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**Original Article**

# Fighting Resistance with Evidence: Antibiogram-Based Stewardship Insights from Mayo Hospital Lahore

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## Abstract

***Background*** Antimicrobial resistance threatens patient outcomes in resource-limited healthcare settings such as hospitals in Pakistan, where unregulated antibiotic access and inadequate surveillance contribute to the accelerated emergence of antibiotic resistance. Institutional antibiograms provide practical surveillance and guide empiric therapy, yet published data from Punjab's public-sector teaching hospitals remain sparse.

***Objective*** To determine antimicrobial susceptibility patterns of bacterial pathogens from diverse clinical specimens at a tertiary care hospital in Lahore and generate actionable stewardship data.

***Methods*** This descriptive cross-sectional study was conducted at the Microbiology Section, Department of Pathology, King Edward Medical University/Mayo Hospital, Lahore, from July to December 2025. A total of 4,000 non-duplicate, clinically significant bacterial isolates met the eligibility criteria and were included in the analysis. Non-duplicate isolates from pus, wound swabs, blood, urine, body fluids, respiratory samples, tissue, and catheter tips were identified by standard methods. Antimicrobial susceptibility testing was performed by the Kirby-Bauer disc diffusion method and interpreted according to the Clinical and Laboratory Standards Institute (CLSI) document M100, 35th edition (2025).

***Results*** Methicillin-sensitive and methicillin-resistant Staphylococcus aureus showed 100% susceptibility to vancomycin and linezolid but low susceptibility to erythromycin and clindamycin (10-53%). Enterococcus species exhibited ampicillin susceptibility of 66-76%. Escherichia coli displayed extensive cephalosporin (0-25%) and fluoroquinolone resistance (ciprofloxacin 0-52%) but retained colistin efficacy (100%). Klebsiella pneumoniae showed cephalosporin susceptibility below 33% and carbapenem susceptibility of 22-82%. Acinetobacter baumannii exhibited critical pan-resistance with carbapenem susceptibility of 0-45%; only colistin remained effective. Pseudomonas species retained better susceptibility to ceftazidime (14-75%) and piperacillin-tazobactam (21-73%).

***Conclusion*** The high resistance observed against cephalosporins, fluoroquinolones, and carbapenems highlights an urgent need for structured antimicrobial stewardship and routine antibiogram surveillance in public-sector hospitals across Pakistan.

***Keywords*** Antimicrobial resistance; Antibiogram; Antimicrobial stewardship; Antimicrobial susceptibility testing; Multidrug resistance.

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## Introduction

Antimicrobial resistance, defined as the ability of microorganisms to survive and multiply in the presence of antimicrobial agents that would normally inhibit or kill them, has emerged as one of the most pressing global health challenges of the twenty-first century. A landmark systematic analysis estimated that bacterial antimicrobial resistance was

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directly responsible for roughly 1.27 million deaths worldwide in 2019, with an additional 4.95 million deaths associated with drug-resistant infections. Low- and middle-income countries bear a disproportionate share of this burden, largely owing to inadequate diagnostic infrastructure, high rates of over-the-counter antibiotic sales, incomplete treatment courses, and the absence of structured stewardship programs.[1,2]

Pakistan ranks among the countries most severely affected by the antimicrobial resistance crisis. It is the third-largest consumer of antibiotics among low- and middle-income nations, and resistance rates across key pathogen groups have been climbing steadily over the past decade.[3] A recent systematic review covering Pakistani data from 2012 to 2022 reported that Escherichia coli exhibited high median resistance to first-line agents, methicillin-resistant Staphylococcus aureus (MRSA) accounted for nearly half of all reported S. aureus isolates, and Acinetobacter species displayed high-level resistance to virtually all available antimicrobials except colistin and tigecycline.[4] The situation is further complicated by the emergence of extensively drug-resistant typhoid and the detection of carbapenem-resistance genes such as blaNDM-1 and blaKPC-2 in Enterobacterales from multiple centers across the country.[4,5]

In this challenging landscape, the hospital antibiogram has become an indispensable surveillance and clinical decision-support tool. Defined as a periodic cumulative summary of antimicrobial susceptibility data for bacterial isolates recovered at a given institution, the antibiogram provides clinicians with locally relevant evidence to guide empiric therapy before culture results become available.[6] International guidelines, including those from the Clinical and Laboratory Standards Institute (CLSI) and the Infectious Diseases Society of America, recommend that healthcare facilities generate and disseminate antibiograms at least annually.[7] Beyond their clinical utility, antibiograms enable infection-control teams to detect emerging resistance phenotypes, track temporal trends, and benchmark institutional data against regional or national surveillance networks.[6,7]

