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Antimicrobial resistance in pediatric and adults intensive care units in Kinshasa: insights from artificial intelligence for improving critical care

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Keypoints

Artificial intelligence offers a powerful, data-driven approach to predict resistance patterns, guide targeted therapy, and enhance real-time surveillance.

Abstract

Antimicrobial resistance (AMR) represents a major threat to global health, with critically ill patients in intensive care units (ICUs) particularly vulnerable. In Kinshasa, Democratic Republic of Congo, both pediatric and adult ICUs face a high prevalence of multidrug-resistant pathogens, including *Escherichia coli*, *Klebsiella pneumoniae*, *Staphylococcus aureus*, extended-spectrum beta-lactamase (ESBL)-producing, and carbapenem-resistant strains. Limited laboratory capacity, weak antimicrobial stewardship, widespread empirical antibiotic use, and suboptimal infection control exacerbate the problem, contributing to prolonged hospital stays, higher morbidity and mortality, and increased healthcare costs. Innovative approaches are urgently needed to improve detection, management, and prevention of resistant infections in resource-limited settings. Artificial intelligence (AI) offers a transformative solution by integrating clinical, microbiological, and environmental data to predict resistant infections, guide individualized therapy, detect outbreaks in real time, and support stewardship programs. Evidence from pediatric ICUs shows reductions in inappropriate antibiotic use and improved clinical outcomes, while predictive models in adult ICUs can anticipate sepsis and early mortality. Successful implementation in Kinshasa requires adaptation to local epidemiology, staff training, high-quality data systems, and integration into existing workflows. Combining AI with robust antimicrobial stewardship and infection control measures could enhance patient care, optimize antibiotic use, and inform public health strategies, offering a sustainable approach to mitigating AMR in critically ill populations in low-resource environments.

Keywords

adult ICU, antimicrobial resistance, artificial intelligence, antibiotic stewardship, intensive care, pediatric ICU

Introduction

Antimicrobial resistance (AMR) represents one of the most pressing threats to global health, causing rising morbidity, mortality, and substantial economic burden across all healthcare settings [1,2]. Worldwide, multi-drug-resistant infections have already been implicated in millions of deaths, and projections suggest that by 2050, AMR could surpass cancer as a leading cause of mortality if urgent interventions are not implemented [1]. The problem is particularly acute in low- and middle-income countries, where weak health systems, limited laboratory capacity, suboptimal antibiotic stewardship, and restricted access to effective drugs exacerbate the emergence and spread of resistant pathogens [3,4,5].

In sub-Saharan Africa, the burden of AMR is compounded by high rates of infectious diseases, widespread empirical use of broad-spectrum antibiotics, and inadequate microbiological surveillance [3,4]. Children are especially vulnerable, with infections caused by *Escherichia coli*, *Klebsiella pneumoniae*, and *Staphylococcus aureus* frequently demonstrating multidrug resistance [3,6]. Adult populations in ICUs face similar threats, with increasing reports of extended-spectrum beta-lactamase (ESBL)-producing and carbapenem-resistant organisms [5,7]. These resistant infections in intensive care units (ICUs) are associated with prolonged hospital stays, higher rates of complications, elevated mortality, and significantly increased healthcare costs [4,5,8].

In the Democratic Republic of Congo (DRC), although national surveillance systems remain limited, existing data indicate a high prevalence of AMR in both pediatric and adult ICUs [3,6,7]. The intensive care environment amplifies the impact of AMR due to the frequent use of invasive devices, immunocompromised patient populations, and the severity of critical illnesses [6,8]. This combination of high vulnerability and limited therapeutic options makes ICU patients particularly susceptible to the negative consequences of antimicrobial resistance, compromising the quality of critical care and limiting treatment efficacy [4,9].

Addressing AMR is therefore an urgent priority, particularly in resource-limited countries such as the DRC, where healthcare infrastructure is often insufficient, laboratory diagnostic capacity is constrained, and human resources are scarce [10,11]. In this context, innovative approaches such as artificial intelligence (AI) provide promising avenues to enhance the detection, monitoring, and management of resistant infections. AI and machine learning models can integrate clinical, microbiological, and environmental data to predict the likelihood of resistant infections, optimize antimicrobial therapy, and enable early detection of nosocomial outbreaks within ICU settings [12,13,14].

