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REVIEW

Progress on the Global Research Agenda for Antimicrobial Resistance in Human Health in Pakistan: Findings and Implications

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Background and Objective: Antimicrobial resistance (AMR) poses a formidable challenge to global public health, with low- and middle-income countries (LMICs) including Pakistan being particularly vulnerable. This study assesses the progress made in Pakistan following the Global Research Agenda for AMR, which builds on the key activities and goals of its national action plan to reduce AMR. The intention is to identify key gaps, achievements, and future areas of focus to help reduce rising AMR rates in Pakistan.

Methods: Utilizing a systematic-narrative hybrid literature review methodology approach, recent research publication and policy initiatives related to AMR, including those published on the internet, were examined and documented.

Findings: The findings from 349 published studies were divided into the 40 research priority areas. This included 23 papers (9.95%) specifically related to prevention and 55 (22.9%) to diagnosis, 64 (26.7%) for treatment and care of patients with infectious diseases, 59 (24.5%) for cross-cutting, and 44 (18.33%) for drug-resistant tuberculosis (TB). Currently, research on AMR in Pakistan is primarily concentrated in major urban centers across a limited number of cities. This needs addressing going forward. To effectively combat AMR in Pakistan, prioritizing prevention is crucial to curb disease spread and reduce reliance on prophylactic treatments, especially inappropriate prescribing and dispensing of antimicrobials. Enhancing diagnostic facilities, strengthening antimicrobial surveillance systems and promoting appropriate management of patients with infectious diseases, supported by robust antimicrobial stewardship programs, can also help enhance judicious antibiotic use in Pakistan and reduce AMR going forward.

Conclusion and Interpretation: There are ongoing concerns regarding current research activities in Pakistan to reduce AMR. The pathway forward in Pakistan includes leveraging global partnerships to share knowledge, resources, and strategies to enhance the use of Access antibiotics as well as reduce AMR to reach agreed United Nations' goals.

Plain Language Summary: Antimicrobial resistance (AMR) poses a substantial threat to public health, as it reduces the number of effective antibiotics to combat infections, as well as increasing costs and the number of deaths. Pakistan is a critical country, with high and growing rates of AMR. Consequently, this issue must be addressed. The Global Research Agenda for AMR provided guidance on approaches that key stakeholders in Pakistan should undertake to reduce AMR. Our findings uncovered 20 published studies covering multiple aspects to reduce AMR. These included studies related to ways to reduce infections and the associated use of antibiotics and

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improve the care of patients with infectious diseases, including tuberculosis (TB), resistant to the current antimicrobials. Going forward, health authorities and others in Pakistan need to prioritize activities to reduce infections, including better hygiene, as well as reduce unnecessary prescribing and dispensing of antibiotics. This includes activities called antimicrobial stewardship programs to improve antibiotic use. The pathway forward also included leveraging global partnerships to share knowledge, resources, activities and strategies to improve the future use of antibiotics. We believe that this is the first study among low- and middle-income countries to fully explore current activities as part of the Global Research Agenda for AMR to provide guidance to other researchers and countries operating in this field.

Keywords: antibiotics, antimicrobial resistance, antimicrobial surveillance, AWaRe, global research, health policy, Pakistan

Introduction

Antimicrobial resistance (AMR) is one of the greatest threats to global public health[1–5] and occurs when pathogens become resistant to prescribed antimicrobials. As a result, making infections harder and more expensive to treat.[6] AMR has a direct influence on morbidity and mortality, the length of hospital stays, the safety of patients including with other medical procedures, the overall costs of treatment and the global economy.[2,4,7–9] Risk factors for emergence and transmission of AMR include challenges within the healthcare system, the water sanitation and hygiene (WASH) infrastructure, patient-related underlying health conditions and the inappropriate use of antibiotics especially those with appreciable resistance potential.[6,10–12] In 2019, there were 1.27 million deaths directly attributable to AMR and 4.5 million deaths were associated with AMR, with the highest mortality observed in sub-Saharan and South Asia.[2] There are also concerns with increasing anti-fungal resistance especially in low- and middle-income countries (LMICs) and the implications going forward.[13–15]

To help address rising rates of AMR and the resultant implications, the World Health Organization (WHO) launched the Global Action Plan (GAP) for AMR in 2015.[16] The principal suggested activities to enhance appropriate antibiotic use included training and education to improve awareness of concerns regarding AMR, increasing surveillance and research, improvements in infection prevention and sanitation improvement, as well as developing the economic case for the development for sustainable investment.[16] The GAP led to the development of National Action Plans (NAP) aligned with the objectives of GAP, which included Pakistan.[17,18] However, there have been challenges with their implementation including resource issues of both personnel and available funding, which has resulted in variable implementation of the NAPs especially among LMICs.[19–22] Various factors, including the impact of COVID-19, has hindered the progress of Pakistan's NAP in AMR, necessitating immediate rejuvenation of efforts to combat this silent pandemic.[17,18,23]

In addition, the WHO launched AWaRe (Access, Watch, Reserve) for antibiotics to help limit the use of antibiotics, espeically those that are prone to developing resistance. In this system, the Access group of antibiotics includes those with a lower potential of AMR development, the Watch group includes those with greater potential to develop resistance, with the Reserve group the last resort antibiotics, which should be reserved for life-threatening conditions given the rise in multi drug resistant (MDR) cases.[24–26] The previous target for antibiotic use was at least 60% of antibiotics used in any given sector should be Access antibiotics.[12,24,25] Guidance to reach this target was enhanced by the launch of the WHO AWaRe book giving suggested treatments for 35 common infectious diseases across sectors.[24,27] More recently, the United Nations General Assembly (UN GA) on AMR set an updated target of 70% antibiotic use in sectors being from the Access list.[5,28]

Other WHO initiatives include crafting a Microbiology Laboratories Database, a Microbiologists Database, and a Data Sharing Portal for GLASS (the Global Antimicrobial Surveillance System) and PASS (Pakistan Antimicrobial Surveillance System).[29] Leveraging whole-genome sequencing for AMR surveillance and fostering educational platforms including the "Microbiology and Antimicrobial Resistance" Virtual Journal Club underline Pakistan's holistic approach.[30,31]

In contrast to the WHO's recommended benchmark of US$ 86 per capita spending on health, Pakistan's per capita health expenditure currently stands at just US$ 36.[32] In addition to the US$36 spent by the government, nearly 75% of total spending on medicines in Pakistan is out-of-pocket. As a result, there is substantial purchasing of antimicrobials out of pocket especially where citizens cannot afford physician fees in addition to the cost of medicines, with the potential of driving up AMR.[17,33–35]

This is because studies have shown that excessive purchasing of antibiotics without a prescription from the Watch list, exacerbated by concerns with the current Drug Laws.[33,34,36] Inappropriate dispensing of antibiotics without a prescription coupled with inappropriate prescribing practices urgently needs addressing in Pakistan given continued high rates of AMR.[33,34,37–43] Alongside this, there is currently appreciable prescribing of antibiotics from the Watch list across both primary care and hospital sectors in Pakistan, including during the COVID-19 pandemic, where up to 100% of patients hospitalized with COVID-19 were prescribed antibiotics from the Watch and Reserve lists.[44–48]

As a result of inappropriate and excessive prescribing of antimicrobials, in 2019 Pakistan recorded a number of deaths linked to antibiotic-resistant pathogens. This included 34,400 deaths attributed to *Klebsiella pneumoniae*, 31,300 to *Escherichia coli*, 28,600 to *Staphylococcus aureus*, 23,300 to *Salmonella Typhi*, and 20,300 to *Streptococcus pneumoniae*. These pathogens were identified as the primary causes of various infections, including bloodstream, lower respiratory tract, peritoneal, and intra-abdominal infections. Pakistan appears to be the principal country among the five leading Asian countries with the highest age-standardized mortality with an AMR burden of 221,300 deaths,[49] 611000 TB incidence cases and 16000 MDR-TB incidence cases in 2022.[50] This again needs to be urgently addressed to reduce deaths due to AMR as part of the NAP. Globally, there were an estimated 450,000 new cases of rifampicin and multi-drug-resistant tuberculosis in 2021. Alongside this, there are concerns that invasive fungal infections are increasing globally, with an associated impact on morbidity, mortality, and costs.[14,15,20,51–53] This is also a concern, including among patients in Pakistan.[47,54–56]

In view of growing issues, concerns and challenges, national policies and international health commitments are now being integrated into a framework in Pakistan established by the Ministry of National Health Services Regulations and Coordination (MNHSR&C) to help tackle AMR through the NAP. The establishment of an Intersectoral Core Steering Committee by the MNHSR&C marked the first step in this process, leading to the creation of the National AMR Strategic Framework in 2016 coupled with the activation of the AMR NAP in 2017. The National Institutes of Health (NIH) emerged as a crucial entity in Pakistan,[57] serving as both the national focal point for AMR and International Health Regulation (IHR) activities.[58] The launch of GLASS by NIH in 2016,[59] and subsequently PASS in 2018,[29] laid the groundwork for effective AMR monitoring and management in Pakistan. Pakistan's efforts to improve future antibiotic use, as well as reduce AMR, also incorporate initiatives including the AMR Tricycle program and repeated point prevalence surveys (PPS) on antimicrobial usage generating critical insights.[46,60–63] Further national and international efforts to reduce AMR in Pakistan include: Pakistan Global Antibiotic Resistance Partnership (GARP),[17] Pakistan AMR surveillance system,[29] and the National TB Control Program.[50] At a micro level, AMR is being tackled through the introduction of the Antibiotic Stewardship Initiative in Pakistan (ASIP) and the Pakistan Antimicrobial Resistance Network (PARN) under the umbrella of Medical Microbiology and Infectious Diseases Society of Pakistan (MMIDSP).[64]

To fill the research gap created by a lack of knowledge, the WHO developed a Global Research Agenda for AMR.[65] This initiative aims to provide a transparent and global control and prevention of resistant bacteria-related knowledge gaps assessment in the human health sector, which includes drug-resistant *M. Tuberculosis*, sexually transmitted diseases (STD) and fungal infections, within a time frame of 2023–2030. Alongside this, catalyze scientific interest, as well as focus attention, on the development of new and critical evidence on AMR to assist in the implementation of additional global, regional and national policies to reduce AMR especially among LMICs. This agenda, with its focus on the human health sector, will complement the WHO one health priority research agenda currently being developed in parallel, which focuses on interfaces between humans, animals, and plants and their shared environment.[23] Consequently, the primary aim of this review was to analyze current AMR research activities in Pakistan under the Global Health Research Agenda, identifying study types, geographic and thematic distributions, as well as existing gaps. As a result, guide future research, policy-making, and AMR control strategies in Pakistan in line with the Global Research Agenda for AMR.[65] The findings can be subsequently be used to guide all key stakeholders in Pakistan concerning future initiatives to reduce rising rates of AMR and their implications to meet NAP and UN GA goals.

Method

A systematic-narrative hybrid literature review covering five thematic areas and 40 research priorities of the global research agenda for AMR in human health was undertaken to evaluate the advancement of this agenda within Pakistan.[66] This approach was used in order to try and include all relevant articles and documents, which included those published

on the internet. We have adopted this approach before when reviewing ongoing activities and their implications to improve future antibiotic use across LMICs.[20,67–71] The findings will be used to provide suggestions for all key stakeholder groups in Pakistan to achieve the goals of global research agenda to reduce antibiotic resistant pathogens incidence by investigating preventive strategies. In addition, increasing activities including antimicrobial stewardship programs (ASPs), building on current activities.

Global Health Research Agenda for AMR in Human Health

This policy brief outlines a comprehensive research agenda on AMR with five main themes, 13 subthemes, and 40 specific research areas. These five main themes include Prevention (3 subthemes, four areas), Diagnosis (one subtheme, six areas), Treatment and Care (three subthemes, 11 areas), Cross-Cutting Research (3 subthemes, 12 areas), and Drug-Resistant Tuberculosis (TB) (3 subthemes, 7 areas). Each theme addresses critical aspects such as WASH, rapid diagnostics, antimicrobial stewardship (AMS), epidemiology, and drug-resistant TB interventions aimed at guiding evidence-based practice policies in the future and improve AMR management both in Pakistan and globally.

Developing the Protocol

A protocol specifying the objectives, inclusion criteria, and methods for the narrative review was developed based on the study objectives. This included a number of subsections.

Eligibility Criteria and Population

The inclusion and exclusion criteria were based on the scope of the review. For example, studies focusing on AMR only on human health within Pakistan and published within a specific timeframe. The time frame included studies published from January 2000 until October 2024 to capture the most relevant and recent data on AMR research progress in Pakistan, building upon the launch of the NAP. Consequently, the most emphasis was placed on publications following the launch of the NAP and its initial challenges.[17] The general population, physicians, students, pharmacists, hospitalized patients, outpatients, nurses, dentists, healthcare workers (HCWs) and other healthcare professionals (HCPs) were included.

Concept

Papers for the narrative review included those dealing with the following categories in Pakistan:

(i) prevention (WASH) and infection control practices; (ii) immunization against antibiotic resistant infections; (iii) diagnosis through biochemical, multiplex, and antigen-based testing; (iv) implementation of ASPs and their components; (v) antibiotic use and consumption, especially those broken down by the AWaRe classification; (vi) antibiotic treatment regimens for drug resistant typhoidal and non-typhoidal infections; (vii) treatments regimen for bloodstream infections; (viii) treatment of critical group fungi; (ix) treatment of sexually transmitted diseases caused by *Neisseria gonorrhoeae*; (x) epidemiology, burden of urinary tract, respiratory tract, and bloodstream infections as common infections in Pakistan; (xi) antibiotic resistance awareness and education; (xii) implementation of policies, regulations, and frameworks to mitigate AMR including those surrounding ASPs; (xiii) drug-resistant TB prevention through BCG vaccine; (xiv) diagnosis of drug-resistant, extrapulmonary, and pulmonary TB infections and (xv) new and existing regimens for TB treatment.

Recognizing and Generating Research Questions (RQ)

As mentioned, the primary objective of this review is to comprehensively analyze AMR research currently being conducted in Pakistan, as reported under the Global Health Research Agenda.

This analysis aims to identify the types of studies performed, the geographic distribution of these studies, the specific themes and sub-themes of ongoing research efforts, and the time periods over which the studies were conducted. In addition, this review seeks to identify the prevailing gaps in AMR research and practice in Pakistan, with the ultimate goal of informing future research directions, policy-making, and the implementation of effective AMR control strategies in Pakistan to meet NAP targets.

Search Strategy

Google Scholar and PubMed were used to search for relevant literature. The search strategies were drafted according to the database protocol. These included the terms related to prevention practices, antibiotic infection control practices in hospitals, antibiotic infection immunization, antibiotic infection diagnosis, ASPs, fungal infection diagnosis, antibiotic use and consumption across sectors, treatment of typhoidal and non-typhoidal infections, the epidemiology of urinary tract, respiratory tract, and blood stream infections in community and healthcare settings as well as drug-resistant TB infection prevention, diagnosis and treatment.

The grey literature and government reports were also searched to ensure comprehensive coverage in this area since many Government and other documents would not typically be published in scientific journals.

Selecting Studies and Screening Process

This study used a two-stage screening process. This began with the titles and abstracts, followed by full-text screening according to inclusion criteria. At least two reviewers were included in this study independently assessing studies for eligibility to minimize bias.

Charting the Data

Data Extraction

An agreed standardized form was used to extract data from included studies. Information collected included the study characteristics (eg, year, study design), focus areas of AMR research, findings, and implications for the global research agenda and health policy in Pakistan.

Collecting, Summarizing, and Reporting Results

The findings, in line with the objectives of the review, were organized and categorized. Tables were used to summarize key information and trends. Any gaps in research were highlighted and suggested areas for future investigation.

Stakeholder Consultation

Engaging stakeholders (eg, researchers, policymakers, and clinicians) was also considered to add depth to the review, validate the findings, and identify additional resources including unpublished studies.

A structured approach was used to help ensure that the narrative review comprehensively captures and analyses the progress and implications of AMR research in human health in Pakistan, aligning with global research agendas and identifying areas needing further investigation. Moreover, key recommendations, expected outcomes, and Priority levels are based on the considerable experience of the co-authors working in this field.

Ethical Review

No ethical approval was required for this study as it did not involve humans or animals. It was a review of published studies and references.

Results

This comprehensive review synthesized findings from 349 published studies in 40 research priority areas from 2000 until 2024. This included 23 publications (9.95%) specifically relevant to prevention, 55 (22.9%) to diagnosis, 64 (26.7%) to treatment and care, 59 (24.5%) to cross cutting, ie interconnected factors that influence the development and spread of resistance, and 44 (18.33%) relevant to drug-resistant TB. The research spans various cities in Pakistan, although predominantly in major urban centers including Karachi, Lahore, and Islamabad, focusing on different aspects of AMR (Figure 1). The types of studies included observational and intervention-based research that explored WASH practices as well as those researching diagnostic techniques, AMS, and the effectiveness of immunization against drug-resistant pathogens.

During 2001–2020, prevention-related studies mostly came from Karachi and endorsed the WASH and Infection, prevention and control (IPC) practices in curbing infectious diseases especially diarrhea and, by extension, AMR (Table 1). Encouragingly, an appreciable increase in vaccination uptake resulted in a significant step forward in

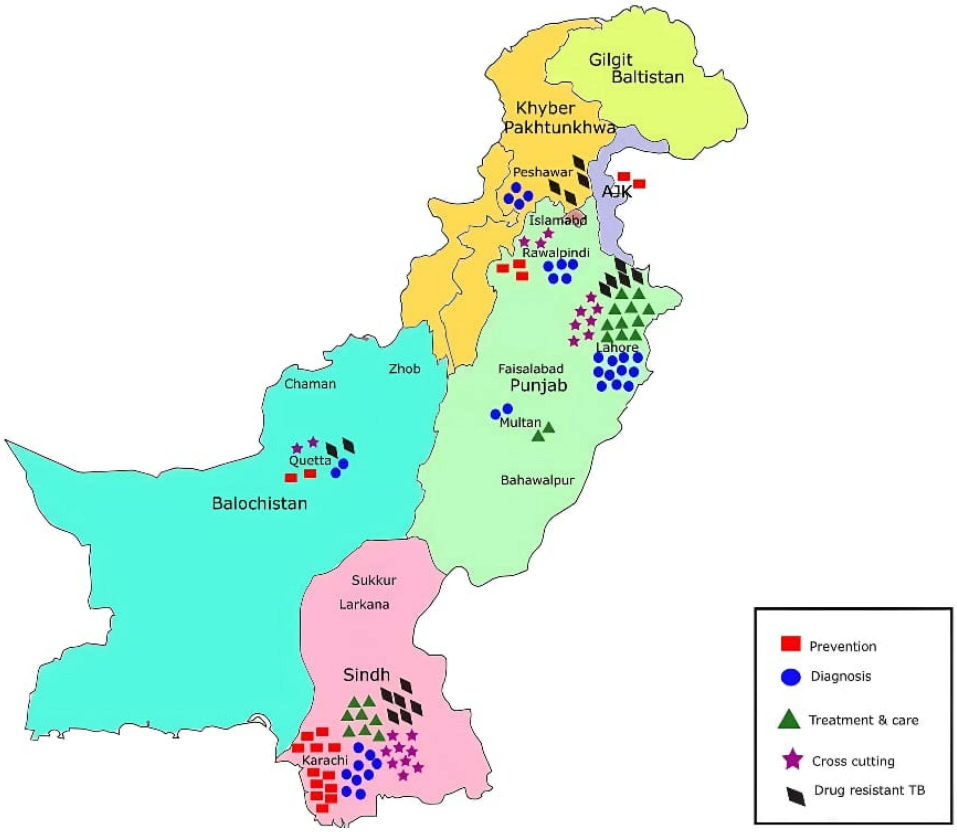

Figure 1 Geographical distribution and focus of 5 AMR areas of GHRA in Pakistan.

vaccine-driven AMR prevention in the country. Nevertheless, the persistent gap in effective practices in both hospital and community settings suggests a need for more robust policy implementation, including public health initiatives, to further reduce infectious diseases and AMR in Pakistan.

