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Containing the Silent Pandemic: A Narrative Review of a One-Health Approach to Antimicrobial Resistance from Laboratory to Bedside to Community

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Abstract

Background: Antimicrobial resistance (AMR) is a quintessential "One Health" crisis, propelled by interconnected drivers in human, animal, and environmental ecosystems. Containing AMR demands an integrated, multidisciplinary response that transcends traditional silos in healthcare delivery. **Aim:** This narrative review synthesizes evidence from 2015-2024 to analyze a coordinated AMR containment framework integrating the roles of laboratory science, epidemiology, pharmacy, radiology, nursing, community health, and health administration. **Methods:** A systematic search of PubMed, Scopus, CINAHL, and Web of Science informed a narrative synthesis of themes including rapid diagnostics, stewardship interventions, infection prevention, surveillance, and public engagement. **Results:** Evidence confirms that fragmented efforts are ineffective. Success hinges on laboratory-driven rapid diagnostics guiding pharmacist-led antimicrobial stewardship at the bedside, underpinned by nursing-led infection prevention. Radiology provides critical diagnostic and therapeutic support, while public health and administration build population-level surveillance and enable policy. Key barriers include diagnostic access disparities, interprofessional communication gaps, and conflicting economic incentives. **Conclusion:** AMR is a systems failure requiring a systems solution. A proactive, integrated One-Health model, where data seamlessly flows from the community to the lab and back to the point of care, is essential to preserve antimicrobial efficacy. Future efforts must prioritize interoperable data systems, standardized metrics, and economic models that reward stewardship.

Keywords: Antimicrobial resistance, One Health, antimicrobial stewardship, rapid diagnostic testing, infection prevention

Introduction

Antimicrobial resistance (AMR) represents one of the most complex and pressing global health threats of the 21st century, often termed the "silent pandemic" (Rochford et al., 2018). Its etiology is fundamentally rooted in the One Health paradigm, acknowledging that the health of humans, animals, and ecosystems is inextricably linked (Robinson et al., 2016). The relentless selection pressure exerted by antimicrobial overuse and misuse across these domains has accelerated the evolution and spread of multidrug-resistant organisms (MDROs), such as methicillin-resistant *Staphylococcus aureus* (MRSA), extended-spectrum beta-lactamase (ESBL)-producing Enterobacterales, and carbapenem-resistant *Acinetobacter baumannii* (CRAB)

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(Dadgostar, 2019). The consequences are dire: prolonged illnesses, increased hospitalizations, higher healthcare costs, and elevated mortality. Without decisive action, a post-antibiotic era, where common infections and minor injuries can once again kill, is a realistic prospect (O'Neill, 2016).

The traditional healthcare response to AMR has often been siloed and reactive. Clinicians prescribe, pharmacists dispense, microbiologists report, and infection control practitioners contain outbreaks—often with limited real-time collaboration. This fragmentation is a critical vulnerability. Effective AMR containment requires a seamless, proactive, and integrated system where intelligence from the laboratory directly informs prescribing at the bedside, where infection prevention measures protect the community within the hospital, and where public health surveillance connects hospital-acquired resistance to broader community and environmental trends (Laxminarayan et al., 2015). It is a battle fought simultaneously at the molecular level in the lab, the clinical level at the patient's side, and the societal level in communities and agricultural settings. Figure 1 illustrates the interconnected roles of laboratory science and epidemiology, clinical antimicrobial stewardship, public health policy, and environmental health in addressing antimicrobial resistance.

