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REVIEW
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Revolutionizing the fight against antimicrobial resistance with Artificial Intelligence

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Abstract: Antimicrobial resistance (AMR) is a major public health threat, responsible for millions of deaths annually. Current efforts to combat AMR include antibiotic stewardship programs, infection prevention and control measures, and the development of new antimicrobial agents. However, traditional laboratory techniques used to identify antibiotic-resistant genes are inadequate. Artificial intelligence (AI) has emerged as a promising tool to combat AMR, with the potential to facilitate rapid diagnosis, predict antibiotic resistance patterns, and identify new treatments. AI can analyze large amounts of data from a wide range of sources and identify patterns and correlations that may be missed by humans. However, there are potential challenges and risks associated with implementing AI in the fight against AMR, including ethical concerns and data quality issues.

Keywords: antimicrobial resistance, artificial intelligence, rapid diagnosis, predicting resistance patterns, new treatment identification

Introduction

Antimicrobial resistance (AMR) is a growing public health concern responsible for millions of deaths yearly. Approximately 1.27 million deaths have occurred each year due to AMR worldwide [1]. AMR refers to the ability of microorganisms, such as bacteria, viruses, fungi, and parasites, to resist the effects of antimicrobial drugs, making infections difficult or even impossible to treat [2]. AMR is a global public health threat that poses significant challenges to the effectiveness of modern medicine. AMR can lead to more extended hospital stays, higher healthcare costs, and increased mortality rates, particularly among vulnerable populations such as the elderly [3], young children [4], and those with compromised immune systems.

Current efforts to combat AMR include the appropriate use of antibiotics, infection prevention and control measures, and the development of new antimicrobial agents[5]. However, the widespread use of antibiotics in clinical practice has resulted in drug resistance and increased the threat of super-resistant bacteria emergence [6]. Antibiotic stewardship programs have effectively reduced antibiotic use and slowed the spread of resistant organisms, but they require a significant investment in resources and personnel [7]. Infection prevention and control measures, such as hand hygiene and isolation protocols, can prevent the spread of resistant organisms, but they are not always effective and can be challenging to implement in resource-limited settings [8].

Currently, characterization and diagnostic techniques used in laboratories do not provide enough information to perform surveillance effectively [9]. The development of new antimicrobial agents has been slow, with few new antibiotics coming to market in recent years. This phenomenon is partly due to the high cost of drug development and the relatively low profitability of antibiotics compared to other drugs. Furthermore, the emergence of resistance to new antibiotics can occur rapidly, making the development of new medicines a constant race against evolving resistance mechanisms [10].

Traditional laboratory techniques used to identify antibiotic-resistant genes (ARG) are inadequate for practical treatment and surveillance due to low accuracy and inconsistent results[9]. However, the advancement of computing power and data storage has enabled the application of artificial intelligence (AI) techniques, such as machine learning (ML) and deep learning (DL), which are increasingly being used in the medical sector [11]. Given the limitations of current methods, there is an urgent need for innovative approaches to combat AMR.