In terms of diagnosis, the review highlights diagnostic methods for resistance pathogens, susceptibility detection, use of minimum inhibitory concentration (MIC) determination and the use of advanced diagnostics, all showing the potential of distinguishing bacterial infections from viral infections (Table 2). However, the findings to date highlight a deficiency in current routine laboratory surveillance in Pakistan and the integration of ASPs at the diagnostic level, suggesting that diagnostic capacities are currently being underutilized for AMR management in Pakistan, similar to other LMICs.[71] This is seen by currently limited use of culture and sensitivity testing even in tertiary hospitals in Pakistan because of the costs involved. As a result, high levels of empiric prescriptions in hospitals Pakistan, which need addressing going forward.[60,95]

Encouragingly in recent years, treatment and care strategies have seen improvements with an increasing number of ASPs being undertaken to promote the judicious antibiotic use in Pakistan given the previous concerns (Table 3).[43,44,95,151,162,207] However, whilst good ASP knowledge was observed in studies among doctors, pharmacists and nurses, there were concerns with the actual implementation of ASPs in practice. This suggests the need for implementing education surrounding ASP and policies to all key stakeholder groups going forward as well as ensuring that pharmacist and other HCPs play a key role in their implementation after receiving appropriate ASP training to overcome potential barriers in their implementation.[151,152,154–156]

Cross-cutting efforts highlight the importance of an integrated approach for tackling resistant pathogens (see Table 4). This involves health system strengthening, emergency preparedness, and enhanced sanitation practices especially in countries such as Pakistan. Surveillance studies across various Pakistani regions have provided invaluable data on AMR

Table 1 Theme 1 of GHRA-Prevention

Sub Themes of GHRA	Research Priority Areas Covered as Per GHRA	References	Year of Published Studies	No. of Studies	Targeted Population	Key Findings	Study Highlights
1.WASH:	Area 1 WASH practices effect on AMR and diarrhea burden	[72–81]	2003-2022	10	Physicians, children, HCP, Quack, children and their mothers, LHV's, LHW's	Diarrhea management by • Hand washing • WASEP and HOPE interventions • Diarrhea pack • Bismuth sub-salicylate	Study demonstrating the effective diarrhea management without antibiotics
	Area 2: Effect of WASH-related interventions on burden of HAI	[82–85]	2001-2022	4	HCP's	• Awareness on importance of adopting preventive measures • Improvement in outcomes of health-care waste, water and sanitation and hand hygiene by WASH-FIT	Studies showing the effectiveness of WASH interventions in infection prevention and control
2.Infection, prevention and control	Area 4 Effect of different IPC practices on mitigation of HAI	[86–90]	2005-2023	5	Auxiliary health-care staff, nurses, HCW's	Improved waste disposal rate, hand hygiene, use of personal protective equipment by educational interventions and training session	Studies highlighting reduction in infection burden in health-care setting by use of IPC practices
3. Immunization	Area 4 Infection prevention by vaccination	[91–94]	2012-2023	4	9 months-15 year of children	Prevention of drug-resistant infections like typhoid by TCV, Typbar TCV	Studies showing the preventive effect of vaccines
Implications	Poor WASH practices in hospital and community highlights need of simple, effective preventive measures against AMR						

Abbreviations: LHSs, Lady Health Supervisors; LHWs, Lady Health Workers; WASEP, Water and Sanitation Extension Program; HCP, Healthcare provider; WASH-FIT, Water, Sanitation, and Hygiene Facility Improvement Tool; HAI, healthcare-associated infections; TCV, typhoid conjugate vaccine; XDR, extensive drug resistance.

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Table 2 Theme 2 of GHRA-Diagnosis

Sub Themes of GHRA	Research Priority Areas Covered as per GHRA	References	Year of Published Studies	No. of Studies	Targeted Population	Key Findings	Study Highlights
4. Diagnosis and diagnostics:	Area 5 Discrimination of viral and bacterial infections by using diagnostic algorithm or by biomarkers	[96–98]	2019-2022	3	Patients' samples	• Raman spectroscopy by using PCA and LDA algorithm techniques for HCV detection • Detection by using specific biomarkers like PCT, CRP, TLC	Studies demonstrating the use of advanced diagnostics for differentiation of bacterial and viral infections
	Area 6 Antimicrobial resistance and susceptible detection by using phenotypic and genotypic methods	[99–117]	2013-2023	19	Patients	• Phenotypic detection by Kirby Bauer disc diffusion, double disc synergy, combined disk • Genotypic detection by monoplex and multiplex PCR	Successful identification of resistant, susceptible and gene responsible for conferring resistance was achieved
	Area 7 Identification of resistant and susceptible antimicrobials by using rapid point of care tests	[118–140]	2004-2023	23	Patients' samples	Point-of-care tests include phenotypic methods like double disk synergy, combination disk, biochemical testing and gram staining, genotypic characterization by single plex, multiplex, nested and regular PCR, qualitative assay by real-time PCR	Highlight the use of novel point-of-care diagnosis tests for resistance and susceptibility detection
	Area 8 Detection of WHO critical group fungal priority pathogens	[141–145]	2015-2023	5	Patients' samples	For *Candida* spp detection carried out by biofilm method, by micro titer plate method, by disk diffusion method while *Aspergillus* spp were detected by IgG cut-off diagnosis and by dilution method	Studies demonstrating the effectiveness of different diagnostics test for identification of resistant fungal pathogens
	Area 9 Determination of diagnostic accuracy of phenotypic antifungal susceptibility testing	[146,147]	2013-2020	2	Patients' samples	Diagnostic tests like antifungal agar screening method, MIC determination by microdilution method used for detection of *Candida* and *Aspergillus* spp	Studies showing the importance of MIC determination for selection of antifungal treatment regimen
	Area 10 Evaluate the performance of rapid point-of-care test for detection of *Neisseria gonorrhoeae*	[148–150]	2016-2021	3	Patients' samples	*Neisseria gonorrhoeae* was successfully detected by multiplex PCR, by multiantigen sequence typing, calibrated dichotomous sensitivity disk diffusion, MIC and by E test	Studies showing the identification of resistant antibiotic for *Neisseria gonorrhoeae* to reduce inappropriate prescribing
Implications	Lack of laboratory surveillance, antibiograms, low capacity of laboratory for ASP integration supports the designing of appropriate antibiotic regimen and rational use of antibiotics						

Abbreviations: HCV, hepatitis C virus; PCT, procalcitonin; ASP, antimicrobial stewardship program; ESBL, extended spectrum beta lactamase; MDR, Multi-Drug resistance; PCR, polymerase chain reaction; MRSA, methicillin-resistant Staphylococcus aureus; MSSA, methicillin-susceptible Staphylococcus aureus; S. Typhi, Salmonella Typhi; MIC, minimum inhibitory concentration.

Table 3 Theme 3 of GHRA-Treatment & Care

Sub Themes of GHRA	Research Priority Areas Covered as per GHRA	References	Year of Published Studies	No. of Studies	Targeted Population	Key Findings	Study Highlights
5.Antimicrobial stewardship:	Area 11 Implementation of antimicrobial stewardship interventions to reduce antimicrobial misuse	[151–153]	2020-2022	3	HCP's	Following AMS related interventions were adopted • Consideration of regular audit & feedback by nurses, physicians & pharmacists • Participation in educational sessions	Studies demonstrating the importance of ASP for AMR mitigation in community as well as in health-care settings
	Area 12 Role of pharmacist dispensing practices in implementation of antimicrobial stewardship	[154–158]	2018-2023	5	Hospital staff and community pharmacies staff	Pharmacists played significant role in • Discouragement of non-prescription antibiotic dispensing practices • Patient education • Compliance with DTC's guidelines	Studies highlighting the positive role of pharmacist in ASP implementation and practices
	Area 13 Optimization of empirical antibiotic therapy by various strategies	[159–161]	2019-2023	3	Hospitalized patients	Empirical therapy practices were improved by • Selection and initiation of antibiotics according to recommended guideline • De-escalation of antibiotics • PAP audit	Studies highlighting the need of evidence based empirical therapy
6.Antimicrobial use and consumption	Area 14 Methods to monitor antimicrobial use and consumption	[45, 46, 95, 162–171]	2015-2023	13	Patients from OPD's, emergency, medicine, gynecology, physicians, general population HCW's	Methods to determine irrational antibiotic use were • Dispensing of partial antibiotic course by pharmacists • Absence of guidelines or policies for antibiotic prescription • Completion of incomplete antibiotic course by patients • Self-medication and empirical therapy	Studies determining the overall consumption and use of antibiotics by different methods
	Area 15 Use and consumption of AWaRe group antibiotics	[33, 35, 62,172–182]	2017-2023	14	Term neonates, hospitalized patients, student, pharmacy staff, drugstore staff, children, pharmacy technician	Highly prescribed/used antibiotics were from watch group followed by access and reserve group	Studies showing the overall consumption of AWaRe group antibiotics
	Area 16 Monitoring of antimicrobial consumption and resistance surveillance data to inform antimicrobial stewardship programs and treatment guidelines	[183–187]	2015-2023	5	Inpatients and outpatients	Emergence of MDR, XDR organisms especially in enteric fever confirmed by surveillance methods like active surveillance which demand the ASP implementation	Studies demonstrating the importance of antimicrobial surveillance data in ASP

(*Continued*)

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Table 3 (Continued).

Sub Themes of GHRA	Research Priority Areas Covered as per GHRA	References	Year of Published Studies	No. of Studies	Targeted Population	Key Findings	Study Highlights
7.Antimicrobial medicines	Area 17 Safe and effective antibiotic monotherapy & combination therapy for ESBL enterobacterales or CRE	[188–190]	2022-2023	3	Patients	Efficacy of in-vitro Ceftazidime-Avibactam (CAZ-AVI) and Meropenem-Vaborbactam (MEV) combination is decreasing day by day due to MBL and serine presence while cefiderocol was highly effective as only 4% isolated were resistant against this antibiotic	Studies showing the effective antibiotic options for *Enterobacterales*
	Area 18 Safe and effective antibiotic regimen for infection by typhoidal and non-typhoidal *Salmonellae*	[91, 94, 191–195]	2020-2023	7	Children, patients, general population	For XDR typhoid monotherapy with meropenem, azithromycin was more effective as compared to combination therapy with meropenem + azithromycin TCV also proved as beneficial	Studies showing the efficacious antibiotics for typhoidal and non-typhoidal infections
	Area 19 Safe and effective antibiotic regimen for bloodstream infections and sepsis	[196–201]	2012-2023	6	NICU neonates, patients, infants, hematology children	Use of colistin alone or in combination therapy was effective	Studies showing the effective antibiotics for BSI and sepsis
	Area 20 Safe and effective treatment regimen for infections caused by WHO fungal priority pathogens	[202–205]	2012-2021	4	Hospitalized patients	Effective antibiotics for *Candida* spp were • Fluconazole 150 mg in a single dose and itraconazole 200 mg twice for 1 day For *Aspergillus* spp were • Voriconazole 400 mg per day and surgery	Studies demonstrating the overall efficacious antibiotics for critical group fungal pathogens
	Area 21 Safe and effective antibiotic treatment regimen for STD's caused by *Neisseria gonorrhoeae* and *Mycoplasma genitalium*	[206]	2022	1	Patients	Effective treatment for *N. gonorrhoeae* was injection of 500mg ceftriaxone and 2gm spectinomycin	Studies showing the antibiotics used for STD's management
Implications	Barriers in implementation of ASP like knowledge gaps, incomplete compliance, absence of ASP core elements, absence of effective methods and metrices for estimating the national or regional level antibiotic consumption need to be addressed						

Abbreviations: OPD, outpatient department; AWaRe, Access, Watch, Reserve; BSI, bloodstream infection.

Table 4 Theme 4 of GHRA-Cross Cutting

Sub Themes of GHRA	Research Priority Areas Covered as per GHRA	References	Year of Published Studies	No. of Studies	Targeted Population	Key Findings	Study Highlights
8.Antimicrobial resistance epidemiology, burden and drivers	Area 22 Epidemiology and socioeconomic impact of health-care associated and community acquired infections	[208–217]	2014-2023	10	Patients including Indoor, outdoor, pediatric), neonates	Varied incidence, prevalence, mortality and morbidity of different bacterial infections among different age groups were observed	Studies showing the epidemiology of respiratory tract, urinary tract, bloodstream and surgical site infections
	Area 23 Incidence, prevalence, morbidity, mortality caused by WHO fungal priority pathogens among co morbid and vulnerable population	[55, 218, 219]	2019-2022	3	Patients from Gynae& Obstetrics, pediatric patients	High prevalence of *Candida* spp especially *Candida albicans* was observed in females especially in pregnant women and high mortality rate in hospitals occurred due to *Candida auris*	Studies determining the overall epidemiology of WHO critical group fungal pathogens
	Area 24 Impact of health system factors such as hospital microbiome on bacterial and fungal colonization	[220–226]	2013-2024	7	Neonates, hospital personnel, ICU patients, pediatric patients	Hospital microbiome was found to be associated with the high colonization rate of vancomycin-resistant and vancomycin-susceptible enterococci among hospitalized neonates, pediatrics	Studies showing the relation between hospital microbiome and drug-resistant infections colonization rate
	Area 25 Optimal surveillance data on epidemiology and burden of AMR in community and health-care settings	[183, 184, 227–231]	2006-2020	7	Patients (inpatients, outpatients pediatrics, community)	Burden of multi-drug-resistant organisms estimated by surveillance methods like • Population based • Laboratory based • Active • Sentinel • Prospective • Passive	Studies defining the role of surveillance methods for estimation of AMR burden

(*Continued*)

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Table 4 (Continued).

Sub Themes of GHRA	Research Priority Areas Covered as per GHRA	References	Year of Published Studies	No. of Studies	Targeted Population	Key Findings	Study Highlights
	Area 26 Short- and long-term impact of AMR on use of antimicrobial medicines especially among vulnerable population	[232–238]	2019-2023	7	Medical inpatients, outpatients, neonates and children, pediatrics	Some long- and short-term impact of antimicrobial resistance were increased risk of HAI, increased risk of side effects, increased antibiotic resistance and increase in drug resistance of different infections like MDR and XDR typhoid	Studies demonstrating the long term and short-term effects of AMR
	Area 27 Impact of unnecessary and inappropriate antibiotic prescribing and potential consequences caused by *Neisseria gonorrhoeae*	[239–241]	2011-2022	3	Female patients, infertile women	Harmful antimicrobial consequences of currently recommended STD's management were increase in antibiotic resistance of *N. gonorrhoeae*, increased fertility rate, increased risk of pelvic inflammatory disease	Studies demonstrating the potential consequence of inappropriate antibiotic prescribing in STD's
9.Antimicrobial resistance awareness and education	Area 28 Mitigation of antimicrobial resistance by awareness and education among general population	[242–248]	2018-2022	7	Students, adults, patients, clinical staff	Awareness regarding AMR was raised by ASP introduction, AMR week, student moderated session, Global Antimicrobial Resistance Surveillance System (GLASS) and campaigns for antimicrobial misuse and abuse	Studies showing that how AMR reduction can be achieved by increasing awareness

10.Policies and regulations related to antimicrobial resistance	Area 29 Mitigation of AMR by implementation of AMR related policies and regulations	[249–251]	2019-2023	3	Doctors, pharmacist, administrative staff, patients, clinical microbiologists, associate professor, head of clinical department	Treatment failure and high mortality rate due to irrational antibiotic use can be controlled by introduction of ASP as carbapenem ASP intervention resulted in low mortality and improved clinical outcomes	Studies demonstrating the role of AMR policies
	Area 30 Cost-effective implementation of national policies, regulation to improve patient care and infection prevention	[252, 253]	2007-2017	2	ICU patients, pharmacists, residents, MS, AMS, DMS, HOD's of different wards	To tackle the situations like lack of IPC policies lack of well-defined system for human resources different interventions like 7S McKinsey framework and restriction of broad-spectrum antibiotics use were adopted	Studies highlighting the role of AMR regulations and policies in infection prevention
	Area 31 Cost-effective interventions for the mitigation of AMR in human health sector	[254–256]	2009-2024	3	Community pharmacists, hospitalized patients, health-care students	Educational interventions, training sessions and ASP knowledge helped to raise awareness regarding AMR	Studies demonstrating the importance of AMR related intervention
	Area 32 Integration of antimicrobial resistance intervention into broader health to reduce AMR burden	[43, 257–259]	2020-2023	4	AMS, MS, DMS, outpatients, sick infants	AMR problems like incorrect prescribing, dispensing, high antibiotic usage rate of AWaRe group antibiotics can be addressed by emphasizing all the health-care stakeholders to take substantial measures for implementation of ASP and its core elements	Studies depicting the expansion of AMR interventions at a large scale
	Area 33 Effect of existing regulatory framework and sustainable financing models on development and availability of new antimicrobial medicines	[260–262]	2017-2022	3		Current gaps in drug monitoring laws, policy investment in drug regulation, absence of guidelines for sale of OTC antibiotics led to emergence of resistant pathogens which can be addressed by use of antibiotics that are highly susceptible against these pathogens should be considered	Studies highlighting the role of regulatory framework in antibiotic development and its availability
Implication	Lack of enhanced infrastructure, education, training, proper surveillance, poor public awareness, lack of antimicrobial audit and feedback in hospitals highlights the need for a multifaceted strategy against AMR						

Abbreviations: MDRO, Multi Drug Resistant Organisms; VRSA, Vancomycin Resistant Staphylococcus aureus; HOD, Head of Department.

trends in active, passive, and sentinel surveillance pinpointing the high prevalence of drug-resistant pathogens across healthcare settings in the country.

Although there are currently considerable efforts to map the epidemiology of resistant pathogens in Pakistan, studies highlight a lack of comprehensive data collection that integrates findings into national health policies. This suggests the urgent need for a unified national surveillance system to improve understand and respond to AMR trends. Moreover, there is also an evident lack of widespread AMR awareness and education among both the general population and healthcare workers in Pakistan.[71,162] This underscores the necessity for national campaigns and regular training programs to enhance understanding and appropriate responses to AMR among all key stakeholder groups.[71]

Antitubercular therapy (ATT) and fluoroquinolones have proven effective in treating and preventing drug-resistant TB both pulmonary and extrapulmonary drug-resistant TB, particularly when used in combination regimens. This is important in Pakistan, given the current concerns (Table 5). The addition of medicines, including bedaquiline and delamanid, into treatment regimens have resulted in higher success rates and addressed the safety and efficacy concerns, which is encouraging.

Diagnostic advancements, including molecular assays and public-private models, enhance TB detection, which is also encouraging. Strategies adopted to combat drug resistant TB include vaccination (BCG),[263–267] early screening (by Genotypic MTBDRplus and MTBDRsl assay and/or GeneXpert MTB/RIF assay),[271–276] and complete adherence to TB treatment protocols (shorter treatment regimens, longer treatment regimen either in the form of monotherapy or combination therapy, and DOT therapy).[290,292–294]

Cost-effective preventive treatments and strategies including DOT proved impactful in increasing treatment completion rates and managing comorbid conditions. These should be routinely available in Pakistan.

Discussion

We believe this study represents the first extensive examination of the Global Research Agenda for AMR in human health and specific to any LMIC. In this case, highlighting key areas for research gaps in AMR within Pakistan to meet NAP and UN GA goals.

Notably, the studies predominantly originate from urban centers, reflecting a common trend in global health research where major cities act as focal points for scientific inquiry, owing to their better healthcare infrastructures and access to resources. In addition, Universities are typically located in urban versus rural areas. Geographically, the concentration of AMR research in urban areas highlights a significant gap in our understanding of AMR dynamics in rural settings.[306] This disparity suggests potential variations in AMR prevalence and management, which may be driven by differences in healthcare access, community health practices, and local policy enforcement.[307,308] For instance, we are aware that there can be greater purchasing of antibiotics without a prescription in rural areas of LMICs where there are high co-payment levels due to the costs and time involved with seeing HCPs in primary care clinics versus the convenience of community pharmacies.[69,309,310] In addition, community pharmacists may often be the principal HCP available in rural settings.[36,69,311] Addressing this gap is crucial for developing region-specific strategies that are inclusive of rural healthcare dynamics. Implementing comprehensive strategies including preventive measures, rapid diagnostics, awareness strategies among patients and HCPs and implementing pertinent ASPs, will significantly reduce AMR levels and the subsequent deaths caused by resistant pathogens in Pakistan.[307]

The GHRA prioritizes WASH practices and infection prevention measures as essential for reducing AMR burden in community and healthcare settings. Among the studies evaluated in Pakistan,[72–75,82] adopting hand hygiene interventions as part of IPC practices appeared to result in a reduction in antibiotic associated diarrhea. However, there was insufficient knowledge and lack of awareness among HCWs regarding hand hygiene in Pakistan,[83,84] alongside an absence of IPC standards in Islamabad public hospitals in 2019. This also needs addressing going forward to reduce AMR in the future.

