isolates obtained from a range of clinical specimens among hospitalized patients at a teaching hospital in Andhra Pradesh. By detailing species distribution, specimen-wise susceptibility patterns, and resistance trends, the study aims to generate actionable evidence to support evidence-based empirical therapy, targeted stewardship interventions, and improved patient outcomes in the local health-care setting.

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Materials and Methods

Study Design and Setting

A cross-sectional, laboratory-based observational study was conducted in the Department of Pharmacology, in collaboration with the Department of Microbiology, Konaseema Institute of Medical Sciences and Research Foundation (KIMS & RF), Amalapuram, Andhra Pradesh, India. The study period extended from January 2024 to September 2024. KIMS & RF is a tertiary-care teaching hospital serving both rural and semi-urban populations of the Konaseema region, catering to approximately 900 inpatient beds across medical, surgical, pediatric, and intensive-care units.

Study Population and Sample Collection

Clinical specimens were obtained from inpatients admitted to various wards and ICUs with suspected bacterial infections. A total of 5,747 clinical samples were processed during the study period. Samples included urine, blood, sputum, pus/wound swabs, and other body fluids collected under aseptic precautions following standard protocols. Duplicate isolates from the same patient were excluded to ensure only the first clinically significant isolate per patient was included, consistent with CLSI M39 guidelines (20).

Each sample was transported promptly to the microbiology laboratory in sterile containers and processed within two hours of collection. Blood cultures were incubated in automated systems (BACTEC™ FX 40, Becton Dickinson, USA), while other samples were inoculated on appropriate culture media such as blood agar, MacConkey agar, and nutrient agar, and incubated aerobically at 37 °C for 18–24 h.

Isolation and Identification of Bacteria

Bacterial growth was examined for colony morphology, Gram staining, and standard biochemical tests, including indole, methyl red, Voges–Proskauer, citrate utilization, catalase, coagulase, oxidase, urease, and triple-sugar-iron reactions as applicable (21). Identification was further confirmed using an automated identification and susceptibility testing system (VITEK-2 Compact, bioMérieux, France) whenever available.

Antimicrobial Susceptibility Testing (AST)

Antimicrobial susceptibility of all isolates was determined by the Kirby–Bauer disk diffusion method on Mueller–Hinton agar according to Clinical and Laboratory Standards Institute (CLSI) guidelines, 34th edition, 2024 (22). Inocula were standardized to 0.5 McFarland turbidity. The antibiotic panels tested were selected based on the organism group and hospital formulary and included the following drug classes:

β-lactams: ampicillin, amoxicillin–clavulanate, ceftriaxone, ceftazidime, cefepime, piperacillin–tazobactam
Carbapenems: imipenem, meropenem
Aminoglycosides: gentamicin, amikacin
Fluoroquinolones: ciprofloxacin, levofloxacin
Others: tetracycline, cotrimoxazole, chloramphenicol, nitrofurantoin (for urinary isolates), and linezolid or vancomycin (for Gram-positive cocci).

The interpretive breakpoints were taken as per CLSI M100 (2024) standards. Quality control strains used were Escherichia coli ATCC 25922, Staphylococcus aureus ATCC 25923, and Pseudomonas aeruginosa ATCC 27853. Isolates resistant to three or more classes of antimicrobials were defined as multidrug-resistant (MDR) according to international consensus definitions (23).

Data Analysis and Preparation of Antibiogram

Antibiotic susceptibility data were entered into Microsoft Excel 365 and analyzed using IBM SPSS version 28.0 (IBM Corp., Armonk, NY). Descriptive statistics were employed to calculate frequency and percentage resistance for each antibiotic against the corresponding species. A cumulative antibiogram was prepared following CLSI M39 recommendations (20), representing the percentage of susceptible isolates to each antimicrobial agent. Isolates were grouped by specimen type and bacterial species.

