The Role of Artificial Intelligence in Antimicrobial Susceptibility Testing: Perceptions and Expectations of Medical Doctors of South Punjab, Pakistan.

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ABSTRACT:

Objective: To evaluate clinicians' reliance on antimicrobial susceptibility testing (AST) and their perceptions, trust, and readiness to adopt artificial intelligence (AI)-enabled AST in clinical practice.

Methodology: A descriptive cross-sectional study was conducted among 366 healthcare workers in South Punjab, Pakistan. Data on reliance, perceptions of AI-enabled AST, trust, implementation, and concerns were analyzed using chi-square (χ^2) tests.

Results: Demographic analysis showed that 51.0% of participants had less than five years of clinical experience, with medical officers comprising 48.9% (P<0.001). Females predominated (59.2% vs. 40.7%; P<0.01). Most respondents practiced in Lahore (37.7%) or Multan (33.0%; P<0.001), with surgery (34.4%) and pediatrics (22.9%) being the leading departments (P<0.001). Reliance on AST was high: 69.6% strongly agreed and 21.5% agreed that AST guided prescribing decisions, though 72.9% noted delays limited optimal selection. Interpretation was seen as judgment-dependent (41.5% strongly agree). Perceptions of AI were highly positive: 84.4% strongly agreed AI could improve accuracy, 76.2% reduce inappropriate use, and 82.2% aid earlier decisions. Trust and willingness to adopt were strong (95.9% trusted validated AI; 93.4% were willing to use it alongside conventional AST). Concerns included transparency (35.2%), bias (59.8%), unclear legal responsibility (78.9%), and infrastructure (75.9%). Most supported training (81.1%) and regulatory oversight (71.8%). Significant variation was observed across responses (P<0.001).

Conclusion: Clinicians view AI-enabled AST as a promising complementary tool, contingent on validation, governance, training, and integration.

Keywords: Antimicrobial susceptibility testing; Artificial intelligence; Antimicrobial resistance; Clinical decision support; Stewardship; Healthcare workers.

Cite as: Saleem I, Usmani U, Kanwal S, Raza AA, Zafar S, Javeed M. The Role of Artificial Intelligence in Antimicrobial Susceptibility Testing: Perceptions and Expectations of Medical Doctors of South Punjab, Pakistan. J Muhammad Med Coll. 17(1) May-October 2026

Introduction:

Antimicrobial resistance (AMR) has emerged as an increasing threat to global public health, with the potential to undermine the effectiveness of antibiotics and other antimicrobial drugs, which are the cornerstone of modern medicine.[1,2] The leading cause of bacterial resistance is the widespread use of β-lactam antibiotics, which induce the production of β-lactamase enzymes.[3] A prevalent representative of Gram-positive bacteria, such as methicillin-resistant *Staphylococcus aureus*, has spread rapidly around the world due to its ability to express β-lactamase. Thus, it becomes a primary source of infections in both community and healthcare-associated settings.[4] Other Gram-negative bacteria exhibit a progressive development of resistance to β-lactam antibiotics because of β-lactamases and thereby have led to a widespread dissemination of multiple-resistant strains around the world.[5] Thus, early correct detection and confirmation of drug-resistant bacteria are essential, particularly because of a probable future increase in the seriousness of an antimicrobial resistance (AMR) crisis.[6]

Artificial Intelligence (AI) offers numerous opportunities in the detection, treatment and prevention of disease.[7] AI involves machine learning and deep learning paradigms that have been recognized as a revolutionary technology to combat AMR. Recent reviews highlight the potential to integrate diverse clinical and genomic data including AST results to accurately identify patterns and predict trends.[8] AI-powered surveillance tools enable early identification of drug-resistant strains by processing data from hospital, lab, and public health sources in real time.[9] Moreover, models created using algorithms such as Random Forest, Support Vector Machine, and neural networks can adequately identify the resistance phenotype of an organism from its genomic details.[10] In the medical setting, AI-driven decision support tools assist medical professionals in optimizing the use of antibiotics through data-driven personalized treatment options.[9,11]