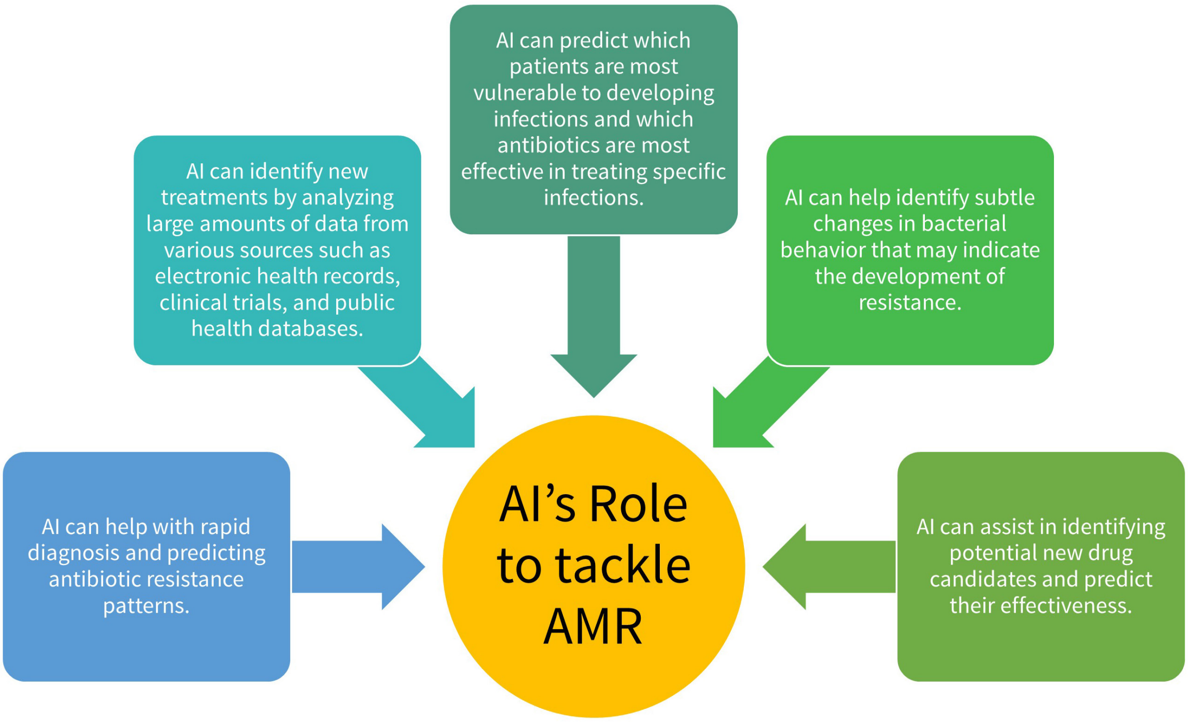

Figure 1. Artificial Intelligence's role to tackling AMR

Artificial intelligence (AI) has emerged as a promising tool in the fight against AMR, with the potential to facilitate rapid diagnosis, predict antibiotic resistance patterns, and identify new treatments. AI in AMR research has shown promise in predicting which microorganisms are likely to develop resistance to certain drugs, identifying emerging resistance patterns, and optimizing antimicrobial use in healthcare settings [12]. However, the application of ML/DL models in the field of antimicrobials faces several challenges, including the availability of high-quality data, validation of results, and environmental variability [13]. As such, further research is necessary to bridge these gaps and open new doors in the field of antibiotics. This opinion article argues that AI represents a significant opportunity to address this pressing challenge by enabling more rapid and accurate diagnosis, predicting antibiotic resistance patterns, and identifying new treatments. In short, AI has the potential to transform the way we combat antimicrobial resistance, offering hope for a healthier and more sustainable future.

The role of Artificial Intelligence (AI)

Antimicrobial resistance is a complex and multifaceted problem that requires a multifaceted solution. One promising solution is the use of artificial intelligence (AI). AI has the potential to revolutionize our approach to tackling antimicrobial resistance by facilitating rapid diagnosis, predicting antibiotic resistance patterns, and identifying new treatments [12,14]. AI can analyze large amounts of data from a wide range of sources, including electronic health records, clinical trials, and public health databases. By analyzing this data, AI algorithms can identify patterns and correlations that may be missed by human analysts [9]. For example, AI can predict which patients are at a vulnerable risk of developing infections, which antibiotics are most likely effective for treating specific infections, and which combinations of antibiotics are most effective at combating resistant strains of bacteria (Figure 1).

There are already several AI initiatives underway to tackle antimicrobial resistance. One such initiative is using machine learning algorithms to analyze the genetic sequences of bacteria and identify mutations that may lead to resistance. Another initiative is the development of AI-powered diagnostic tools that can quickly and accurately identify the presence of bacteria and determine their susceptibility to antibiotics [15].

The advantages of employing AI to combat antimicrobial resistance are manifold. AI algorithms excel at swiftly and precisely analyzing extensive datasets, which is crucial for discerning patterns and correlations within complex information. Moreover, AI can detect nuanced shifts in bacterial behavior—indicators of emerging resistance—thereby enabling clinicians to preempt bacterial adaptation. Another significant advantage is AI's ability to unearth new antimicrobial resistance treatments. By analyzing clinical trial data and other sources, AI algorithms can spotlight promising drug candidates and forecast their efficacy with high accuracy. [9,12,14,15].