Ethical Considerations

The study protocol was reviewed and approved by the Institutional Ethics Committee (IEC), Konaseema Institute of Medical Sciences and Research Foundation, Amalapuram (IEC No.: KIMS/IEC/PHARM/2023/014). Since the study utilized anonymized routine laboratory data without direct patient identifiers, the need for informed consent was waived by the IEC.

Results

A total of 5,747 clinical specimens were processed during the study period (January 2024 – September 2024) at the Department of Microbiology, KIMS & RF, Amalapuram. Among these, 2,170 (37.7 %) yielded significant bacterial growth.

Sample-wise Culture Positivity

Out of 1,945 blood cultures, 470 (24.1 %) showed growth. Among 1,720 urine samples, 624 (36.2 %) were culture-positive. Respiratory samples (n = 830) had 434 (52.2 %) positivity. Pus/wound samples (n = 940) recorded the highest culture positivity (604; 64.2 %), while body fluids (n = 312) had 38 (12.1 %) positive cultures (Table 1).

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Table 1. Distribution of culture-positive samples

Specimen type	Total samples	Culture positive (n)	Positivity (%)
Blood	1,945	470	24.1
Urine	1,720	624	36.2
Respiratory	830	434	52.2
Pus/Wound	940	604	64.2
Body fluids	312	38	12.1
Total	**5,747**	**2,170**	**37.7**

Bacterial Isolates

Among the isolates, Gram-negative bacilli (GNB) constituted the majority (≈72 %), followed by Gram-positive cocci (GPC) (≈28 %). Enterobacterales (mainly E. coli, Klebsiella spp., Enterobacter spp.) were predominant among GNBs. Non-fermenters such as Pseudomonas aeruginosa and Acinetobacter baumannii were the next most frequent. Among GPCs, Staphylococcus aureus (including MRSA) and Enterococcus spp. were common.

Antibiotic Susceptibility Patterns

1. Enterobacterales

First-line agents: moderate susceptibility to third-generation cephalosporins (ceftriaxone ≈ 45–55 %) and aminoglycosides (amikacin ≈ 70 %).
Second-line agents: piperacillin-tazobactam and cefepime showed 60–70 % susceptibility.
Reserved drugs: carbapenems (imipenem, meropenem) retained high activity (75–85 %).
Urinary isolates: good response to nitrofurantoin (> 80 %).

2. Non-fermenters (Pseudomonas and Acinetobacter)

First-line agents: low susceptibility to fluoroquinolones (ciprofloxacin ≈ 35–45 %).
Second-line agents: amikacin and piperacillin-tazobactam are effective in 55–65 % of isolates.
Reserved agents: meropenem/imipenem susceptibility around 60 %; colistin remained most active (> 95 %).

3. Gram-positive cocci

Staphylococcus aureus exhibited methicillin resistance in ~40 % of isolates (MRSA).
High susceptibility to vancomycin (100 %), linezolid (98 %), and teicoplanin (95 %).
Enterococcus spp. showed good susceptibility to vancomycin (90 %) and linezolid (96 %), while intrinsic resistance to cephalosporins and low-level resistance to high-concentration gentamicin were noted.

Drug-resistant Organisms

MDR prevalence: approximately 35–40 % among Enterobacterales, 45 % among Acinetobacter spp., and 30 % among Pseudomonas spp.
MRSA: 40 % of S. aureus isolates.
No vancomycin-resistant Enterococcus (VRE) was detected.

Antibiogram Summary

Overall susceptibility trends demonstrated that carbapenems, amikacin, and β-lactam/β-lactamase inhibitor combinations remain the most effective options against GNBs, while glycopeptides and oxazolidinones continue to be effective for GPCs. Periodic surveillance and antibiogram updates are essential for guiding empirical therapy and strengthening antibiotic stewardship at the institutional level.