The study setting is the largest public-sector teaching hospital in Pakistan, affiliated with one of the oldest medical institutions in South Asia. The hospital provides free or subsidized care to a vast and diverse patient population, including referrals from across Punjab and neighboring provinces.[8] Given its size, patient volume, and the complexity of cases managed in its intensive-care and surgical units, robust antimicrobial resistance surveillance at this facility is of considerable public-health significance. To the best of our knowledge, no comprehensive institution-wide cumulative antibiogram has previously been published from this hospital; earlier reports have been limited to single specimen types or individual clinical units rather than a hospital-wide, specimen-stratified summary. This absence of consolidated antibiogram data creates a gap in the evidence base available to its clinicians and to policymakers formulating regional stewardship strategies.[9]

A recent multi-centre surveillance study from Pakistan covering data collected between February and August 2024 underscored the heterogeneity of resistance patterns across different hospitals and regions, reinforcing the argument that each institution must generate its own antibiogram rather than relying on aggregated national data.[10] Similarly, a 2024 study from another tertiary hospital in Lahore documented E. coli as the predominant isolate with widespread resistance to fluoroquinolones, beta-lactams, and cephalosporins, while carbapenem resistance was also emerging.[11] These findings highlight that the resistance problem extends beyond intensive-care settings to community-acquired infections as well.

The present study was therefore designed to construct a comprehensive, specimen-stratified cumulative antibiogram for bacterial pathogens isolated at this teaching hospital over a six-month

period (July-December 2025). By documenting the prevailing susceptibility patterns of both Gram-positive and Gram-negative organisms across multiple specimen types, this study aims to provide an evidence-based framework for empiric therapy selection, to strengthen ongoing antimicrobial stewardship efforts, and to contribute to the broader resistance surveillance network in Pakistan.

## Methods

This descriptive cross-sectional study was conducted over a six-month period (July to December 2025) at the Microbiology Section of the Central Diagnostic Laboratory, Department of Pathology, King Edward Medical University/Mayo Hospital, Lahore, a 2500-bed tertiary care teaching facility that processes a high volume of clinical specimens daily from both inpatient and outpatient departments. The study was conducted after obtaining departmental permission from the Department of Pathology; as the work involved only routine, anonymised laboratory data with no patient contact or identifiable information, formal review board approval and individual informed consent were not required.

Consecutive non-probability sampling was used. All non-duplicate, clinically significant bacterial isolates recovered from patients with clinically suspected bacterial infection whose specimens were submitted to the laboratory during the study period were included, irrespective of age or sex. Eligible specimens comprised pus, wound swabs, blood, urine, body fluids (ascitic, pleural, and cerebrospinal fluid), respiratory specimens (sputum, bronchoalveolar lavage, and tracheal secretions), tissue biopsy material, and central venous catheter tips. Duplicate isolates (the same organism from the same patient and same specimen type within the study period), contaminated specimens, non-bacterial isolates, and specimens with incomplete antimicrobial susceptibility data were excluded to limit selection bias and ensure reproducibility. During the six-month study period, a total of 4,000 non-duplicate, clinically significant bacterial isolates were processed and met the eligibility criteria, and all were included in the final analysis. As a cumulative antibiogram derived from all eligible isolates over a fixed period, a formal a priori sample size calculation was not applicable; consistent with CLSI M39 recommendations, which require a minimum of 30 isolates per organism-antibiotic combination for reliable cumulative susceptibility estimates, all qualifying isolates accrued during the study window were analysed, and every reported organism group met or exceeded this threshold.

Specimens were processed by standard microbiological methods, with inoculation onto appropriate primary media and identification based on colony morphology, Gram staining, and conventional biochemical tests. Antimicrobial susceptibility testing was performed by the Kirby-Bauer disc diffusion method on Mueller-Hinton agar using a 0.5 McFarland inoculum and commercially available discs (Oxoid, UK), and results were interpreted as susceptible, intermediate, or resistant according to the Clinical and Laboratory Standards Institute (CLSI) document M100, 35th edition (2025). Quality control was maintained using reference strains Staphylococcus aureus ATCC 25923, Escherichia coli ATCC 25922, and Pseudomonas aeruginosa ATCC 27853. Organism-specific antibiotic panels were applied, and intrinsic resistances were excluded from reporting in accordance with CLSI guidelines.