Encouragingly, during a catch-up campaign in Karachi, the Typhoid Conjugate Vaccine (TCV) proved to be 98% effective for children 9 months-15 yr during 2020.[91] Similar findings have also been observed in other LMICs including Bangladesh, Zimbabwe, and Malawi. They also revealed the efficacy of existing vaccines including PCV, TCV against pneumonia and typhoid resistant pathogens in children, adults and neonates.[312–317] As a result, it is imperative that these vaccines be encouraged going forward in Pakistan.[318]

Table 5 Theme 5 of GHRA-Drug-Resistant TB

Sub Themes of GHRA	Research Priority Areas Covered as per GHRA	References	Year of Published Studies	No. of Studies	Targeted Population	Key Findings	Study Highlights
Prevention	Area 34 Impact of TB preventive practices on infection prevention, recurrence, on incidence of drug-resistant TB	[263–270]	1998-2023	8	Index patients, adults, infants, children residing with index patients	Preventive treatment with fluoroquinolones and BCG vaccine proved effective against pulmonary and extra pulmonary TB especially among children	Studies showing the preventive measures for reduction of TB burden
Diagnosis	Area 35 Detection of drug resistance among people with pulmonary and extra-pulmonary TB from non-respiratory specimens	[271–285]	2002-2021	15	Patients (inpatients & outpatients) samples	• Detection by conventional diagnostic methods along with molecular assays Xpert MTB/RIF assay, Genotype MTBDRplus and MTBDRsl assay • Phenotypic and genotypic detection by probe line assay • Phenotypic detection by BACTEC MGIT 960 medium • Direct detection by FAST Plaque TB assay • Molecular assay by drug proportion method	Studies assessing the overall performance of TB diagnostics methods
	Area 36 Optimal diagnostic and treatment models to improve drug-resistant TB detection especially among vulnerable population	[286–289]	2004-2019	4	Patients' samples	• Improved TB case detection by models like public private mix model • Detection by acid –fast bacilli among prisoners' Serological test for TB detection especially among co morbid patients like HIV, hepatitis	Studies showing effective and feasible methods adopted for TB detection

(*Continued*)

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Table 5 (Continued).

Sub Themes of GHRA	Research Priority Areas Covered as per GHRA	References	Year of Published Studies	No. of Studies	Targeted Population	Key Findings	Study Highlights
Treatment and care	Area 37 Effective, optimally dosed and shorter combination regimen for treating all forms of drug-resistant TB	[201, 290, 291]	2021-2023	3	Patients, children, adolescents	Improved treatment outcomes by • Shorter regimen with isoniazid and combination regimen with isoniazid + rifapentine • Use of Antitubercular therapy (ATT) and antiretroviral therapy (ART) co-administration among co-infected patients	Studies demonstrating the effectiveness of TB treatment with shorter combination regimen
	Area 38 Cost effective, safest and shortest duration TB preventive treatment for contact of people with drug-resistant TB	[292–297]	2006-2023	6	Patients	Use of shorter treatment regimen, interventions like educational, nutritional, psychological and economic support showed successful treatment completion rate among TB patients	Studies showing the efficacy of safe TB treatment regimen prescribed for short duration
	Area 39 Strategies to improve treatment outcomes among vulnerable population and those who have known risk factors and co-occurring conditions	[298–302]	2001-2021	5	Patients	DOT strategy, use of 2nd line antibiotics was adopted to improve treatment outcomes not only among TB patients but also in co morbid patients like with diabetes, depression, HIV	Studies showing the use of various strategies like directly observed treatment, short course (DOTS) for improving outcomes
	Area 40 Safety of currently used WHO recommended treatment regimen including combinations with bedaquiline, delamanid and/ or pretomanid for drug resistant TB	[303–305]	2021-2022	3	Children and patients	Conventional treatment without bedaquiline showed a high death rate, treatment failure rate while addition of bedaquiline and delamanid with longer treatment regimen result in high treatment completion rate	Studies demonstrating the effectiveness of combination treatment regimen with bedaquiline and delamanid
Implications	Lack of preventive measures in rural areas, inaccurate diagnostics, partial or incomplete compliance to existing TB treatment protocol emphasize the importance of rapid detection methods, DOTS strategy and evidence-based use of WHO recommended TB treatment regimen						

One significant barrier to AMR management in Pakistan is the limited availability and usage of reliable diagnostic facilities including culture and susceptibility testing within hospitals, including even within tertiary hospitals.[62,319] This diagnostic gap leads to high dependence on empirical prescribing across facilities in Pakistan, a common trend seen also across many LMICs.[67,68,320] Diagnostic advancements, including point-of-care testing and phenotypic and genotypic methods for pathogen resistance identification, have significantly contributed to AMR management.[321] The use of rapid diagnostics helps differentiate bacterial from viral infections, minimizing unnecessary antibiotic prescriptions. Different biomarkers levels including Procalcitonin (PCT), C-reactive protein (CRP) levels and total leukocyte count (TLC) have also been used to discriminate between bacterial from viral infections.[322] These are possibilities for Pakistan in the future to achieve its NAP goals.

Our findings also reveal appreciable AMR level in Pakistan, which again needs to be urgently addressed for Pakistan to achieve its NAP as well as UN GA goals. This includes a high prevalence of resistant pathogens including *K. pneumoniae, S. Typhi, E. coli*, and *S. aureus*, which have been documented to cause bloodstream, respiratory, and abdominal infections.[323–325] This aligns with findings from neighboring countries, including India and Bangladesh, where overuse of antibiotics, particularly in urban healthcare centers, has resulted in similar high rates of resistant bacterial pathogens.[326,327] In Pakistan, *S. Typhi* pathogens were found to be resistant against 1st and 2nd line antibiotics, which incorporate nalidixic acid, azithromycin, and 3rd generation cephalosporins detected by phenotypic and genotypic methods.[99–101] However, in another study, *S. Typhi* pathogens were found to be resistant against chloramphenicol, ampicillin and ciprofloxacin while showing a higher susceptibility against azithromycin, imipenem and meropenem detected by molecular characterization.[102] Resistant rates need continual monitoring to guide future empiric prescribing in the locality.

Epidemiological data regarding resistant bacterial and fungal pathogens has also been used to understand how AMR evolves and spreads over time.[328] In addition, how AMR impacts on public health both immediately and in future. Some common short and long-term effects include an increase in drug resistance cases of *S. Typhi* from MDR to XDR.[232–234] Alongside this, an increase in healthcare-associated infections among hospitalized patients in Pakistan, including among neonates and children.[235,236] Alongside this, increased risk of side-effects among medical inpatients.[237] Due to an increase in resistant *E. coli*, which is the causative agent for urinary tract infections (UTIs), limited treatment options are now available in Pakistan with imipenem, amikacin, and tazobactam.[118–121] However, in Nishtar Hospital of Multan, the susceptibility patterns were different. *E. coli* showed 80% resistance to imipenem; however, tazocin, nitrofurantoin, and amikacin were found as highly susceptible antibiotics in urinary tract infections.[122] We believe these different susceptibility patterns are due to different antibiotic usage practices and resistance profiles of bacteria in the different regions of Pakistan. This knowledge is essential to help health-care providers select effective antibiotic treatments for the different bacterial infections they see in the different regions in Pakistan. The different resistance patterns identified can subsequently be incorporated into revised WHO AWaRe guidance by locality and region in Pakistan.[24,25,27]

The epidemiological data for urinary, respiratory and blood stream infections in different cities in Pakistan were compared. For UTIs, *E. coli* was found as causative agent followed by *K. pneumoniae* and its prevalence was lower in males (8.9%) compared to females (13.8%) in Khyber Pakhtunkhwa.[208] Similar results were obtained in Gilgit Baltistan in which the prevalence of UTIs in males was 33.6% versus females at 66.5%.[209] The rising UTI burden, especially in females, was also observed globally with *E. coli* found as the most predominant causative organism.[329–332] Most prevalent causative agents for blood stream infections in Pakistan include coagulase negative *Staphylococci* at 33.1%, *S. aureus* at 23.1%,[210] and *P. aeruginosa* and *S. Typhi* at 21.6%, with the prevalence of blood stream infections high in children aged ≤48 months (69.30%) or those with low socioeconomic status (56.8%).[211] A varied prevalence pattern of respiratory tract infections (RTIs) was observed among different age groups in Pakistan, which included 61.6% in males, 38.4% in females and 36.2% in infants aged ≤6 months.[212] However, adult males with a low socioeconomic status (54.16%) and infected with UTIs were more prone to RTIs.[213] Different surveillance methods, including active, passive, prospective, population based and hospital-based surveillance, have been used to estimate the epidemiology of different pathogens in Pakistan. These include *Proteus* spp, *Acinetobacter* spp, *K. pneumoniae, Haemophilus influenza* type B, *S. pneumonia, Neisseria meningitides, Shigella* spp, *S. Typhi* and *Paratyphi* in Pakistan.[183,184,227–231]

Epidemiological data of fungal pathogens indicate a high prevalence *Candida albicans* in vulvovaginal candidiasis (37.2%) and oropharyngeal candidiasis (68.6%). Alongside this, a high prevalence of vulvovaginal candidiasis among females aged 26–30 (65.6%) as well as in pregnant women (43.2%).[218] A few studies have demonstrated the effectiveness of antifungals including itraconazole for vaginal candidiasis and voriconazole for mycetoma, which emphasize the importance of choosing the appropriate anti-fungal regimen for treatment based on resistance patterns to specific fungi.[202–204] Otherwise, rates of resistant fungal pathogens like *Candida auris* will continue to grow if antifungal agents are prescribed inappropriately.[333]

Epidemiological data from hospitals has also shown that hospital microbiomes play an important role in infection transmission either by high colonization with vancomycin-resistant and vancomycin susceptible *enterococci*[220] or through transmission of *S aureus* by hospital personnel.[221] There was also an appreciable presence of *S. aureus*, resistant vancomycin strains, and MRSA among hospitalized patients in Pakistan,[222] with tourniquets the potential transmission source for MRSA.[223]

There are also concerns for the management of sexually transmitted diseases (STDs) in Pakistan, including gonorrhea, for which there was an increase in the resistant pathogen rate from 0% in 1992 to 70.8% in 2009.[239] Alongside increased infertility rates,[240] and an increased risk of pelvic inflammatory disease among women infected with *Chlamydia trachomatis* infection was also observed.[241] This increase in antibiotic resistant strains to STDs in Pakistan, particularly gonorrhea, necessities urgent action to develop new antibiotic treatment strategies. About 29.17% susceptibility of ciprofloxacin against *N. gonorrhoeae* suggests its use as first line therapy is currently in question in Pakistan.[148] This is in contrast with the findings of Karachi, which recommend the use of ceftriaxone and spectinomycin as first line therapy in gonorrhea due to 100% susceptibility to *N. gonorrhoeae*. Alongside this, the exclusion of ciprofloxacin from 1st line antibiotic therapy owing to 86% resistance.[149] In a study conducted in Kohat and Bannu, the response rate for 2g spectinomycin injection was high as compared to a 500 g ceftriaxone injection for *N. gonorrhoeae*. However, there was concern that spectinomycin must be used cautiously because it is contraindicated in pregnancy.[206] These studies implicate that the current treatment guidelines for STDs need to be updated in Pakistan to address emerging resistance patterns and to ensure effective treatment.

Previously, the implementation of ASPs has faced barriers across LMICs including a lack of funding and pertinent personnel. However, this is now changing in LMICs with an appreciable number of ASPs now being implemented across sectors.[68,71,242,334–337] When an ASP was introduced for patients who were on carbapenem therapy in Karachi, there was an improvement in antibiotic use, duration, and dose in 84.6% of patients, with an acceptance rate of 87.3%.[249] Other ASPs in Pakistan have also resulted in a reduction in irrational antimicrobial prescribing and dispensing across sectors alongside improved communication between prescribers and pharmacists to improve future prescribing.[243,338] High rates of antibiotic prescribing among for instance pediatric patients in Pakistan, with the majority from the Watch group (72.1%), coupled with a limited number from Reserve group (2.2%), similar to other studies in Pakistan, demand robust ASPs going forward.[318,339] However, a current concern is the lack of knowledge and application of ASPs among physicians treating pediatric patients even in tertiary hospitals in Pakistan. Consequently, ASPs should be urgently instigated in these hospitals, with trainee physicians in these hospitals becoming the prescribers of tomorrow when qualified.[340] In addition, the effectiveness of ASPs typically requires the need for DTCs for approval for the prescribing of restricted antibiotics in formularies to enhance their appropriate use.[153,155,156] However, a concern going forward is the appreciable dispensing of non-prescribed antibiotics especially in Punjab (96.9%) Swat (78.4%), Lahore (67.1% for diarrhea and 50.9% for URTI) and Karachi (52%) due to a lack of education among key stakeholder groups and the absence of guidelines relating to their rational use.[33,163,164] Alongside this, high rates of empiric antibiotic prescribing were the main cause of unnecessary antibiotic use, with metronidazole, ciprofloxacin, ceftriaxone and vancomycin all highly consumed antibiotics across the sectors.[35,46,163,165,166,172]

As mentioned, another identified area of concern in Pakistan was generally the high prescribing of antibiotics, particularly those from the Watch group, among children and neonates.[172,173,318] The overuse of antibiotics from the Watch group has also been observed in other LMICs, enhanced by dispensing of antibiotics without a prescription, which demands targeted AWaRe-based ASPs, with increasing use of the AWaRe system in practice to document utilization patterns.[71,341,342] Similar results were obtained from the study involving 76 countries, which also showed a high consumption rate of antibiotics from the Watch

group. As a result, meeting the previous WHO target of at least 60% of antibiotic consumption being from the Access group is difficult to achieve with increasing AMR and the need for new antibiotics.[12,26,71,343] There are also concerns in Pakistan with the appreciable availability of antibiotics from the Watch list, including multiple branded generics, exacerbating their use.[344] This also needs addressing going forward to help attain UN GA targets for Access antibiotics.[28] Several studies in Pakistan have also highlighted the importance of education regarding antibiotics and AMR. Alongside this, how increased awareness through educational campaigns, changes in behavior, have helped to reduce antibiotic resistance and resulted in a reduction of nosocomial infections.[71,206,254,338,341] Improved surveillance as well as ASPs have also helped.[67,68,148,244]

Pakistan currently faces a high burden of drug-resistant TB, exacerbated by incomplete adherence to treatment protocols and limited access to timely diagnostics. Different studies were conducted to evaluate the efficacy of different preventative therapies for drug-resistant TB. In different cities of Pakistan, the BCG vaccine scar presence (55.19%) or absence (44.18%) ratio was less than one, which results in the lack of effectiveness of BCG vaccine against TB.[267] Although in other studies conducted in Greenland, Kazakhstan, and the UK BCG vaccine was effective against *M. tuberculosis*.[345–347]The efficacy of fluoroquinolones-based preventive therapy was demonstrated by a 70% complete cure rate with no side-effects among index patients in Karachi,[263] coupled with a 65% reduction in TB exposure rate among children and adults residing with index patients.[264,345–347]

Different conventional susceptibility testing methods, which include MTBDRplus and MTBDRsl assays, along with GeneXpert MTB/RIF assay, were used to detect gene mutation that confer drug resistance in *M. tuberculosis*.[271,272] In a study conducted in Karachi, the rrs gene mutation was shown by all XDR TB strains, and this mutation was responsible for conferring resistance to amikacin and kanamycin.[277] The rpoB gene mutation was responsible for conferring resistance to rifampicin isolates detected by phenotypic methods,[278] especially important in areas with high TB burden. However, there is still a need for specific probe assays,[271] improvement in infrastructure,[275] and the introduction of the GeneXpert MTB/RIF assay especially in rural areas in Pakistan, for improved diagnosis and management of TB in the country.[279]

Regarding the treatment of drug-resistant TB, different strategies have been introduced in Pakistan to try and address the problem. These include both short treatment regimen, long treatment regimen and directly observed treatment (DOT) strategies. The first study in Pakistan to assess the outcomes of the short treatment regimen for TB treatment was undertaken between 2018 and 2019. This showed an 87.3% treatment success rate,[292] with only a 73.2% treatment success with the long treatment regimen.[294] Having said this, treatment with the longer treatment regimen of bedaquiline and delamanid resulted in an 81.7% treatment success rate, 18.3% treatment failure rate and 16.4% death rate among rifampicin resistant MDR-TB patients.[303] Encouragingly, a study in eight TB facilities of Karachi showed a treatment completion rate higher than 90% among 678 household contacts with one month of daily isoniazid and rifapentine (1HP).[290] The findings of these studies were consistent with the findings from other countries showing the efficacy of a shorter treatment regimen for patients with TB in terms of the treatment completion rate, successful treatment outcomes, and lower costs compared with the longer treatment regimen.[348–352] A DOT strategy was more effective, with a 64% cure rate,[298] as well as costs for key groups.[299] However, owing to higher costs and time, including those associated with travelling to clinics, the DOT strategy was less effective for the poor with monthly incomes of less than $7.2 $ as the cost of DOT was more than $10.8.[295] Contrastingly, community-based DOT was seen as more effective, with enhanced accessibility for patients living in remote areas, as there was enhanced adherence especially when administered within community compared with the health facility-based DOT.[353–355] When drivers and risk factors for unfavorable TB outcomes were checked, being male above 60 years and having co-morbidities including Human Immunodeficiency Virus (HIV), diabetes, and XDR-TB, and a treatment history with 1st and 2nd line anti-TB drugs, were found as key drivers of drug-resistant TB in Pakistan.[300,304] All these factors highlight the need of comprehensive care strategies and targeted interventions for the prevention of drug -resistant TB in vulnerable population in Pakistan. This aspect will be explored in future studies.

Suggested Next Steps

Several activities have evolved from the findings of this review to help reduce AMR in Pakistan. These are summarized in Table 6.

We will be following up a number of these suggestions in future studies.

Table 6 Recommendations

Theme	Recommendations	Target Stakeholders	Expected Outcomes	Priority Level
Prevention	- Enhance WASH Initiatives: Strengthen WASH programs in healthcare and community settings.	Government, NGOs, Community Leaders	Reduced incidence of healthcare-associated and community-acquired infections.	High
	- Expand Infection Prevention Controls: Develop and enforce stricter IPC measures and provide routine training for healthcare workers.	Hospital Administrators, Healthcare Workers	Improved compliance with IPC protocols, reducing the spread of AMR and use of antimicrobials as prophylaxis.	Very High
Diagnosis	- Broaden Access to Diagnostic Tools: Increase accessibility to advanced diagnostic tools, especially in rural areas.	Government, Healthcare Providers	Enhanced early detection and targeted therapy based on antibiogram.	High
	- Integrate Diagnostic Training: Incorporate training on the use and interpretation of diagnostic tests into medical education.	Educational Institutions, Healthcare Providers	Increased accuracy and efficiency in AMR diagnosis.	Medium
Treatment and Care	- Strengthen ASPs: Enhance the implementation of antimicrobial stewardship programs across all healthcare facilities.	Hospitals, Clinics Community Pharmacies	Optimized the use of available antimicrobials, reducing the inappropriate sale of antibiotics without a prescription especially Watch antibiotics through reducing their availability enhanced by targeted educational programs among community pharmacists and patients	Very High
	- Promote Evidence-Based Practices: Encourage the use of evidence-based guidelines for antibiotic use among healthcare providers.	Healthcare Providers, Policy Makers	Routine adoption of AWaRe antibiotic classification system and the WHO AWaRe book guidance by all healthcare workers to help meet UN GA target of 70% Access antibiotics	Very High
Cross-Cutting Issues	- Implement National Surveillance Systems: Develop comprehensive AMR surveillance systems to monitor and respond to AMR trends.	Government, Research Institutions	Better informed public health strategies and resource allocation based on accurate AMR data.	High
	- Policy and Regulation Enforcement: Ensure consistent enforcement of existing policies and develop new regulations as needed.	Policy Makers, Regulatory Bodies	Stronger regulatory compliance and more effective containment of AMR. This includes Regulatory Agencies focusing on priority antibiotics for registration	Very High
	- Public Health Campaigns: Launch extensive public health campaigns to raise awareness about AMR and promote responsible antibiotic use.	Government, Public Health Officials	Increased public and professional awareness of antibiotics and AMR leading to more judicious use of antimicrobial agents - especially with the growing influence of patients requesting antibiotics in Pakistan	Medium to High

(*Continued*)

Table 6 (Continued).

Theme	Recommendations	Target Stakeholders	Expected Outcomes	Priority Level
TB Specific	- Enhance TB Prevention Measures: Implement targeted interventions to reduce transmission and recurrence of TB, particularly drug-resistant strains.	Government, Healthcare Providers	Reduced transmission and improved management of TB, particularly drug-resistant forms.	High
	- Improve TB Diagnostic Tools and Strategies: Enhance the use of rapid diagnostic tests for early and accurate detection of TB and drug-resistant TB.	Healthcare Providers, Diagnostic Labs	Faster and more accurate diagnosis of TB, leading to timely and effective treatment interventions.	High
	- Optimize TB Treatment Protocols: Develop and disseminate updated guidelines for the treatment of all forms of drug-resistant TB.	Healthcare Providers, Policy Makers	Improved treatment outcomes and reduced TB mortality rates through effective use of treatment protocols.	High

We are aware our approach has several limitations that may influence the interpretation of our findings. Primarily, as a narrative review, we focused on synthesizing broad thematic areas within the published literature, which may have led to the exclusion of certain studies, particularly those not indexed in major databases. This methodological approach, while effective for mapping out the landscape of AMR research in Pakistan, might have missed nuanced details or emerging research in academic publications. The selection criteria also prioritized published studies, potentially overlooking insights from unpublished research and ongoing projects that could offer valuable perspectives on AMR strategies. Additionally, the geographical representation of AMR research within Pakistan might be skewed towards more accessible urban centers, thereby under representing rural and remote areas where AMR challenges may be greater. The review also relied on the availability and accuracy of reported data that may not capture the full spectrum of AMR-related initiatives, or the nuances of their implementation across different regions. Finally, the evolving nature of AMR and the continuous emergence of new resistance patterns, necessitate ongoing research, suggesting that our review, while extensive, represents a snapshot within a dynamic field of study. However, despite these limitations, we believe that our findings will be of interest to all the key stakeholders in Pakistan.

