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Revolutionizing Healthcare: The Role of Artificial Intelligence in Antibiotic Stewardship and Resistance Management

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Abstract
Artificial intelligence (AI) has great potential to transform the way antibiotics are managed in healthcare by providing creative ways to fight antibiotic resistance and enhance patient outcomes. This paper examines the various aspects of AI's function in the management of antibiotics, including diagnosis, tailored treatment, infection surveillance, and future implications. The talk focuses on the potential advantages of AI-driven methods, such as improved diagnostic precision, customized treatment plans, and proactive monitoring of patterns of antibiotic resistance. But there are several obstacles to overcome before AI can be fully applied in the healthcare industry. These include issues with technical complexity, data accessibility and quality, clinical acceptability, regulatory concerns, and long-term financial viability. Collaboration amongst partners, financial support for infrastructure and resources, and a dedication to moral, patient-centered care are all necessary to meet these obstacles. Notwithstanding these challenges, AI-driven antibiotic management has enormous potential to revolutionize global patient outcomes, fight antibiotic resistance, and change healthcare delivery.

INTRODUCTION

One of the biggest risks to world health is antibiotic resistance, which has the potential to make many of the medicines available today useless and to bring in a new era of medical uncertainty. Once heralded as "miracle medications," antibiotics are now confronted with the problem of their effectiveness waning as bacteria develop defense mechanisms against them. The overuse and abuse of antibiotics in both human medicine and agriculture, together with a deficiency in the creation of novel drugs, have all contributed to the acceleration of this antibiotic resistance phenomena. Antibiotic resistance arises from the adaptation of bacteria to the administration of antibiotics, which leads to the persistence and expansion of resistant strains [1].

This can occur via a number of processes, including the synthesis of enzymes that break down the antibiotic, modifications to the bacterial cell wall that stop the antibiotic from penetrating, and adjustments to the antibiotic's target areas within the bacteria. Resistance in bacteria can result in more difficult-to-treat diseases, lengthier hospital stays, higher medical expenses, and a higher death rate [2]. Antibiotic resistance has been designated as a global health priority by the World Health Organization (WHO), which is calling on countries to take coordinated action to counter this expanding threat. Artificial Intelligence (AI) can help address the pressing need for novel solutions to the problem of antibiotic resistance.

Artificial intelligence (AI) has the potential to revolutionize several industries, including healthcare, especially in the areas of machine learning (ML) and deep learning (DL) algorithms. Artificial intelligence (AI) is an effective tool for tackling complicated health challenges like antibiotic resistance because of its capacity to analyse large datasets, spot patterns, and forecast outcomes with high accuracy [3]. AI is being used in the healthcare industry to improve treatment plans, streamline operations, and improve diagnostics. Large amounts of medical data can be sorted through by AI algorithms to find insights that would be challenging, if not impossible, for humans to find. These powers are being used to address the antibiotic resistance issue in a number of ways.

Artificial Intelligence in Antibiotic Discovery: Conventional techniques for finding novel medicines are expensive and time-consuming. By forecasting the effectiveness of possible new chemicals and discovering possibilities that conventional approaches might miss, artificial intelligence (AI) can greatly speed up this process. The discovery process can be sped up using machine learning models, which can evaluate chemical structures and forecast their antibacterial qualities [4].

Optimizing Antibiotic Stewardship: Programmed for antibiotic stewardship work to make the best use of antibiotics possible in the fight against resistance. By giving prescribers real-time decision support, tracking antibiotic usage trends, and spotting overuse or misuse, AI can improve these programmers. This guarantees the prudent and efficient use of

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antibiotics. AI systems can improve surveillance efforts in the areas of infection surveillance and monitoring by detecting and tracking outbreaks of resistant illnesses by analyzing data from lab reports, electronic health records, and even social media. With faster reaction times and containment strategies made possible by this real-time surveillance, a widespread transmission may be avoided [5]. The use of AI in healthcare presents a viable solution to the problem of antibiotic resistance. Artificial Intelligence (AI) has the potential to transform the way we fight antibiotic resistance and protect public health by boosting surveillance, optimizing stewardship, personalizing treatments, improving diagnostics, and increasing drug discovery. The upcoming segments of this study will examine these applications in further detail, emphasizing the most recent developments and potential opportunities in this quickly developing subject.