Table 2. Antibiotic Sensitivity Pattern of Bacterial Isolates

Organism	Amikacin	Ceftriaxone	Pip-Tazo	Meropenem	Ciprofloxacin	Vancomycin	Linezolid
E. coli	75.0	50.0	70.0	85.0	45.0	-	-
Klebsiella spp.	70.0	45.0	65.0	80.0	40.0	-	-
Enterobacter spp.	68.0	48.0	60.0	78.0	42.0	-	-
Pseudomonas aeruginosa	60.0	-	55.0	60.0	38.0	-	-
Acinetobacter baumannii	55.0	-	50.0	58.0	35.0	-	-

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Staphylococcus aureus	-	-	-	-	-	100.0	98.0
Enterococcus spp.	-	-	-	-	-	90.0	96.0

Figure 1. Antibiotic Sensitivity Pattern of Gram-negative Bacteria

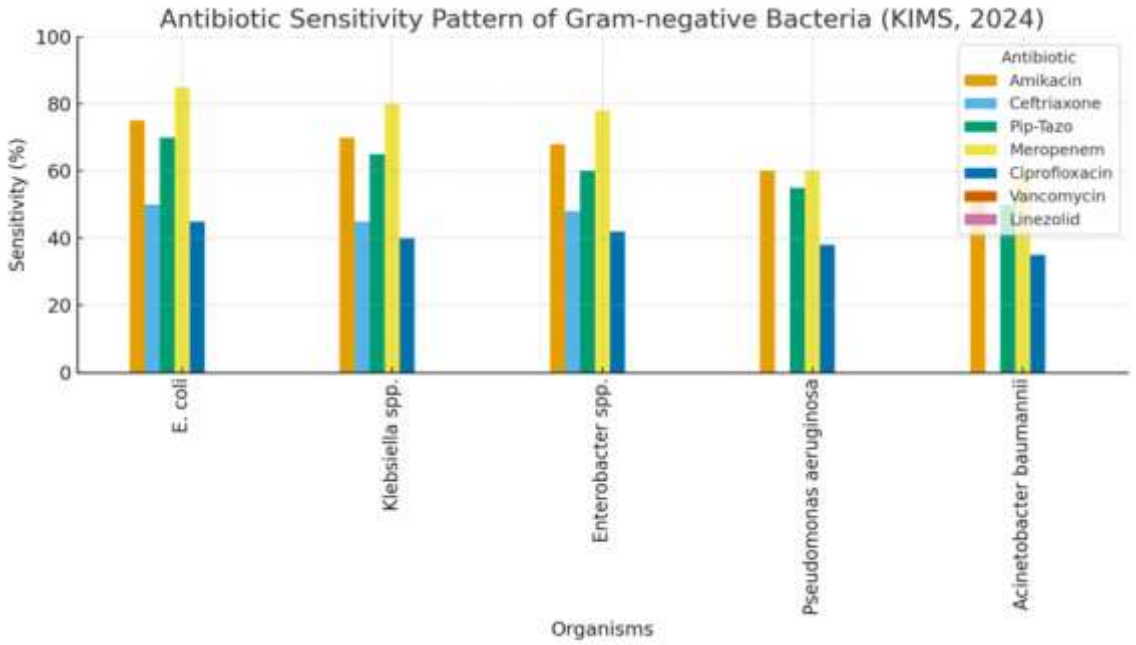
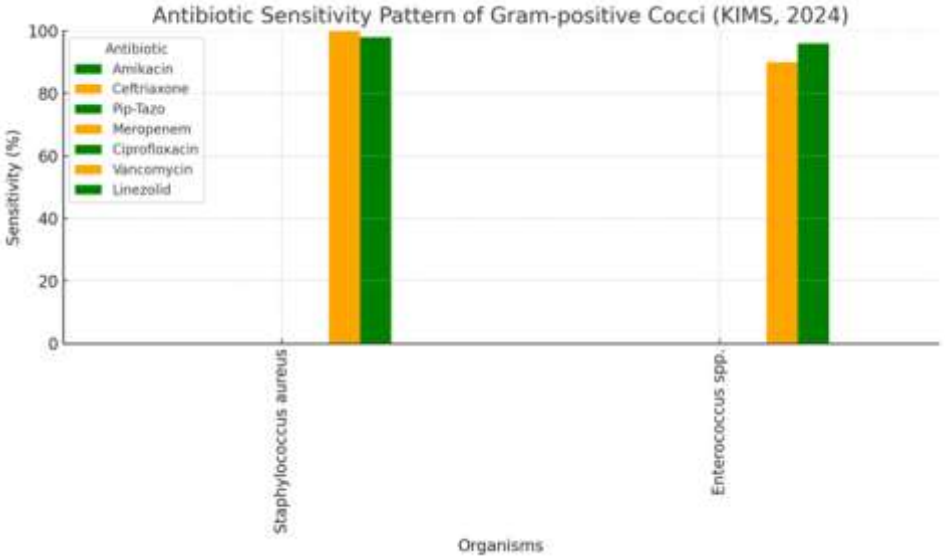