The standardized application of antimicrobial susceptibility testing (AST) in developing countries is often hindered by inadequate laboratory infrastructure and the absence of uniform strategies, despite AST being a critical tool for identifying resistant microbes and guiding pharmacological decisions. Healthcare workers (HCWs) play a pivotal role

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Received: May 2026, Revised: August 2026
Accepted: October 2026

in controlling infectious diseases, yet gaps in knowledge and practice contribute to the growing challenge of antimicrobial resistance (AMR). Continuous professional development is therefore essential, requiring HCWs to remain updated on emerging advancements in disease control. Integrating artificial intelligence (AI) into AST and AMR surveillance offers the potential to enhance early detection of resistance patterns and strengthen clinical decision-making. Accordingly, this study aimed to evaluate HCWs' awareness, perceptions, and reliance on AST, as well as their trust, readiness, and willingness to adopt AI-enabled AST in South Punjab, Pakistan.

Methodology:

This descriptive cross-sectional study was conducted among HCWs in the province of South Punjab, Pakistan. This research was conducted to determine HCWs' awareness levels and perceptions of the role of AST, as well as the use of AI in AST. The study period was six months, from 01-April-2025 to 30-September-2025. Ethical approval was obtained from the Institutional Review Board of Nishtar Medical University, located in Multan. Data Collection was conducted among HCWs in different regions of South Punjab, Pakistan, including Multan, Lahore, Kasur, Sialkot, and Sheikhupura, using a simple random sampling method. A total of 366 healthcare professionals voluntarily participated in this study, with informed consent obtained through detailed information forms. The sample size was determined in line with established principles for community health research, considering practical limitations and expert consultation for early exploratory studies. Standard references such as WHO guidelines on sample size determination and Cochran's sampling techniques informed this process.[12-14]

The inclusion criteria comprised licensed healthcare workers (HCWs) actively practicing in hospitals across South Punjab, Pakistan. Only those who voluntarily consented to participate were enrolled. Exclusion criteria included administrative staff, nursing staff, and HCWs serving as interns or volunteers. This was a questionnaire-based study, developed and validated by a panel of experts. The instrument consisted of two parts. The first part captured demographic variables such as gender, clinical experience, professional role, department, and city of residence. The second part was divided into five sections (A-E):

Section A: Clinical utilization of AST, including its importance in prescribing, timeliness of reporting, and role in antimicrobial stewardship.

Section B: Contribution of AI to AST, assessing its potential to expand antimicrobial options, reduce use of non-susceptible antibiotics, and enable rapid decision-making.

Section C: Trust, implementation, and use of AI-enabled AST in healthcare settings.

Section D: Unfavorable evaluations, including concerns about future expectations, training, orders, and possible applications of AI-enabled AST.

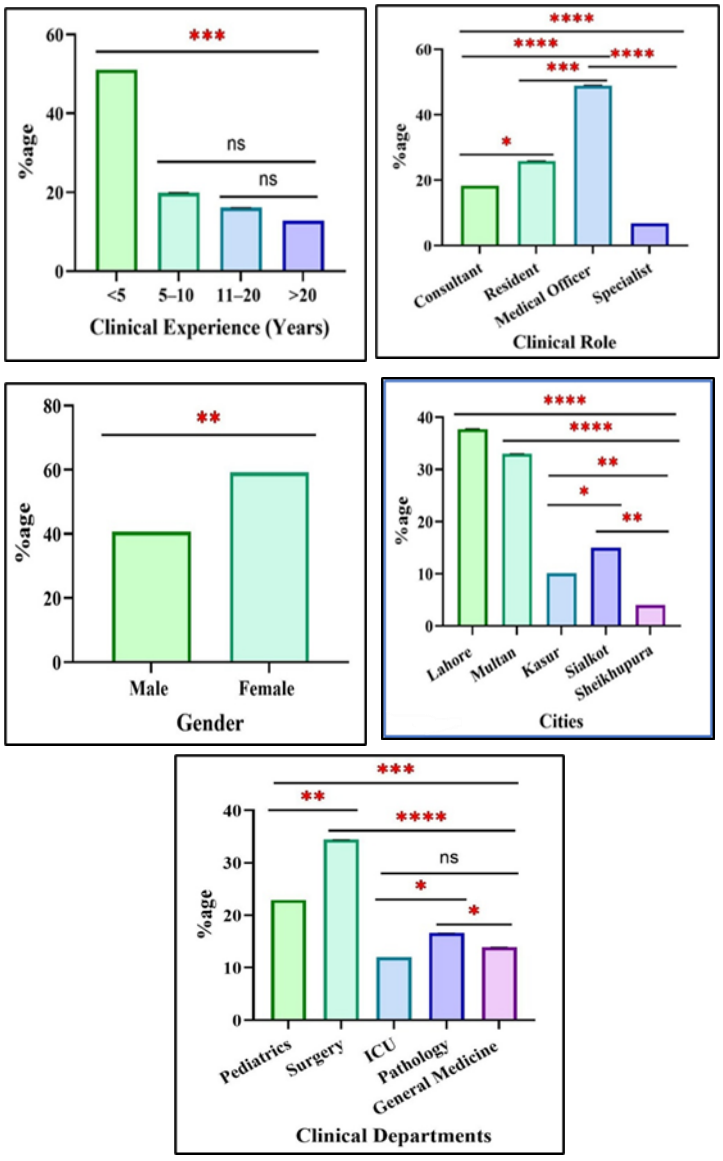
Section E: Adverse assessments of hurdles, focusing on decision-making processes, data quality, liabilities, and limitations of AI-enabled tools.

