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Original Research Article

Evaluation of antimicrobial susceptibility pattern of common pathogens isolated from routine specimens of patients in a tertiary care teaching hospital in Central India: a prospective observational study

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ABSTRACT

Background: Antimicrobial resistance (AMR) is a significant global health concern, especially in developing countries such as India, where heavy antibiotic use has led to rising resistance in common pathogens and made treatment harder. This study evaluated the antimicrobial susceptibility pattern of common pathogens isolated from routine clinical specimens.

Methods: This prospective observational study was conducted in the Department of Microbiology, Government Medical College, Gondia, from 1 April 2024 to 31 October 2025, after Institutional Ethics Committee approval (GMCG/Pharmac/IEC/51/31-3-2024). A total of 1,000 routine clinical specimens (urine, blood, sputum, high vaginal and wound swabs, stool and body fluids) were cultured on blood agar, MacConkey agar and chocolate agar. Antimicrobial susceptibility testing was performed by the Kirby-Bauer disk diffusion method and interpreted according to CLSI and EUCAST guidelines. Data were analysed with SPSS version 20 using the chi-square test, and $p<0.05$ was considered significant.

Results: *Escherichia coli* (23.2%), *Staphylococcus aureus* (22.2%; MRSA 11.8%) and *Klebsiella pneumoniae* (19.1%) were the commonest isolates. MRSA formed 53.2% of *S. aureus* and was fully susceptible to vancomycin and linezolid. *E. coli* and *K. pneumoniae* were highly resistant to third-generation cephalosporins (ceftazidime resistance 69.0% and 75.7%), while amikacin retained about 78% susceptibility. Carbapenem resistance in *Acinetobacter baumannii* exceeded 85%, with colistin about 95% susceptible.

Conclusions: The occurrence of multidrug-resistant organisms such as MRSA and ESBL-suggestive Enterobacterales highlights the need for continuous surveillance and rational antibiotic use. Local susceptibility patterns are important when starting empirical treatment.

Keywords: Antimicrobial resistance, Susceptibility testing, Central India, MRSA, *Klebsiella pneumoniae*, Kirby-Bauer

INTRODUCTION

Antimicrobial resistance (AMR) is one of the most serious public health threats of the 21st century, undermining the treatment of common infections and the safety of modern surgery and chemotherapy.[1] In 2019, bacterial AMR was directly responsible for an estimated 1.27 million deaths worldwide, and South Asia was among the regions with the highest AMR-attributable death rates.[2] India carries a particularly heavy burden because of the high prevalence of infectious disease, widespread self-medication, over-the-counter sale of antibiotics and uneven infection control.[3] Resistance patterns also differ between regions, hospitals and even wards within one institution, so national

surveillance, such as that of the Indian Council of Medical Research Antimicrobial Resistance Surveillance Network, cannot replace local data.[4] Data from central India, especially from hospitals serving tribal and underserved populations, remain scarce, which makes it difficult to frame empirical treatment guidelines suited to local needs.[5] Culture and antimicrobial susceptibility testing (AST) of routine clinical specimens remain the basis of targeted therapy, and the Kirby-Bauer disk diffusion method is still widely used because it is simple, inexpensive and reliable.[6,7] Cumulative local antibiograms built from such data allow early detection of emerging resistance and guide empirical therapy, stewardship and infection control policy.

The present study was therefore conducted in a tertiary care teaching hospital in central India that serves a diverse population, including tribal communities, to evaluate the antimicrobial susceptibility pattern of common pathogens isolated from routine clinical specimens. The aim is to evaluate the antimicrobial susceptibility pattern of common pathogens isolated from routine clinical specimens in patients attending a tertiary care teaching hospital in central India. The objectives of the study are to identify the most common pathogens isolated from routine clinical specimens; determine the antimicrobial susceptibility patterns of the isolated pathogens using standard microbiological methods; assess the prevalence of resistant strains (MDR/XDR) among the isolates; and generate a local antibiogram to support rational antibiotic use and institutional antibiotic policy.

METHODS

Study design, setting and period

This prospective observational study was conducted in the Department of Microbiology, Government Medical College, Gondia, Maharashtra, a tertiary care teaching hospital in central India, from 1 April 2024 to 31 October 2025.