Figure 2 Antibiotic Sensitivity Pattern of Gram-positive Cocci



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Discussion

This study provides a focused appraisal of the bacterial spectrum and antimicrobial susceptibility profiles among inpatients at a tertiary-care teaching hospital in Andhra Pradesh, generating practical evidence to guide empirical antibiotic selection and strengthen antimicrobial stewardship. The overall culture positivity rate (37.7%) aligns with observations from comparable Indian tertiary-care settings, where positivity commonly ranges from 30% to 45%, depending on specimen mix, case severity, and antecedent antibiotic exposure [24,25].

On specimen-wise assessment, the highest culture positivity was observed in pus and wound samples (64.2%), followed by respiratory specimens (52.2%) and urine (36.2%). This distribution is consistent with reports by Joshi et al. and Nandagopal et al., who documented a predominance of infections involving surgical sites, the respiratory tract, and the urinary system among hospitalized cohorts [26,27]. The comparatively lower blood culture positivity (24.1%) may plausibly reflect antibiotic administration before sampling and conservative diagnostic thresholds for bacteremia, patterns noted in earlier hospital-based studies [28].

In agreement with regional and national surveillance patterns, Gram-negative bacilli accounted for the majority of isolates (≈72%), with Enterobacterales forming the principal group. *Escherichia coli* and *Klebsiella pneumoniae* were the most frequently recovered pathogens, echoing findings from South Indian tertiary centers and similar low- and middle-income country contexts [29,30]. Among non-fermenters, *Pseudomonas aeruginosa* and *Acinetobacter baumannii* were commonly isolated, reinforcing their growing role in healthcare-associated infections, particularly in high-dependency and critical care units [31].

Antimicrobial susceptibility trends showed that carbapenems and β-lactam/β-lactamase inhibitor combinations continue to provide the most consistent coverage against Enterobacterales and non-fermenters, with susceptibility in the range of 70%–85%. Conversely, the diminished activity of third-generation cephalosporins and fluoroquinolones (40%–50%) suggests ongoing selection pressure driven by frequent empirical use and consequent resistance amplification [32]. Amikacin retained meaningful activity against most Gram-negative isolates, supporting its continued value as a therapeutic option, as also reported in Indian studies and global surveillance summaries [33,34].

The burden of multidrug resistance is a major concern. Approximately 35–40% of Enterobacterales, 45% of *Acinetobacter* spp., and 30% of *Pseudomonas* spp. exhibited MDR phenotypes, aligning with resistance trends reported from other tertiary centers in South India [27,29]. Carbapenem resistance in *Acinetobacter baumannii* is particularly alarming, given its association with limited therapeutic options and poorer clinical outcomes [35].