Susceptibility was expressed as the percentage of tested isolates classified as susceptible for each organism-antibiotic-specimen combination. Data were compiled and summarised using descriptive statistics (frequencies and percentages) in Microsoft Excel and presented in cumulative antibiogram format stratified by specimen type. Because the study was descriptive and aimed at generating empirical susceptibility estimates rather than testing comparative hypotheses, no inferential statistical tests were applied. In accordance with CLSI M39 guidance on cumulative antibiogram reporting, susceptibility data are presented separately by

organism group and specimen source rather than consolidated into a single grid. This deliberate structure is necessary because each organism group is tested against a largely distinct antibiotic panel (for example, vancomycin and linezolid for staphylococci versus colistin and carbapenems for non-fermenters), so that combining them would introduce numerous non-tested cells and produce misleading pooled susceptibility figures. Specimen-level stratification is retained because resistance differs substantially by source (for example, a bronchoalveolar lavage isolate versus a urinary isolate), and this granularity is the principal clinical value of the antibiogram, allowing prescribers to select empiric therapy on the basis of the suspected site of infection. The resulting number of tables is therefore a direct and intentional consequence of following the recommended reporting standard, and consolidation would compromise both interpretability and clinical utility.

## Results

The antibiogram of Mayo Hospital Lahore data is presented below for each organism group. Results are expressed as percentage susceptibility for each antibiotic-specimen combination. Intrinsic resistances, as defined by CLSI, are excluded from the tables and noted separately.

### *Gram-Positive Organisms*

***Staphylococcus aureus (MSSA):*** Methicillin-sensitive S. aureus isolates (cefoxitin-susceptible) showed universal susceptibility (100%) to vancomycin, linezolid, and cefoxitin across all specimen types. Erythromycin susceptibility was notably poor, ranging from 10% in fluid specimens to 21% in pus and blood cultures. Clindamycin susceptibility was similarly variable (10-53%). Fusidic acid susceptibility ranged from 42-55%, while co-trimoxazole susceptibility was particularly low in blood (19%) and fluid (21%) specimens **(Table 1)**.

***Methicillin-Resistant Staphylococcus aureus (MRSA):*** As expected, MRSA isolates were uniformly resistant to cefoxitin (0% susceptibility) and, by extension, to all beta-lactam agents. Vancomycin and linezolid retained 100% efficacy across all specimen types. Erythromycin susceptibility ranged from 13-33%, and clindamycin from 23-34%. Fusidic acid showed variable effectiveness, with susceptibility as low as 8% in blood isolates and as high as 56% in tissue specimens. Co-trimoxazole susceptibility ranged from 18-29% **(Table 1)**.

***Streptococcus pneumoniae and Streptococcus pyogenes:*** S. pneumoniae isolated from throat swab specimens showed 76% susceptibility to ceftriaxone, 100% to ampicillin, and universal susceptibility to linezolid and vancomycin. Erythromycin susceptibility stood at 45-52%, and co-trimoxazole at 36-69%. S. pyogenes from wound swabs demonstrated 88% ceftriaxone susceptibility, 100% ampicillin and linezolid susceptibility, and 100% vancomycin susceptibility **(Table 2)**.

**Table 1** Antimicrobial susceptibility (%) of Staphylococcus aureus (MSSA and MRSA) by specimen type.

| *Organism* | *Specimen* | *E* | *CD* | *VA* | *LZD* | *FD* | *COT* | *FOX* |
|---|---|---|---|---|---|---|---|---|
| MSSA | Pus | 21 | 36 | 100 | 100 | 52 | 52 | 100 |
| | Wound swab | 12 | 46 | 100 | 100 | 42 | 45 | 100 |
| | Blood | 21 | 53 | 100 | 100 | 46 | 19 | 100 |
| | Fluid | 10 | 10 | 100 | 100 | 55 | 21 | 100 |
| MRSA | Pus | 33 | 27 | 100 | 100 | 46 | 25 | 0 |
| | Wound swab | 13 | 34 | 100 | 100 | 25 | 27 | 0 |
| | Tissue | 27 | 25 | 100 | 100 | 56 | 29 | 0 |
| | Blood | 16 | 23 | 100 | 100 | 8 | 18 | 0 |

E: Erythromycin; CD: Clindamycin; VA: Vancomycin; LZD: Linezolid; FD: Fusidic acid; COT: Co-trimoxazole; FOX: Cefoxitin.