Integrating AI into pediatric and adult ICUs in Kinshasa could serve as a strategic lever to improve patient management, support antimicrobial stewardship, and inform local public health policies [12,13,15]. By enabling more precise and timely interventions, AI could mitigate the detrimental impact of AMR on critically ill patients and strengthen overall critical care delivery in resource-constrained settings. This Perspective highlights the burden of AMR in ICUs in Kinshasa, discusses the potential of AI as a tool to enhance surveillance and intervention, and underscores the importance of leveraging such innovations to improve outcomes in both pediatric and adult critical care populations.

The burden of antimicrobial resistance in Kinshasa ICUs

Antimicrobial resistance (AMR) in intensive care units (ICUs) represents a complex interplay of global and local drivers. Globally, resistance rates are rising steadily, threatening the effectiveness of commonly used antibiotics and complicating the management of severe infections [1,2]. In sub-Saharan Africa, limited access to diagnostic laboratories, a high burden of infectious diseases, and widespread empirical use of broad-spectrum antibiotics exacerbate the emergence and spread of multidrug-resistant organisms [3,4,5].

In Kinshasa, both pediatric and adult ICUs face significant challenges. Pediatric ICUs report a high prevalence of multidrug-resistant *Escherichia coli*, *Klebsiella pneumoniae*, and *Staphylococcus aureus*, often resistant to first-line therapies [3,6]. Adult ICUs show similar trends, with frequent detection of extended-spectrum beta-lactamase (ESBL)-producing organisms and an increasing prevalence of carbapenem-resistant strains [5,7]. These resistant infections contribute directly to prolonged ICU stays, higher morbidity, increased treatment costs, and elevated mortality rates, creating a substantial burden for both patients and healthcare systems [4,5,8].

Contributing factors in the Kinshasa ICU context include insufficient laboratory capacity, reliance on broad-spectrum empiric antibiotic therapy, suboptimal infection prevention and control practices, and limited surveillance networks [6,9]. Moreover, national guidelines and strategic frameworks for AMR management, although available through the DRC National Action Plan, are not fully operationalized in most ICU settings [10]. Innovative approaches, including artificial intelligence (AI), have been proposed to support decision-making, optimize therapy, and strengthen surveillance in such resource-limited contexts [11].

To provide a clear overview of the local epidemiology, Table 1 summarizes the prevalence and resistance patterns of the most common pathogens in pediatric and adult ICUs in Kinshasa. This table illustrates the limited efficacy of first-line antibiotics, underscoring the urgent need for targeted interventions, enhanced stewardship, and AI-guided strategies [3-7].

Pathogen	Pediatric ICU Resistance (%)	Adult ICU Resistance (%)	First-line Antibiotic Efficacy (%)	Reference
Escherichia coli	58	62	40	[3,6]
Klebsiella pneumoniae	64	67	35	[3,5,7]
Staphylococcus aureus	49	52	45	[3,6]
Pseudomonas aeruginosa	40	45	50	[5,6]
ESBL-producing organisms	55	60	30	[5,7]
Carbapenem-resistant strains	20	28	15	[5,7]

Table 1. Local Antimicrobial Resistance Profiles in Kinshasa ICUs. *Commentary:* This table provides a concise snapshot of AMR in Kinshasa ICUs, highlighting the high prevalence of multidrug-resistant organisms and the limited efficacy of conventional first-line antibiotics. It emphasizes the critical need for integrated interventions combining antimicrobial stewardship, infection prevention measures, and emerging technologies such as AI [10,11].

Harnessing artificial intelligence to tackle AMR

Artificial intelligence (AI) has emerged as a transformative tool in the fight against antimicrobial resistance (AMR), offering the capacity to integrate vast, heterogeneous datasets into actionable insights. In the complex and high-stakes environment of intensive care units (ICUs), where timely decision-making can be lifesaving, AI can synthesize clinical parameters, laboratory results, microbiological profiles, and environmental monitoring data to guide interventions with unprecedented precision.

By leveraging machine learning and predictive modeling, AI can provide clinicians with individualized risk assessments for resistant infections, enabling early interventions, targeted antimicrobial selection, and proactive patient management [12,13].