Among Gram-positive cocci, *Staphylococcus aureus* predominated, with a methicillin-resistant prevalence of 40%, consistent with multicenter Indian estimates [36]. Glycopeptides and oxazolidinones, including vancomycin and linezolid, retained excellent efficacy, reinforcing their role as cornerstone agents for serious Gram-positive infections [37]. The absence of vancomycin-resistant *Enterococcus* in this cohort is reassuring, especially when contrasted with rising VRE rates reported from northern India and parts of Southeast Asia [38].

Overall, the antibiogram generated in this study highlights the continued reliance on broad-spectrum antibiotics in empirical practice, often driven by delayed culture reporting and diagnostic uncertainty. Incorporation of regularly updated, institution-specific antibiogram data into prescribing algorithms, as advocated by CLSI M39 and WHO GLASS frameworks, can promote more rational antibiotic selection and reduce unnecessary broad-spectrum exposure [20,34]. The collaborative stewardship model involving microbiologists, pharmacologists, and clinicians demonstrated here provides a pragmatic and sustainable approach for optimizing antimicrobial use within tertiary-care hospitals [39].

Generalizability

Although conducted at a single tertiary-care teaching hospital, the findings of this study are broadly generalizable to similar institutions across Andhra Pradesh and other regions of India with comparable patient demographics, health-care infrastructure, and antimicrobial usage patterns. The predominance of Gram-negative pathogens, high multidrug resistance rates, and preserved activity of carbapenems and last-resort agents reflect trends reported nationwide. However, local variations in resistance underscore the need for institution-specific antibiograms rather than reliance on regional or national averages.

Conclusion

This study demonstrates that Gram-negative bacteria continue to dominate the infectious landscape among hospitalized patients, with a considerable burden of multidrug resistance observed among Enterobacterales and non-fermenting organisms. Despite this challenge, carbapenems, piperacillin–tazobactam, and amikacin remain relatively effective therapeutic options for Gram-negative infections, while glycopeptides and oxazolidinones continue to show reliable activity against Gram-positive cocci. The findings underscore the critical role of periodic, institution-specific antibiogram

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generation in supporting rational empirical therapy and minimizing inappropriate broad-spectrum antibiotic use. Sustained surveillance, coupled with robust antimicrobial stewardship programs and strengthened infection-control practices, is essential to slow resistance emergence and improve clinical outcomes in tertiary-care teaching hospitals.

Limitations

The study was limited to isolates obtained from inpatients and did not include outpatients or environmental surveillance. Molecular typing and detection of resistance genes were beyond its scope, though they would provide further insight into transmission dynamics. Nonetheless, the large dataset and use of standardized CLSI methods add robustness to the findings.

Recommendations

Regular preparation and dissemination of hospital-specific antibiograms should be institutionalized to guide empirical antibiotic therapy and update local treatment guidelines. Antimicrobial stewardship programs must be strengthened through multidisciplinary collaboration, with active involvement of clinicians, microbiologists, and pharmacologists to promote judicious antibiotic use. Early culture sampling before antibiotic initiation, timely reporting of susceptibility results, and de-escalation based on antibiogram data should be encouraged. Continuous training of health-care personnel on antimicrobial resistance and infection-control practices is essential. Strengthening hand hygiene, environmental sanitation, and isolation protocols, along with periodic audit and feedback on antibiotic prescribing, can significantly reduce resistance and improve patient outcomes.

Acknowledgement

The authors sincerely acknowledge the Department of Microbiology and the Department of Pharmacology, Konaseema Institute of Medical Sciences and Research Foundation (KIMS & RF), Amalapuram, for their invaluable technical support and interdepartmental collaboration throughout the study period. We extend our gratitude to the laboratory technical staff for their meticulous processing of clinical samples and accurate reporting of antimicrobial susceptibility data. The authors also thank the hospital administration for permitting access to laboratory records and for facilitating the conduct of this study.