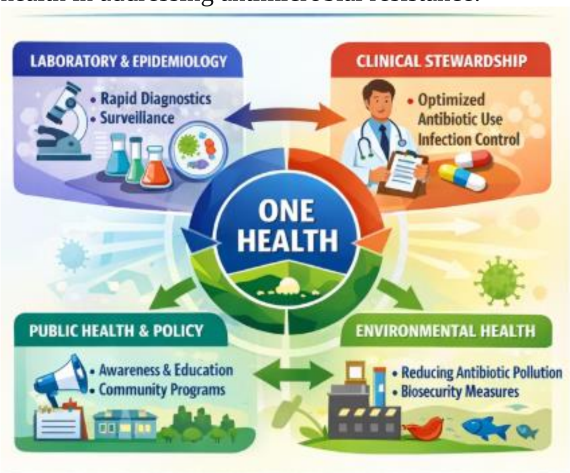

Figure 1: Integrated One-Health Framework for Combating Antimicrobial Resistance

This narrative review aims to synthesize contemporary evidence (2015-2024) on a cohesive, multidisciplinary framework for AMR containment. It moves beyond examining single-discipline interventions to analyze how the integrated functions of laboratory science & epidemiology, pharmacy, radiology, nursing, community health, and health administration can create a synergistic defense. We will explore how rapid diagnostics must catalyze stewardship, how radiological findings can guide therapy, how nursing practice is the frontline of prevention, and how administrative and public health policy must create the enabling environment for this collaboration. The goal is to provide a roadmap for healthcare systems to transition from fragmented defense to a unified, One-Health-oriented offense against AMR.

Methodology

A narrative review methodology was employed to synthesize a broad and interdisciplinary evidence base, encompassing diverse study designs and grey literature relevant to the multifactorial challenge of AMR. A systematic search was conducted in PubMed, Scopus, CINAHL, and Web of Science for literature published between January 2015 and December 2024. Search strings combined key terms and MeSH headings: ("antimicrobial resistance" OR "antibiotic resistance") AND ("One Health" OR "multidisciplinary" OR "stewardship") AND ("rapid diagnostic test*" OR "stewardship" OR "infection prevention" OR "surveillance") AND ("laboratory" OR "pharmacy" OR "nursing" OR "radiology" OR "public health" OR "administration"). Reference lists of key articles and relevant reports from the World Health Organization (WHO), Centers for Disease Control and Prevention (CDC), and European Centre for Disease Prevention and Control (ECDC) were manually screened.

Inclusion criteria covered peer-reviewed primary research (including interventional trials, observational studies, and cost-analyses), systematic reviews, meta-analyses, consensus guidelines, and authoritative policy reports. Articles were excluded if published before 2015, not available in English, or solely focused on veterinary or environmental aspects without clear links to human health integration. Thematic analysis was performed on selected literature to identify convergent and divergent findings across seven core professional domains, structuring the synthesis to reflect the patient and pathogen journey from community to laboratory to bedside and back.

The Foundational Role of Laboratory Science and Epidemiology

The clinical microbiology laboratory and public health epidemiology function as the central nervous system for AMR containment, generating the actionable intelligence upon which all other interventions depend (Table 1).

Rapid Diagnostic Testing (RDT)

The paradigm shift from traditional culture-based methods, which can take 48-72 hours, to rapid molecular and phenotypic tests is transformative (Adams et al., 2023). Technologies like multiplex PCR panels (for respiratory, gastrointestinal, and bloodstream infections) and fluorescence *in situ* hybridization (FISH) can identify pathogens and key resistance markers (*mecA*, *vanA*, *bla*KPC) within hours (Bauer et al., 2014; Clark et al., 2023). The clinical impact of RDT is most potent when paired with stewardship. Randomized trials demonstrate that providing RDT results with interpretive guidance ("MRSA negative, consider de-escalation") significantly reduces time to optimal therapy, decreases broad-spectrum antibiotic use, and can improve patient outcomes in sepsis (Beganovic et al., 2019; Timbrook et al., 2016). For epidemiology, RDT enables near real-time detection of emerging resistance patterns and outbreaks within a facility.