AI IN THE SEARCH FOR ANTIBIOTICS

Quickening the Process of Drug Discovery: Historically, the search for novel antibiotics has been a protracted, costly, and unpredictable undertaking. It entails a large financial commitment, repeated testing, and a great deal of laboratory work, frequently with poor success rates. The need to find novel antimicrobial drugs has increased due to the rise of germs that are resistant to antibiotics. In this case, artificial intelligence (AI) offers a game-changing strategy that can greatly improve and speed up the drug discovery process [6]. Artificial intelligence (AI), in particular machine learning (ML) and deep learning (DL), provides strong capabilities to accelerate several stages of antibiotic discovery. These technologies can reduce the time and cost associated with traditional methods by analyzing large datasets quickly and accurately, identifying trends, and predicting the features of possible drug candidates.

Predictive Drug Discovery Modelling: AI systems can be trained to forecast the antibacterial activity of novel drugs using chemical and biological data that is currently available [7]. Prior to conducting any physical testing, the pool of possible candidates can be reduced by using these predictive algorithms, which have the ability to screen millions of molecules in silico. Through the use of virtual screening, potentially ignored compounds by traditional approaches can be found. Deep learning models, for example, are able to anticipate if a substance will suppress bacterial growth by analyzing its structural properties. These models understand the correlations between chemical structure and antibacterial efficacy using data from other bioactive chemicals and known antibiotics. AI can then recommend changes to already-existing substances to improve their efficacy or lessen their toxicity [8].

Finding New Antimicrobial Substances: Finding new compounds that haven't been thought of before is one of the most promising uses of AI in the field of antibiotic development. AI is capable of analyzing biological data to find novel mechanisms of action and possible therapeutic targets. This skill is especially helpful in the search for novel modes of action for antibiotics, which are essential for circumventing current resistance mechanisms. AI has been used by researchers, for instance, to examine enormous volumes of data from proteomic, metabolomics, and genomic investigations. By connecting these datasets with established biological routes and mechanisms, AI can find novel bacterial weaknesses [9]. As a result, novel classes of antibiotics that function differently from currently available medications may be discovered, offering more weapons in the fight against bacteria that are resistant to treatment.

Enhancing Lead Substances: Artificial intelligence (AI) can further optimize these leads to enhance their drug-like qualities once possible antibiotic candidates have been identified. They can be made more potent, have fewer possible adverse effects, and have better pharmacokinetic and pharmacodynamics characteristics. Artificial intelligence (AI)-powered models can mimic the interactions between drugs and bacterial targets and forecast how changes can improve those interactions. By quickly developing and testing chemical modification hypotheses, AI can help with the iterative process of drug optimization [10]. This raises the possibility of creating safe and effective antibiotics by hastening the refining of lead compounds.

Cutting Expenses and Time: The time and expense involved in bringing new medications to market are greatly decreased by the incorporation of AI into the antibiotic discovery processes. Conventional drug research has a high development phase attrition rate and can take over ten years and billions of dollars [11]. By expediting the discovery and optimization procedures, artificial intelligence (AI) shortens this timetable and frees up resources for research on the most promising candidates. AI, for example, can rank compounds according to their expected safety and efficacy profiles before recommending them for production and biological testing. This focused strategy concentrates on the compounds with the best chance of success, reducing the need for extensive and expensive empirical testing of thousands of compounds [12].

Case Studies and Triumphant Narratives: A number of noteworthy case studies demonstrate how well AI works in the search for new antibiotics. The discovery of the antibiotic helicon, which was made possible by an AI model developed by MIT researchers, is one such instance. Because of its unique mechanism of action, helicon—which is physically different from conventional antibiotics—showed strong efficacy against a wide range of bacteria, including types that are resistant to drugs [13]. This finding highlights how AI has the power to completely transform medicine by finding novel antibiotics that conventional approaches might overlook. Another illustration is how pharmaceutical companies are using AI to bring new life to their current medication libraries.