Ethical considerations

The study protocol was approved by the Institutional Ethics Committee before the study began (approval number GMCG/Pharmac/IEC/51/31-3-2024). Patient confidentiality was strictly maintained, and the data were used only for research.

Sample size

The sample size for estimating a proportion was calculated as $n=Z^2p(1-p)/d^2$, with Z=1.96 (95% confidence), an assumed resistance prevalence (p) of 50% because no local data were available, and an absolute error (d) of 5%, giving n≈384. To improve robustness, 1,000 routine clinical specimens were included.

Study sample

Patients of all ages and both sexes with suspected infection, attending the outpatient departments or admitted to the wards, were included, including those who acquired infection during their hospital stay. Routine clinical specimens (urine, blood, sputum, high vaginal and wound swabs, pus, stool, cerebrospinal fluid and other body fluids) were eligible. Specimens with incomplete or missing clinical data were excluded.

Laboratory procedures

Specimens were cultured by the streaking method on blood agar, MacConkey agar and for cerebrospinal fluid and sputum, chocolate agar. Bacterial and fungal isolates were identified by standard microbiological techniques. AST was performed by the Kirby-Bauer disk diffusion method on Mueller-Hinton agar using commonly prescribed antimicrobial discs, including amoxicillin, ampicillin and aztreonam. MRSA was confirmed with a cefoxitin (30 µg) disc. Zone diameters were interpreted as susceptible, intermediate or resistant according to CLSI M100 and EUCAST guidelines.[8,9]

Statistical analysis

Data were entered in Microsoft Excel and analysed with SPSS version 20. Results are expressed as percentages and proportions, associations between categorical variables were tested with the chi-square test, and a $p<0.05$ was considered statistically significant.

RESULTS

Patient characteristics

Out of the 1,000 patients, 648 (64.8%) were female, 341 (34.1%) were male and 11 (1.1%) had no recorded sex (Table 1). Age ranged from 5 days to 95 years (mean±SD, 35±17.85 years); the 21–30-year group was the largest (34.5%), and children up to 10 years contributed 6.5%. Inpatients supplied 739 specimens (73.9%) and outpatients 261 (26.1%). The post-operative, postnatal, labour room and antenatal wards together accounted for 45.7% of all specimens, whereas intensive care units contributed 6.5%.

Specimens and pathogens

High vaginal swabs (34.5%) and urine (26.2%) formed more than 60% of specimens, followed by sputum (18.5%) and pus or wound swabs (14.8%); blood, stool and body fluids together contributed 6.0% (Table 2). High vaginal swab and urine specimens came significantly more often from women aged 21–40 years ($p<0.001$), and sputum and pus specimens from men aged 51–75+ years ($p<0.05$).

Escherichia coli was the most frequent isolate (23.2%), followed by *Staphylococcus aureus* (22.2%; MRSA 11.8%, MSSA 10.4%) and *Klebsiella pneumoniae* (19.1%)

(Figure 1); *E. coli* and *K. pneumoniae* together made up 42.3% of isolates. Non-fermenting Gram-negative bacilli were less common (*Pseudomonas aeruginosa* 7.6%, *Acinetobacter baumannii* 6.2%). Polymicrobial growth occurred mainly in sputum, diabetic foot pus and complex high vaginal swab cultures, most often *K. pneumoniae* with *Candida* species or *Streptococcus pneumoniae*, and *E. coli* with MSSA. Such cultures were significantly more likely to come from post-operative and intensive care wards ($p<0.05$).