Abbreviations

AMR – Antimicrobial resistance
ASPs – Antimicrobial stewardship programs
BL–BLI – β-lactam/β-lactamase inhibitor
CLSI – Clinical and Laboratory Standards Institute
ESBL – Extended-spectrum β-lactamase
GNB – Gram-negative bacilli
GPC – Gram-positive cocci
GLASS – Global Antimicrobial Resistance Surveillance System
KIMS & RF – Konaseema Institute of Medical Sciences and Research Foundation
MDR – Multidrug resistant
MRSA – Methicillin-resistant *Staphylococcus aureus*
VRE – Vancomycin-resistant *Enterococcus*

Source of funding

The study had no funding.

Conflict of interest

The authors declare no conflict of interest.

Author contributions

AA-Concept and design of the study, results interpretation, review of literature, and preparation of the first draft of the manuscript. Statistical analysis and interpretation, revision of manuscript.**GL**-Concept and design of the study, results interpretation, review of literature, preparing the first draft of the manuscript, and revision of the manuscript.**NRK**-Review of literature and preparing the first draft of the manuscript. Statistical analysis and interpretation.

Data availability

Data available on request

Author Biography

Dr. Anand Acharya, MBBS, MD (Pharmacology), currently serves as Dean and Professor, Department of Pharmacology, at the Konaseema Institute of Medical Sciences & Research Foundation (KIMS&RF), Amalapuram, Andhra Pradesh, India. A distinguished academician, researcher, and medical education leader, he has been pivotal in transforming KIMS&RF from its formative phase into a premier medical institution with over 200 undergraduate and 100 postgraduate seats.

With more than 18 years of teaching and administrative experience, Dr. Acharya has held several leadership positions, including Vice Principal, Principal, Chief Warden, Member Secretary of Institutional Ethics and Animal Ethics Committees, and is an approved PhD Guide under Dr. NTR University of Health Sciences, Vijayawada. His visionary leadership has significantly enhanced the institution's academic quality, clinical exposure, research infrastructure, and postgraduate training standards.

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He has successfully completed prestigious national faculty development programs such as the Revised Basic Course Workshop (rBCW), Advanced Course in Medical Education (ACME), and National Teacher Training Course (NTTC, JIPMER, Puducherry). He also serves as Coordinator for Pharmacovigilance and Materiovigilance Programs under IPC–PvPI and MoHFW, Government of India, contributing actively to national drug safety and regulatory initiatives.

A prolific academician, Dr. Acharya has authored and co-authored more than 100 scientific publications in reputed national and international indexed journals. His wide-ranging research covers toxicology, pharmacovigilance, antimicrobial resistance, endocrinology, neuropharmacology, and clinical pharmacology. His recent studies include long-term analyses of pyrethroid, paraquat, and chlorpyrifos poisoning, investigations into antimicrobial resistance trends, and predictive models for treatment outcomes in dermatological and toxicological emergencies.

Dr. Acharya's professional interests include clinical pharmacology, toxicovigilance, rational drug use, pharmacovigilance systems, and innovations in medical education technologies. He continues to mentor numerous postgraduate and undergraduate researchers while playing an integral role in curriculum reform, ethics governance, and institutional academic advancement.**ORCID iD**: https://orcid.org/0009-0000-7967-9092

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e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol.6 No. 12 (2025): December 2025 Issue
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Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
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https://doi.org/10.51168/sjhrafrica.v6i12.2338
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Student's Journal of Health Research Africa
e-ISSN: 2709-9997, p-ISSN: 3006-1059
Vol.6 No. 12 (2025): December 2025 Issue
https://doi.org/10.51168/sjhrafrica.v6i12.2338
Original Article

PUBLISHER DETAILS

Student's Journal of Health Research (SJHR)
(ISSN 2709-9997) Online
(ISSN 3006-1059) Print
Category: Non-Governmental & Non-profit Organization
Email: studentsjournal2020@gmail.com
WhatsApp: +256 775 434 261
Location: Scholar's Summit Nakigalala, P. O. Box 701432, Entebbe Uganda, East Africa