Several studies have explored the application of AI to combat antimicrobial resistance. For instance, machine learning has been used in sequencing-based methods and resources to analyze AMR [16], as well as in novel bioinformatics approaches to study AMR [17]. Additionally, transcriptome profiling of antimicrobial resistance in *Pseudomonas aeruginosa* has been investigated using AI techniques [18]. Another application of AI in this field is the design of new antibiotics, as well as the identification of effective combinations of drugs. However, predicting synergistic drug interactions remains a challenge due to the vast number of possible drug combinations [19]. Various computational methods, including mechanism-based synergy prediction, have been developed to prioritize the most effective treatments [19,20].

Potential challenges and risks

AI has the potential to revolutionize the approach to tackling antimicrobial resistance and has shown its critical role in optimizing drug combinations [21]. By analyzing vast datasets and uncovering patterns that may elude human analysis or be prone to human error, AI has the potential to facilitate rapid diagnosis, predict patterns of antibiotic resistance, and identify novel treatments [9]. Current AI initiatives in this area include the development of machine learning models to predict antimicrobial resistance and using AI to analyze genomic data to identify new drug targets [22].

However, there are also potential challenges and risks associated with implementing AI in the fight against antimicrobial resistance. Ethical concerns may arise, such as the use of AI in decision-making and the potential for biases in the data used to train AI models [23]. There are also data privacy issues to consider, as well as the need for human oversight to ensure AI's safe and responsible use. Establishing guidelines and regulations for using AI in the context of antimicrobial resistance to address these challenges will be necessary. This may involve developing data collection and analysis standards, ensuring decision-making transparency, and establishing human oversight protocols. It will also be important to engage with stakeholders, including healthcare professionals, policymakers, and patients, to ensure that the use of AI in the fight against antimicrobial resistance is ethical and responsible.

Conclusion

Artificial intelligence has enormous potential to revolutionize our approach to tackling antimicrobial resistance by facilitating rapid diagnosis, predicting antibiotic resistance patterns, and identifying new treatments. However, there are also potential challenges and risks associated with implementing AI, including ethical concerns, data privacy issues, and the need for human oversight. By addressing these challenges and leveraging the advantages of AI, we can harness the power of technology to combat antimicrobial resistance and safeguard the health of future generations.

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Declaration of conflict interest

None.

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References

1. 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. https://doi.org/10.1016/S0140-6736(21)02724-0
2. O'Neill J. Tackling drug-resistant infections globally: Final Report and Recommendation. Arch Pharm Pract. 2016;7(3):110. https://doi.org/10.4103/2045-080X.186181
3. Kusuma IY, Matuz M, Bordás R, et al. Antibiotic use in elderly patients in ambulatory care: A comparison between Hungary and Sweden. Front Pharmacol. 2022;13:1042418. https://doi.org/10.3389/fphar.2022.1042418
4. Benko R, Matuz M, Silva A, et al. Cross-national comparison of paediatric antibiotic use in Norway, Portugal and Hungary. Basic Clin Pharmacol Toxicol. 2019;124(6):722-729. https://doi.org/10.1111/bcpt.13198
5. Miljković N, Polidori P, Kohl S. Managing antibiotic

shortages: lessons from EAHP and ECDC surveys. Eur J Hosp Pharm Sci Pract. 2022;29(2):90-94. doi:10.1136/ejhpharm-2021-003110. https://doi.org/10.1136/ejhpharm-2021-003110