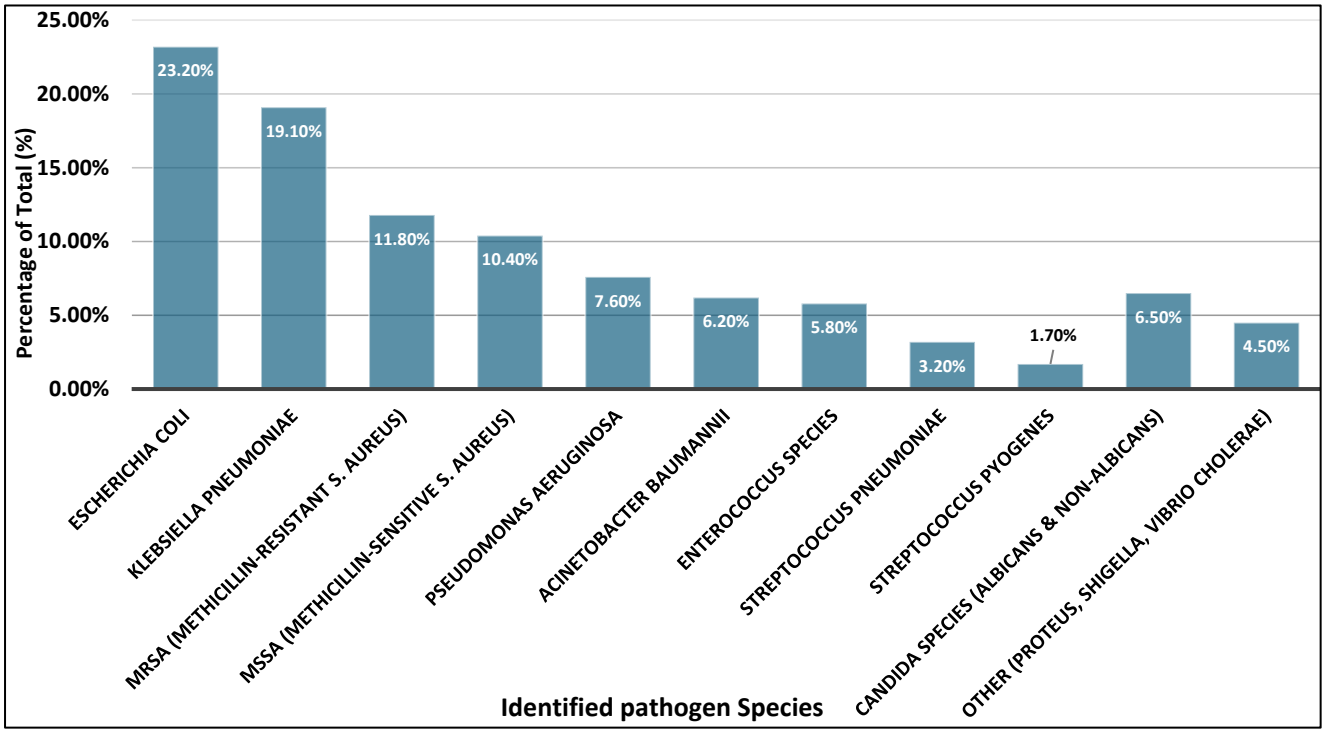


Figure 1: Distribution of pathogens isolated from routine clinical specimens (n=1000).

MRSA=methicillin-resistant S. aureus; MSSA=methicillin-sensitive S. aureus. Candida species include C. albicans and non-albicans Candida. †Other=Proteus mirabilis, Shigella species and Vibrio cholerae.

Gram-negative bacilli

Susceptibility results are summarised in Table 3. Among *E. coli* (n=232), resistance was highest to ampicillin (83.8%), ceftazidime (69.0%), ciprofloxacin (51.4%) and ceftriaxone (48.6%), a pattern suggestive of ESBL production, whereas fosfomycin (86.4%), nitrofurantoin (83.3%), tobramycin (81.2%), amikacin (78.1%) and piperacillin-tazobactam (71.8%) remained largely active. Third-generation cephalosporin resistance did not differ significantly between outpatient and inpatient isolates ($p>0.05$). *K. pneumoniae* (n=191) was significantly associated with sputum and deep pus specimens ($p<0.01$) and was more resistant than *E. coli*: all isolates were ampicillin-resistant, resistance exceeded 85% for amoxicillin-clavulanate and cefazolin, and it reached 75.7% for ceftazidime and 67.8% for ceftriaxone. Amikacin (77.8%) and tobramycin (78.7%) remained the most active agents, although a subset of isolates was simultaneously resistant to piperacillin-tazobactam, amikacin and fluoroquinolones, suggesting carbapenem-resistant Enterobacterales.