Antimicrobial Susceptibility Testing (AST) and Reporting

Beyond detection, precise phenotypic AST remains the gold standard for guiding therapy. Innovations like rapid AST systems and next-generation sequencing for comprehensive resistance gene detection are refining this guidance (Burnham et al., 2017). However, the *reporting* of AST is equally critical. The implementation of cascading or selective reporting, where only first-line or narrow-spectrum susceptible results are automatically released, is a powerful behavioral nudge to curb unnecessary broad-spectrum use (Langford et al., 2019). Furthermore, the epidemiological function aggregates laboratory data to create institutional antibiograms and, at the public health level, national surveillance networks like the CDC's Antimicrobial Resistance Laboratory Network. These tools map the geographic and temporal spread of MDROs, identify high-risk populations, and inform empirical treatment guidelines at regional and national levels (Satlin et al., 2023). Figure 2 shows a schematic representation of the antimicrobial stewardship continuum, demonstrating how rapid diagnostics and surveillance in the laboratory inform optimized therapy and infection prevention at the bedside, with downstream impacts on community education, monitoring, and resistance containment.

Table 1: Key Rapid Diagnostic Technologies and Their Stewardship Impact

Technology/Assay	Time to Result	Key Information Provided	Primary Stewardship Application
Blood Culture PCR Panels (e.g., BioFire® FilmArray)	1-2 hours	Identification of common pathogens & resistance markers (e.g., *mecA*, *vanA/B*, *bla*KPC) from positive blood cultures.	Early de-escalation or escalation in sepsis; guiding definitive therapy 24-48 hours earlier.
Direct Specimen PCR (e.g., for MRSA/SA nasal swab)	<2 hours	Detection of colonization.	Pre-operative prophylaxis optimization; contact isolation decisions.
Multiplex Respiratory PCR Panels	1-2 hours	Detection of viral & bacterial pathogens.	Discontinuation of unnecessary antibiotics in viral bronchitis/influenza.
MALDI-TOF Mass Spectrometry	Minutes after colony growth	Rapid microbial identification from culture.	Speeds identification by ~24 hours, enabling earlier targeted therapy.
Rapid Phenotypic AST (e.g., Accelerate Pheno®)	~7 hours	Minimum Inhibitory Concentration (MIC) data.	Provides definitive susceptibility data hours, not days, after culture positivity.

Figure 2: Flow of Antimicrobial Stewardship from Laboratory to Bedside to Community

Pharmacy as The Engine of Antimicrobial Stewardship Programs

Armed with diagnostic intelligence from the laboratory, the pharmacy department, through Antimicrobial Stewardship Programs (ASPs), operationalizes evidence-based antimicrobial use. ASPs are coordinated interventions designed to measure and improve the appropriateness of antimicrobial prescribing (Barlam et al., 2016).

Core ASP Strategies

Prospective audit and feedback (PAF), where a pharmacist or physician reviews prescribed antimicrobials and provides direct, non-confrontational recommendations to the prescriber, is a cornerstone of effective ASPs and supported by strong evidence for improving prescribing patterns (Karanika et al., 2016). Formulary restriction and pre-authorization for specific high-risk antibiotics (e.g., carbapenems) effectively control their use but require 24/7 availability to avoid care delays (Yarahuan et al., 2023). Guideline and clinical pathway development, co-created with infectious diseases, laboratory, and nursing, standardize empirical therapy for common syndromes like community-acquired pneumonia or urinary tract infections, reducing inappropriate variation (Tamma et al., 2019).

Pharmacist-Driven Interventions

Beyond program coordination, pharmacists execute critical point-of-care interventions. IV-to-oral conversion protocols facilitate early switch for stable patients, reducing complications and costs associated with IV therapy and enabling earlier discharge (Heck et al., 2020). Dose optimization, through therapeutic drug monitoring (e.g., for vancomycin, aminoglycosides) and renal/hepatic dosing adjustments, ensures efficacy while minimizing toxicity and resistance selection. Pharmacists are also pivotal in managing antimicrobial shortages, recommending evidence-based alternatives to preserve first-line agents for critical needs (Pulia et al., 2020).

Radiology as the Visual Guide for Diagnosis and Intervention

Medical imaging plays an underappreciated yet vital role in the AMR containment cascade, serving both diagnostic and therapeutic functions.