Conclusion

Overall, current research regarding research activities relating to AMR in Pakistan is primarily concentrated in major urban centers across a limited number of cities including Karachi, Islamabad, Lahore and Rawalpindi. This is a concern going forward. Alongside this, GHRA's research priority areas were addressed in only limited scope across various cities. This included the fact that studies focusing on prevention were conducted in Karachi, studies related to diagnosis were concentrated in Lahore, studies related to treatment and care took place in both Karachi and Lahore and studies related to cross-cutting and drug-resistant TB were carried out in Karachi. As a result, a number of gaps and potential activities were identified to address AMR in Pakistan going forward. These included addressing current poor IPC practices, absence or incomplete implementation of AMS activities alongside typically a lack of ASPs across sectors according to WHO AWaRe classification and guidance, lack of laboratory surveillance, educational gaps among all key stakeholder groups, poor diagnostic accuracy, lack of enhanced infrastructure, and the loss of TB treatment efficacy. To address these challenges, Pakistan's second National Action Plan emphasizes comprehensive IPC strategies, improved surveillance systems and ASPs, as well as educational campaigns aimed at all key stakeholder groups including physicians, community pharmacists and patients. Pakistan must prioritize its policies that support AMR sustainable practices and international collaboration. The pathway forward includes leveraging global partnerships to share knowledge, resources, and strategies, ensuring that Pakistan can effectively contribute to and benefit from the global efforts to mitigate AMR. We will be following this up in future research projects.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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References

1. Gautam A. Antimicrobial resistance: the next probable pandemic. *JNMA*. 2022;60(246):225. doi:10.31729/jnma.7174
2. Murray CJ, Ikuta KS, Sharara F, et al. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. *The Lancet*. 2022;399 (10325):629–655. doi:10.1016/S0140-6736(21)02724-0
3. Sartorius B, Gray AP, Weaver ND, et al. The burden of bacterial antimicrobial resistance in the WHO African region in 2019: a cross-country systematic analysis. *The Lancet Global Health*. 2024;12(2):e201–e216. doi:10.1016/S2214-109X(23)00539-9
4. Naghavi M, Vollset SE, Ikuta KS, et al. Global burden of bacterial antimicrobial resistance 1990–2021: a systematic analysis with forecasts to 2050. *The Lancet*. 2024;404(10459):1199–1226. doi:10.1016/S0140-6736(24)01867-1
5. Mendelson M, Lewnard JA, Sharland M, et al. Ensuring progress on sustainable access to effective antibiotics at the 2024 UN General Assembly: a target-based approach. *The Lancet*. 2024;403(10443):2551–2564. doi:10.1016/S0140-6736(24)01019-5
6. Allel K, Day L, Hamilton A, et al. Global antimicrobial-resistance drivers: an ecological country-level study at the human–animal interface. *The Lancet Planetary Health*. 2023;7(4):e291–e303. doi:10.1016/S2542-5196(23)00026-8
7. Patel J, Harant A, Fernandes G, et al. Measuring the global response to antimicrobial resistance, 2020–21: a systematic governance analysis of 114 countries. *The Lancet Infectious Diseases*. 2023;23(6):706–718. doi:10.1016/S1473-3099(22)00796-4
8. World Bank Group. Pulling together to beat superbugs: knowledge and implementation gaps in addressing antimicrobial resistance. World Bank. 2019. Available from: https://www.worldbank.org/en/topic/agriculture/publication/pulling-together-to-beat-superbugs-knowledge-and-implementation-gaps-in-addressing-antimicrobial-resistance. Accessed July 14, 2025.
9. Hofer U. The cost of antimicrobial resistance. *Nature Reviews Microbiology*. 2019;17(1):3. doi:10.1038/s41579-018-0125-x
10. Naylor NR, Atun R, Zhu N, et al. Estimating the burden of antimicrobial resistance: a systematic literature review. *Antimicrobial Resistance & Infection Control*. 2018;7(1):58. doi:10.1186/s13756-018-0336-y
11. Collignon P, Beggs JJ, Walsh TR, Gandra S, Laxminarayan R. Anthropological and socioeconomic factors contributing to global antimicrobial resistance: a univariate and multivariable analysis. *The Lancet Planetary Health*. 2018;2(9):e398–e405. doi:10.1016/S2542-5196(18)30186-4
12. Klein EY, Milkowska-Shibata M, Tseng KK, et al. Assessment of WHO antibiotic consumption and access targets in 76 countries, 2000–15: an analysis of pharmaceutical sales data. *The Lancet Infectious Diseases*. 2021;21(1):107–115. doi:10.1016/S1473-3099(20)30332-7
13. Fisher MC, Denning DW. The WHO fungal priority pathogens list as a game-changer. *Nature Reviews Microbiology*. 2023;21(4):211–212. doi:10.1038/s41579-023-00861-x
14. Banerjee S, Denning DW, Chakrabarti A. One Health aspects & priority roadmap for fungal diseases: a mini-review. *Indian Journal of Medical Research*. 2021;153(3):311–319. doi:10.4103/ijmr.IJMR_768_21
15. de Oliveira HC, Bezerra BT, Rodrigues ML. Antifungal development and the urgency of minimizing the impact of fungal diseases on public health. *ACS Bio & Med Chem Au*. 2022;3(2):137–146. doi:10.1021/acsbiomedchemau.2c00055
16. Mendelson M, Matsoso MP. The World Health Organization Global Action Plan for antimicrobial resistance. *S Afr Med J*. 2015;105(5):354. doi:10.7196/samj.9644
17. Saleem Z, Godman B, Azhar F, et al. Progress on the national action plan of Pakistan on antimicrobial resistance (AMR): a narrative review and the implications. *Expert Review of Anti-Infective Therapy*. 2022;20(1):71–93. doi:10.1080/14787210.2021.1935238
18. Saleem Z, Hassali MA, Hashmi FK. Pakistan's national action plan for antimicrobial resistance: translating ideas into reality. *The Lancet Infectious Diseases*. 2018;18(10):1066–1067. doi:10.1016/S1473-3099(18)30516-4
19. Charani E, Mendelson M, Pallett SJ, et al. An analysis of existing national action plans for antimicrobial resistance—gaps and opportunities in strategies optimising antibiotic use in human populations. *The Lancet Global Health*. 2023;11(3):e466–e474. doi:10.1016/S2214-109X(23) 00019-0
20. Godman B, Egwuenu A, Wesangula E, et al. Tackling antimicrobial resistance across sub-Saharan Africa: current challenges and implications for the future. *Expert Opinion on Drug Safety*. 2022;21(8):1089–1111. doi:10.1080/14740338.2022.2106368
21. Iwu CD, Patrick SM. An insight into the implementation of the global action plan on antimicrobial resistance in the WHO African region: a roadmap for action. *International Journal of Antimicrobial Agents*. 2021;58(4):106411. doi:10.1016/j.ijantimicag.2021.106411
22. Chua AQ, Verma M, Hsu LY, Legido-Quigley H. An analysis of national action plans on antimicrobial resistance in Southeast Asia using a governance framework approach. *The Lancet Regional Health–Western Pacific*. 2021;7:100084. doi:10.1016/j.lanwpc.2020.100084
23. Hamers RL, Cassini A, Asadinia KS, Bertagnolio S. Developing a priority global research agenda for antimicrobial resistance in the human health sector: protocol for a scoping review. *BMJ open*. 2022;12(6):e060553. doi:10.1136/bmjopen-2021-060553
24. Sharland M, Zanichelli V, Ombajo LA, et al. The WHO essential medicines list AWaRe book: from a list to a quality improvement system. *Clinical Microbiology and Infection*. 2022;28(12):1533–1535. doi:10.1016/j.cmi.2022.08.009

25. Sharland M, Gandra S, Huttner B, et al. Encouraging AWaRe-ness and discouraging inappropriate antibiotic use—the new 2019 Essential Medicines List becomes a global antibiotic stewardship tool. *The Lancet Infectious Diseases*. 2019;19(12):1278–1280. doi:10.1016/S1473-3099(19)30532-8
26. Sulis G, Sayood S, Katukoori S, et al. Exposure to World Health Organization's AWaRe antibiotics and isolation of multidrug resistant bacteria: a systematic review and meta-analysis. *Clinical Microbiology and Infection*. 2022;28(9):1193–1202. doi:10.1016/j.cmi.2022.03.014
27. Moja L, Zanichelli V, Mertz D, et al. WHO's essential medicines and AWaRe: recommendations on first-and second-choice antibiotics for empiric treatment of clinical infections. *Clinical Microbiology and Infection*. 2024;30:S1–S51. doi:10.1016/j.cmi.2024.02.003
28. United Nations. UN general assembly high-level meeting on antimicrobial resistance 2024. Available from: https://www.un.org/pga/wp-content/uploads/sites/108/2024/09/FINAL-Text-AMR-to-PGA.pdf. Accessed March 10, 2025.
29. Pakistan Antimicrobial Resistance Surveillance System Surveillance Report. 2017-2018. Available from: https://www.nih.org.pk/wp-content/uploads/2020/03/Report_2017-2018-NIH-Final.pdf. Accessed March 10, 2025.
30. NIH Islamabad. Antimicrobial Resistance (AMR) Quarterly Newsletter - AMR Virtual Journal Club. 2021. Available from: https://www.nih.org.pk/wp-content/uploads/2021/09/AMR-Quarterly-Newsletter-Vol-VI.pdf. Accessed July 14, 2025.
31. Qamar MU. Exploring a one health approach to AMR in Pakistan. microcosm fall 2023. Available from: https://asm.org:443/magazine/2023/fall/exploring-a-one-health-approach-to-amr-in-pakistan. Accessed July 14, 2025.
32. The News Web Desk. Economic survey 2021-22: Pakistan's economy grew by 6%, says Finance Minister Miftah Ismail. Available from: https://www.thenews.com.pk/latest/964686-live-govt-launches-economic-survey-of-pakistan-2021-22. Accessed April 10, 2025.
33. Saleem Z, Hassali MA, Godman B, et al. Sale of WHO AWaRe groups antibiotics without a prescription in Pakistan: a simulated client study. *Journal of Pharmaceutical Policy and Practice*. 2020;13(1):1–8. doi:10.1186/s40545-020-00233-3
34. Aslam A, Zin CS, Jamshed S, et al. Self-medication with antibiotics: prevalence, practices and related factors among the Pakistani public. *Antibiotics*. 2022;11(6):795. doi:10.3390/antibiotics11060795
35. Malik UR, Chang J, Hashmi F, et al. A simulated client exploration of nonprescription dispensing of antibiotics at drugstores for pediatric acute diarrhea and upper respiratory infection in Lahore, Pakistan. *Infection and Drug Resistance*. 2021;14:1129–1140. doi:10.2147/IDR.S301812
36. Saleem Z, Sono TM, Godman B. *Concerns with Current Drug Laws Regarding the Purchasing Antibiotics Without a Prescription in Pakistan; Ways Forward to Assist the National Action Plan*. Expert Review of Anti-Infective Therapy; 2023:1163–1165.
37. Ali M, Abbasi BH, Ahmad N, Fazal H, Khan J, Ali SS. Over-the-counter medicines in Pakistan: misuse and overuse. *The Lancet*. 2020;395(10218):116. doi:10.1016/S0140-6736(19)32999-X
38. Javaid N, Sultana Q, Rasool K, et al. Trends in antimicrobial resistance amongst pathogens isolated from blood and cerebrospinal fluid cultures in Pakistan (2011-2015): a retrospective cross-sectional study. *PLoS One*. 2021;16(4):e0250226. doi:10.1371/journal.pone.0250226
39. Ali S, Khan MT, Khan AS, et al. Prevalence of multi-drug resistant Mycobacterium tuberculosis in Khyber Pakhtunkhwa–a high tuberculosis endemic area of Pakistan. *Polish Journal of Microbiology*. 2020;69(2):133–137. doi:10.33073/pjm-2020-005
40. Jabeen F, Khan Z, Sohail M, Tahir A, Tipu I, Murtaza Saleem HG. Antibiotic Resistance Pattern Of Acinetobacter Baumannii Isolated From Bacteremia Patients In Pakistan. *J Ayub Med College Abbottabad-Pakistan*. 2022;34(1):1.
41. Iqbal Z, Sheikh AS, Basheer A, et al. Antibiotic Drug Resistance Pattern of Uropathogens in Pediatric Patients in Pakistani Population. *Antibiotics*. 2023;12(2):395. doi:10.3390/antibiotics12020395
42. Saleem Z, Haseeb A, Abuhussain SSA, et al. Antibiotic susceptibility surveillance in the Punjab Province of Pakistan: findings and implications. *Medicina*. 2023;59(7):1215. doi:10.3390/medicina59071215
43. Alam M, Saleem Z, Haseeb A, et al. Tackling Antimicrobial Resistance in Primary Care Facilities across Pakistan: current Challenges and Implications for the Future. *Journal of Infection and Public Health*. 2023;16:97–110. doi:10.1016/j.jiph.2023.10.046
44. Saleem AF, Pethani A. Antimicrobial Stewardship-Do we need it in Pakistan? *JPMA*. 2020;70(12B):2449–2453. doi:10.47391/JPMA.1084
45. Hayat K, Mustafa ZU, Ikram MN, et al. Perception, attitude, and confidence of physicians about antimicrobial resistance and antimicrobial prescribing among COVID-19 patients: a cross-sectional study from Punjab, Pakistan. *Frontiers in Pharmacology*. 2022;12:794453. doi:10.3389/fphar.2021.794453
46. Ambreen S, Safdar N, Ikram A, et al. Point Prevalence Survey of Antimicrobial Use in Selected Tertiary Care Hospitals of Pakistan Using WHO Methodology: results and Inferences. *Medicina*. 2023;59(6):1102. doi:10.3390/medicina59061102
47. Mustafa ZU, Suleman A, Masood MF, et al. Predictors and outcomes of patients with COVID-19 admitted to intensive care units in Pakistan and the development of nosocomial fungal infections: findings and implications. *IJID Regions*. 2024;13:100445. doi:10.1016/j.ijregi.2024.100445
48. Gul B, Sana M, Saleem A, et al. Antimicrobial dispensing practices during COVID-19 and the implications for Pakistan. *Antibiotics*. 2023;12(6):1018. doi:10.3390/antibiotics12061018
49. IHME. The burden of antimicrobial resistance (AMR) in Pakistan. 2023. Available from: https://www.healthdata.org/sites/default/files/2023-09/Pakistan.pdf. Accessed March 10, 2023.
50. NTP. *National TB Control Programme*. 2022. Available from: https://www.cmu.gov.pk/ntp-national-tb-control-programme/#:~:text=TB%20Programme%20is%20providing%20free%20of%20Cost%20state,more%20than%20424%2C000%20TB%20cases%20were%20successfully%20treated. Accessed April 10, 2025.
51. Fisher MC, Alastruey-Izquierdo A, Berman J, et al. Tackling the emerging threat of antifungal resistance to human health. *Nature Reviews Microbiology*. 2022;20(9):557–571. doi:10.1038/s41579-022-00720-1
52. Rayens E, Norris KA. *Prevalence and Healthcare Burden of Fungal Infections in the United States, 2018*. Open Forum Infect Dis. 2022;9(1):ofab593. doi:10.1093/ofid/ofab593
53. Hendrickson JA, Hu C, Aitken SL, Beyda N. Antifungal resistance: a concerning trend for the present and future. *Current Infectious Disease Reports*. 2019;21(12):1–8. doi:10.1007/s11908-019-0702-9
54. Saleem F, Jabeen K, Farooqi J, Fasih N, Zafar A. Clinical Profile of Patients and Antifungal Susceptibility Pattern of Invasive Cryptococcus neoformans Isolates from Pakistan. *Infectious Diseases Journal of Pakistan*. 2018;27(3):55–58.
55. Sayeed MA, Farooqi J, Jabeen K, Awan S, Mahmood SF. Clinical spectrum and factors impacting outcome of Candida auris: a single center study from Pakistan. *BMC Infectious Diseases*. 2019;19(1):1–8. doi:10.1186/s12879-019-3999-y

56. Ismail F, Ghani A, Akbar S. Emergence of Antifungal Azole Resistance in the Fungal Strains of Tinea corporis, Tinea capitis, Tinea cruris and Tinea pedis from the Locality of Southern Punjab, Pakistan. *RADS Journal of Biological Research & Applied Sciences*. 2021;12(1):24–38. doi:10.37962/jbas.v12i1.348
57. NIH Islamabad. National institute of health, Pakistan - antimicrobial resistance. Available from: https://www.nih.org.pk/antimicrobial-resistance. Accessed April 10, 2025.
58. CDC. International health regulations. Global Health. 2024. Available from: https://www.cdc.gov/global-health/topics-programs/ihr.html. Accessed May 10, 2025.
59. WHO. Global Antimicrobial Resistance and Use Surveillance System (GLASS) Report: 2022. Available from: https://iris.who.int/handle/10665/364996. Accessed 10 March 2025.
60. Saleem Z, Hassali MA, Versporten A, et al. A multicenter point prevalence survey of antibiotic use in Punjab, Pakistan: findings and implications. *Expert Review of Anti-Infective Therapy*. 2019;17(4):285–293. doi:10.1080/14787210.2019.1581063
61. Mustafa ZU, Saleem MS, Ikram MN, et al. Co-infections and antimicrobial use among hospitalized COVID-19 patients in Punjab, Pakistan: findings from a multicenter, point prevalence survey. *Pathogens and Global Health*. 2022;116(7):421–427. doi:10.1080/20477724.2021.1999716
62. Mustafa ZU, Salman M, Yasir M, et al. Antibiotic consumption among hospitalized neonates and children in Punjab province, Pakistan. *Expert Review of Anti-Infective Therapy*. 2022;20(6):931–939. doi:10.1080/14787210.2021.1986388
63. Khursheed N, Ahsan Q, Rattani S, et al. Point prevalence probing of antimicrobial prescription patterns from a developing country. *Expert Review of Anti-Infective Therapy*. 2023;21(11):1269–1276. doi:10.1080/14787210.2023.2259098
64. MMIDSP. Medical microbiology & infectious diseases society of Pakistan - MMIDSP. Available from: https://www.mmidsp.com/. Accessed 10 May 2025.
65. WHO. *Global Research Agenda for Antimicrobial Resistance in Human Health*. 2023. Available from: https://www.who.int/publications/m/item/global-research-agenda-for-antimicrobial-resistance-in-human-health. Accessed 10 May 2025.
66. Peters MDJ, Marnie C, Tricco AC, et al. Updated methodological guidance for the conduct of scoping reviews. *JBI Evidence Synthesis*. 2020;18(10):2119–2126. doi:10.11124/JBIES-20-00167
67. Haseeb A, Saleem Z, Maqadmi AF, et al. Ongoing strategies to improve antimicrobial utilization in hospitals across the Middle East and North Africa (MENA): findings and implications. *Antibiotics*. 2023;12(5):827. doi:10.3390/antibiotics12050827
68. Saleem Z, Godman B, Cook A, et al. Ongoing efforts to improve antimicrobial utilization in hospitals among African countries and implications for the future. *Antibiotics*. 2022;11(12):1824. doi:10.3390/antibiotics11121824
69. Sono TM, Yeika E, Cook A, et al. Current rates of purchasing of antibiotics without a prescription across sub-Saharan Africa; rationale and potential programmes to reduce inappropriate dispensing and resistance. *Expert Review of Anti-Infective Therapy*. 2023;21(10):1025–1055. doi:10.1080/14787210.2023.2259106
70. Mwita JC, Ogunleye OO, Olalekan A, et al. Key issues surrounding appropriate antibiotic use for prevention of surgical site infections in low- and middle-income countries: a narrative review and the implications. *International Journal of General Medicine*. 2021;14:515–530. doi:10.2147/IJGM.S253216
71. Godman B, Egwuenu A, Haque M, et al. Strategies to improve antimicrobial utilization with a special focus on developing countries. *Life*. 2021;11(6):528. doi:10.3390/life11060528
72. Luby SP, Agboatwalla M, Painter J, et al. Combining drinking water treatment and hand washing for diarrhoea prevention, a cluster randomised controlled trial. *Tropical Medicine & International Health*. 2006;11(4):479–489. doi:10.1111/j.1365-3156.2006.01592.x
73. Luby SP, Agboatwalla M, Painter J, Altaf A, Billhimer WL, Hoekstra RM. Effect of intensive handwashing promotion on childhood diarrhea in high-risk communities in Pakistan: a randomized controlled trial. *JAMA*. 2004;291(21):2547–2554. doi:10.1001/jama.291.21.2547
74. Nanan D, White F, Azam I, Afsar H, Hozhabri S. Evaluation of a water, sanitation, and hygiene education intervention on diarrhoea in northern Pakistan. *Bulletin of the World Health Organization*. 2003;81(3):160–165.
75. Luby SP, Agboatwalla M, Hoekstra RM, Rahbar MH, Billhimer W, Keswick BH. Delayed effectiveness of home-based interventions in reducing childhood diarrhea, Karachi, Pakistan. *The American Journal of Tropical Medicine and Hygiene*. 2004;71(4):420–427. doi:10.4269/ajtmh.2004.71.420
76. Habib MA, Soofi S, Sadiq K, et al. A study to evaluate the acceptability, feasibility and impact of packaged interventions for prevention and treatment of childhood diarrhea in rural Pakistan. *BMC Public Health*. 2013;13(1):922. doi:10.1186/1471-2458-13-922
77. Rabbani F, Khan HA, Piryani S, et al. Changing perceptions of rural frontline workers and caregivers about management of childhood diarrhea and pneumonia despite several inequities: the Nigraan plus trial in Pakistan. *Journal of Multidisciplinary Healthcare*. 2021;14:3343–3355. doi:10.2147/JMDH.S334844
78. Qureshi S, Resham S, Hashmi M, Naveed AB, Haq Z, Ali SA. A retrospective review on antibiotic use in acute watery diarrhea in children in a tertiary care hospital of Karachi, Pakistan. *PLoS One*. 2021;16(7):e0253712. doi:10.1371/journal.pone.0253712
79. Khaliq A, Amreen, Jameel N, Krauth SJ. Knowledge and practices on the prevention and management of diarrhea in children under-2 years among women dwelling in urban slums of Karachi, Pakistan. *Maternal and Child Health Journal*. 2022;26(7):1442–1452. doi:10.1007/s10995-022-03391-9
80. Joseph HA, Agboatwalla M, Hurd J, Jacobs-Slifka K, Pitz A, Bowen A. What happens when: perceptions of antimicrobial resistance in the context of diarrheal disease treatment among laypersons and health-care providers in Karachi, Pakistan. *The American Journal of Tropical Medicine and Hygiene*. 2016;95(1):221. doi:10.4269/ajtmh.15-0661
81. Bowen A, Agboatwalla M, Pitz A, Salahuddin S, Brum J, Plikaytis B. Effect of Bismuth Subsalicylate vs Placebo on Use of Antibiotics Among Adult Outpatients With Diarrhea in Pakistan: a Randomized Clinical Trial. *JAMA Network Open*. 2019;2(8):e199441–e199441. doi:10.1001/jamanetworkopen.2019.9441
82. Luby S, Agboatwalla M, Raza A, et al. Microbiologic effectiveness of hand washing with soap in an urban squatter settlement, Karachi, Pakistan. *Epidemiology & Infection*. 2001;127(2):237–244. doi:10.1017/S0950268801005829
83. Zia I, Cheema SS, Sheikh NS, Ashraf H. Hand hygiene knowledge, attitudes, and self-reported practices among medical and nursing staff of a tertiary-care military hospital: a cross-sectional study. *Int JInfect Control*. 2022;18:1.
84. Ahmed J, Malik F, Memon ZA, et al. Compliance and Knowledge of Healthcare Workers Regarding Hand Hygiene and Use of Disinfectants: a Study Based in Karachi. *Cureus*. 2020;12(2):e7036. doi:10.7759/cureus.7036