P. aeruginosa (n=76) and *A. baumannii* (n=62) were strongly associated with invasive specimens from critical care wards ($p<0.001$), and ICU specimens were more likely than outpatient specimens to yield multidrug-resistant non-fermenters ($p<0.01$). Half of the *P. aeruginosa* isolates were resistant to ceftazidime and 60% to cefepime, and only 60% were susceptible to piperacillin-tazobactam, while amikacin (88.6%), netilmicin (86.7%) and ciprofloxacin (77.8%) retained activity. In *A. baumannii*, resistance exceeded 70% for piperacillin-tazobactam and 85% for carbapenems, so most isolates were carbapenem-resistant; colistin (about 95%) and minocycline (71.1%) were the only agents with substantial activity.

Gram-positive cocci

MRSA constituted 118 of 222 *S. aureus* isolates (53.2%) (Table 4). MRSA isolates were uniformly penicillin-resistant and also highly resistant to erythromycin (94.7%), ciprofloxacin (88.9%) and clindamycin (85.9%), while all were susceptible to vancomycin and linezolid and 95.8% to doxycycline. MSSA (n=104) was far more susceptible, with gentamicin, co-trimoxazole and ciprofloxacin susceptibility of 94.4%, 90.5% and 87.5%, although 88.2% were penicillin-resistant. Among enterococci (n=58), ampicillin susceptibility was 82.0%, high-level gentamicin resistance was 28.9%, and all isolates were susceptible to vancomycin and linezolid.

Table 1: Sex, age and patient setting of the study population (n=1000).

Characteristics	N	%
Sex		
Female	648	64.8
Male	341	34.1
Not recorded	11	1.1
Age group (years)		
0–10	65	6.5
11–20	80	8.0
21–30	345	34.5
31–40	142	14.2
41–50	128	12.8
51–60	115	11.5
61–75+	125	12.5
Patient setting		
Outpatient department	261	26.1
Inpatient department	739	73.9
Post-operative ward (obstetrics and gynaecology, surgery)	153	15.3
Medicine general wards	158	15.8
Postnatal care	124	12.4
Labour room	108	10.8
Antenatal care	72	7.2
Intensive care units (SICU, MICU, SNCU)	65	6.5
Paediatric ward	59	5.9

Percentages are of the total sample (n=1,000). Age: mean±SD 35±17.85 years; range 5 days to 95 years. SICU = surgical intensive care unit; MICU = medical intensive care unit; SNCU = special newborn care unit.

Table 2: Specimen types and their association with sex and age group.

Specimen type	N (%)	Predominant sex (%)	Predominant age group, years (N, %)	P value
High vaginal swab	345 (34.5)	Female (100)	21–40 (280, 81.2)	<0.001
Urine	262 (26.2)	Female (70.2)	21–40 (185, 70.6)	<0.001
Sputum	185 (18.5)	Male (62.1)	51–75+ (120, 64.8)	<0.05
Pus / wound swab	148 (14.8)	Male (59.5)	51–75+ (95, 64.1)	<0.05
Blood	35 (3.5)	–	–	–
Stool / rectal swab	15 (1.5)	–	–	–
Body fluids (pleural, ascitic, CSF)	10 (1.0)	–	–	–

P values by chi-square test (SPSS version 20). – =association not analysed. CSF = cerebrospinal fluid.

Table 3: Antimicrobial susceptibility of gram-negative bacilli (% susceptible / % resistant).

Antimicrobial	*E. coli* (n=232)	*K. pneumoniae* (n=191)	*P. aeruginosa* (n=76)	*A. baumannii* (n=62)
Ampicillin	16.2 / 83.8	0 / 100	–	–
Amoxicillin-clavulanate	40.0 / 57.7	9.7 / 89.2	–	–
Piperacillin-tazobactam	71.8 / 25.5	70.2 / 27.7	60.0 / 33.3	30.0 / >70
Cefazolin	–	14.3 / 85.7	–	–
Ceftriaxone	46.7 / 48.6	30.0 / 67.8	–	–
Ceftazidime	29.0 / 69.0	22.1 / 75.7	45.7 / 50.0	–
Cefepime	–	–	32.7 / 60.0	–
Carbapenems (meropenem, imipenem)	–	–	–	15.0 / >85
Amikacin	78.1 / 19.7	77.8 / 20.0	88.6 / 8.6	–
Tobramycin	81.2 / 17.6	78.7 / 20.0	76.9 / 18.5	–
Netilmicin	–	–	86.7 / 11.7	–

Continued.