All items were measured using a five-point Likert scale (strongly agree to strongly disagree). Statistical analysis was performed using chi-square (χ^2) tests to evaluate associations across variables.

Results:

Among the study participants (n = 366), more than half had less than five years of clinical experience (51.0%), followed by 5–10 years (19.9%), 11–20 years (16.1%), and more than 20 years (12.8%). The distribution across experience groups was statistically significant ($p < 0.001$), indicating a predominance of early-career professionals in the sample. With respect to clinical roles, medical officers constituted the largest group (48.9%), followed by residents (25.9%), consultants (18.3%), and specialists (6.8%), with significant variation across categories ($p < 0.001$). Female participants comprised 59.2% of the sample compared to 40.7% males, reflecting a significant gender difference ($p < 0.01$). Geographically, the majority of respondents practiced in Lahore (37.7%) and Multan (33.0%), while smaller proportions were from Sialkot (15.0%), Kasur (10.1%), and Sheikhupura (4.0%), with significant variation across cities ($p < 0.001$). Departmental affiliation showed that most participants worked in Surgery (34.4%) and Pediatrics (22.9%), followed by Pathology (16.6%), General Medicine (13.9%), and ICU (12.0%), with statistically significant differences in distribution ($p < 0.001$) (Figure 1).

Figure 1: Demographic and professional distribution of healthcare workers included in the study.



Most respondents emphasized the critical role of AST in guiding antibiotic prescriptions, with 69.6% strongly agreeing and 21.5% agreeing; this distribution was statistically significant ($p < 0.001$). A considerable proportion also highlighted that delays in obtaining AST results hindered optimal antibiotic selection, with 72.9% strongly agreeing and 15% agreeing ($p < 0.001$). Interpretation of AST reports was perceived as requiring substantial clinical judgment, as 41.5% strongly agreed and 30.3% agreed, while 17.4% disagreed—indicating variability in perceptions ($p < 0.001$). Regarding AI-assisted AST, participants expressed strong optimism. A total of 84.4% strongly agreed and 15.5% agreed that AI could improve antimicrobial selection ($p < 0.001$). Similarly, 76.2% strongly agreed and 23.7% agreed that AI-based systems could reduce inappropriate antibiotic use ($p < 0.001$). Furthermore, 82.2% strongly agreed that AI-driven AST could facilitate earlier decision-making compared to conventional methods, and 86.6% strongly agreed it could enhance clinical outcomes (both $p < 0.001$). Respondents also supported the role of AI in strengthening antimicrobial stewardship programs, with 70.7% strongly agreeing and 26.2% agreeing ($p < 0.001$).