**Table 2** Antimicrobial susceptibility (%) of Streptococcus species by specimen type.

| *Organism* | *Specimen* | *CTR* | *AMP* | *LZD* | *VA* | *E* | *COT* | *DO/TE* | *CTX* |
|---|---|---|---|---|---|---|---|---|---|
| S. pneumoniae | Throat swab | 76 | 100 | 100 | 100 | 45 | 69 | 42 | 72 |
| | Sputum | 85 | 78 | 100 | 100 | 52 | 36 | 54 | 78 |
| S. pyogenes | Wound swab | 88 | 100 | 100 | 46 | 63 | 100 | 75 | 82 |
| | Pus | 100 | 78 | 100 | 55 | 68 | 100 | 34 | 82 |

CTR: Ceftriaxone; AMP: Ampicillin; LZD: Linezolid; VA: Vancomycin; E: Erythromycin; COT: Co-trimoxazole; DO/TE: Doxycycline/Tetracycline; CTX: Cefotaxime.

**Table 3** Antimicrobial susceptibility (%) of Enterococcus species by specimen type.

| *Specimen* | *IPM* | *AMP* | *AK* | *F* | *MRP* | *VA* | *FOS* | *LZD* | *TE* | *CIP* | *CN-120* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Urine | 66 | 76 | 34 | 22 | 55 | 76 | 16 | 73 | 8 | 30 | – |
| Wound swab | 88 | 67 | 11 | – | 59 | 100 | – | 100 | 10 | 25 | – |
| Blood | 0 | 66 | 23 | – | – | 100 | – | 100 | 15 | 30 | 45 |

IPM: Imipenem; AMP: Ampicillin; AK: Amikacin; F: Nitrofurantoin; MRP: Meropenem; VA: Vancomycin; FOS: Fosfomycin; LZD: Linezolid; TE: Tetracycline; CIP: Ciprofloxacin; CN-120: High-level gentamicin. – = not tested.

**Table 4** Antimicrobial susceptibility (%) of Salmonella species (blood isolates).

| CTR | COT | IPM | AZM | CIP | MRP | AMP | CFM | TE |
|---|---|---|---|---|---|---|---|---|
| 56 | 52 | 100 | 100 | 77 | 100 | 58 | 39 | 25 |

CTR: Ceftriaxone; COT: Co-trimoxazole; IPM: Imipenem; AZM: Azithromycin;
CIP: Ciprofloxacin; MRP: Meropenem; AMP: Ampicillin; CFM: Cefixime; TE: Tetracycline.

***Enterococcus species:*** Enterococcal isolates from urine specimens showed 76% susceptibility to ampicillin, 66% to imipenem, 76% to vancomycin, 73% to linezolid, and 30% to ciprofloxacin. Wound swab isolates demonstrated 88% imipenem susceptibility, 67% ampicillin, 100% vancomycin, and 100% linezolid susceptibility. Blood isolates showed 0% imipenem susceptibility, 66% ampicillin, and 100% susceptibility to both vancomycin and linezolid **(Table 3)**.

### *Gram-Negative Organisms*

***Salmonella species:*** Blood culture isolates of Salmonella demonstrated favorable susceptibility to carbapenems (imipenem and meropenem both 100%), azithromycin (100%), ampicillin (58%), and ceftriaxone (56%). Co-trimoxazole susceptibility stood at 52%, ciprofloxacin at 77%, and tetracycline susceptibility was only 25% **(Table 4)**.

***Escherichia coli:*** E. coli demonstrated extensive resistance to third-generation cephalosporins across all specimen types, with cefotaxime and ceftriaxone susceptibility as low as 0% in urinary isolates and no higher than 25% in pus. Fluoroquinolone susceptibility was poor: ciprofloxacin ranged from 0% (sputum) to 52% (urine). Amikacin remained the most effective aminoglycoside (8-45%). Carbapenem susceptibility was moderate and specimen-dependent imipenem ranged from 26% (BAL) to 78% (pus), and meropenem from 25% (BAL) to 79% (sputum). Colistin was the only agent with universal 100% susceptibility. For urinary isolates, fosfomycin showed 82% susceptibility and nitrofurantoin 52% **(Table 5)**.

***Citrobacter species:*** Citrobacter isolates displayed extensive cephalosporin resistance, with cefotaxime and ceftriaxone susceptibility between 9-17%. Ciprofloxacin susceptibility ranged from 35% (pus) to 62% (BAL). Carbapenem susceptibility was moderate to good. imipenem 56-88% and meropenem 69-82% and amikacin ranged from 44-92%. Colistin was universally effective at 100% **(Table 6)**.