Antimicrobial	*E. coli* (n=232)	*K. pneumoniae* (n=191)	*P. aeruginosa* (n=76)	*A. baumannii* (n=62)
Ciprofloxacin	43.8 / 51.4	–	77.8 / 16.7	–
Levofloxacin	–	55.8 / 41.2	–	–
Co-trimoxazole	–	45.9 / 52.9	–	–
Nitrofurantoin	83.3 / 14.0	–	–	–
Fosfomycin	86.4 / 11.8	–	–	–
Colistin	–	–	–	95.0 / ~5
Minocycline	–	–	–	71.1 / –

The remainder of each isolate set was intermediate. – = not tested or not reported. For A. baumannii, resistance to piperacillin-tazobactam, carbapenems and colistin is approximate.

Table 4: Antimicrobial susceptibility of gram-positive cocci (% susceptible / % resistant).

Antimicrobial	MRSA (n=118)	MSSA (n=104)	*Enterococcus* spp. (n=58)
Penicillin	0 / 100	11.8 / 88.2	67.3 / 26.9
Ampicillin	–	–	82.0 / 16.0
Erythromycin	4.2 / 94.7	53.3 / 43.3	–
Clindamycin	11.8 / 85.9	70.6 / 27.1	–
Ciprofloxacin	8.9 / 88.9	87.5 / 7.5	31.3 / 64.6
Gentamicin (high-level for enterococci)	–	94.4 / 3.3	66.7 / 28.9
Co-trimoxazole	54.5 / 43.6	90.5 / 8.4	–
Tetracycline	87.6 / 8.6	–	–
Doxycycline	95.8 / 3.2	–	–
Vancomycin	100 / 0	100 / 0	100 / 0
Linezolid	100 / 0	100 / 0	100 / 0

The remainder of each isolate set was intermediate. – = not tested or not reported. MRSA was confirmed with a cefoxitin (30 µg) disc.

Other pathogens

Vibrio cholerae and *Shigella* species were susceptible to doxycycline (90%) and aminoglycosides (88%) but largely resistant to ampicillin (70%) and norfloxacin (60%). *Streptococcus pyogenes* was uniformly susceptible to penicillin, whereas macrolide resistance was marked in both streptococcal species. Sixty-five *Candida* isolates (6.5%) were recovered, almost exclusively in polymicrobial sputum and pus cultures.

DISCUSSION

Women made up nearly two-thirds of the patients, and young adults aged 21–40 years formed the largest age band. This mirrors the hospital's case mix: obstetric, gynaecological and post-operative wards supplied almost half of the specimens, and pregnancy, delivery and the short female urethra all predispose to genital and urinary tract infection. It also explains why high vaginal swabs and urine dominated the specimen profile (Table 2). The excess of sputum and pus specimens from older men is compatible with the burden of chronic lung disease and diabetic foot infection in this group.[10] Infection was seen at both extremes of age, from a five-day-old neonate to a 95-year-old, groups made vulnerable to resistant organisms by immature or waning immunity and comorbid illness.

Three-quarters of the specimens came from inpatients, in whom invasive procedures, indwelling devices and repeated antibiotic exposure favour selection of resistant strains. The strong link between *Pseudomonas* and *Acinetobacter* and critical care specimens fits their ability to persist on ventilator circuits, catheters and central lines. Stewardship and surgical-site infection prevention should therefore be concentrated in obstetric, surgical and intensive care areas.