Diagnostic Clues to Resistant Infections

While not pathognomonic, certain imaging patterns should raise suspicion for MDROs, prompting more aggressive diagnostic workup and empirical coverage. In the lungs, necrotizing pneumonia with rapid cavitation, particularly in a healthcare-exposed patient, can suggest *Pseudomonas aeruginosa* or MRSA (Franquet, 2001). In soft tissues and bones, extensive, multifocal, or rapidly progressive abscesses or osteomyelitis may indicate resistant pathogens. Abdominal imaging may reveal complex, loculated collections in postoperative or healthcare-associated intra-abdominal infections that are more likely to harbor MDROs. Radiologists' interpretive comments flagging these possibilities can directly alert clinicians to consider resistant organisms (Field et al., 2023).

Interventional Radiology (IR) for Source Control

Perhaps the most direct contribution is through IR-guided procedures. For deep-seated infections—such as intra-abdominal, hepatic, pulmonary, or soft tissue abscesses—image-guided percutaneous drainage is a minimally invasive method to achieve source control (Palumbo et al., 2020). Effective drainage is a fundamental principle of infection management; it reduces the microbial burden, enhances antibiotic penetration, and can be curative for well-localized infections, thereby reducing the duration and spectrum of required antimicrobial therapy. In cases of device-related infections (e.g., infected cholecystostomy tubes), IR can facilitate exchange or removal.

Nursing as the Bedside Bastion of Prevention and Stewardship

Nurses are the constant healthcare presence at the patient's bedside, positioning them as essential agents in both preventing infections and ensuring the success of stewardship interventions.

Infection Prevention and Control (IPC)

Nursing practice is the primary execution point for IPC measures that prevent the transmission of MDROs. Meticulous adherence to hand hygiene, contact precautions for patients colonized or infected with MDROs, and proper care of invasive devices (central lines, urinary catheters, ventilators) are nursing-driven actions that directly reduce cross-transmission and healthcare-associated infections (HAIs) (Saint et al., 2010). Nurse-driven protocols for catheter and line necessity assessments have proven highly effective in reducing device utilization and subsequent infections (Saint et al., 2016).

Specimen Collection and Stewardship Support

The accuracy of laboratory diagnostics is entirely dependent on pre-analytical quality. Nurses ensure proper specimen collection technique (sterile blood culture draws, minimizing contamination in urine samples), which is critical for avoiding false-positive results that lead to unnecessary antibiotics (Cadamuro et al., 2022). Furthermore, nurses are key stewards in monitoring for treatment response and failure. They are often the first to identify clinical deterioration, new fevers, or adverse drug reactions, triggering re-evaluation of the therapeutic plan. Their role in patient and family education regarding the importance of completing prescribed antibiotic courses and not sharing medications is a direct community-facing stewardship activity (Greendyke et al., 2018).

Community Health and Health Administration

The hospital-based efforts described above cannot succeed in isolation. They require a supportive macro-environment shaped by community health initiatives and astute health administration (Table 2).

Public Education and Community Engagement

Misconceptions about antibiotics drive demand. Community health campaigns aimed at the public and primary care providers are essential to reduce inappropriate antibiotic expectations for viral illnesses. The CDC's "Be Antibiotics Aware" campaign is a prime example (Fleming-Dutra et al., 2018). Furthermore, regulating over-the-counter antibiotic sales, a major driver of resistance in many low- and middle-income countries, is a critical public health policy challenge requiring legislative action and enforcement (Auta et al., 2019). Community pharmacists are pivotal partners in these efforts, providing patient counseling and refusing inappropriate requests.

Health Administration's Policy, Finance, and Data Infrastructure

Hospital administrators and health system leaders create the conditions for success. They must prioritize and fund ASP and IPC programs, including dedicated personnel (e.g., stewardship pharmacists, infection preventionists). This involves making a business case that balances upfront costs against long-term savings from reduced HAIs, drug costs, and length of stay (Nelson et al., 2023). Administration is responsible for establishing clear institutional policies that define stewardship responsibilities, empower ASP interventions, and integrate stewardship metrics into quality dashboards and provider performance evaluations. Finally, investing in health information technology (HIT) is non-negotiable. Electronic health records (EHRs) with clinical decision support (CDS) tools that embed local guidelines, prompt IV-to-oral conversion, and facilitate audit and feedback are force multipliers for ASPs (Same et al., 2021).