85. Sehar B, Yaqoob M, Hanif A, Akhter AM, Gilani SA. Development of Health Care Facilities in Rural Areas of District Bagh, Azad Jammu, and Kashmir: a study of the application of the WASH-FIT tool. *Journal of Sheikh Zayed Medical College*. 2022;13(3):23.
86. Khan N, Azam N, Mahmood H, Iftikhar A, Afzal A. Impact of Intensive Training Programme on The Knowledge and Practice of Infection Control Among Auxiliary Staff in a Tertiary Care Hospital. *Pakistan Armed Forces Medical Journal*. 2022;72(1):54–57. doi:10.51253/pafmj.v72i1.5637
87. Rasheed S, Iqbal S, Baig LA, Mufti K. Hospital waste management in theTeaching hospitals of Karachi. *JPMA*. 2005;55:192.
88. Akram A, Abbas S, Batool I, Abbas B. HAND HYGIENE: WEAPON AGAINST COVID–19 AND HEALTH CARE-ASSOCIATED INFECTIONS. *Pakistan Armed Forces Medical Journal*. 2020;70(1):363–368.
89. Batool S, Kousar S, Chandio K, Memon KN, Wilson NR. Infection Control Practices Among Nurses Working at Tertiary Care Hospitals of Quetta, Pakistan. *RADS Journal of Pharmacy and Allied Health Sciences*. 2023;1(1):1–6.
90. Savul S, Lalani FK, Ikram A, Khan MA, Khan MA, Ansari J. Infection prevention and control situation in public hospitals of Islamabad. *The Journal of Infection in Developing Countries*. 2020;14(09):1040–1046. doi:10.3855/jidc.12779
91. Thobani RS, Yousafzai MT, Sultana S, et al. Field evaluation of typhoid conjugate vaccine in a catch-up campaign among children aged 9 months to 15 years in Sindh, Pakistan. *Vaccine*. 2022;40(36):5391–5398. doi:10.1016/j.vaccine.2022.06.072
92. Batool R, Yousafzai MT, Qureshi S, et al. Parental acceptance of typhoid conjugate vaccine for children aged 6 months to 15 years in an outbreak setting of Lyari Town Karachi, Pakistan. *Vaccine*. 2023;41(37):5376–5382. doi:10.1016/j.vaccine.2023.07.003
93. Khan MI, Soofi SB, Ochiai RL, et al. Effectiveness of Vi capsular polysaccharide typhoid vaccine among children: a cluster randomized trial in Karachi, Pakistan. *Vaccine*. 2012;30(36):5389–5395. doi:10.1016/j.vaccine.2012.06.015
94. Yousafzai MT, Karim S, Qureshi S, et al. Effectiveness of typhoid conjugate vaccine against culture-confirmed Salmonella enterica serotype Typhi in an extensively drug-resistant outbreak setting of Hyderabad, Pakistan: a cohort study. *The Lancet Global Health*. 2021;9(8):e1154–e1162. doi:10.1016/S2214-109X(21)00255-2
95. Altaf U, Saleem Z, Akhtar MF, et al. Using culture sensitivity reports to optimize antimicrobial therapy: findings and implications of antimicrobial stewardship activity in a hospital in Pakistan. *Medicina*. 2023;59(7):1237. doi:10.3390/medicina59071237
96. Naseer K, Saleem M, Ali S, Mirza B, Qazi J. Identification of new spectral signatures from hepatitis C virus infected human sera. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*. 2019;222:117181. doi:10.1016/j.saa.2019.117181
97. Bibi A, Basharat N, Aamir M, Haroon ZH. Procalcitonin as a biomarker of bacterial infection in critically ill patients admitted with suspected Sepsis in Intensive Care Unit of a tertiary care hospital. *Pakistan Journal of Medical Sciences*. 2021;37(7):1999. doi:10.12669/pjms.37.7.4183
98. Rizvi A, Saeed MU, Nadeem A, et al. Evaluation of bi-lateral co-infections and antibiotic resistance rates among COVID-19 patients in Lahore, Pakistan. *Medicina*. 2022;58(7):904. doi:10.3390/medicina58070904
99. Khurshid MB, Ahmed S, Javed S, et al. Therapeutic Guidelines and Antimicrobial Resistance of Helicobacter Pylori in Patients with Peptic Ulcer at Tertiary Care Hospitals of Rawalpindi and Islamabad. *Pakistan Journal of Medical & Health Sciences*. 2022;16(8):672. doi:10.53350/pjmhs22168672
100. Mohsin M, Hassan B, Khan AU, Ali A, Swedberg G, Hasan B. Genomic characterization of high-risk Escherichia coli and Enterobacter hormaechei clones recovered from a single tertiary-care hospital in Pakistan. *Journal of Applied Microbiology*. 2022;132(5):3907–3914. doi:10.1111/jam.15482
101. Imtiaz W, Syed Z, Rafaque Z, Andrews SC, Dasti JI. Analysis of antibiotic resistance and virulence traits (genetic and phenotypic) in Klebsiella pneumoniae clinical isolates from Pakistan: identification of significant levels of carbapenem and colistin resistance. *Infection and Drug Resistance*. 2021;14:227–236. doi:10.2147/IDR.S293290
102. Saeed M, Rasool MH, Rasheed F, et al. Extended-spectrum beta-lactamases producing extensively drug-resistant Salmonella Typhi in Punjab, Pakistan. *The Journal of Infection in Developing Countries*. 2020;14(02):169–176. doi:10.3855/jidc.12049
103. Furqan W, Ali S, Usman J, et al. Assessing Colistin Resistance by Phenotypic and Molecular Methods in Carbapenem-resistant Enterobacterales in a Tertiary Care Hospital in Pakistan. *Infection and Drug Resistance*. 2022;15:5899–5904. doi:10.2147/IDR.S376490
104. Jabeen K, Saleem S, Jahan S, et al. Molecular Characterization of Extensively Drug Resistant Salmonella Enterica Serovar Typhi Clinical Isolates from Lahore, Pakistan. *Infection and Drug Resistance*. 2023;16:2987–3001. doi:10.2147/IDR.S406253
105. Noureen S, Haq M, Ahmad A. In Vito Identification Of Antimicrobial Susceptibility Patterns Of Typhoid Salmonellae Isolated From Blood Culture At Peshawar Pakistan. *Jf Pharm Negative Results*. 2023;2023:3788–3793.
106. Ain Q, Tahir M, Sadaqat A, et al. First detection of extensively drug-resistant Salmonella typhi isolates harboring VIM and GES genes for carbapenem resistance from Faisalabad, Pakistan. *Microbial Drug Resistance*. 2022;28(12):1087–1098. doi:10.1089/mdr.2022.0094
107. Riaz S, Bashir MF. Phenotypic and molecular characterization of plasmid-encoded extended spectrum beta-lactamases produced by Escherichia coli and Klebsiella spp from Lahore, Pakistan. *Tropical Journal of Pharmaceutical Research*. 2015;14(9):1597–1604. doi:10.4314/tjpr.v14i9.8
108. Khan AA, Ali A, Tharmalingam N, Mylonakis E, Zahra R. First report of mecC gene in clinical methicillin resistant S. aureus (MRSA) from tertiary care hospital Islamabad, Pakistan. *Journal of Infection and Public Health*. 2020;13(10):1501–1507. doi:10.1016/j.jiph.2020.05.017
109. Sabir R, Alvi SFD, Fawwad A. Antimicrobial susceptibility pattern of aerobic microbial isolates in a clinical laboratory in Karachi-Pakistan. *Pakistan Journal of Medical Sciences*. 2013;29(3):851. doi:10.12669/pjms.293.3187
110. Ullah A, Qasim M, Rahman H, et al. High frequency of methicillin-resistant Staphylococcus aureus in Peshawar Region of Pakistan. *Springerplus*. 2016;5(1):1–6. doi:10.1186/s40064-016-2277-3
111. Rao MH, Khan S, Waseem T, Naeem S, Sabir S. Sepsis in infants: analysis of bacterial pathogens and their antibiotic susceptibility, a study at Government Tertiary Care Hospital, Karachi. *Journal of the Dow University of Health Sciences*. 2013;7(1):35–40.
112. Muhammad A, Khan SN, Jamal T, Haq IU, Jabbar A, Ihsan A. Bacterial Spectrum and Antimicrobial Profile of Pediatric Blood Stream Infection at a Tertiary Care Hospital in Pakistan. *Chinese Medical Sciences Journal*. 2020;35(4):315–322. doi:10.24920/003675
113. Kim C, Latif I, Neupane DP, et al. The molecular basis of extensively drug-resistant Salmonella Typhi isolates from pediatric septicemia patients. *PLoS One*. 2021;16(9):e0257744. doi:10.1371/journal.pone.0257744
114. Qamar MU, Ambreen A, Batool A, et al. Molecular detection of extensively drug-resistant Salmonella typhi and carbapenem-resistant pathogens in pediatric septicemia patients in Pakistan–a public health concern. *Future Microbiology*. 2020;16(10):731–739. doi:10.2217/fmb-2021-0036
115. Qamar MU, Walsh TR, Toleman MA, et al. Dissemination of genetically diverse NDM-1,-5,-7 producing-Gram-negative pathogens isolated from pediatric patients in Pakistan. *Future Microbiology*. 2019;14(8):691–704. doi:10.2217/fmb-2019-0012

116. Qamar MU, Ejaz H, Mohsin M, et al. Co-existence of NDM-, aminoglycoside-and fluoroquinolone-resistant genes in carbapenem-resistant Escherichia coli clinical isolates from Pakistan. *Future Microbiology*. 2023;18(14):959–969. doi:10.2217/fmb-2023-0068
117. Rehman S, Ali NM, Pier GB, Liaqat I, Mazhar B. In vitro Susceptibility of Pseudomonas aeruginosa Isolated from Acute and Chronic Pulmonary Infection to Antibiotics, Lactobacillus Competition and Metal Nanoparticles. *Pakistan Journal of Zoology*. 2018;50(6). doi:10.17582/journal.pjz/2018.50.6.2165.2171
118. Kausar A, Akram M, Shoaib M, et al. Isolation and identification of UTI causing agents and frequency of ESBL (extended spectrum beta lactamase) in Pakistan. *Amer JPhytomed Clin Ther*. 2014;2:963–975.
119. Shah DA, Wasim S, Abdullah FE. Antibiotic resistance pattern of Pseudomonas aeruginosa isolated from urine samples of Urinary Tract Infections patients in Karachi, Pakistan. *Pakistan Journal of Medical Sciences*. 2015;31(2):341. doi:10.12669/pjms.312.6839
120. Shabbir M, Iman NU, Shah MZ. Multidrug resistant uropathogens in urinary tract infections and their antibiotic susceptibility patterns. *Journal of Medical Sciences*. 2018;26(1):24–27.
121. Kidwai SS, Nageen A, Ghaznavi S, Bashir F, Ara J, Ara J. Antibiotic susceptibility in commonly isolated pathogens from urinary tract infection in a cohort of subjects from low socioeconomic strata. *Pakistan Journal of Medical Sciences*. 2017;33(2):254. doi:10.12669/pjms.332.11569
122. Fatima T, Rafiq S, Iqbal A, Husnain S. Prevalence and Antibiogram of MDR E. coli strains isolated from UTI patients—1-year retrospective study at Nishtar Medical Hospital, Multan. *SN Comprehensive Clinical Medicine*. 2020;2(4):423–431. doi:10.1007/s42399-020-00246-8
123. Kalsoom U, Ghauri SM, Abrar S, Riaz S, Sabri AN. Evaluation of bla SHV, bla TEM and bla OXA encoding Clinical Isolates from Chronic Tonsillitis using Phenotypic and Molecular Technique: first report from Pakistan. *Annals of PIMS-Shaheed Zulfiqar Ali Bhutto Medical University*. 2017;13(4):301–305.
124. Saleem S, Bokhari H. Resistance profile of genetically distinct clinical Pseudomonas aeruginosa isolates from public hospitals in central Pakistan. *Journal of Infection and Public Health*. 2020;13(4):598–605. doi:10.1016/j.jiph.2019.08.019
125. Rathi SK, Ahmed R. Pakistan prevalence survey in acute pharyngitis. *J Pak Med Assoc*. 2014;64(8):928–931.
126. Ali A, Haque A, Haque A, et al. Multiplex PCR for differential diagnosis of emerging typhoidal pathogens directly from blood samples. *Epidemiology & Infection*. 2009;137(1):102–107. doi:10.1017/S0950268808000654
127. Saghir S, Faiz M, Saleem M, Younus A, Aziz H. Characterization and anti-microbial susceptibility of gram-negative bacteria isolated from bloodstream infections of cancer patients on chemotherapy in Pakistan. *Indian Journal of Medical Microbiology*. 2009;27(4):341–347. doi:10.4103/0255-0857.55454
128. Niamatullah H, Nasir N, Jabeen K, et al. Post-COVID-19 Pneumocystis pneumonia cases from Pakistan: an observational study. *Access Microbiology*. 2023;5(1). doi:10.1099/acmi.0.000406.
129. Baker S, Sarwar Y, Aziz H, et al. Detection of Vi-negative Salmonella enterica serovar typhi in the peripheral blood of patients with typhoid fever in the Faisalabad region of Pakistan. *Journal of Clinical Microbiology*. 2005;43(9):4418–4425. doi:10.1128/JCM.43.9.4418-4425.2005
130. Gul N, Mujahid TY, Ahmad S. Isolation, identification and antibiotic resistance profile of indigenous bacterial isolates from urinary tract infection patients. *Pakistan Journal of Biological Sciences*. 2004;7(12):2051–2054. doi:10.3923/pjbs.2004.2051.2054
131. Nisar MI, Nayani K, Akhund T, et al. Nasopharyngeal carriage of Streptococcus pneumoniae in children under 5 years of age before introduction of pneumococcal vaccine (PCV10) in urban and rural districts in Pakistan. *BMC Infectious Diseases*. 2018;18(1):1–8. doi:10.1186/s12879-018-3608-5
132. Abrar S, Ain NU, Liaqat H, Hussain S, Rasheed F, Riaz S. Distribution of bla CTX− M, bla TEM, bla SHV and bla OXA genes in Extended-spectrum-β-lactamase-producing Clinical isolates: a three-year multi-center study from Lahore, Pakistan. *Antimicrobial Resistance & Infection Control*. 2019;8(1):1–10. doi:10.1186/s13756-019-0536-0
133. Mansoor S, Qadir S, Javed S, Shah Jehan F, Kundi M. Antimicrobial susceptibility of organisms isolated from sputum culture of Karachi, Pakistan. *Pakistan Journal of Pharmaceutical Sciences*. 2017;30(6):2247–2252.
134. Nizamuddin S, Ching C, Kamal R, Zaman MH, Sultan F. Continued outbreak of ceftriaxone-resistant Salmonella enterica serotype Typhi across Pakistan and assessment of knowledge and practices among healthcare workers. *The American Journal of Tropical Medicine and Hygiene*. 2021;104(4):1265. doi:10.4269/ajtmh.20-0783
135. Khalil U, Younus M, Asghar N, et al. Phenotypic and genotypic characterization of enteroaggregative Escherichia coli isolates from pediatric population in Pakistan. *Apmis*. 2016;124(10):872–880. doi:10.1111/apm.12577
136. Ahmed I, Jabeen K, Inayat R, Hasan R. Susceptibility testing of extensively drug-resistant and pre-extensively drug-resistant Mycobacterium tuberculosis against levofloxacin, linezolid, and amoxicillin-clavulanate. *Antimicrobial Agents and Chemotherapy*. 2013;57(6):2522–2525. doi:10.1128/AAC.02020-12
137. Khatoon I, Khanam S, Azam A, Qadeer S, Naz S, Hassan NU. Incidence Pattern, Antibiotic Susceptibility Pattern and Associated Risk Factors of Bacterial Uropathogens Among General Population of Pakistan. *Infection and Drug Resistance*. 2023;16:4995–5005. doi:10.2147/IDR.S418045
138. Saaiq M, Ahmad S, Zaib MS. Burn wound infections and antibiotic susceptibility patterns at Pakistan Institute of Medical Sciences, Islamabad, Pakistan. *World Journal of Plastic Surgery*. 2015;4(1):9.
139. Khan FB, Shahzad K, Khan NB, Kokab Z, Iqbal Z, Mansoor K. Common uropathogens and their antimicrobial susceptibility patterns at a tertiary care hospital in Pakistan. *Journal of Rawalpindi Medical College*. 2020;24(4):306–310. doi:10.37939/jrmc.v24i4.1289
140. Mohsin S, Aziz Q, Muurlink O, Taylor-Robinson A. Burden of antibiotic resistance among children with typhoid in Gadap Town, Karachi, Pakistan. *Microbes and Infectious Diseases*. 2022;3(1):81–91.
141. Erum R. Phenotypic identification and biofilm formation of candida species isolated from patients with surgical site infection in Karachi Pakistan. *Pak J Sci*. 2015;67(1):1.
142. Erum R, Samad F, Khan A, Kazmi SU. A comparative study on production of extracellular hydrolytic enzymes of Candida species isolated from patients with surgical site infection and from healthy individuals and their co-relation with antifungal drug resistance. *BMC Microbiology*. 2020;20(1):1–12. doi:10.1186/s12866-020-02045-6
143. Jabeen K, Farooqi J, Iqbal N, Wahab K, Irfan M. Aspergillus fumigatus and Aspergillus flavus-specific IgG cut-offs for the diagnosis of chronic pulmonary aspergillosis in Pakistan. *Journal of Fungi*. 2020;6(4):249. doi:10.3390/jof6040249
144. Jabeen G, Naz SA, Rangel DE, Jabeen N, Shafique M, Yasmeen K. In-vitro evaluation of virulence markers and antifungal resistance of clinical Candida albicans strains isolated from Karachi, Pakistan. *Fungal Biology*. 2023;127(7–8):1241–1249. doi:10.1016/j.funbio.2023.04.003