Through the use of AI models to screen compounds that were previously rejected, scientists have discovered novel antibiotic possibilities that were previously disregarded because of their complexity or lack of apparent activity. AI has the potential to completely transform antibiotic discovery by accelerating, decreasing, and improving the process. Artificial Intelligence (AI) tackles numerous contemporary obstacles in antibiotic research by means of predictive

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modelling, discovery of innovative compounds, lead optimization, and cost-cutting development. The use of AI in drug discovery not only gives a possible answer to the growing problem of antibiotic resistance, but it also marks a significant advancement in the production of potent antimicrobial drugs for future generations [14].

AI-POWERED DIAGNOSTICS

Improving the Precision of Diagnosis: For bacterial infections to be effectively treated, an accurate and prompt diagnosis is essential. Conventional diagnostic techniques frequently entail drawn-out procedures, including culture germs, which can postpone the necessary medical intervention. Rapid and accurate diagnostics are now more crucial than ever to guarantee that the appropriate antibiotics are provided and to reduce the usage of broad-spectrum antibiotics, which are a major contributor to antibiotic resistance [15]. With its improved accuracy and speed, artificial intelligence (AI) is revolutionizing the field of diagnostic procedures.

AI-Driven Diagnostic Instruments: AI algorithms are capable of analyzing complicated medical data, such as imaging, genetic sequencing, and electronic health records. This is especially the case for algorithms that are based on machine learning (ML) and deep learning (DL). These instruments are extremely useful for identifying bacterial illnesses and the resistance profiles associated with them because of their excellent precision in pattern recognition and prediction. AI-powered diagnostic devices, for example, can examine X-rays and MRI scans to identify illness indicators that may not be readily apparent to the human eye [16]. By distinguishing between bacterial and viral infections, these instruments enable more focused administration of antibiotics. Large-scale medical picture datasets are used to train deep learning models, which can attain diagnostic accuracy on par with or even higher than that of skilled radiologists.

Quick Identification of Pathogens: The quick diagnosis of infections is one of the major advances in diagnostics that AI has brought about. It can take many days to discover bacterial infections using traditional procedures like culture tests [17]. However, findings from AI-driven methods can be obtained in a couple of hours or even minutes. Artificial intelligence (AI) systems are capable of swiftly identifying pathogen genetic material by analyzing data from polymerase chain reaction (PCR) and next-generation sequencing (NGS) tests. With the use of these methods, it is possible to precisely identify the causing agent by comparing the genetic sequences extracted from patient samples with extensive databases of known bacterial genomes. AI systems, for instance, are capable of analyzing met genomic data to identify particular bacterial strains and the genes that confer antibiotic resistance, thereby producing a thorough resistance profile [18].

Antibiotic Resistance Prediction: Understanding the resistance profiles of bacteria is essential for accurate diagnosis of illnesses. AI algorithms that examine genetic data and other pertinent patient data can forecast antibiotic resistance. This eliminates the need for trial and error, which frequently results in inadequate therapy and increased resistance, and enables medical professionals to select the most potent antibiotic right away [19]. Datasets including details on bacterial strains, their resistance genes, and patient outcomes can be used to train machine learning algorithms. Based on the genetic composition of the bacteria and the patient's attributes, these models can then forecast the chance of resistance to particular medications. This prediction power is essential for individualized treatment planning and stopping the spread of resistant types of the disease.

Clinical Decision Support System Integration: Clinical decision support systems (CDSS) are progressively integrating AI-driven diagnostics to help medical professionals make well-informed treatment decisions. These systems are capable of delivering recommendations in real time that are based on examination of patient data, diagnostic findings, and the most recent clinical guidelines. An AI-driven CDSS, for instance, has the ability to notify medical professionals about possible bacterial infections and recommend suitable diagnostic procedures and course of treatment. In addition, it can identify circumstances where antibiotic resistance is likely to occur and suggest substitute therapies. By ensuring that patients receive prompt and appropriate therapy, this integration serves to improve overall outcomes by lowering the need for broad-spectrum antibiotics [20].

Applications and Case Studies: Numerous real-world examples demonstrate how AI-driven diagnostics can enhance patient care. For example, the time it takes to diagnose bloodstream infections has drastically decreased with the introduction of AI models for analyzing blood cultures. Targeted therapy can be started quickly thanks to these models, which can identify infections and their resistance profiles in a matter of hours. The use of AI to diagnose pneumonia by analyzing respiratory sample data is another noteworthy application. AI systems are able to distinguish between viral and bacterial pneumonia rapidly, which helps determine whether to administer medications [21]. AI-based diagnostic tools have the potential to improve diagnostic precision; in one investigation, they were able to identify pneumonia bacteria with an accuracy rate higher than traditional methods.

