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Leveraging Hospital Information Data for Effective Antibiotic Stewardship

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ABSTRACT

Clinical informatics has emerged as a valuable approach to enhance antimicrobial stewardship programs in healthcare settings. By integrating information technology with healthcare services, hospitals can systematically collect, store, and utilize medical data to improve antibiotic management. Studies have demonstrated that information technology interventions improve antibiotic prescription appropriateness and patient outcomes. The implementation of effective antimicrobial stewardship employs a multifaceted approach that incorporates diagnostic tools, laboratory findings, and clinical situations through advanced dashboard systems and rule-based feedback mechanisms. Recent advances in artificial intelligence have shown promising results in predicting antibiotic resistance, and the integration of hospital information systems with clinical informatics offers sustainable solutions for enhancing antimicrobial stewardship programs in clinical practice.

Keywords: Antibiotic Stewardship; Clinical Informatics; Artificial Intelligence

INTRODUCTION

Antimicrobial resistance and effective stewardship represent critical challenges in modern healthcare, particularly given the global shortage of specialists in infectious disease (ID). Although antibiotic stewardship programs (ASPs) involve collaborative efforts from various healthcare professionals, including pharmacists, nurses, and information system specialists, the shortage of ID specialists remains a significant concern.[1,2] Recent studies from Korea illustrated this challenge, with approximately 300 practicing ID physicians nationwide.[2,3] The situation is further complicated by declining fellowship program enrollment since the COVID-19 pandemic, with only 15–20 new physicians entering annually. These specialists, primarily working in tertiary care and general hospitals, manage 350–400 patient beds, typically with just 2–3 ID doctors per facility.[2] Their weekly workload averages 60 hours, predominantly focusing on patient services and consultations, with minimal time allocated to infection control and antibiotic stewardship.[3]

While Korea has established the Korean National Healthcare-associated Infections Surveillance System (KONAS) to monitor antimicrobial use and resistance patterns, its current limitations include delayed data updates and incomplete hospital participation.[4]

The government of Korea recently initiated ASP pilot projects in November 2024, aiming to optimize antibiotic use and combat antimicrobial resistance. These pilot projects mark an important step towards institutionalizing stewardship practices across the nation. However, implementation faces considerable challenges, particularly owing to the lack of integrated hospital information systems. The absence of such systems hinders efficient data collection, real-time monitoring, and feedback mechanisms that are essential for the success of ASP initiatives. In the case of the Epic system in the United States, standardized ASP activities are facilitated through integrated platforms, whereas Korean hospitals must develop their own individual computerized systems.[5] This fragmentation in hospital information systems creates significant barriers to implementing standardized ASP protocols and sharing data across institutions, potentially limiting the effectiveness of stewardship efforts.

In this review, we discuss how hospital information systems and emerging technologies can be effectively utilized to enhance ASPs in healthcare settings with limited resources for ID specialists. We outline a systematic strategy for implementing technology-enhanced ASP and explore various technological approaches, from clinical informatics to artificial intelligence (AI) applications.

CLINICAL INFORMATICS AND DATA MANAGEMENT

Clinical informatics has emerged as a promising strategy for addressing these challenges in ASPs. By integrating information technology with healthcare services, clinical informatics automates the collection, storage, and utilization of medical data.[6] This field, a subset of medical informatics that focuses on clinical practice, offers significant potential for enhancing ASPs. Studies have consistently demonstrated that information technology interventions improve antibiotic prescription appropriateness and positively impact mortality rates.[7] Digital interventions have proven particularly effective in reducing inappropriate antibiotic use, while enhancing prescription practices across various healthcare settings.[8] An example demonstrating the real-world impact of clinical informatics is a tertiary care hospital in the United States that implemented a clinical decision support system to monitor and intervene in restricted antimicrobial prescribing for inpatients. This intervention led to a reduced length of hospital stay and cost savings, without a significant difference in mortality.[9] In a related approach, a multicenter study conducted across 12 hospitals in Spain found that machine-learning-based software demonstrated non-inferiority in antibiotic prescribing decisions compared to traditional physician practices,[10] further supporting the feasibility and effectiveness of informatics-driven ASP interventions.

Data utilization plays a crucial role in modern healthcare management. Advanced dashboard systems enable healthcare providers to monitor various metrics, including the influenza immunization status, across different patient populations and hospital services. Combined with other healthcare metrics such as hand hygiene performance and clinical guideline adherence, these systems provide comprehensive insights into prevention strategies.[11] ASP programs have also begun to develop and utilize these tools to streamline data collection and analysis, further supporting stewardship. For instance, dashboard systems and analytics tools can assist in monitoring antibiotic use patterns and identifying areas of improvement. Notable developments include an open-source software application from the Netherlands that allows detailed analysis of antibiotic prescriptions, utilizing metrics like ‘Defined Daily Dose’ and ‘Days of Therapy.’[12]

The complexity of antibiotic prescription is further illustrated by studies from the United States and China, which have developed different approaches for assessing prescription appropriateness.[13,14] In the United States, the evaluation focused on the appropriateness of antibiotic use at each prescribing stage, emphasizing a step-by-step review of decision-making processes.[11] In contrast, a study from Beijing evaluated appropriateness based on diagnostic indications for antibiotic use, and assessed whether prescriptions were justified by specific diagnoses.[14] These findings also highlight the challenges of applying informatics solutions to such evaluations, given the complexity and variability of prescribing practices across healthcare systems.