145. Munir G, Farhad S, Alam S, et al. Epidemiology and Susceptibility Profile of Aspergillus Species: an Experience from Tertiary Care Hospital. *Pakistan Journal of Medical & Health Sciences*. 2022;16(7):634. doi:10.53350/pjmhs22167634
146. Moin S, Farooqi J, Jabeen K, Laiq S, Zafar A. Screening for triazole resistance in clinically significant Aspergillus species; report from Pakistan. *Antimicrobial Resistance & Infection Control*. 2020;9(1):1–8. doi:10.1186/s13756-020-00731-8
147. Farooqi J, Jabeen K, Saeed N, et al. Invasive candidiasis in Pakistan: clinical characteristics, species distribution and antifungal susceptibility. *Journal of Medical Microbiology*. 2013;62(2):259. doi:10.1099/jmm.0.048785-0
148. Waseem H, Naeem A, Ali S, Sarfraz S, Usman J, Gilani M. MULTIPLEX POLYMERASE CHAIN REACTION (PCR) FOR THE DETECTION OF NEISSERIA GONORRHOEAE AND THE QUINOLONE RESISTANCE GENE IN PAKISTAN. *Pakistan Armed Forces Medical Journal*. 2021;71(3):866–869. doi:10.51253/pafmj.v71i3.4692
149. Jabeen K, Bhawan Mal P, Khan E, Chandio S, Jacobsson S, Unemo M. Antimicrobial resistance and Neisseria gonorrhoeae multiantigen sequence typing (NG-MAST) genotypes in N. gonorrhoeae during 2012–2014 in Karachi, Pakistan. *BMC Infectious Diseases*. 2016;16(1):1–6. doi:10.1186/s12879-016-1673-1
150. Mal PB, Jabeen K, Farooqi J, Unemo M, Khan E. Antimicrobial susceptibility testing of Neisseria gonorrhoeae isolates in Pakistan by Etest compared to Calibrated Dichotomous Sensitivity and Clinical Laboratory Standards Institute disc diffusion techniques. *BMC Microbiology*. 2016;16(1):1–8. doi:10.1186/s12866-016-0707-6
151. Atif M, Ihsan B, Malik I, et al. Antibiotic stewardship program in Pakistan: a multicenter qualitative study exploring medical doctors' knowledge, perception and practices. *BMC Infectious Diseases*. 2021;21(1):1–11. doi:10.1186/s12879-021-06043-5
152. Mustafa ZU, Manzoor MN, Shahid A, et al. Nurses' Perceptions, Involvement, Confidence and Perceived Barriers Towards Antimicrobial Stewardship Program in Pakistan: findings from a Multi-Center, Cross-Sectional Study. *Journal of Multidisciplinary Healthcare*. 2022;15:2553–2562. doi:10.2147/JMDH.S376664
153. Hayat K, Rosenthal M, Gillani AH, et al. Perspective of key healthcare professionals on antimicrobial resistance and stewardship programs: a multicenter cross-sectional study from Pakistan. *Frontiers in Pharmacology*. 2020;10:1520. doi:10.3389/fphar.2019.01520
154. Akbar Z, Saleem Z, Shaukat A, Farrukh MJ. Perception and practices of community pharmacists towards antimicrobial stewardship in Lahore, Pakistan. *Journal of Global Antimicrobial Resistance*. 2021;25:157–161. doi:10.1016/j.jgar.2021.03.013
155. Rehman IU, Asad MM, Bukhsh A, et al. Knowledge and practice of pharmacists toward antimicrobial stewardship in Pakistan. *Pharmacy*. 2018;6(4):116. doi:10.3390/pharmacy6040116
156. Sarwar MR, Saqib A, Iftikhar S, Sadiq T. Knowledge of community pharmacists about antibiotics, and their perceptions and practices regarding antimicrobial stewardship: a cross-sectional study in Punjab, Pakistan. *Infection and Drug Resistance*. 2018;11:133–145. doi:10.2147/IDR.S148102
157. Saleem Z, Hassali MA, Hashmi FK, Godman B, Ahmed Z. Snapshot of antimicrobial stewardship programs in the hospitals of Pakistan: findings and implications. *Heliyon*. 2019;5(7):e02159. doi:10.1016/j.heliyon.2019.e02159
158. Hashmi A, Haq MIU, Malik M, Hussain A, Gajdács M, Jamshed S. Perceptions of community pharmacists regarding their role in antimicrobial stewardship in Pakistan: a way forward. *Heliyon*. 2023;9(4):e14843. doi:10.1016/j.heliyon.2023.e14843
159. Khan Z, Ahmed N, Khan FU, Martins MAP, Martins M. Practice of prophylactic antibiotic and timing of administration in two common elective surgeries in Pakistan: an audit-based study. *Bulletin of Faculty of Pharmacy, Cairo University*. 2019;57(1):88–95. doi:10.21608/bfpc.2019.13532.1039
160. Haseeb A, Saleem Z, Altaf U, et al. Impact of positive culture reports of E. coli or MSSA on de-escalation of antibiotic use in a teaching hospital in Pakistan and the implications. *Infection and Drug Resistance*. 2023;16:77–86. doi:10.2147/IDR.S391295
161. Khan Z, Ahmed N, Rehman AU, et al. Audit of pre-operative antibiotic prophylaxis usage in elective surgical procedures in two teaching hospitals, Islamabad, Pakistan: an observational cross-sectional study. *PLoS One*. 2020;15(4):e0231188. doi:10.1371/journal.pone.0231188
162. Saleem Z, Hassali MA, Godman B, Hashmi FK, Saleem F. Antimicrobial prescribing and determinants of antimicrobial resistance: a qualitative study among physicians in Pakistan. *International Journal of Clinical Pharmacy*. 2019;41(5):1348–1358. doi:10.1007/s11096-019-00875-7
163. Khan FU, Khan FU, Hayat K, et al. Knowledge, attitude and practices among consumers toward antibiotics use and antibiotic resistance in Swat, Khyber-Pakhtunkhwa, Pakistan. *Expert Review of Anti-Infective Therapy*. 2020;18(9):937–946. doi:10.1080/14787210.2020.1769477
164. Haseeb A, Bilal M. Prevalence of using non prescribed medications in economically deprived rural population of Pakistan. *Archives of Public Health*. 2016;74(1):1–7. doi:10.1186/s13690-015-0113-9
165. Saleem Z, Haseeb A, Godman B, et al. Point prevalence survey of antimicrobial use during the COVID-19 pandemic among different hospitals in Pakistan: findings and implications. *Antibiotics*. 2022;12(1):70. doi:10.3390/antibiotics12010070
166. Atif M, Azeem M, Sarwar MR, et al. WHO/INRUD prescribing indicators and prescribing trends of antibiotics in the Accident and Emergency Department of Bahawal Victoria Hospital, Pakistan. *Springerplus*. 2016;5(1):1–7. doi:10.1186/s40064-016-3615-1
167. Khan FU, Mallhi TH, Khan FU, et al. Evaluation of consumers perspective on the consumption of antibiotics, antibiotic resistance, and recommendations to improve the rational use of antibiotics: an exploratory qualitative study from post-conflicted region of Pakistan. *Frontiers in Pharmacology*. 2022;13:881243. doi:10.3389/fphar.2022.881243
168. Rakhshani NS, Kaljee LM, Khan MI, et al. A Formative Assessment of Antibiotic Dispensing/Prescribing Practices and Knowledge and Perceptions of Antimicrobial Resistance (AMR) among Healthcare Workers in Lahore Pakistan. *Antibiotics*. 2022;11(10):1418. doi:10.3390/antibiotics11101418
169. Sarwar MR, Saqib A, Iftikhar S, Sadiq T. Antimicrobial use by WHO methodology at primary health care centers: a cross sectional study in Punjab, Pakistan. *BMC Infectious Diseases*. 2018;18(1):1–9. doi:10.1186/s12879-018-3407-z
170. Atif M, Asghar S, Mushtaq I, et al. What drives inappropriate use of antibiotics? A mixed methods study from Bahawalpur, Pakistan. *Infection and Drug Resistance*. 2019;12:687–699. doi:10.2147/IDR.S189114
171. Bin YB, Rozina A, Junaid M, Saima K, Farhan N, Maham T. A study of unnecessary use of antibiotics at a tertiary care hospital: urgent need to implement antimicrobial stewardship programs. *Journal of Young Pharmacists*. 2015;7(4):311. doi:10.5530/jyp.2015.4.5
172. Mustafa ZU, Khan AH, Salman M, Syed Sulaiman SA, Godman B. Antimicrobial Utilization among Neonates and Children: a Multicenter Point Prevalence Study from Leading Children's Hospitals in Punjab, Pakistan. *Antibiotics*. 2022;11(8):1056. doi:10.3390/antibiotics11081056
173. Khalid M, Rasheed J, Nawaz I. Pattern of hospital antibiotic use in term neonates using WHO Access, Watch and Reserve Classification (AWaRe). *Pakistan Journal of Medical Sciences*. 2022;38(8):2169. doi:10.12669/pjms.38.8.6098

174. Gillani AH, Ji W, Hussain W, et al. Antibiotic self-medication among non-medical university students in Punjab, Pakistan: a cross-sectional survey. *International Journal of Environmental Research and Public Health*. 2017;14(10):1152. doi:10.3390/ijerph14101152
175. Limaye D, Ziesenis P, Limaye V, et al. Knowledge, attitude and practices of antibiotic usage among university students from Karachi, Pakistan. *International Journal of Research in Medical Sciences*. 2019;7(2):520–525. doi:10.18203/2320-6012.ijrms20185502
176. Saleem Z, Saeed H, Hassali M, et al. Pattern of inappropriate antibiotic use among hospitalized patients in Pakistan: a longitudinal surveillance and implications. *Antimicrob Resist Infect Control*. 2019;8(1):188. doi:10.1186/s13756-019-0649-5
177. Shaikh Q, Sarfaraz S, Rahim A, et al. WHO Point Prevalence Survey to Describe the Use of Antimicrobials at a Tertiary Care Center in Pakistan: a Situation Analysis for Establishing an Antimicrobial Stewardship Program. *Antibiotics*. 2022;11(11):1555. doi:10.3390/antibiotics11111555
178. Mustafa ZU, Nazir M, Majeed HK, et al. Exploring knowledge of antibiotic use, resistance, and stewardship programs among pharmacy technicians serving in ambulatory care settings in Pakistan and the implications. *Antibiotics*. 2022;11(7):921. doi:10.3390/antibiotics11070921
179. Majid Aziz M, Haider F, Rasool MF, et al. Dispensing of non-prescribed antibiotics from community pharmacies of Pakistan: a cross-sectional survey of pharmacy staff's opinion. *Antibiotics*. 2021;10(5):482. doi:10.3390/antibiotics10050482
180. Raees I, Atif HM, Aslam S, et al. Understanding of Final Year Medical, Pharmacy and Nursing Students in Pakistan towards Antibiotic Use, Antimicrobial Resistance and Stewardship: findings and Implications. *Antibiotics*. 2023;12(1):135. doi:10.3390/antibiotics12010135
181. Saleem Z, Ahsan U, Haseeb A, et al. Antibiotic utilization patterns for different wound types among surgical patients: findings and implications. *Antibiotics*. 2023;12(4):678. doi:10.3390/antibiotics12040678
182. Saleem Z, Faller EM, Godman B, et al. Antibiotic consumption at community pharmacies: a multicenter repeated prevalence surveillance using WHO methodology. *Medicine Access@ Point of Care*. 2021;5:23992026211064714. doi:10.1177/23992026211064714
183. Zaidi SK, Khalil H, Ahmed I, Akbar H, Saleem K, Ali W. ACTIVE SURVEILLANCE FOR ASYMPTOMATIC COLONIZATION WITH MULTIDRUG RESISTANT GRAM-NEGATIVE BACILLI IN PRE-OPERATIVE PAEDIATRIC CONGENITAL CARDIAC DISEASE PATIENTS; PRELIMINARY RESULTS. *Pakistan Armed Forces Medical Journal*. 2015;65(SUPPL):S39–42.
184. Yousafzai MT, Irfan S, Thobani RS, et al. Burden of culture confirmed enteric fever cases in Karachi, Pakistan: surveillance for Enteric Fever in Asia Project (SEAP), 2016–2019. *Clinical Infectious Diseases*. 2020;71(Supplement_3):S214–S221. doi:10.1093/cid/ciaa1308
185. Saleem Z, Hassali MA, Hashmi FK, et al. Evaluating consumption and expenditure patterns of antibiotics in tablet and capsule dosage forms: Pakistan Antibiotic Consumption Surveillance (PACS). *Journal of Pharmacy Practice and Research*. 2020;50(1):36–41. doi:10.1002/jppr.1584
186. Saman A, Chaudhry M, Ijaz M, et al. Assessment of knowledge, perception, practices and drivers of antimicrobial resistance and antimicrobial usage among veterinarians in Pakistan. *Preventive Veterinary Medicine*. 2023;212:105836. doi:10.1016/j.prevetmed.2022.105836
187. Ul Mustafa Z, Salman M, Aldeyab M, Kow CS, Hasan SS. Antimicrobial consumption among hospitalized patients with COVID-19 in Pakistan. *SN Comprehensive Clinical Medicine*. 2021;3(8):1691–1695. doi:10.1007/s42399-021-00966-5
188. Nasrullah A, Tayyab N, Furqan W, et al. CEFIDEROCOL: a TROJAN HORSE FOR THE MANAGEMENT OF MULTIDRUG-RESISTANT ENTEROBACTERALES IN A TERTIARY CARE HOSPITAL IN PAKISTAN. *Annals of Allied Health Sciences*. 2022;8(2):40–44.
189. Mehwish A, Iftikhar I. EMERGENCE OF CEFTAZIDIME-AVIBACTAM RESISTANCE IN ENTERO-BACTERALES AND PSEUDOMONAS AERUGINOSA. *Pakistan Journal of Pathology*. 2023;34(4):113–117. doi:10.55629/pakjpathol.v34i4.755
190. Ali F, Mirza IA, Waseem H, et al. Correlation between Mechanism of Carbapenem Resistance and in vitro Efficacy of Ceftazidime-Avibactam and Meropenem-Vaborbactam on Carbapenem-Resistant Enterobacterales and Pseudomonas Aeruginosa. *Pakistan Armed Forces Medical Journal*. 2023;73(6):1602. doi:10.51253/pafmj.v73i6.7377
191. Siddiqi FG, Rais H, Zafar F, et al. Treatment of 21st Century typhoid fever in children with mono vs combination drug therapy: an open-label randomized comparative trial. 2021;9:384.
192. Razzaq MM, Khan WUH, Hussain M, Hayat Q, Wazir S, Waqar H. Comparison of Culture Proven Enteric Fever Treatment with Meropenem Alone Vs Combination of Meropenem and Azithromycin. *Journal of Health and Rehabilitation Research*. 2023;3(2):941–945. doi:10.61919/jhrr.v3i2.263
193. Ishaque S, Syed B, Dodani SK, Anwar S. Comparison of single vs combination drug therapy in extensively drug resistant Salmonella typhi: an observational study from Pakistan. *Infection and Drug Resistance*. 2022;15:6093–6100. doi:10.2147/IDR.S372136
194. Tahir MJ, Zaman M, Saffi J, et al. Knowledge, attitudes, and practices of the general population of Pakistan regarding typhoid conjugate vaccine: findings of a cross-sectional study. *Frontiers in Public Health*. 2023;11:1151936. doi:10.3389/fpubh.2023.1151936
195. Qureshi S, Naveed AB, Yousafzai MT, et al. Response of extensively drug resistant Salmonella Typhi to treatment with meropenem and azithromycin, in Pakistan. *PLoS Neglected Tropical Diseases*. 2020;14(10):e0008682. doi:10.1371/journal.pntd.0008682
196. Babar ZU, Dodani SK, Nasim A. Treatment outcome and adverse effects of colistin in adult patients with carbapenem-resistant gram-negative bacteremia from Pakistan. *International Journal of Infectious Diseases*. 2021;106:171–175. doi:10.1016/j.ijid.2021.03.004
197. Ambreen G, Salat MS, Hussain K, et al. Efficacy of colistin in multidrug-resistant neonatal sepsis: experience from a tertiary care center in Karachi, Pakistan. *Archives of Disease in Childhood*. 2020;105(9):830–836. doi:10.1136/archdischild-2019-318067
198. Qadir M, Qamar FN, Resham S, et al. Effectiveness of simple strategies in reducing multidrug resistant blood stream infections in Neonatal Intensive Care Unit of tertiary care hospital in Karachi, Pakistan. *J Pak Med Assoc*. 2015;65(1):72–75.
199. Qureshi S, Fatima P, Mukhtar A, Zehra A, Qamar FN. Clinical profile and outcome of antibiotic lock therapy for bloodstream infections in pediatric hematology/oncology patients in a tertiary care hospital, Karachi, Pakistan. *International Journal of Pediatrics and Adolescent Medicine*. 2019;6(1):25–28. doi:10.1016/j.ijpam.2019.01.004
200. Atif M, Zia R, Malik I, Ahmad N, Sarwar S. Treatment outcomes, antibiotic use and its resistance pattern among neonatal sepsis patients attending Bahawal Victoria Hospital, Pakistan. *PLoS One*. 2021;16(1):e0244866. doi:10.1371/journal.pone.0244866
201. Shafiq M, Zafar S, Ahmad A, et al. Second-Line Antiretroviral Treatment Outcome in HIV-Infected Patients Coinfected with Tuberculosis in Pakistan. *BioMed Research International*. 2023;2023(1). doi:10.1155/2023/4187488.
202. Akhtar S, Masood S, Tabassum S, Rizvi DA. Efficacy of itraconazole versus fluconazole in vaginal candidiasis. *J Pak Med Assoc*. 2012;62(10):1049–5102.
203. Abd Mallick Y, Yaqoob N, Aftab K, Abd Mallick F. Successful treatment of human eumycetomas caused by Aspergillus species with voriconazole. *Journal of Pakistan Association of Dermatologists*. 2021;31(1):15–22.