Table 2: Interdisciplinary AMR Containment Strategies Across the Care Continuum

Domain	Prevention Focus	Diagnostic/Therapeutic Focus	Policy/Surveillance Focus
Lab & Epidemiology	Outbreak detection via molecular typing.	Rapid Dx, precise AST, cascading reporting.	Regional/national surveillance networks; antibiogram development.
Pharmacy	Optimizing prophylaxis regimens.	Prospective audit & feedback; dose optimization; IV-to-oral conversion.	Formulary management; stewardship program leadership.
Radiology	--	Identifying imaging patterns suggestive of resistance; achieving image-guided source control.	--
Nursing	Hand hygiene, contact precautions, device care.	High-quality specimen collection; monitoring treatment response.	Patient education on antibiotic use.
Community Health	Public campaigns on appropriate antibiotic use.	--	Advocacy for regulations on OTC antibiotics; community-level surveillance.
Health Administration	Funding IPC infrastructure.	Funding ASP, HIT/CDS systems.	Setting institutional policy; integrating AMR metrics into quality benchmarks.

The Integrated One-Health Defense Model

The evidence consistently demonstrates that the disciplines reviewed do not operate in parallel but in a necessary, dynamic sequence. The model functions as a continuous cycle: Community-level pressures (misuse, agricultural use) increase the prevalence of MDROs. These enter healthcare settings, where nursing-led IPC attempts to block transmission. When infections occur, high-quality nursing specimen collection triggers the laboratory's rapid diagnostic engine, generating intelligence. This intelligence is immediately acted upon by pharmacy-led ASPs (via PAF, guideline adherence) to optimize therapy, while radiology aids in diagnosis and offers therapeutic drainage. Throughout, nursing monitors the clinical response. Epidemiology aggregates data from the lab to track trends, informing updates to administrative policy and public health guidelines, which in turn shape community education and prescriber behavior, closing the loop. A breakdown in any node weakens the entire network. For example, a rapid diagnostic test is useless if the result is ignored by the prescriber or if the initial specimen was contaminated.

Barriers and Future Directions

Significant barriers impede this ideal integration: Diagnostic access disparities limit RDT benefits to well-resourced settings. Siloed professional cultures and communication gaps between departments persist. Misaligned economic incentives (e.g., fee-for-service models that reward volume over appropriate use) undermine stewardship. Data interoperability between laboratory, pharmacy, and EHR systems is often lacking.

Future efforts must focus on: 1) Developing and validating affordable, point-of-care RDTs for low-resource settings. 2) Implementing interoperable HIT with advanced analytics and "push" alerts to fully leverage diagnostic data. 3) Creating blended payment models that financially reward hospitals for effective stewardship and infection prevention outcomes. 4) Expanding One-Health surveillance to integrate human, animal, and environmental AMR data. 5) Fostering interdisciplinary education from undergraduate training through continuing professional development to build a shared mental model for AMR containment.

Conclusion

Antimicrobial resistance is the archetypal example of a problem that cannot be solved by a single profession or sector. This review underscores that containment is achievable only through a proactive, integrated, One-Health model. The laboratory must be the intelligence hub, pharmacy the operational engine, nursing the unwavering frontline, radiology the visual guide, and epidemiology the connecting thread—all enabled by visionary administration and informed by an engaged community. The goal is a learning health system where data on resistance seamlessly flows from the community and environment to the laboratory, is rapidly translated into optimized action at the bedside, and feeds back into refined policies and public health strategies. Preserving the efficacy of antimicrobials for future generations depends on our collective ability to break down silos and function as this coordinated, multidisciplinary defense network.

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