In practice, AI can optimize both empirical and targeted antibiotic therapy. Through analysis of historical patient data, local resistance patterns, and real-time microbiological surveillance, AI algorithms can suggest the most effective antibiotic regimens, minimize unnecessary exposure to broad-spectrum agents, and reduce the selective pressures that drive resistance [13,14]. Furthermore, AI systems can detect subtle temporal or spatial clustering of infections within ICUs, identifying emerging outbreaks before they escalate and allowing for immediate containment measures [14]. This capacity for real-time surveillance is particularly valuable in high-density settings such as pediatric and adult ICUs, where multidrug-resistant organisms can spread rapidly among vulnerable patients.

Evidence from pediatric ICUs demonstrates the tangible benefits of AI-driven antimicrobial stewardship. Programs employing AI support have reported reductions in inappropriate antibiotic prescribing, shorter durations of therapy, and measurable improvements in clinical outcomes, including lower infection-related complications [7,9]. In adult ICUs, predictive models that incorporate resistome dynamics, patient comorbidities, and environmental surveillance can anticipate the onset of sepsis and early mortality, enabling proactive interventions that can be lifesaving [4]. These examples highlight the potential for AI not merely as a diagnostic tool but as a strategic component of ICU management, shaping both clinical decisions and operational planning.

Implementing AI in Kinshasa's ICUs requires careful contextualization. Algorithms must be adapted to local epidemiology and resistance patterns, reflecting the unique bacterial ecology and healthcare constraints of the region [11,12]. Healthcare personnel—including clinicians, microbiologists, and nurses—need proper training to interpret AI-generated recommendations and integrate them into existing workflows [13,14]. Ensuring that AI outputs are actionable, interpretable, and compatible with resource-limited ICU environments is critical for successful adoption.

To better illustrate the practical applications of AI in addressing AMR in ICU settings, Table 2 summarizes key interventions, their target populations, and expected clinical benefits. This table highlights how AI can bridge complex data analytics and bedside decision-making, offering tangible strategies to improve patient care and optimize antimicrobial use in both pediatric and adult ICUs.

AI Application	Target Population	Expected Benefit	Reference
Predictive modeling of resistant infections	Adult ICU	Early detection of sepsis and mortality risk	[4,15]
AI-driven stewardship support	Pediatric ICU	Optimize antibiotic selection, reduce inappropriate use	[7,9,12]
Outbreak detection and monitoring	Pediatric & Adult ICUs	Real-time identification of infection clusters	[14]
Personalized therapy recommendation	Adult ICU	Tailor treatment based on patient comorbidities and resistome	[4,12]
Workflow integration & decision support	Pediatric & Adult ICUs	Facilitate rapid clinical decision-making	[12,13]

Table 2. Applications of Artificial Intelligence in Kinshasa ICUs. *Commentary:* This table illustrates how AI can be applied in ICU settings to tackle AMR, providing concrete examples of interventions and their anticipated clinical impact. It bridges technology and patient care, highlighting the transformative potential of AI in resource-limited environments like Kinshasa.

Challenges and limitations

Despite its considerable promise, deploying AI in ICUs faces several interrelated challenges. First, the quality and availability of data are fundamental: AI algorithms require accurate, digitized, and standardized microbiological and clinical datasets to train reliable predictive models [6,12]. In many ICUs in Kinshasa, laboratory capacity is limited, and electronic health records are either absent or incomplete, creating barriers to robust AI deployment.

Second, human resources remain a key constraint. Clinicians and microbiologists must be equipped not only to understand AI outputs but also to act upon them in real time, which necessitates ongoing training, mentorship, and institutional support [13,14].

Third, ethical, legal, and regulatory considerations cannot be overlooked. Protecting patient privacy, ensuring transparency of algorithms, validating predictive models, and maintaining accountability in decision-making are essential to the responsible use of AI in critical care [14].

Finally, contextual adaptation is crucial. AI models developed in high-income countries may not generalize to ICUs in Kinshasa without recalibration to local microbial ecology, patient populations, and resource constraints [11,15]. Overcoming these challenges demands sustained investment in digital health infrastructure, capacity building, and governance frameworks that ensure AI is both effective and equitable.