***Klebsiella pneumoniae:*** K. pneumoniae isolates showed extensive multidrug resistance. Third-generation cephalosporin susceptibility was critically

**Table 5** Antimicrobial susceptibility (%) of Escherichia coli by specimen type.

| *Specimen* | *CTX* | *CTR* | *AMC* | *SCF* | *CIP* | *LEV* | *AK* | *IPM* | *MRP* | *TE* | *PTZ* | *CN* | *COT* | *NOR* | *NA* | *FOS* | *F* | *CT* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pus | 25 | 25 | 18 | 44 | 12 | 54 | 25 | 78 | 62 | 7 | 34 | 10 | 17 | – | – | – | – | 100 |
| W. swab | 18 | 22 | 16 | 6 | 32 | 33 | 38 | 56 | 48 | 18 | 22 | 21 | 34 | – | – | – | – | 100 |
| Blood | 21 | 21 | 14 | 33 | 11 | 21 | 23 | 66 | 57 | 11 | 46 | 23 | 29 | – | – | – | – | 100 |
| Ascitic fl. | 14 | 21 | 8 | 32 | 40 | 23 | 45 | 79 | 59 | 10 | 44 | 54 | 8 | – | – | – | – | 100 |
| Sputum | 15 | 15 | 8 | 35 | 0 | 45 | 21 | 56 | 79 | 11 | 14 | 23 | 11 | – | – | – | – | 100 |
| BAL | 11 | 11 | 8 | 66 | 21 | 21 | 8 | 26 | 25 | 0 | 33 | 44 | – | – | – | – | – | 100 |
| Urine | 0 | 0 | 0 | 45 | 52 | – | 33 | 52 | 77 | 12 | 33 | 42 | 13 | 21 | 33 | 82 | 52 | 100 |

CTX: Cefotaxime; CTR: Ceftriaxone; AMC: Amoxicillin-clavulanate; SCF: Cefoperazone-sulbactam; CIP: Ciprofloxacin; LEV: Levofloxacin; AK: Amikacin; IPM: Imipenem; MRP: Meropenem; TE: Tetracycline; PTZ: Piperacillin-tazobactam; CN: Gentamicin; COT: Co-trimoxazole; NOR: Norfloxacin; NA: Nalidixic acid; FOS: Fosfomycin; F: Nitrofurantoin; CT: Colistin. = not tested.

**Table 6** Antimicrobial susceptibility (%) of Citrobacter species by specimen type.

| *Specimen* | *CTX* | *CTR* | *AMC* | *CPM* | *CIP* | *AK* | *IPM* | *MRP* | *DO* | *CT* |
|---|---|---|---|---|---|---|---|---|---|---|
| Pus swab | 10 | 9 | 15 | 21 | 48 | 67 | 88 | 71 | 44 | 100 |
| Pus | 11 | 11 | 0 | 23 | 35 | 44 | 56 | 73 | 33 | 100 |
| BAL | 17 | 17 | 17 | 0 | 62 | 44 | 62 | 74 | 21 | 100 |
| Blood | 11 | 11 | 7 | 33 | 50 | 92 | 72 | 82 | 32 | 100 |
| CVP tip | 9 | 8 | 12 | 21 | 52 | 92 | 87 | 69 | 65 | 100 |

CTX: Cefotaxime; CTR: Ceftriaxone; AMC: Amoxicillin-clavulanate; CPM: Cefepime; CIP: Ciprofloxacin; AK: Amikacin; IPM: Imipenem; MRP: Meropenem; DO: Doxycycline; CT: Colistin.