E. coli and *K. pneumoniae* together accounted for 42.3% of isolates, and *E. coli* led the list, as it did in a North Indian tertiary hospital where it formed 25.1% of isolates (Table 5).[11] The high resistance of *E. coli* to third-generation cephalosporins, combined with ciprofloxacin and ampicillin resistance, is typical of CTX-M-type ESBL producers, whose plasmids frequently carry genes for several drug classes. Loss of ciprofloxacin as a dependable oral option for urinary infection is clinically important, whereas nitrofurantoin and fosfomycin remained active against more than 83% of isolates and are sensible first choices for uncomplicated cystitis. The similar proportion of cephalosporin-resistant *E. coli* in outpatient and inpatient isolates suggests that these strains already circulate in the community.

K. pneumoniae was more resistant than *E. coli* (ceftazidime resistance 75.7% versus 69.0%), in line with an eastern Indian teaching hospital where ESBL production exceeded

70%.[12] The subset resistant to piperacillin-tazobactam, amikacin and fluoroquinolones probably include carbapenemase producers, since NDM-1 and OXA-48 are widespread in India, but without molecular testing this remains presumptive. Amikacin and tobramycin kept useful activity against both Enterobacterales and *P. aeruginosa*, so aminoglycosides can form the backbone of combination regimens for serious infection, provided renal function and drug levels are monitored.

MRSA formed 53.2% of *S. aureus* isolates, comparable to the roughly 48% reported from a tertiary hospital in Puducherry and well above the levels in northern and western Europe.[13] The near-complete loss of macrolide, fluoroquinolone and clindamycin activity leaves vancomycin, linezolid and, for community-onset skin and soft-tissue infection, doxycycline (95.8%) as dependable options. MSSA kept broad susceptibility, so both oral and intravenous alternatives exist. Because vancomycin-intermediate and linezolid-resistant staphylococci are emerging worldwide, these two drugs should be restricted to confirmed MRSA infection, and clindamycin should be prescribed only after a D-test excludes inducible resistance. In enterococci, ampicillin remained effective (82.0%), but high-level gentamicin resistance in 28.9% would defeat the synergy needed for severe infections such as endocarditis.

P. aeruginosa could no longer be trusted to respond to ceftazidime or cefepime, and amikacin, netilmicin and ciprofloxacin were the better empirical partners. A. baumannii posed the greatest therapeutic challenge: carbapenem resistance above 85% matches the figure of over 80% from an Indian intensive care unit (Table 5) and leaves colistin as the main option.[14] The roughly 5% colistin resistance seen here is an early warning that this last-resort drug is at risk, and minocycline (71.1% susceptible) is a safer alternative.

Doxycycline and aminoglycosides remained effective against *Vibrio cholerae* and *Shigella*, whereas the high resistance to ampicillin and norfloxacin probably reflects long-standing community use and argues for revising empirical protocols for diarrhoeal disease. Macrolide resistance among streptococci questions the routine empirical use of azithromycin for undifferentiated respiratory infection in the outpatient department. The isolation of *Candida* from deep and respiratory specimens, almost always alongside bacteria, points to selection pressure from prolonged broad-spectrum therapy and supports antifungal stewardship alongside antibacterial stewardship. Overall, the resistance pattern in this hospital resembles that of other Indian tertiary centres and is distinctly worse than in northern and western Europe, where stricter infection control, regulated dispensing and national action plans have kept MRSA and carbapenem resistance low.[15] Developing-country settings are also described as particularly exposed to antibiotic misuse and weak regulation (Table 5).[16]

Table 5: Comparison of the present findings with other studies.

Ref.	Study and setting	Reported finding	Comparison with present study
11	Taneja et al, North India (tertiary care hospital)	*E. coli* commonest isolate (25.1%); high ESBL rates in urinary isolates	Similar: *E. coli* commonest (23.2%) with high third-generation cephalosporin resistance
12	Dash et al, Odisha (teaching hospital)	*K. pneumoniae* second commonest; ESBL >70%	Similar: *Klebsiella* prominent (19.1%); ceftazidime resistance 75.7%
13	Devi et al, Puducherry (tertiary care hospital)	MRSA about 48% of *S. aureus*; vancomycin 100% susceptible	Similar: MRSA 53.2%; vancomycin 100% susceptible
14	Prakash et al, Karnataka (intensive care unit)	*A. baumannii* carbapenem resistance >80%; colistin preserved	Similar: carbapenem resistance > 85%; colistin about 95% susceptible
15	ECDC EARS-Net 2022, northern and western Europe	MRSA <5% in many Nordic countries; carbapenem resistance in *E. coli* and *Klebsiella* <2%; ampicillin resistance about 60%	Contrast: far higher resistance here, reflecting weaker stewardship, over-the-counter antibiotic use and infection control
16	Ayukekbong et al, Cameroon (West Africa)	Blood cultures >45% of specimens; fosfomycin not routinely tested; colistin resistance in *Pseudomonas* > 10%	Contrast: specimen mix here is dominated by high vaginal swabs (34.5%); colistin resistance is only about 5%