One important development in the fight against antibiotic resistance is the use of AI-driven diagnostics. Artificial intelligence (AI) is revolutionizing the diagnosis and treatment of bacterial infections by improving diagnostic accuracy, offering quick pathogen identification, forecasting antibiotic resistance, and integrating with clinical decision support systems. By guaranteeing prompt and appropriate therapy, these technologies not only enhance patient outcomes but also support international efforts to maintain the effectiveness of currently available antibiotics. AI's application in diagnostics will surely grow as it develops further, presenting fresh chances to battle antibiotic resistance and enhance patient care [22].

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PROGNOSTIC ANALYTICS FOR CUSTOMIZED INTERVENTIONS

The discipline of personalized medicine is expanding and has significant potential to improve healthcare outcomes by customizing medical care to each patient's unique traits. Personalized strategies can improve treatment plans, reduce side effects, and more successfully fight antibiotic resistance in the context of antibiotic therapy [23]. This revolution is being led by artificial intelligence (AI), which uses predictive analytics to provide precise and efficient personalized antibiotic therapy.

Obstacles and Prospects for the Future: personalized antibiotic therapy powered by AI has a lot of potential, but it also has drawbacks. Because genetic and health information is sensitive, protecting data privacy and security is crucial. Furthermore, the acceptability and usefulness of AI technologies by healthcare personnel must be carefully considered before integrating them into clinical workflows. Expanding the datasets needed to train AI algorithms, improving the accuracy and resilience of predictive models, and tackling potential biases in AI predictions should be the main areas of future research and development [24]. To fully utilize AI in personalized antibiotic therapy, cooperation between researchers, physicians, and legislators will be necessary. An important development in the battle against antibiotic resistance and the pursuit of the best possible patient outcomes is personalized antibiotic therapy. Predictive analytics powered by AI can customize medications to the particulars of each patient, increasing efficacy, decreasing side effects, and slowing the emergence of resistance. The precision and efficacy of antibiotic therapy will surely be improved by the incorporation of AI technologies into clinical practice as they develop, improving patient outcomes and promoting a more sustainable use of antibiotics [25].

Tracking and Reducing the Usage of Antibiotics

Antibiotic stewardship programmers work to minimize the development of antibiotic resistance and lower the risk of adverse effects while optimizing the use of antibiotics to ensure successful treatment. These initiatives are essential to the fight against antibiotic resistance, which is a major global health concern. By giving healthcare professionals real-time monitoring, decision support, and predictive analytics, artificial intelligence (AI) offers creative ways to improve antibiotic stewardship. One of the main causes of the rise in antibiotic-resistant bacteria is the overuse and misuse of antibiotics. The spread of resistant strains can be caused by inappropriate prescribing practices, such as using broad-spectrum antibiotics when narrow-spectrum medications would be more effective [26]. By encouraging the prudent use of antibiotics, educating patients and healthcare professionals, and putting evidence-based procedures into practice to maximize antibiotic prescribing, antibiotic stewardship programmers seek to address these problems.

Artificial intelligence-driven systems have the capability to track antibiotic prescription trends in real time, giving medical professionals prompt feedback on their prescription choices. These systems can detect inappropriate antibiotic use, such as needless prescriptions or extended treatment regimens, by analyzing pharmacy data and electronic health records (EHRs) [27]. AI systems, for instance, are able to identify situations in which antibiotics are provided for viral diseases, in which there is evidence of antibiotic abuse, or in which there would be no benefit. AI aids in encouraging adherence to antibiotic stewardship standards and minimizing the needless use of antibiotics by warning healthcare professionals about these situations. At the point of care, AI-driven decision support systems (DSS) give doctors evidence-based recommendations for prescribing antibiotics. To provide individualized therapy suggestions, these systems evaluate patient data, including clinical signs and symptoms, test findings, and microbiological data [28].