204. Nabi MS, Chaudhary A, Ayyaz DM, Musharaf MS, Bashir F. Treatment of Pulmonary Aspergilloma-Is Surgery A Safe Option? A Review of 289 Cases at Two Centers in Pakistan. *Esculapio Journal of SIMS*. 2019;15(1):42–46.
205. Raza A, Zafar W, Mahboob A, Nizammudin S, Rashid N, Sultan F. Clinical features and outcomes of Candidaemia in cancer patients: results from Pakistan. *The Journal of the Pakistan Medical Association*. 2016;66(5):584–589.
206. Hussain S, Mustafa A, Mumtaz A, Shaheen G, Qaiser F, Ahmad S. A Comparison of Spectinomycin with Ceftriaxone as Treatment for Uncomplicated Gonorrhea. *Pakistan Journal of Medical & Health Sciences*. 2022;16(8):587. doi:10.53350/pjmhs22168587
207. Hayat K, Rosenthal M, Zhu S, et al. Attitude of clinicians towards hospital-based antimicrobial stewardship programs: a multicenter cross-sectional study from Punjab, Pakistan. *Expert Review of Anti-Infective Therapy*. 2019;17(8):661–669. doi:10.1080/14787210.2019.1647780
208. Ullah A, Shah S, Almugadam B, Sadiqui S. Prevalence of symptomatic urinary tract infections and antimicrobial susceptibility patterns of isolated uropathogens in kohat region of Pakistan. *MOJ Biol Med*. 2018;3(4):85–89. doi:10.15406/mojbm.2018.03.00082
209. Khalil A, Raja I, Hussain I, et al. Prevalence of Escherichia coli in suspected urinary tract infected patients and their sensitivity pattern against various antibiotics in Gilgit-Baltistan, Pakistan. *Pak J Zool*. 2014;46(6):2.
210. Ayaz I, Hameed H, Amber W, Zafar T. Nosocomial Blood Stream Infections in Pediatric Intensive Care Unit of Fauji Foundation Hospital, Rawalpindi Pakistan. *Journal of Islamabad Medical & Dental College*. 2020;9(4):269–274. doi:10.35787/jimdc.v9i4.533
211. Ishrat HM, Ehsan S, Fatima N, Anwar T. Bacterial Spectrum and Associated Sociodemographic Factors in Pediatric Blood Stream Infections at Tertiary Care Hospital. *Pakistan Journal of Medical & Health Sciences*. 2023;17(1):66. doi:10.53350/pjmhs202317166
212. Khan MA. Epidemiological studies on lower respiratory tract infection in children in the District Bannu, Khyber Pakhtunkhwa, Pakistan. *The Egyptian Journal of Bronchology*. 2022;16(1):17. doi:10.1186/s43168-022-00119-9
213. Moqaddes S, Mehwish M, Gohar M, Qaiser H, Khan A. Determination of Association Between Respiratory Tract Infections with Age, Gender and Socio-economic Status. *Lahore Garrison University Journal of Life Sciences*. 2020;2(3):203–209. doi:10.54692/lgujls.2018.020332
214. Batool A, Yaqoob A, Anwar Z, et al. Outbreak investigation of NDM-producing Burkholderia cepacia causing neonatal sepsis in Pakistan. *Future Microbiology*. 2023;18(16):1159–1169. doi:10.2217/fmb-2023-0063
215. Tariq A, Ali H, Zafar F, et al. Assessment of predictor variables and clinical consequences associated with surgical site infection in tertiary care setting, Karachi, Pakistan. *Pakistan Journal of Pharmaceutical Sciences*. 2018;31(1):31.
216. Khan MO, Uddin NS, Khamisani AM, Shah R. Frequency, Causative Organisms, Excess Cost and Short-Term Outcomes of Peripheral and Central Line Associated Nosocomial Blood Stream Infection in Adult Patients Admitted in a Tertiary Care Hospital. *Pakistan Journal of Medical & Health Sciences*. 2022;16(12):521. doi:10.53350/pjmhs20221612521
217. Khan FU, Fang Y, Khan Z, et al. Occurrence, associated risk factors, and treatment of surgical site infections in Pakistan. *European Journal of Inflammation*. 2020;18:2058739220960547. doi:10.1177/2058739220960547
218. Hussain MS, Cheema UK, Ashaq A, Sajjad M, Habib M, Anwar M. Prevalence of Candida albicans isolated from High vaginal swab among Gynae/Obstetrics patients in Sheikh Zayed Hospital Rahim Yar Khan. *The Professional Medical Journal*. 2022;29(06):888–894. doi:10.29309/TPMJ/2022.29.06.4602
219. Shirazi JH, Ali MI, Alghamdi HA, et al. Pediatric oropharyngeal candidiasis: a comprehensive study on risk factors and most prevalent species of Candida. *Pakistan Journal of Pharmaceutical Sciences*. 2019;32:1.
220. Yameen MA, Iram S, Mannan A, Khan SA, Akhtar N. Nasal and perirectal colonization of vancomycin sensitive and resistant enterococci in patients of paediatrics ICU (PICU) of tertiary health care facilities. *BMC Infectious Diseases*. 2013;13(1):1–10. doi:10.1186/1471-2334-13-156
221. Rashid Z, Farzana K, Sattar A, Murtaza G. Prevalence of nasal Staphylococcus aureus and methicillin-resistant Staphylococcus aureus in hospital personnel and associated risk factors. *Acta Poloniae Pharmaceutic*. 2012;69:985
222. Riaz S, Hussain A, Sohail M, Rehman SU, Javed N, Abbas Z. Isolation and characterization of Vancomycin resistant Staphylococcus aureus (VRSA) from Intensive Care Units (ICU) of different hospitals in Lahore, Pakistan. *Advancements in Life Sciences*. 2021;8(4):339–344.
223. Mehmood Z, Mubeen SM, Afzal MS, Hussain Z. Potential risk of cross-infection by tourniquets: a need for effective control practices in Pakistan. *International Journal of Preventive Medicine*. 2014;5(9):1119.
224. Qureshi S, Maria N, Zeeshan M, Irfan S, Qamar FN. Prevalence and risk factors associated with multi-drug resistant organisms (MDRO) carriage among pediatric patients at the time of admission in a tertiary care hospital of a developing country. A cross-sectional study. *BMC Infectious Diseases*. 2021;21(1):1–9. doi:10.1186/s12879-021-06275-5
225. Nasir A, Khawaja F, Khan GN. Risk of Developing Central Line-Associated Bloodstream Infections in Integrated Health Care System of Pakistan-A Meta-Analysis. *Allied Medical Research Journal*. 2023;1(1):5–19. doi:10.59564/AMRJ/01.01/003
226. Saleem AF, Ahmed I, Mir F, Ali SR, Zaidi AK. Pan-resistant Acinetobacter infection in neonates in Karachi, Pakistan. *The Journal of Infection in Developing Countries*. 2010;4(01):030–037. doi:10.3855/jidc.533
227. Zaidi AK, Khan H, Lasi R, Mahesar W, Group SM. Surveillance of pneumococcal meningitis among children in Sindh, southern Pakistan. *Clinical Infectious Diseases*. 2009;48(Supplement_2):S129–S135. doi:10.1086/596491
228. Soofi SB, Habib MA, Von Seidlein L, et al. A comparison of disease caused by Shigella and Campylobacter species: 24 months community based surveillance in 4 slums of Karachi, Pakistan. *Journal of Infection and Public Health*. 2011;4(1):12–21. doi:10.1016/j.jiph.2010.10.001
229. Qamar FN, Yousafzai MT, Sultana S, et al. A retrospective study of laboratory-based enteric fever surveillance, Pakistan, 2012–2014. *The Journal of Infectious Diseases*. 2018;218(suppl_4):S201–S205. doi:10.1093/infdis/jiy205
230. Tahseen S, Khanzada FM, Rizvi AH, et al. Isoniazid resistance profile and associated levofloxacin and pyrazinamide resistance in rifampicin resistant and sensitive isolates/from pulmonary and extrapulmonary tuberculosis patients in Pakistan: a laboratory based surveillance study 2015-19. *PLoS One*. 2020;15(9):e0239328. doi:10.1371/journal.pone.0239328
231. Khan MI, Sahito SM, Khan MJ, et al. Enhanced disease surveillance through private health care sector cooperation in Karachi, Pakistan: experience from a vaccine trial. *Bulletin of the World Health Organization*. 2006;84(1):72–77. doi:10.2471/BLT.05.023630
232. Ahdi SG, Batool A, Siddique AW, Waqas A, Gul R, Saleem F. The Menace of Drug Resistant Salmonella Typhi in Children: experience from a Tertiary Care Hospital in Pakistan. *Pak Pediatr J*. 2022;46(3):260–267.
233. Hussain A, Satti L, Hanif F, et al. Typhoidal Salmonella strains in Pakistan: an impending threat of extensively drug-resistant Salmonella Typhi. *European Journal of Clinical Microbiology & Infectious Diseases*. 2019;38(11):2145–2149. doi:10.1007/s10096-019-03658-0
234. Fida S, Mansoor H, Saif S, Iqbal J, Khan AQ. Clinical Perspectives of Multiple and Extensively Drug-Resistant Typhoid; result from a tertiary care hospital from Pakistan. *The Journal of Infection in Developing Countries*. 2021;15(04):530–537. doi:10.3855/jidc.13539

235. Mustafa ZU, Khan AH, Salman M, et al. Healthcare-associated infections among neonates and children in Pakistan: findings and the implications from a point prevalence survey. *Journal of Hospital Infection*. 2023;141:142–151. doi:10.1016/j.jhin.2023.09.011
236. Hussain A, Baloch B, Ahmad M, Khosa SM, Tahir M, Sasoli NA. Antibiotic Resistant Pseudomonas Aeruginosa Causing Nosocomial Infection in Burn Patients of Quetta, Pakistan. *1 Rise in Population Growth and Its Disadvantages*. 2020;31(9):1.
237. Mansoor H, Ahmed K, Fida S, Uzair M, Asghar A, Iqbal J. Gastrointestinal and hepatobiliary complications of extensively drug-resistant typhoid at a tertiary care hospital in Pakistan. *Cureus*. 2020;12(10):1.
238. Imran H, Khan Z, Saleem F, Gull S, Tahir A. The growing threat of antibiotic resistance in wound infections: evidence from tertiary care in Pakistan. *Archives of Biological Sciences*. 2023;21:1.
239. Jabeen K, Nizamuddin S, Irfan S, Khan E, Malik F, Zafar A. Increasing Trend of Resistance to Penicillin, Tetracycline, and Fluoroquinolone Resistance in Neisseria gonorrhoeae from Pakistan (1992–2009). *Journal of Tropical Medicine*. 2011;2011:1–5. doi:10.1155/2011/960501
240. Yousuf S, Ikram A, Ikram S, Nadeem S, Hussain SS, Ali SS. Chlamydia Trachomatis–A Cause of Infertility at Tertiary Care Hospital, Pakistan. *Pakistan Armed Forces Medical Journal*. 2022;72(4):1202–1205. doi:10.51253/pafmj.v72i4.3166
241. Naeem A, Waseem H, Ali S, Usman J, Gilani M, Javed A. Molecular Detection of Chlamydia Trachomatis in Patients with Pelvic Inflammatory Disease Visiting a Tertiary Care Hospital in Pakistan. *Pakistan Armed Forces Medical Journal*. 2022;72(4):1253–1257. doi:10.51253/pafmj.v72i4.7047
242. Hussain K, Khan MF, Ambreen G, et al. An antibiotic stewardship program in a surgical ICU of a resource-limited country: financial impact with improved clinical outcomes. *Journal of Pharmaceutical Policy and Practice*. 2020;13(1):1–10. doi:10.1186/s40545-020-00272-w
243. Butt SZ, Ahmad M, Saeed H, Saleem Z, Javaid Z. Post-surgical antibiotic prophylaxis: impact of pharmacist's educational intervention on appropriate use of antibiotics. *Journal of Infection and Public Health*. 2019;12(6):854–860. doi:10.1016/j.jiph.2019.05.015
244. Qamar K, Irfan H, Johar N. ANTIMICROBIAL DRUG RESISTANCE-SIMULATION BASED METHODICAL ASSESSMENT. *Pakistan Armed Forces Medical Journal*. 2018;68(4):986–991.
245. Shan H, Mashhadi SF, Mahmood H. AWARENESS OF ANTIMICROBIAL RESISTANCE FROM ONE HEALTH PERSPECTIVE AND ITS RELATION TO SOCIAL DETERMINANTS IN RESIDENTS OF WAH: antimicrobial Resistance. *Pakistan Armed Forces Medical Journal*. 2018;68(3):556–564.
246. Hashmi H, Sasoli NA, Sadiq A, et al. Prescribing patterns for upper respiratory tract infections: a prescription-review of primary care practice in Quetta, Pakistan and the implications. *Frontiers in Public Health*. 2021;9:787933. doi:10.3389/fpubh.2021.787933
247. Israr Y, Zaman S, Yousufi S, Riaz Z, Gilani S. The Awareness of Dentists Regarding Antibiotic Resistance in Dental Teaching Hospitals of Peshawar, Pakistan. *Dent Health Curr Res*. 2021;7:8.
248. Taj U, Schmidtke KA, Vlaev I, Read D. Choice of methods can determine which behavioral determinates are identified for targeting in future behavior change interventions: increasing antibiotic adherence in Pakistan. *Journal of Health Psychology*. 2022;27(4):1006–1013. doi:10.1177/1359105320962267
249. Ali F, Zehra T, Solangi NA, Makki KU, Siddiqui HA, Abidi S. Evaluation of carbapenem antimicrobial stewardship program at a tertiary care hospital: a prospective interventional study. *Pakistan Journal of Pharmaceutical Sciences*. 2022;35(6):1595–1601.
250. Mushtaque M, Khalid F, Ishaqui AA, Masood R, Maqsood MB, Muhammad IN. Hospital Antibiotic Stewardship Programs-Qualitative analysis of numerous hospitals in a developing country. *Infection Prevention in Practice*. 2019;1(3–4):100025. doi:10.1016/j.infpip.2019.100025
251. Pethani A, Riaz A, Perveen S, Saleem AF. Situational analysis of antimicrobial stewardship program (ASP) among public and private sector tertiary care hospitals in Karachi, Pakistan: a qualitative case study. *Antimicrobial Stewardship & Healthcare Epidemiology*. 2023;3(1):e161. doi:10.1017/ash.2023.427
252. Perveen S, Habib SS. Identifying constraints for hospital infection control management via McKinsey 7s framework in Pakistan. *Pakistan Journal of Public Health*. 2017;7(4):213. doi:10.32413/pjph.v7i4.81
253. Siddiqui S, Hussein K, Manasia R, et al. Impact of antibiotic restriction on broad spectrum antibiotic usage in the ICU of a developing country. *Journal of Pakistan Medical Association*. 2007;57(10):484.
254. Khan M, Siddiqui S, Haider S, et al. Infection control education: impact on ventilator-associated pneumonia rates in a public sector intensive care unit in Pakistan. *Transactions of the Royal Society of Tropical Medicine and Hygiene*. 2009;103(8):807–811. doi:10.1016/j.trstmh.2009.03.002
255. Ahmed S, Tareq AH, Ilyas D. The Impact of Antimicrobial Resistance and Stewardship Training Sessions on Knowledge of Healthcare Students of Wah Cantonment, Pakistan. *INQUIRY: The Journal of Health Care Organization, Provision, and Financing*. 2024;61:00469580241228443. doi:10.1177/00469580241228443
256. Atif M, Asghar S, Mushtaq I, Malik I. Community pharmacists as antibiotic stewards: a qualitative study exploring the current status of Antibiotic Stewardship Program in Bahawalpur, Pakistan. *Journal of Infection and Public Health*. 2020;13(1):118–124. doi:10.1016/j.jiph.2019.07.003
257. Mubarak N, Khan AS, Zahid T, et al. Assessment of adherence to the core elements of hospital antibiotic stewardship programs: a survey of the tertiary care hospitals in Punjab, Pakistan. *Antibiotics*. 2021;10(8):906. doi:10.3390/antibiotics10080906
258. Bhura M, Ariff S, Qazi SA, et al. Evaluating implementation of in primary health care facilities in Sindh province, Pakistan. *PLoS One*. 2020;15(10):e0240688. doi:10.1371/journal.pone.0240688
259. Raheem M, Anwaar S, Aziz Z, Raja SA, Saif-ur-Rehman N, Mubarak N. Adherence to the core elements of outpatient antibiotic stewardship: a cross-sectional survey in the tertiary care hospitals of Punjab, Pakistan. *Infection and Drug Resistance*. 2020;13:3833–3841. doi:10.2147/IDR.S268574
260. Saeed DK, Hasan R, Naim M, et al. Readiness for antimicrobial resistance (AMR) surveillance in Pakistan; a model for laboratory strengthening. *Antimicrobial Resistance & Infection Control*. 2017;6(1):1–7. doi:10.1186/s13756-017-0260-6
261. Jabeen R, Rabbani U, Abbas N. Situation analysis of antimicrobial resistance control, policy and regulation-a reflection of Pakistan. *Pakistan Journal of Pharmaceutical Sciences*. 2021;34(5):1723–1728.
262. Noorulamin MN, Zarafsah ZB, Janjua A, Iqbal A, Humerah S, Shaiq PA. Future trends in the treatment of MRSA in Pakistan. *Journal of Islamabad Medical & Dental College*. 2022;11(2):96–102. doi:10.35787/jimdc.v11i2.672

263. Malik AA, Fuad J, Siddiqui S, et al. Tuberculosis preventive therapy for individuals exposed to drug-resistant tuberculosis: feasibility and safety of a community-based delivery of fluoroquinolone-containing preventive regimen. *Clinical Infectious Diseases*. 2020;70(9):1958–1965. doi:10.1093/cid/ciz502
264. Malik AA, Gandhi NR, Lash TL, et al. Effectiveness of preventive therapy for persons exposed at home to drug-resistant tuberculosis, Karachi, Pakistan. *Emerging Infectious Diseases*. 2021;27(3):805. doi:10.3201/eid2703.203916
265. Khan SA, Zahid S, Ahmad S, Rehman IU, Samad A, Hamid K. Proper Bacillus Calmette-Guérin (BCG) Scar Formation and Administration in Children under 2 years in a Tertiary Care Hospital. *International Journal of Pathology*. 2022;2022:62–66.
266. Farooq H, Khan H, Akhtar N. Frequency of BCG vaccination among children with pulmonary tuberculosis at a tertiary care hospital. *JMMC*. 2023;13(2):61–65.
267. Gillani S, Kazmi NHS, Kamal M. Role of BCG in preventing childhood tuberculosis. *Pakistan Journal of Physiology*. 2018;14(2):46–49.
268. Hasan Z, Irfan M, Khan JA, et al. BCG vaccination is associated with decreased severity of tuberculosis in Pakistan. *International Journal of Mycobacteriology*. 2012;1(4):201–206. doi:10.1016/j.ijmyco.2012.10.007
269. MAJROOH UA, CHOUDHRY AJ. Pole Of Bcg Vaccine In Prevention Of Tubeculosis In Children Under 5 Years Of Age. *PAKISTAN POSTGRADUATE MEDICAL JOURNAL*. 1998;9(3):185.
270. Rahman M, Rahman AA. Status of BCG vaccination in a semi urban community. *Rawal Med J*. 2013;38(4):422–424.
271. Javed H, Bakuła Z, Pleń M, et al. Evaluation of genotype MTBDR plus and MTBDR sl assays for rapid detection of drug resistance in extensively drug-resistant Mycobacterium tuberculosis isolates in Pakistan. *Frontiers in Microbiology*. 2018;9:2265. doi:10.3389/fmicb.2018.02265
272. Javaid M, Ahmed A, Asif S, Raza A. Diagnostic plausibility of MTBDRplus and MTBDRsl line probe assays for rapid drug susceptibility testing of drug resistant Mycobacterium tuberculosis Strains in Pakistan. *International Journal of Infection*. 2016;3(3). doi:10.17795/iji-34903
273. Ullah I, Shah AA, Basit A, et al. Rifampicin resistance mutations in the 81 bp RRDR of rpoB gene in Mycobacterium tuberculosis clinical isolates using Xpert MTB/RIF in Khyber Pakhtunkhwa, Pakistan: a retrospective study. *BMC Infectious Diseases*. 2016;16(1):1–6. doi:10.1186/s12879-016-1745-2
274. Mengal MZ, Ali H, Asmat R, et al. Detection of Mutations in 81-bpRifampin Resistance Determining Region (RRDR) of rpoB gene in Mycobacterium tuberculosis using GeneXpert MTB/RIF in Clinical Specimens from Quetta, Pakistan. *Pakistan Journal of Zoology*. 2021;53(1):1.
275. Shah RH, Inayat N, Bouk GR, Akhtar M, Khooharo MA, Qayoom S. Rapid Detection of Tuberculosis and Rifampicin Resistance with automated Genexpert MTB/RIF Assay. *Pakistan Journal of Chest Medicine*. 2016;22(2):61–64.
276. Jan F, Yasin M, Khan MA, et al. Prevalence of Mycobacterium Tuberculosis Strains in both Respiratory and Non-Respiratory Clinical Specimens and their Resistance to Rifampicin at a Tertiary Care Teaching Hospital in Pakistan. *Pakistan Journal of Chest Medicine*. 2020;26(4):194–200.
277. Ali A, Hasan R, Jabeen K, Jabeen N, Qadeer E, Hasan Z. Characterization of mutations conferring extensive drug resistance to Mycobacterium tuberculosis isolates in Pakistan. *Antimicrobial Agents and Chemotherapy*. 2011;55(12):5654–5659. doi:10.1128/AAC.05101-11
278. Shah T, Hayat A, Shah Z, Jadoon A, Ahmad S, Khan SB. Molecular detection of multi drug resistant tuberculosis (mdr-tb) in mdr-tb patients'attendant in north western Pakistan. *Pakistan Armed Forces Medical Journal*. 2017;(6):982–987.
279. Awais M, Ahmad R, Jan F, et al. Prevalence and detection of drug-resistant tuberculosis in Hazara Division, Pakistan. *Acad J Biotechnol*. 2018;6(9):116–123.
280. Muzaffar R, Batool S, Aziz F, Naqvi A, Rizvi A. Evaluation of the FASTPlaqueTB assay for direct detection of Mycobacterium tuberculosis in sputum specimens. *The International Journal of Tuberculosis and lung Disease*. 2002;6(7):635–640.
281. Munir S, Mahmood N, Shahid S, Khan MI. Molecular detection of Isoniazid, Rifampin and Ethambutol resistance to M. tuberculosis and M. bovis in multidrug resistant tuberculosis (MDR-TB) patients in Pakistan. *Microbial Pathogenesis*. 2017;110:262–274. doi:10.1016/j.micpath.2017.07.005
282. Amin I, Idrees M, Awan Z, Shahid M, Afzal S, Hussain A. PCR could be a method of choice for identification of both pulmonary and extra-pulmonary tuberculosis. *BMC Research Notes*. 2011;4(1):1–5. doi:10.1186/1756-0500-4-332
283. Ullah I, Javaid A, Masud H, et al. Rapid detection of Mycobacterium tuberculosis and rifampicin resistance in extrapulmonary tuberculosis and sputum smear-negative pulmonary suspects using Xpert MTB/RIF. *Journal of Medical Microbiology*. 2017;66(4):412–418. doi:10.1099/jmm.0.000449
284. Karamat A, Ambreen A, Ishtiaq A, Tahseen S, Rahman MA, Mustafa T. Isolation of non-tuberculous mycobacteria among tuberculosis patients, a study from a tertiary care hospital in Lahore, Pakistan. *BMC Infectious Diseases*. 2021;21(1):381. doi:10.1186/s12879-021-06086-8
285. Codlin AJ, Javaid M, Qazi F, Khan MS. Novel methodology to assess sputum smear microscopy quality in private laboratories. *BMC Infectious Diseases*. 2012;12(1):1–5. doi:10.1186/1471-2334-12-331
286. Ahmed J, Ahmed M, Laghari A, Lohana W, Ali S, Fatmi Z. Public private mix model in enhancing tuberculosis case detection in District Thatta, Sindh, Pakistan. *Journal of the Pakistan Medical Association*. 2009;59(2):82.
287. Kakar N, Abbas F, Shafee M, Asmat T. Study on Accuracy and Efficiency of Molecular Diagnostic Techniques used for Tuberculosis and Analysis of Associated Risk Factors for Tuberculosis in Jail Inmates of Quetta, Pakistan. *Pakistan Journal of Zoology*. 2018;50(4). doi:10.17582/journal.pjz/2018.50.5.1461.1465
288. Wali A, Khan D, Safdar N, et al. Prevalence of tuberculosis, HIV/AIDS, and hepatitis; in a prison of Balochistan: a cross-sectional survey. *BMC Public Health*. 2019;19(1):1–8. doi:10.1186/s12889-019-8011-7
289. Khan N, Mian I, Ullah Z, Muhammad J. Performance of ICT-TB test in the detection of pulmonary and extra-pulmonary tuberculosis. *J Ayub Med College Abbottabad*. 2004;16(2):1.
290. Malik AA, Farooq S, Jaswal M, et al. Safety and feasibility of 1 month of daily rifapentine plus isoniazid to prevent tuberculosis in children and adolescents: a prospective cohort study. *The Lancet Child & Adolescent Health*. 2021;5(5):350–356. doi:10.1016/S2352-4642(21)00052-3
291. Yuen CM, Majidulla A, Jaswal M, et al. Cost of delivering 12-dose isoniazid and rifapentine versus 6 months of isoniazid for tuberculosis infection in a high-burden setting. *Clinical Infectious Diseases*. 2021;73(5):e1135–e1141. doi:10.1093/cid/ciaa1835