Limitations

This single-centre study in one tertiary teaching hospital cannot be generalised to other regions or to smaller facilities. Numbers were small for neonatal, cerebrospinal fluid and stool specimens, which limits conclusions for these groups. Only disk diffusion was used, and resistance genes such as *bla*NDM-1, *mec*A and *van*A were not sought, so the underlying mechanisms remain unknown. Prior antibiotic exposure and duration of admission were not fully recorded, which prevented a clear separation of community-acquired from hospital-acquired infection, and patient outcomes (treatment response, hospital stay and mortality) were not followed, so the clinical effect of the observed resistance could not be assessed.

CONCLUSION

Among 1,000 routine clinical specimens from a tertiary care teaching hospital in central India, *E. coli* (23.2%) and *K. pneumoniae* (19.1%) were the leading gram-negative pathogens, and their high resistance to third-generation cephalosporins (ceftazidime resistance 69.0% and 75.7%, respectively) shows that these drugs can no longer be relied on empirically; the absence of a significant difference between outpatient and inpatient *E. coli* isolates indicates that this resistance has spread into the community. MRSA made up more than half of *S. aureus* isolates but stayed fully susceptible to vancomycin and linezolid, *A. baumannii* was carbapenem-resistant in more than 85% of isolates, leaving colistin and minocycline as the main options, and aminoglycosides, nitrofurantoin and fosfomycin retained dependable activity against Gram-negative and urinary pathogens. By providing a locally derived antibiogram from a region where such data are scarce, this study advances understanding of how resistance is distributed across community, ward and intensive care settings and supplies the evidence needed to replace generic empirical regimens with antibiotic policy informed by local data.

Recommendations

Empirical antibiotic therapy and the hospital antibiotic policy should be revised in line with local susceptibility data and updated regularly, with a stewardship programme strictly implemented. Nitrofurantoin or fosfomycin should be preferred for uncomplicated urinary tract infection, and third-generation cephalosporins and fluoroquinolones should not be used empirically for serious Gram-negative infection. Amikacin and tobramycin can serve as backbone agents in combination regimens for ESBL-associated and presumptive carbapenem-resistant infections, with therapeutic drug monitoring and dose adjustment, and the hospital antibiotic policy committee should draw up structured guidelines for their use.

Vancomycin and linezolid should be kept in reserve for confirmed MRSA infection, supported by MRSA screening in surgical wards and intensive care units and prompt de-escalation once culture results are available; doxycycline is a low-cost oral option for outpatient MRSA. The laboratory should report D-test results for all erythromycin-resistant *S. aureus*, and clindamycin should not be prescribed without D-test clearance. Azithromycin should no longer be the first-choice empirical drug for undifferentiated respiratory infection in the outpatient department; amoxicillin is preferable for low-risk community-acquired pneumonia, with macrolides reserved for confirmed atypical pathogens.

For carbapenem-resistant *A. baumannii*, a colistin stewardship protocol should be established, using validated weight-based dosing and combination therapy (with a carbapenem, rifampicin or sulbactam) rather than monotherapy, and minocycline should be added to the treatment algorithm as a safer oral option. Finally, the policy on fluconazole prophylaxis for high-risk patients should be revisited, and antifungal therapy (fluconazole for patients who are not critically ill, echinocandins in the intensive care unit) should be guided by clinical scoring such as the Candida score to avoid both under-treatment and unnecessary use.

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