Based on the patient's diagnosis, area patterns of antibiotic resistance, and personal risk factors, a DSS can, for example, recommend the best medication and dosage [29]. AI-driven DSS can ensure that physicians have access to the most recent guidelines and evidence-based practices while streamlining the prescribing process by integrating with EHRs and clinical workflows. Predictive analytics is another tool that AI may use to detect patterns in antibiotic resistance and pinpoint high-risk groups or environments that require antibiotic stewardship measures. Artificial intelligence (AI) algorithms can identify patterns of antibiotic resistance emergence and transmission by examining data from infection surveillance systems, healthcare utilization databases, and microbiology lab collections. For instance, depending on genetic traits and environmental variables, AI models may forecast which bacterial strains are most likely to become resistant to specific medications. By focusing treatments on locations where resistance is most likely to occur and directing the choice of empirical antibiotic therapy, this data can support antibiotic stewardship initiatives [30].

AI has the potential to decrease antibiotic-related adverse medication events while also optimizing the use of antibiotics. AI algorithms are able to identify patients who are more likely to experience adverse reactions or drug interactions and can provide clinicians recommendations or warnings to reduce these risks by evaluating patient data and clinical results. AI can, for instance, identify patients who have comorbidities or allergies that make them more vulnerable to adverse medication events and recommend different antibiotics or dose changes. AI-driven technologies help to enhance patient safety and reduce the unwanted effects of antibiotic treatment by customizing antibiotic medication to each patient's unique traits [31].

Several research have shown how AI can be used to optimize antibiotic stewardship procedures. For instance, a study carried out in a sizable healthcare system discovered that the adoption of an AI-driven DSS resulted in a notable decrease in the improper prescription of antibiotics for respiratory tract illnesses. The DSS was able to decrease needless antibiotic use and increase adherence to antibiotic stewardship standards by giving clinicians real-time suggestions based on patient-specific data [32]. In a different study, researchers predicted patterns of antibiotic resistance in hospitalized patients by analyzing microbiology data using AI algorithms. The AI system helped physicians to target antibiotic stewardship

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treatments, including medication de-escalation or early discontinuation, to patients who would benefit most from them by identifying patients at high risk of developing antibiotic-resistant illnesses.

By giving healthcare practitioners access to real-time monitoring, decision assistance, and predictive analytics, artificial intelligence (AI) offers creative ways to improve antibiotic stewardship initiatives [33]. AI-driven solutions help to maintain the effectiveness of antibiotics and enhance patient outcomes by optimizing antibiotic use, lowering the frequency of adverse medication events, and predicting trends in antibiotic resistance. Antibiotic resistance will be fought, and the sustainable use of antibiotics in healthcare will be ensured, in part, by the increasing incorporation of AI technology into antibiotic stewardship programmers.

EARLY EPIDEMIC DETECTION

In public health, infection surveillance and monitoring are essential because they allow for the early identification of outbreaks, the tracking of disease patterns, and the prompt implementation of measures to stop the spread of infection. Manual reporting is a common component of traditional monitoring methods, but it can be laborious and prone to delays. Through the analysis of various datasets and the identification of patterns suggestive of newly emerging infectious dangers, artificial intelligence (AI) provides creative ways to improve infection surveillance and monitoring [34]. Effective public health response and containment of infectious disease epidemics depend on early detection. Public health officials can take action to stop the spread of the outbreak by implementing measures including vaccination, contact tracing, and quarantine as soon as an outbreak is identified. Surveillance systems track not only infectious diseases but also increases in antibiotic resistance, infections linked to healthcare, and other important public health indicators [35].

Artificial intelligence (AI) algorithms are capable of analyzing a wide range of data sources, such as electronic health records, lab reports, social media posts, and internet search queries, in order to detect indicators of newly emerging infectious dangers. AI systems are able to identify trends and abnormalities that may point to outbreaks or shifts in the dynamics of disease transmission by analyzing massive amounts of data in real time [36]. AI, for instance, can examine information from ambulance calls, pharmacy sales, and ER visits to identify patterns in respiratory symptoms or drug purchases that would indicate a flu outbreak. Similarly, AI systems can keep an eye out on internet forums and social media for talk about unusual disease clusters or talks about signs of illnesses, giving early notice of possible outbreaks.