Table No 1: Healthcare workers' responses on clinical reliance, perceptions, trust, and barriers related to AI-enabled antimicrobial susceptibility testing

No.	Questions	Options					
	Statement	**Strongly Agree n (%)**	**Agree n (%)**	**Neutral n (%)**	**Disagree n (%)**	**Strongly Disagree n (%)**	**Chi-square test**
Section A: Clinical Reliance on AST							
4	AST results are critical in my antibiotic prescribing decisions	255 (69.6)	79 (21.5)	32 (8.7)	0 (0)	0 (0)	*p < 0.001*
5	The timeliness of current AST results limits optimal antibiotic selection	267 (72.9)	55 (15.0)	44 (12.0)	0 (0)	0 (0)	*p < 0.001*
6	Interpretation of AST reports requires significant clinical judgment.	152 (41.5)	111 (30.3)	39 (10.6)	64 (17.4)	0 (0)	*p < 0.001*
Section B: Perceptions of AI in AST							
7	AI-assisted AST can enhance the precision of antimicrobial selection.	309 (84.4)	57 (15.5)	0 (0)	0 (0)	0 (0)	*p < 0.001*
8	AI-based AST has the potential to reduce inappropriate antibiotic use.	279 (76.2)	87 (23.7)	0 (0)	0 (0)	0 (0)	*p < 0.001*
9	AI-driven AST may support earlier clinical decision-making than conventional methods.	301 (82.2)	47 (12.8)	18 (4.9)	0 (0)	0 (0)	*p < 0.001*
10	AI-assisted AST could contribute to improved patient outcomes in infectious diseases.	317 (86.6)	47 (12.8)	2 (0.5)	0 (0)	0 (0)	*p < 0.001*
11	AI tools in AST can strengthen antimicrobial stewardship programs.	259 (70.7)	96 (26.2)	11 (3.0)	0 (0)	0 (0)	*p < 0.001*
Section C: Trust, Adoption, and Clinical Integration							
12	I would trust AI-assisted AST results if clinically validated.	351 (95.9)	15 (4.0)	0 (0)	0 (0)	0 (0)	*p < 0.001*
13	I am willing to use AI-assisted AST alongside conventional AST.	342 (93.4)	24 (6.5)	0 (0)	0 (0)	0 (0)	*p < 0.001*
14	AI-based AST should be integrated into routine laboratory workflows.	293 (80.0)	55 (15.0)	8 (2.1)	0 (0)	0 (0)	*p < 0.001*
15	AI should support—not replace—clinical judgment in antibiotic prescribing.	333 (90.9)	33 (9.0)	0 (0)	0 (0)	0 (0)	*p < 0.001*
Section D: Barriers and Ethical Concerns							
16	Lack of transparency in AI decision-making reduces my confidence in AI-AST.	129 (35.2)	123 (33.6)	96 (26.2)	18 (4.9)	0 (0)	*p < 0.001*
17	Data quality and algorithmic bias are major concerns in AI-based AST.	219 (59.8)	64 (17.4)	59 (16.1)	24 (6.5)	0 (0)	*p <0.001*
18	Legal responsibility for AI-assisted prescribing decisions remains unclear.	289 (78.9)	77 (21.0)	0 (0)	0 (0)	0 (0)	*p < 0.001*
19	Limited institutional infrastructure may hinder AI-AST implementation.	278 (75.9)	67 (18.3)	21 (5.7)	0 (0)	0 (0)	*p < 0.001*
Section E: Future Expectations and Policy Direction							
20	Formal training on AI-based AST is necessary for medical doctors.	297 (81.1)	59 (16.1)	10 (2.7)	0 (0)	0 (0)	*p <0.001*
21	Regulatory oversight is essential before AI-AST tools are widely deployed.	263 (71.8)	94 (25.6)	9 (2.4)	0 (0)	0 (0)	*p < 0.001*
22	AI-based AST is likely to become standard practice in the future.	169 (46.1)	123 (33.6)	57 (15.5)	17 (4.6)	0 (0)	*p < 0.001*