Recommendations and future directions

To maximize the impact of AI in mitigating AMR in Kinshasa ICUs, a phased and strategic approach is recommended:

1. **Pilot integration of AI-supported decision tools** in select high-risk ICUs to assess feasibility, clinical impact, and workflow integration.
2. **Strengthen antimicrobial stewardship programs**, using AI outputs to refine empirical therapy, monitor adherence, and optimize treatment duration [7,9].
3. **Foster multidisciplinary collaboration** among clinicians, microbiologists, and data scientists to ensure continuous feedback, model refinement, and sustainability.
4. **Continuous local data collection**, including clinical, microbiological, and environmental surveillance, to improve predictive model accuracy and tailor interventions to Kinshasa-specific epidemiology [12,15].
5. **Monitor outcomes and scalability**, ensuring that AI deployment is ethically sound, operationally feasible, and demonstrably improves patient outcomes in resource-limited settings.

Roadmap for AI Implementation to Combat AMR in Kinshasa ICUs

Addressing antimicrobial resistance (AMR) in pediatric and adult intensive care units (ICUs) in Kinshasa requires a structured, phased approach. A roadmap ensures that interventions are targeted, feasible, and sustainable, combining technology, human resources, and policy alignment. The following table summarizes the key steps, actions, and rationale for implementing AI-supported strategies to mitigate AMR and improve critical care outcomes in resource-limited settings. (Table 3)

Step	Key Actions	Rationale / Commentary
1. Situational Assessment	- Conduct baseline surveillance of AMR in pediatric and adult ICUs - Map available laboratory, digital, and human resources	Establishes the foundation by identifying the local AMR burden and resource gaps [3,5,6,10,11].
2. Pilot AI Integration	- Deploy AI decision-support tools in selected high-risk ICUs - Test predictive models for resistant infections, outbreak detection, and therapy optimization	Allows practical evaluation of feasibility, usability, and clinical impact before wider adoption [12,14,15].
3. Capacity Building & Training	- Train clinicians, microbiologists, nurses, and data scientists - Implement continuous education and mentorship programs	Ensures AI outputs are properly interpreted and integrated into ICU workflows [7,9,12,13].
4. Antimicrobial Stewardship Alignment	- Integrate AI insights into stewardship programs - Optimize empirical therapy and monitor adherence	Supports targeted antibiotic use and reduces inappropriate prescribing [7,9,12,14].
5. Infrastructure & Data Enhancement	- Upgrade labs and digital systems for standardized, digitized data - Build local databases for continuous data collection	Provides the high-quality data necessary for AI model reliability and adaptation to local epidemiology [6,12,15].
6. Ethical, Regulatory & Policy Frameworks	- Establish patient privacy, algorithm transparency, and model validation protocols - Align AI implementation with national AMR action plans	Ensures AI deployment is safe, accountable, and compliant with local and international standards [10,11,14].
7. Monitoring, Evaluation & Scale-up	- Continuously assess AI performance and clinical outcomes - Gradually expand to all ICUs, adapting to local context	Facilitates evidence-based scale-up and sustainable improvement in critical care [12,15].

Table 3. Roadmap for AI-Driven AMR Management in Kinshasa ICUs

Conclusion

Antimicrobial resistance in pediatric and adult ICUs in Kinshasa represents a formidable barrier to effective critical care, compromising patient survival and straining already limited healthcare resources. Artificial intelligence offers a powerful, data-driven approach to predict resistance patterns, guide targeted therapy, and enhance real-time surveillance. When strategically implemented alongside robust antimicrobial stewardship and infection control measures, AI has the potential to transform ICU management, improve patient outcomes, and inform local health policies. In resource-limited environments, such integration could pave the way for sustainable, evidence-based improvements in critical care delivery, helping to mitigate the global and local impact of AMR.

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Author Contributions

D. Mayemba and A. Makembi Bunkete conceptualized the article and drafted the manuscript. O. Lunguya, W. Mbombo, G. Lobukulu, D. Lungela, J. Nsiala, M. Bula-Bula, B. Barhayiga, and J. J. Muyembe contributed to critical review, discussion of ideas, and manuscript revision. All authors approved the final version.

Conflict of Interest

The authors declare that they have no conflicts of interest.

Ethical Consideration

Ethical approval was not required for this perspective article, as it does not involve primary data collection or human subjects.

Data Availability

No new data were generated or analyzed for this article. All information presented is based on published literature and publicly available sources.

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