6. Bilal H, Khan MN, Rehman T, Hameed MF, Yang X. Antibiotic resistance in Pakistan: a systematic review of past decade. BMC Infect Dis. 2021;21(1):1-19. https://doi.org/10.1186/s12879-021-05906-1
7. Kusuma IY, Pratiwi H, Pitaloka DAE. Role of Pharmacists in Antimicrobial Stewardship During COVID-19 Outbreak: A Scoping Review. J Multidiscip Healthc. Published online 2022:2605-2614. https://doi.org/10.2147/JMDH.S385170
8. Huang GKL, Stewardson AJ, Grayson ML. Back to basics: hand hygiene and isolation. Curr Opin Infect Dis. 2014;27(4):379. https://doi.org/10.1097/QCO.0000000000000080
9. Rabaan AA, Alhumaid S, Mutair AA, et al. Application of Artificial Intelligence in Combating High Antimicrobial Resistance Rates. Antibiotics. 2022;11(6):784. https://doi.org/10.3390/antibiotics11060784
10. Miethke M, Pieroni M, Weber T, et al. Towards the sustainable discovery and development of new antibiotics. Nat Rev Chem. 2021;5(10):726-749. https://doi.org/10.1038/s41570-021-00313-1
11. Gupta C, Johri I, Srinivasan K, Hu YC, Qaisar SM, Huang KY. A systematic review on machine learning and deep learning models for electronic information security in mobile networks. Sensors. 2022;22(5):2017. https://doi.org/10.3390/s22052017
12. Ali T, Ahmed S, Aslam M. Artificial Intelligence for Antimicrobial Resistance Prediction: Challenges and Opportunities towards Practical Implementation. Antibiotics. 2023;12(3):523. https://doi.org/10.3390/antibiotics12030523
13. Davis JJ, Boisvert S, Brettin T, et al. Antimicrobial resistance prediction in PATRIC and RAST. Sci Rep. 2016;6(1):1-12. https://doi.org/10.1038/srep27930
14. Tran MH, Nguyen NQ, Pham HT. A New Hope in the Fight Against Antimicrobial Resistance with Artificial Intelligence. Infect Drug Resist. Published online 2022:2685-2688. https://doi.org/10.2147/IDR.S362356
15. Wang H, Jia C, Li H, et al. Paving the way for precise diagnostics of antimicrobial resistant bacteria. Front Mol Biosci. 2022;9. https://doi.org/10.3389/fmolb.2022.976705
16. Boolchandani M, D'Souza AW, Dantas G. Sequencing-based methods and resources to study antimicrobial resistance. Nat Rev Genet. 2019;20(6):356-370. https://doi.org/10.1038/s41576-019-0108-4
17. Macesic N, Polubriaginof F, Tatonetti NP. Machine learning: novel bioinformatics approaches for combating antimicrobial resistance. Curr Opin Infect Dis. 2017;30(6):511-517. https://doi.org/10.1097/QCO.0000000000000406
18. Khaledi A, Schniederjans M, Pohl S, et al. Transcriptome profiling of antimicrobial resistance in Pseudomonas aeruginosa. Antimicrob Agents Chemother. 2016;60(8):4722-4733. https://doi.org/10.1128/AAC.00075-16
19. Weinstein ZB, Bender A, Cokol M. Prediction of synergistic drug combinations. Curr Opin Syst Biol. 2017;4:24-28. https://doi.org/10.1016/j.coisb.2017.05.005
20. Nava Lara RA, Aguilera-Mendoza L, Brizuela CA, Peña A, Del Rio G. Heterologous machine learning for the identification of antimicrobial activity in Human-Targeted drugs. Molecules. 2019;24(7):1258. https://doi.org/10.3390/molecules24071258
21. Lv J, Deng S, Zhang L. A review of artificial intelligence applications for antimicrobial resistance. Biosaf Health. 2021;3(01):22-31. https://doi.org/10.1016/j.bsheal.2020.08.003
22. Arango-Argoty G, Garner E, Pruden A, Heath LS, Vikesland P, Zhang L. DeepARG: a deep learning approach for predicting antibiotic resistance genes from metagenomic data. Microbiome. 2018;6:1-15.https://doi.org/10.1186/s40168-018-0401-z
23. Post B, Badea C, Faisal A, Brett SJ. Breaking bad news in the era of artificial intelligence and algorithmic medicine: an exploration of disclosure and its ethical justification using the hedonic calculus. AI Ethics. Published online 2022:1-14. https://doi.org/10.1007/s43681-022-00230-z