Trust and willingness to adopt AI-assisted AST were notably high. Nearly all respondents (95.9%) indicated they would trust AI-assisted AST if clinically validated, and 93.4% expressed willingness to use it alongside conventional methods (both $p < 0.001$). A substantial majority favored integrating AI into routine laboratory workflows (80.0% strongly agree; $p < 0.001$), while emphasizing that AI should support rather than replace clinical judgment (90.9% strongly agree; $p < 0.001$). Despite strong acceptance, participants identified key barriers and ethical concerns. Approximately one-third agreed that lack of transparency in AI decision-making reduced confidence (35.2% strongly agree; 33.6% agree), with 26.2% remaining neutral ($p < 0.001$). Concerns about data quality and algorithmic bias were prominent, with 59.8%

strongly agreeing and 17.4% agreeing ($p < 0.001$). Legal responsibility for prescribing decisions based on AI remained unclear, as 78.9% strongly agreed ($p < 0.001$). Institutional barriers to implementation were also anticipated, with 75.9% strongly agreeing ($p < 0.001$). Looking ahead, respondents overwhelmingly supported structured preparation and regulation. A total of 81.1% strongly agreed on the need for formal training in AI-based AST, while 71.8% strongly agreed that regulatory oversight is essential before widespread deployment (both $p < 0.001$). Finally, 46.1% believed AI-based AST is likely to become standard practice in the future, with one-third agreeing and a minority uncertain or disagreeing ($p < 0.001$) as shown in table 1.

Discussion:

Current study demonstrates a high clinical dependence on antimicrobial susceptibility testing in the healthcare workers of South Punjab. More than 90% of the persons interviewed expressed confidence in using AST results for prescribing action. This degree of reliance is on par with findings from international studies of stewardship as seeing a need to understand AST as a key to rational antimicrobial use and resistance containment.[15] However the perceived limitations of AST were equally prominent. Nearly 88% of the clinicians showed that delays in reporting AST impacted the best choice of antibiotics. Similar concerns have been documented both in high-income and low and middle-income countries, in which conventional culture-based AST require a prolonged time to obtain results (up to 72 hours), resulting in prolonged empirical therapy and increased risk for resistance selection.[15-17]

Perceptions of AI-enable AST were certainly on the positive end of the scale. More than 84% of participants thought that AI could help to improve the accuracy of antimicrobial selection choices and more than 76% thought that AI could help to reduce inappropriate antibiotic use. These views are consistent with growing evidence that machine learning models demonstrate the potential to predict antimicrobial susceptibility more quickly than conventional testing, and provide support to aid in stewardship decisions with high accuracy.[18] The hope that AI could facilitate earlier decision making can be readily understood given the amount of clinical need, as stated by more than 82% of the respondents. Early AI-based models for predicting response to treatment have shown promise in shortening time to effective therapy by combining data from the patient's health record and microbiological patterns before the definitive results of the AST are available.[19] Despite this enthusiasm, the degree of concern was substantial. More than two-thirds of the survey respondents were concerned about the quality of data and the existence of bias in algorithms. This is consistent with reported dangers of AI models that are trained on non-representative data sets that could lead to biased outputs especially in Low- and Middle-Income Countries (LMIC) healthcare systems where data heterogeneity is high.[20,21] Legal Accountability was the most prominent barrier, with almost 79% of clinicians reporting uncertainty about responsibility for AI-assisted prescribing decisions. This is a concern supported by abundant literature where uncertainty in liability has consistently been cited as one of the key challenges for adoption of clinical AI.[22-24]

Limitations: This study was only limited to southern areas of Pakistan which may restrict the generalizability of the findings to other regions and populations.

Conclusion:

This study explored healthcare workers' perceptions, reliance, and expectations regarding antimicrobial susceptibility testing (AST) and the potential role of artificial intelligence (AI) in clinical decision-making. Findings revealed strong dependence on AST for prescribing decisions, coupled with optimism about AI's capacity to enhance accuracy, timeliness, and stewardship. While trust and willingness to adopt AI-assisted AST were high, concerns persisted around transparency, data quality, legal accountability, and institutional infrastructure. Successful implementation will therefore require rigorous clinical validation, structured training, regulatory oversight, and seamless integration into existing laboratory and clinical workflows. These insights provide a foundation for guiding safe, effective, and sustainable adoption of AI-enabled AST in healthcare systems.

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Sajida Zafar	Methodology; Visualization.
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