**Table 7** Antimicrobial susceptibility (%) of Klebsiella pneumoniae by specimen type.

| *Specimen* | *CTX* | *CTR* | *AMC* | *CPM* | *SCF* | *CIP* | *TE* | *AK* | *CN* | *IPM* | *MRP* | *PTZ* | *COT* | *NOR* | *NA* | *F* | *CT* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pus | 21 | 21 | 0 | 11 | 33 | 44 | 32 | 52 | 26 | 52 | 63 | 33 | 42 | – | – | – | 100 |
| Pus swab | 23 | 32 | 18 | 42 | 72 | 42 | 27 | 66 | 56 | 44 | 54 | 27 | 18 | – | – | – | 100 |
| Tr. secr. | 0 | 0 | 0 | 21 | 35 | 12 | 28 | 21 | 17 | 25 | 32 | 25 | 32 | – | – | – | 100 |
| Fluid | 25 | 10 | 10 | 21 | 33 | 44 | 17 | 23 | 32 | 42 | 25 | 22 | 27 | – | – | – | 100 |
| BAL | 33 | 22 | 11 | 16 | 18 | 25 | 33 | 34 | 26 | 64 | 78 | 33 | 23 | – | – | – | 100 |
| Blood | 11 | 11 | 68 | 78 | 21 | 11 | 22 | 22 | 12 | 52 | 72 | 21 | 27 | – | – | – | 100 |
| Tissue | 17 | 17 | 0 | 33 | 27 | 44 | 11 | 35 | 44 | 36 | 55 | 35 | 44 | – | – | – | 100 |
| Sputum | 11 | 11 | 11 | 21 | 33 | 15 | 9 | 52 | 33 | 22 | 21 | 21 | 22 | – | – | – | 100 |
| Urine | 0 | 0 | 0 | 0 | 33 | 21 | 14 | 50 | 67 | 82 | 56 | 14 | 38 | 31 | 35 | 38 | 100 |

CTX: Cefotaxime; CTR: Ceftriaxone; AMC: Amoxicillin-clavulanate; CPM: Cefepime; SCF: Cefoperazone-sulbactam; CIP: Ciprofloxacin; TE: Tetracycline; AK: Amikacin; CN: Gentamicin; IPM: Imipenem; MRP: Meropenem; PTZ: Piperacillin-tazobactam; COT: Co-trimoxazole; NOR: Norfloxacin; NA: Nalidixic acid; F: Nitrofurantoin; CT: Colistin.

low (0-33%), with urinary and sputum isolates at 0%. Carbapenem susceptibility was variable imipenem 22-82% and meropenem 21-78%. Amikacin was the most active aminoglycoside (21-66%). Piperacillin-tazobactam susceptibility was generally poor (14-35%). Colistin retained 100% susceptibility universally **(Table 7)**.

***Proteus species:*** Proteus isolates showed moderate to low susceptibility across most agents. Cefotaxime and ceftriaxone susceptibility ranged from 12-17%. Cefoperazone-sulbactam showed notably better performance in pus (91%) and tissue (85%). Meropenem susceptibility ranged from 35-65%, and imipenem from 27-56% **(Table 8)**.

***Acinetobacter baumannii:*** A. baumannii was the most extensively resistant organism in this study. Carbapenem susceptibility was critically low: imipenem ranged from 0% (BAL) to 45% (blood), and meropenem from 0% (BAL, tracheal secretions) to 33% (urine). Ceftazidime susceptibility ranged from 0-24%, cefepime from 0-45%, and piperacillin-tazobactam from 0-67%. Colistin was the sole

universally effective agent, retaining 100% susceptibility across all specimen types including CSF **(Table 9)**.

***Pseudomonas species:*** Pseudomonas species showed variable but comparatively better susceptibility profiles than A. baumannii. Ceftazidime susceptibility ranged from 14% (tissue, tracheal secretions) to 75% (CSF), and piperacillin-tazobactam from 21% (tip, tracheal secretions) to 73% (BAL). Carbapenem susceptibility was moderate: imipenem 14-50% and meropenem 7-63%. Colistin retained universal 100% effectiveness **(Table 10)**.

## Discussion

This study presents a comprehensive, specimen-stratified institutional antibiogram from one of the largest public-sector teaching hospitals in Pakistan, providing locally actionable data for empiric prescribing and antimicrobial stewardship. The findings reveal alarmingly high resistance levels that are consistent with and in several instances exceed trends reported from comparable facilities in the region.[4,10,12]

**Table 8** Antimicrobial susceptibility (%) of Proteus species by specimen type.

| *Specimen* | *CTX* | *CTR* | *AMC* | *SCF* | *CIP* | *AK* | *MRP* | *IPM* | *CPM* | *CN* | *PTZ* | *CAZ* | *COT* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W. swab | 17 | 17 | 7 | 33 | 43 | 47 | 35 | 28 | 33 | 31 | 16 | 10 | 18 |
| Pus | 12 | 12 | 8 | 91 | 33 | 22 | 40 | 27 | 33 | 21 | 32 | 33 | 34 |
| Tissue | 14 | 14 | 7 | 85 | 36 | 33 | 65 | 56 | 35 | 11 | 55 | 89 | 14 |

CTX: Cefotaxime; CTR: Ceftriaxone; AMC: Amoxicillin-clavulanate; SCF: Cefoperazone-sulbactam; CIP: Ciprofloxacin; AK: Amikacin; MRP: Meropenem; IPM: Imipenem; CPM: Cefepime; CN: Gentamicin; PTZ: Piperacillin-tazobactam; CAZ: Ceftazidime; COT: Co-trimoxazole.