292. Wahid A, Ahmad N, Ghafoor A, et al. Effectiveness of shorter treatment regimen in multidrug-resistant tuberculosis patients in Pakistan: a multicenter retrospective record review. *The American Journal of Tropical Medicine and Hygiene*. 2021;104(5):1784. doi:10.4269/ajtmh.20-1134
293. Khan MA, Aziz A, Ullah U, et al. Treatment Outcomes of Short Course Regimens for Multidrug-Resistant Tuberculosis patients in Peshawar. *Pakistan Journal of Chest Medicine*. 2020;26(4):210–216.
294. Wahid A, Ghafoor A, Khan AW, et al. Comparative effectiveness of individualized longer and standardized shorter regimens in the treatment of multidrug resistant tuberculosis in a high burden country. *Frontiers in Pharmacology*. 2022;13:973713. doi:10.3389/fphar.2022.973713
295. Habib F, Baig L. Cost of DOTS for tuberculous patients. *JOURNAL-PAKISTAN MEDICAL ASSOCIATION*. 2006;56(5):207.
296. Quadir A, Ghafoor A, Shah SK, et al. Optimizing outcomes for drug resistant tuberculosis patients through provision of a comprehensive care package. *Pakistan Journal of Public Health*. 2022;12(1):8–12. doi:10.32413/pjph.v12i1.958
297. Randhawa KS, Khattak LU, Shaukat FA, Rafique S, Nasir M, Hayat S. Outcome Optimization For Patients With Drug-Resistant Tb Via The Implementation Of An All-Inclusive Care Program. *Journal of Pharmaceutical Negative Results*. 2023;2023:4001–4006.
298. Walley JD, Khan MA, Newell JN, Khan MH. Effectiveness of the direct observation component of DOTS for tuberculosis: a randomised controlled trial in Pakistan. *The Lancet*. 2001;357(9257):664–669. doi:10.1016/S0140-6736(00)04129-5
299. Khan M, Walley J, Witter S, Imran A, Safdar N. Costs and cost-effectiveness of different DOT strategies for the treatment of tuberculosis in Pakistan. *Health Policy and Planning*. 2002;17(2):178–186. doi:10.1093/heapol/17.2.178
300. Latif A, Ghafoor A, Wali A, et al. Did diabetes mellitus affect treatment outcome in drug-resistant tuberculosis patients in Pakistan from 2010 to 2014? *Public Health Action*. 2018;8(1):14–19. doi:10.5588/pha.17.0098
301. Pasha A, Siddiqui H, Ali S, Brooks MB, Maqbool NR, Khan AJ. Impact of integrating mental health services within existing tuberculosis treatment facilities. *Medicine Access@ Point of Care*. 2021;5:23992026211011314. doi:10.1177/23992026211011314
302. Mukhtar F, Butt ZA. Cohort profile: the diabetes-tuberculosis treatment outcome (DITTO) study in Pakistan. *BMJ open*. 2016;6(12):e012970. doi:10.1136/bmjopen-2016-012970
303. Naz F, Ahmad N, Wahid A, et al. High rate of successful treatment outcomes among childhood rifampicin/multidrug-resistant tuberculosis in Pakistan: a multicentre retrospective observational analysis. *BMC Infectious Diseases*. 2021;21(1):1–11. doi:10.1186/s12879-021-06935-6
304. Khan FU, Rehman AU, Khan FU, et al. Assessment of factors associated with unfavorable outcomes among drug-resistant TB patients: a 6-year retrospective study from Pakistan. *International Journal of Environmental Research and Public Health*. 2022;19(3):1574. doi:10.3390/ijerph19031574
305. Atif M, Mukhtar S, Sarwar S, Naseem M, Malik I, Mushtaq A. Drug resistance patterns, treatment outcomes and factors affecting unfavourable treatment outcomes among extensively drug resistant tuberculosis patients in Pakistan; a multicentre record review. *Saudi Pharmaceutical Journal*. 2022;30(4):462–469. doi:10.1016/j.jsps.2022.01.015
306. Balachandra SS, Sawant PS, Huilgol PG, Vithya T, Kumar G, Prasad R. Antimicrobial resistance (AMR) at the community level: an urban and rural case study from Karnataka. *Journal of Family Medicine and Primary Care*. 2021;10(3):1404–1411. doi:10.4103/jfmpc.jfmpc_888_20
307. Chowdhury M, Stewart Williams J, Wertheim H, Khan WA, Matin A, Kinsman J. Rural community perceptions of antibiotic access and understanding of antimicrobial resistance: qualitative evidence from the Health and Demographic Surveillance System site in Matlab, Bangladesh. *Global Health Action*. 2019;12(sup1):1824383. doi:10.1080/16549716.2020.1824383
308. Wangai FK, Masika MM, Lule GN, et al. Bridging antimicrobial resistance knowledge gaps: the East African perspective on a global problem. *PLoS One*. 2019;14(2):e0212131. doi:10.1371/journal.pone.0212131
309. Sono TM, Maluleke MT, Ramdas N, et al. Pilot study to evaluate the feasibility of a patient questionnaire for the purpose of investigating the extent of purchasing antibiotics without a prescription in a rural province in South Africa: rationale and implications. *Advances in Human Biology*. 2024;14(2):138–147. doi:10.4103/aihb.aihb_140_23
310. Torres NF, Chibi B, Kuupiel D, Solomon VP, Mashamba-Thompson TP, Middleton LE. The use of non-prescribed antibiotics; prevalence estimates in low-and-middle-income countries. A systematic review and meta-analysis. *Archives of Public Health*. 2021;79(1):1–15. doi:10.1186/s13690-020-00517-9
311. Sono TM, Markovic-Pekovic V, Godman B. Effective programmes to reduce inappropriate dispensing of antibiotics in community pharmacies especially in developing countries. *Adv Hum Biol*. 2024;2024:1–4.
312. Lightowler MS, Manangazira P, Nackers F, et al. Effectiveness of typhoid conjugate vaccine in Zimbabwe used in response to an outbreak among children and young adults: a matched case control study. *Vaccine*. 2022;40(31):4199–4210. doi:10.1016/j.vaccine.2022.04.093
313. Theiss-Nyland K, Qadri F, Colin-Jones R, et al. Assessing the impact of a Vi-polysaccharide conjugate vaccine in preventing typhoid infection among Bangladeshi children: a protocol for a phase IIIb trial. *Clinical Infectious Diseases*. 2019;68(Supplement_2):S74–S82. doi:10.1093/cid/ciy1107
314. Klugman KP, Black S. Impact of existing vaccines in reducing antibiotic resistance: primary and secondary effects. *Proceedings of the National Academy of Sciences*. 2018;115(51):12896–12901. doi:10.1073/pnas.1721095115
315. Batool R, Qamar ZH, Salam RA, Yousafzai MT, Ashorn P, Qamar FN. Efficacy of typhoid vaccines against culture-confirmed Salmonella Typhi in typhoid endemic countries: a systematic review and meta-analysis. *The Lancet Global Health*. 2024;12(4):e589–e598. doi:10.1016/S2214-109X(23)00606-X
316. Nampota-Nkomba N, Nyirenda OM, Khonde L, et al. Safety and immunogenicity of a typhoid conjugate vaccine among children aged 9 months to 12 years in Malawi: a nested substudy of a double-blind, randomised controlled trial. *The Lancet Global Health*. 2022;10(9):e1326–e1335. doi:10.1016/S2214-109X(22)00275-3
317. Jin C, Gibani MM, Moore M, et al. Efficacy and immunogenicity of a Vi-tetanus toxoid conjugate vaccine in the prevention of typhoid fever using a controlled human infection model of Salmonella Typhi: a randomised controlled, phase 2b trial. *The Lancet*. 2017;390(10111):2472–2480. doi:10.1016/S0140-6736(17)32149-9
318. Rehman SU, Siddiqui AR, Ahmed J, et al. Coverage and predictors of routine immunization among 12-23 months old children in disaster affected communities in Pakistan. *International Journal of Health Sciences*. 2017;11(1):1.
319. Mustafa ZU, Salman M, Khan AH, Harun SN, Meyer JC, Godman B. Antimicrobial use among hospitalized neonates and children; findings and implications from a comprehensive point prevalence survey among general tertiary hospitals in Pakistan. *Infection and Drug Resistance*. 2024;17:5411–5428. doi:10.2147/IDR.S491454

320. Antoñanzas F, Juárez-Castelló C, Rodríguez-Ibeas R. Using point-of-care diagnostic testing for improved antibiotic prescription: an economic model. *Health Economics Review*. 2021;11(1):1–12. doi:10.1186/s13561-021-00326-y
321. Heidt B, Siqueira WF, Eersels K, et al. Point of care diagnostics in resource-limited settings: a review of the present and future of PoC in its most needed environment. *Biosensors*. 2020;10(10):133. doi:10.3390/bios10100133
322. Ibrahim KA, Abdel-Wahab AA, Ibrahim AS. Diagnostic value of serum procalcitonin levels in children with meningitis: a comparison with blood leukocyte count and C-reactive protein. *JPMA*. 2011;61(4):346.
323. Khan M, Khattak MT, Gul A, Riaz M, Tu Zahra F. A comparable risk of extensively drug-resistant typhoid fever in the pediatric cohort during the COVID-19 pandemic. *International Journal of Health Sciences*. 2024;18(1):24.
324. Tawfick MM, Adulall AK, El-Kholy AA, El Manakhly AR. Mutation-based fluoroquinolone resistance in carbapenem-resistant Acinetobacter baumannii and Escherichia coli isolates causing catheter-related bloodstream infections. *International Journal of Health Sciences*. 2023;17(3):18.
325. Aldarhami A. Identification of novel bacteriocin against Staphylococcus and Bacillus species. *International Journal of Health Sciences*. 2023;17(5):15.
326. Hoque R, Ahmed SM, Naher N, et al. Tackling antimicrobial resistance in Bangladesh: a scoping review of policy and practice in human, animal and environment sectors. *PLoS One*. 2020;15(1):e0227947. doi:10.1371/journal.pone.0227947
327. Laxminarayan R, Chaudhury RR. Antibiotic resistance in India: drivers and opportunities for action. *PLoS medicine*. 2016;13(3):e1001974. doi:10.1371/journal.pmed.1001974
328. Tabish SA, Tabish SA, Afzal WM, Kirmani A. Recent trends in emerging infectious diseases. *International Journal of Health Sciences*. 2009;3(2):59–62.
329. Zeng Z, Zhan J, Zhang K, Chen H, Cheng S. Global, regional, and national burden of urinary tract infections from 1990 to 2019: an analysis of the global burden of disease study 2019. *World Journal of Urology*. 2022;40(3):755–763. doi:10.1007/s00345-021-03913-0
330. Aiyegoro O, Igbinosa O, Ogunmwonyi I, Odjadjare E, Igbinosa O, Okoh A. Incidence of urinary tract infections (UTI) among children and adolescents in Ile-Ife, Nigeria. *Afr J Microbiol Res*. 2007;1(2):13–19.
331. Ghanbari F, Khademi F, Saberianpour S, et al. An epidemiological study on the prevalence and antibiotic resistance patterns of bacteria isolated from urinary tract infections in central Iran. *Avicenna Journal of Clinical Microbiology and Infection*. 2017;4(3):42214. doi:10.5812/ajcmi.42214
332. Mathai D, Jones R, Pfaller M, America TSPGN. Epidemiology and frequency of resistance among pathogens causing urinary tract infections in 1,510 hospitalized patients: a report from the SENTRY Antimicrobial Surveillance Program (North America). *Diagnostic Microbiology and Infectious Disease*. 2001;40(3):129–136. doi:10.1016/S0732-8893(01)00254-1
333. Shariq A, Rasheed Z, Alghsham RS, Al Abdulmonem W. Candida auris: an emerging fungus that presents a serious global health threat. *International Journal of Health Sciences*. 2023;17(2):1.
334. Otieno PA, Campbell S, Maley S, Obinju Arunga T, Otieno Okumu M. A Systematic Review of Pharmacist-Led Antimicrobial Stewardship Programs in Sub-Saharan Africa. *International Journal of Clinical Practice*. 2022;2022(1):3639943. doi:10.1155/2022/3639943
335. Akpan MR, Isemin NU, Udoh AE, Ashiru-Oredope D. Implementation of antimicrobial stewardship programmes in African countries: a systematic literature review. *Journal of Global Antimicrobial Resistance*. 2020;22:317–324. doi:10.1016/j.jgar.2020.03.009
336. Siachalinga L, Mufwambi W, Lee I-H. Impact of antimicrobial stewardship interventions to improve antibiotic prescribing for hospital inpatients in Africa: a systematic review and meta-analysis. *Journal of Hospital Infection*. 2022;129:124–143. doi:10.1016/j.jhin.2022.07.031
337. Cox JA, Vlieghe E, Mendelson M, et al. Antibiotic stewardship in low-and middle-income countries: the same but different? *Clinical Microbiology and Infection*. 2017;23(11):812–818. doi:10.1016/j.cmi.2017.07.010
338. Saleem Z, Moore CE, Kalungia AC, et al. Status and implications of the knowledge, attitudes and practices towards AWaRe antibiotic use, resistance and stewardship among low-and middle-income countries. *JAC-Antimicrobial Resistance*. 2025;7(2):dlaf033. doi:10.1093/jacamr/dlaf033
339. Sheikh S, Saleem Z, Afzal S, et al. Identifying targets for antibiotic stewardship interventions in pediatric patients in Punjab, Pakistan: point prevalence surveys using AWaRe guidance. *Frontiers in Pediatrics*. 2025;12:1469766. doi:10.3389/fped.2024.1469766
340. Mustafa ZU, Khan AH, Salman M, Harun SN, Meyer JC, Godman B. Paediatricians' knowledge, perceptions, preparedness and involvement towards paediatric antimicrobial stewardship in Pakistan: findings and the implications. *JAC-Antimicrobial Resistance*. 2024;6(6):dlae193. doi:10.1093/jacamr/dlae193
341. Saleem Z, Sheikh S, Godman B, et al. Increasing the use of the WHO AWaRe system in antibiotic surveillance and stewardship programmes in low-and middle-income countries. *JAC-Antimicrobial Resistance*. 2025;7(2):dlaf031. doi:10.1093/jacamr/dlaf031
342. Saleem Z, Mekonnen BA, Orubu ES, et al. Current access, availability and use of antibiotics in primary care among key low-and middle-income countries and the policy implications. *Expert Review of Anti-Infective Therapy*;2025. 1–42. doi:10.1080/14787210.2025.2477198
343. Aftab I, Farwa U, Kaleem F, Riaz H, Khattak M. EFFICACY OF CEFTAROLINE AGAINST METHICILLIN RESISTANT STAPHYLOCOCCUS AUREUS: a CROSS-SECTIONAL STUDY. *Pakistan Journal of Pathology*. 2021;32(3):87–90.
344. Abdullah S, Saleem Z, Godman B, et al. Surge of branded generics and antimicrobial resistance: analyzing the antibiotic market dynamics in Pakistan through the WHO essential medicines and AWaRe lens. *Expert Review of Anti-Infective Therapy*. 2025;23(7):513–521. doi:10.1080/14787210.2025.2511958
345. Katelaris AL, Jackson C, Southern J, et al. Effectiveness of BCG vaccination against Mycobacterium tuberculosis infection in adults: a cross-sectional analysis of a UK-based cohort. *The Journal of Infectious Diseases*. 2020;221(1):146–155. doi:10.1093/infdis/jiz430
346. Michelsen S, Soborg B, Koch A, et al. The effectiveness of BCG vaccination in preventing Mycobacterium tuberculosis infection and disease in Greenland. *Thorax*. 2014;69(9):851–856. doi:10.1136/thoraxjnl-2014-205688
347. Favorov M, Ali M, Tursunbayeva A, et al. Comparative tuberculosis (TB) prevention effectiveness in children of Bacillus Calmette-Guérin (BCG) vaccines from different sources, Kazakhstan. *PLoS One*. 2012;7(3):e32567. doi:10.1371/journal.pone.0032567
348. Hassane-Harouna S, Cherif G-F, Ortuno-Gutierrez N, et al. Better programmatic outcome with the shorter regimen for the treatment of multidrug-resistant tuberculosis (MDR-TB) in Guinea: a retrospective cohort study. *PLoS One*. 2020;15(8):e0237355. doi:10.1371/journal.pone.0237355

349. Doan TN, Fox GJ, Meehan MT, et al. Cost-effectiveness of 3 months of weekly rifapentine and isoniazid compared with other standard treatment regimens for latent tuberculosis infection: a decision analysis study. *Journal of Antimicrobial Chemotherapy*. 2019;74(1):218–227. doi:10.1093/jac/dky403
350. Pease C, Hutton B, Yazdi F, et al. Efficacy and completion rates of rifapentine and isoniazid (3HP) compared to other treatment regimens for latent tuberculosis infection: a systematic review with network meta-analyses. *BMC Infectious Diseases*. 2017;17(1):1–11. doi:10.1186/s12879-017-2377-x
351. Trébucq A, Schwoebel V, Kashongwe Z, et al. Treatment outcome with a short multidrug-resistant tuberculosis regimen in nine African countries. *The International Journal of Tuberculosis and Lung Disease*. 2018;22(1):17–25. doi:10.5588/ijtld.17.0498
352. Macaraig M, Jalees M, Lam C, Burzynski J. Improved treatment completion with shorter treatment regimens for latent tuberculous infection. *The International Journal of Tuberculosis and Lung Disease*. 2018;22(11):1344–1349. doi:10.5588/ijtld.18.0035
353. Zhang H, Ehiri J, Yang H, Tang S, Li Y. Impact of community-based DOT on tuberculosis treatment outcomes: a systematic review and meta-analysis. *PLoS One*. 2016;11(2):e0147744. doi:10.1371/journal.pone.0147744
354. Wandwalo E, Robberstad B, Morkve O. Cost and cost-effectiveness of community based and health facility based directly observed treatment of tuberculosis in Dar es Salaam, Tanzania. *Cost Effectiveness and Resource Allocation*. 2005;3(1):1–9. doi:10.1186/1478-7547-3-6
355. Tian J-H, Lu Z, Bachmann M, Song F. Effectiveness of directly observed treatment of tuberculosis: a systematic review of controlled studies. *The International Journal of Tuberculosis and lung Disease*. 2014;18(9):1092–1098. doi:10.5588/ijtld.13.0867