By keeping an eye on clinical symptoms rather than particular diagnoses, syndrome monitoring systems can identify epidemics early on, even before laboratory confirmation is available. By examining many sources of syndrome data, including emergency department chief complaint statistics, school absenteeism records, and over-the-counter pharmaceutical sales, artificial intelligence (AI) can improve syndrome surveillance. To identify rises in influenza-like disease or other respiratory infections, for example, AI systems can examine patterns in data on respiratory symptoms [37]. Artificial intelligence (AI)-driven syndrome surveillance systems can detect clusters of symptoms that are indicative of infectious diseases and so enable rapid public health response and early epidemic detection.

In order to predict disease outbreaks and future patterns in disease transmission, AI can also make use of predictive modelling approaches [38]. AI algorithms can estimate disease incidence, prevalence, and spatial spread by examining past surveillance data, environmental factors, and other pertinent variables. For instance, using information on the climate, vector abundance, and human population density, AI-driven models may forecast the spread of vector-borne illnesses like dengue fever or Lyme disease. Predictive models help public health officials manage resources, put preventive measures in place, and lessen the impact of infectious illnesses on populations by giving early warning of possible outbreaks. AI is capable of tracking antimicrobial resistance trends and spotting new resistance patterns that could endanger public health in addition to infectious disease surveillance. Artificial intelligence (AI) systems are able to track the transmission of resistant infections and identify changes in resistance rates by analyzing data from microbiology laboratories, healthcare facilities, and public health organizations [39].

Artificial intelligence-powered surveillance systems, for instance, can track patterns in antibiotic susceptibility test results to spot rises in resistance in common bacterial infections. AI assists in informing treatment choices, preventing the spread of antimicrobial-resistant illnesses, and informing antibiotic prescribing practices by giving real-time feedback to public health authorities and healthcare professionals. Numerous practical uses demonstrate how good AI is in monitoring and shriveling infections. Researchers, for instance, have created AI-driven systems that use information from news articles, social media posts, and internet search queries to track patterns in infectious disease epidemics [40]. These systems have proven effective in identifying disease outbreaks, including those caused by the flu, dengue fever, and Ebola, giving public health official's early notice and enabling prompt response actions.

Another example involves the use of AI algorithms to track the spread of antibiotic resistance by analyzing genomic data from bacterial infections. Artificial Intelligence can forecast treatment failure and provide real-time guidance for antibiotic prescribing by detecting genetic markers linked to resistance [41]. By analyzing a variety of datasets, finding patterns suggestive of new infectious dangers, and enabling prompt public health response actions, artificial intelligence provides creative ways to improve infection surveillance and monitoring. Through the utilization of AI-powered data analysis, syndrome surveillance, predictive modelling, and real-time antibiotic resistance monitoring, public health authorities are able to promptly identify outbreaks, monitor disease patterns, and execute focused interventions to impede additional dissemination. AI technologies will become more and more crucial to integrate into infection surveillance systems as they develop, helping to safeguard public health and lessen the effects of infectious illnesses on communities [42].

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CONCLUSION

To sum up, the use of Artificial Intelligence (AI) in the management of antibiotics gives a critical chance to transform medical procedures, tackle antibiotic resistance, and enhance patient results. Artificial Intelligence (AI) holds promise for improving the efficacy, equality, and efficiency of antimicrobial stewardship initiatives through novel applications like infection surveillance, predictive analytics, intelligent diagnostics, and precision medicine. But there are several obstacles in the way of achieving this promise, such as technical difficulty, data accessibility and quality, clinical acceptability, legal and regulatory issues, and long-term financial viability. Healthcare organizations, legislators, industry stakeholders, and the larger healthcare community must work together to address these issues by making strategic investments in workforce training, infrastructure, and resources, encouraging teamwork and innovation, and navigating the intricate legal, ethical, and regulatory environments.

Through the removal of these obstacles and the utilization of AI's revolutionary potential, healthcare systems can open up new avenues for tailored, data-driven antibiotic management that maximizes therapeutic results, reduces side effects, and maintains the effectiveness of already available antibiotics. AI-driven antibiotic management has the potential to usher in a new era of sustainable healthcare that addresses the growing threat of antibiotic resistance and enhances the lives of patients worldwide, provided that there is a shared commitment to responsible innovation, patient-centered care, and global health equity.

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