**Table 9** Antimicrobial susceptibility (%) of Acinetobacter baumannii by specimen type.

| *Specimen* | *CN* | *MRP* | *IPM* | *CAZ* | *LEV* | *PTZ* | *CPM* | *A/S* | *DO* | *CT* |
|---|---|---|---|---|---|---|---|---|---|---|
| W. swab | 19 | 17 | 24 | 11 | 4 | 23 | 26 | 11 | 15 | 100 |
| Pus | 23 | 22 | 27 | 12 | 7 | 28 | 34 | 10 | 19 | 100 |
| BAL | 0 | 0 | 0 | 7 | 13 | 7 | 7 | 0 | 27 | 100 |
| Fluid | 21 | 14 | 14 | 10 | 10 | 14 | 13 | 3 | 28 | 100 |
| Blood | 25 | 22 | 45 | 24 | 17 | 34 | 45 | – | 42 | 100 |
| Tip | 39 | 6 | 17 | 0 | 0 | 6 | 6 | 17 | 39 | 100 |
| Tissue | 14 | 14 | 29 | 14 | 14 | 0 | 29 | 2 | 0 | 100 |
| Tr. secr. | 7 | 0 | 2 | 2 | 2 | 0 | 0 | 2 | 24 | 100 |
| Urine | 0 | 33 | 10 | 17 | 0 | 67 | 84 | 33 | 17 | 100 |
| Sputum | 11 | 11 | 11 | 17 | 22 | 33 | 33 | 0 | 22 | 100 |
| CSF | 33 | 0 | 17 | 0 | 0 | 17 | 17 | 0 | 17 | 100 |

CN: Gentamicin; MRP: Meropenem; IPM: Imipenem; CAZ: Ceftazidime; LEV: Levofloxacin; PTZ: Piperacillin-tazobactam; CPM: Cefepime; A/S: Ampicillin-sulbactam; DO: Doxycycline; CT: Colistin. – = not tested.

**Table 10** Antimicrobial susceptibility (%) of Pseudomonas species by specimen type.

| *Specimen* | *IPM* | *MRP* | *CAZ* | *CPM* | *ATM* | *PTZ* | *GEN* | *LEV* | *CIP* | *TOB* | *AK* | *CT* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W. swab | 18 | 26 | 36 | 29 | 33 | 34 | 4 | 15 | 9 | 21 | 13 | 100 |
| Pus | 24 | 36 | 43 | 40 | 35 | 46 | 3 | 18 | 14 | 33 | 16 | 100 |
| BAL | 36 | 14 | 68 | 66 | 50 | 73 | 5 | 32 | 20 | 63 | 14 | 100 |
| Fluid | 19 | 14 | 41 | 67 | 30 | 41 | 14 | 19 | 11 | 38 | 8 | 100 |
| Tip | 21 | 7 | 43 | 28 | 14 | 21 | 0 | 21 | 0 | 0 | 0 | 100 |
| Tr. secr. | 21 | 7 | 21 | 20 | 7 | 21 | 7 | 0 | 7 | 7 | 7 | 100 |
| Tissue | 14 | 29 | 14 | 28 | 29 | 43 | 14 | 0 | 0 | 14 | 14 | 100 |
| Urine | 36 | 32 | 23 | 41 | 32 | 41 | 0 | 5 | 14 | 23 | 0 | 100 |
| Sputum | 43 | 30 | 57 | 57 | 60 | 70 | 0 | 27 | 23 | 20 | 3 | 100 |
| CSF | 50 | 50 | 75 | 50 | 25 | 50 | 0 | 0 | 50 | 25 | 0 | 100 |
| Blood | 0 | 63 | 57 | 53 | 37 | 57 | 0 | 57 | 30 | 50 | 3 | 100 |

IPM: Imipenem; MRP: Meropenem; CAZ: Ceftazidime; CPM: Cefepime; ATM: Aztreonam; PTZ: Piperacillin-tazobactam; GEN: Gentamicin; LEV: Levofloxacin; CIP: Ciprofloxacin; TOB: Tobramycin; AK: Amikacin; CT: Colistin.