STRATEGIES AND TOOLS

The implementation of effective ASPs requires a comprehensive approach that considers multiple factors in antibiotic prescription. This includes diagnostic tools, laboratory findings, clinical situations, patient comorbidities, and medical history.[15] Based on our experience with these complexities, we propose a systematic three-step strategy for implementing technology-enhanced antimicrobial stewardship. The first step in the development strategy focuses on creating real-time monitoring dashboards for antibiotic prescriptions, allowing healthcare providers to track usage patterns and identify areas requiring intervention. The second step implements rule-based feedback systems for prescribing optimization, including alerts for drug-bug mismatches, opportunities for intravenous (IV)-to-oral conversion, and warnings regarding unnecessary combination therapy. The third step involves the development of sophisticated predictive models powered by AI, enabling more precise antibiotic selection based on local resistance patterns and patient-specific factors.

Additionally, integrating tools to monitor antibiotic resistance data can further enhance these systems.[16] By combining real-time resistance surveillance with predictive analytics, empirical antibiotic regimens tailored to specific patient scenarios can be recommended. These tools can consider factors such as the patient's clinical status, comorbidities, and previous antibiotic exposure, offering data-driven guidance to optimize empirical antibiotic use in hospitalized patients. This approach holds significant potential for improving antibiotic selection while reducing the risk of resistance development.

The practical implementation of the proposed framework requires careful consideration of system integration and maintenance factors. Integration with existing hospital information systems is crucial for successful implementation of the proposed framework. Additionally, the successful operation of such systems requires regular evaluation of the system performance and user feedback to ensure continuous improvement and adaptation to changing clinical needs.

AI APPLICATIONS AND FUTURE DIRECTIONS

Recent advances in AI have shown promising results in antibiotic resistance prediction, particularly for urinary tract infections. Models incorporating various antibiotics achieved area under the receiver operating characteristic curve values of approximately 0.7. SHapley Additive exPlanations analysis has identified key factors influencing resistance, including antibiotic exposure duration, hospitalization length, and specific medical conditions, such as chronic respiratory and kidney diseases. These findings, while not establishing direct causality, provide valuable insights into previously unknown resistance patterns.[17]

The development of technology in this field is further supported by the availability of open data resources.[18] Korea has implemented systems for anonymized medical data sharing, enabling the development and validation of algorithms to predict antibiotic resistance. Similar initiatives using intensive care unit data from the UK and US have demonstrated success in predicting the appropriate timing for IV-to-oral medication transitions.[19] Machine learning applications in hospital settings now span a wide range of functions from monitoring and diagnosis to outcome prediction and treatment decision-making.[20]

Current antimicrobial treatments face challenges due to fragmented data streams from various clinical, diagnostic, and research sources. This fragmentation often results in imprecise, non-personalized treatment approaches, and unnecessary healthcare expenses. The future lies in developing interconnected data systems that facilitate collaboration among healthcare providers, policymakers, and researchers, ultimately enabling more precise antimicrobial treatment strategies.[15] To address hospital information system fragmentation in Korea, we propose three solutions: first, developing standardized data exchange protocols specifically for antimicrobial stewardship metrics; second, establishing a national ASP data repository with standardized reporting templates; and third, providing government incentives for hospitals adopting these standards. This phased approach would significantly enhance ASP data interoperability across Korean healthcare institutions even before complete system standardization becomes feasible.

Recent evaluations of AI in clinical settings have yielded inconsistent results. A study of ChatGPT-4 in bloodstream infection management showed varying degrees of success; while achieving 59% accuracy in diagnosis matching and 80% satisfaction in diagnostic workups, only 2% of cases achieved optimal management.[21] Large language models (LLMs) show promise, but face significant challenges, including information fabrication and contextual limitations.[22] Nevertheless, the rapid advancement of this technology necessitates active involvement of ID specialists to guide its proper implementation as a supportive tool rather than a replacement for clinical expertise.

Despite its promise, AI implementation in ASP faces several critical limitations. First, most current AI models for antibiotic resistance prediction achieve moderate accuracy, which may be insufficient for high-stakes clinical decisions. Second, these models often function as 'black boxes,' limiting clinician trust and adoption. Third, most models are developed using data from single institutions, raising questions about generalizability across different patient populations and resistance patterns. To address these limitations, I would recommend: 1) developing hybrid models that combine rules-based clinical knowledge with machine learning to improve interpretability; 2) establishing multicenter collaborative networks for model development and external validation; and 3) implementing continuous performance monitoring with regular model updating to maintain accuracy as resistance patterns evolve. These approaches could help bridge the gap between AI's theoretical potential and practical clinical implementation in ASP.

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CONCLUSION

In conclusion, although the shortage of infectious disease specialists presents ongoing challenges, the integration of clinical informatics and AI technologies offers promising solutions for enhancing antimicrobial stewardship programs. The complexity of antibiotic prescriptions necessitates comprehensive technological solutions at various decision-making points. While innovative technologies, such as LLMs, show potential, their current limitations emphasize the need for careful implementation alongside human expertise in clinical practice.

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