Among Gram-positive organisms, the sustained universal susceptibility of both MSSA and MRSA to vancomycin and linezolid is reassuring and consistent with national surveillance data reporting 98-99% vancomycin efficacy against S. aureus across Pakistan.[4] However, the poor erythromycin (10-53%) and clindamycin (10-53%) susceptibility observed here reflects the growing macrolide-lincosamide resistance documented regionally, underscoring that empiric macrolide use for staphylococcal infections should be discouraged.[4,12] The enterococcal data are notable for variable vancomycin susceptibility (76% in urine versus 100% in blood) and 0% imipenem susceptibility in blood isolates, suggesting an emerging glycopeptide-resistant Enterococcus burden consistent with increasing VanA/VanB detection in Punjab.[4,13]

The Gram-negative susceptibility profiles are deeply concerning from a stewardship perspective. E. coli showed near-complete loss of cephalosporin efficacy (susceptibility 0-25%) and poor fluoroquinolone susceptibility (ciprofloxacin 0-52%), mirroring results of 69.5% cephalosporin resistance and 76.8% fluoroquinolone resistance reported from another Lahore hospital in 2024.[11] Carbapenem susceptibility ranged as low as 26% (BAL), suggesting a growing carbapenem-resistant E. coli burden in respiratory specimens. For uncomplicated urinary infections, fosfomycin (82%) and nitrofurantoin (52%) remain viable stewardship-friendly options. K. pneumoniae displayed an even more alarming profile, with cephalosporin susceptibility below 33% and carbapenem susceptibility of 22-82%, consistent with the rising prevalence of ESBL- and carbapenemase-producing strains carrying blaNDM-1 across South Asian centres.[4,14,15]

A. baumannii emerged as the most extensively resistant organism, with carbapenem susceptibility as low as 0% in BAL and tracheal secretion specimens, precisely the clinical settings where effective therapy is most critical. This pan-resistance pattern, with colistin as the sole remaining option, is consistent with recent findings from tertiary care hospitals in Lahore, where blaOXA-23 was the predominant carbapenemase among A. baumannii ICU isolates.[16] Pseudomonas species, while less resistant, showed moderate ceftazidime (14-75%) and piperacillin-tazobactam (21-73%) susceptibility but poor aminoglycoside and fluoroquinolone activity, limiting combination regimen options.[17] Salmonella maintained favourable carbapenem and azithromycin susceptibility (100%), though declining ciprofloxacin and co-trimoxazole susceptibility warrants vigilance.[5]

Collectively, these data demonstrate that empiric use of third-generation cephalosporins and fluoroquinolones for Gram-negative infections at this institution is no longer justifiable. Based on the susceptibility patterns observed, we recommend that, at this institution, third-generation cephalosporins (cefotaxime and ceftriaxone) and fluoroquinolones (ciprofloxacin) should no longer be used as empiric agents for Gram-negative infections, given susceptibility consistently below 25% for cephalosporins and below 52% for ciprofloxacin across most specimen types; their use should be restricted to culture-confirmed susceptible isolates. Similarly, empiric macrolide (erythromycin) and clindamycin therapy for staphylococcal infections should be discouraged, as susceptibility did not exceed 53%. Conversely, for empiric treatment of suspected Gram-positive infection, vancomycin and linezolid remain reliable (100% susceptibility), and for uncomplicated lower urinary tract infection, fosfomycin and nitrofurantoin are preferable, stewardship-friendly first-line options. Carbapenems are losing efficacy and must be reserved for documented indications, while colistin, now the last reliable agent against the most resistant pathogens, requires strict stewardship governance to preserve its utility.[15,18] These findings strongly support the implementation of a formal antimicrobial stewardship program incorporating prospective audit and feedback, formulary restriction, regular antibiogram dissemination, and targeted educational interventions.[18-20]

***Limitations*** This study has certain limitations. Molecular characterization of resistance mechanisms was not performed. As a single-center study, the findings may not be directly generalizable The six-month duration may not capture seasonal fluctuations in resistance patterns.

## Conclusion

This institutional antibiogram reveals high levels of antimicrobial resistance among bacterial pathogens at a major teaching hospital in Lahore. Third-generation cephalosporins and fluoroquinolones are now largely ineffective against the predominant Gram-negative organisms, and carbapenem susceptibility is declining. Colistin, vancomycin, and linezolid remain the most reliable last-resort agents and must be protected through disciplined stewardship. Periodic generation and dissemination of institutional antibiograms should be routine practice at tertiary care hospitals in Pakistan.

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***Author's contribution***

**HB:** Substantial contribution to conception and study design, critical review of the manuscript.

**KA:** Substantial contribution to study design, acquisition and interpretation of data, and manuscript writing.

**MA,FS:** Substantial contribution to study design and acquisition of data, and manuscript writing.

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