

Commentary

Brave new world: Leveraging artificial intelligence for advancing healthcare epidemiology, infection prevention, and antimicrobial stewardship

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Most human beings have an almost infinite capacity for taking things for granted. Aldous Huxley, Brave New World

Artificial intelligence (AI) in medicine is pervasive and quickly expanding. AI refers to creating intelligent machines that can perform tasks that typically require human intelligence. Machine learning is a subset of AI that involves training computer systems to learn and improve without being explicitly programmed. Deep learning is a type of machine learning that uses artificial neural networks with multiple layers to analyze and learn from a large amount of data. Common medical applications of AI algorithms include diagnosing diseases and assisting physicians to interpret imaging studies to identify signs of disease or injury. It has also been used for drug discovery and development, and it can analyze electronic health records (EHR) to identify patients at risk of certain conditions, such as heart disease or cancer, and it can help improve patient outcomes through personalized medicine. These are just some of the medical applications of AI.^{1,2} However, the technology is not perfect and has been criticized for applying biased algorithms to patient care, potentially causing harm to certain patient groups.¹ In this commentary, we seek to highlight the early adoption and promise of AI in the respective fields of infection prevention and control, antimicrobial stewardship, and public health while also raising important ethical and logistical challenges to implementation.

Research and publication

A chatbot named ChatGPT (ChatGPT: Optimizing Language Models for Dialogue at openai.com), released in November 2022, caught the attention of the scientific community after debuting as a coauthor in scientific articles.³ ChatGPT is a large language model (LLM), a machine-learning system that autonomously learns from data and can produce sophisticated and intelligent writing after

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training on a massive data set of text >200 billion words.^{3,4} Recently, ChatGPT (also known as ChatGPT 3.5) was updated to ChatGPT-4 (generative pretrained transformer 4), which is the fourth iteration of the OpenAI software that is more accurate and collaborative than the previous iteration, and 40% more likely to produce factual responses.⁵ However, like its predecessor, ChatGPT-4 was trained on data prior to 2021.⁵ This underscores the importance of continuous algorithm model refinement and the importance of human oversight of outputs.⁴

Moreover, ChatGPT is free and easy to use, and it continues to evolve. However, in a recent New York Times profile, even the company's chief executive voiced cautious optimism about its potential.⁶ ChatGPT is just one example of a coming wave of accessible AI technology that can transform scientific exploration and its medical applications. As this technology is used with greater frequency, scientific journals must quickly develop a framework for the safe, balanced, and transparent use of AI in scientific manuscripts. Concerns about plagiarism in automated manuscript generation must also be addressed.⁷

Infection prevention and healthcare epidemiology

AI application can improve hand hygiene compliance by integrating machine-learning algorithms and video processing, and by adopting deep-learning models to improve accuracy of results regarding hand hygiene compliance (eg, adherence to the World Health Organization Five Moments of Hand Hygiene).^{8,9} Data-mining techniques, including machine learning, deep learning, or AI, can be applied to the data stored in the data lake (a central store of vast amounts of data), allowing for predictive analysis to detect HAIs that can be used to provide feedback to healthcare personnel to improve infection prevention practices.^{10,11}

AI has the potential to improve surgical-site infection (SSI) detection by enabling the analysis of large amount of data, including EHRs and surgical videos, to identify patterns and anomalies that may indicate the presence of an SSI.^{10,12} Machine-learning algorithms can be trained to predict the likelihood of SSI based on patient data, such as demographics, comorbidities, and surgical procedures.^{10,12} A recent systematic review of literature and meta-analysis concluded that machine-learning algorithms

developed with structured and textual data provided optimal performance in SSI case detection and prediction: pooled estimates of sensitivity 0.83 (95% confidence interval [CI], 0.78–0.87); specificity 0.92 (95% CI, 0.86–0.95); and area under the curve [AUC] 0.92 (95% CI, 0.89–0.94).¹² AI applications have also been applied to SSI prevention.^{10,12} By predicting which patients are at high risk of SSI, clinicians can take preventive measures such as targeted antibiotic prophylaxis, enhanced surveillance, and enhanced wound care.¹⁰ Another AI application is computer vision, a technology that enables computers and systems to derive meaningful information from digital images.¹³ Computer vision can analyze surgical videos and images in real time to detect anomalies in surgical procedures that could lead to SSI.¹⁴ This technology can detect errors such as inadequate hand hygiene, improper surgical technique, and insufficient sterilization of equipment. By providing real-time feedback to surgeons, computer vision can help prevent SSI by improving surgical technique and reducing the risk of contamination.^{15,16}

Generative AI algorithms may eventually provide real-time guidance to infection prevention challenges. We queried ChatGPT (on February 2, 2023): What value do contact precautions add on top of standard precautions for the control of MRSA infections? We received the following response:

Contact precautions add an additional level of protection on top of standard precautions for the control of MRSA (Methicillin-resistant Staphylococcus aureus) infections. While standard precautions are recommended for all patients to reduce the risk of transmission of infections, contact precautions are used for patients known or suspected to be infected with MRSA or other highly contagious pathogens.

The main difference between contact precautions and standard precautions is the emphasis on preventing direct or indirect contact with the infected patient and their bodily fluids. Contact precautions include using personal protective equipment (such as gloves and gowns), practicing good hand hygiene, using barrier precautions, and performing regular environmental cleaning.

By following contact precautions, healthcare workers can reduce the risk of getting infected with MRSA or spreading the infection to others. Additionally, isolating infected patients can help to prevent the spread of MRSA within a healthcare setting, reducing the risk of outbreaks and limiting the spread of the infection to other patients, healthcare workers, and visitors.

Therefore, the value of contact precautions lies in providing an extra layer of protection over standard precautions and helping to minimize the spread of MRSA and other highly contagious pathogens within healthcare settings.

Although the performance of the AI chatbot ChatGPT is impressive and accurate for a “textbook” IP concept, ChatGPT did not acknowledge the controversies, subtleties, and nuances in the application of contact precautions.^{17,18} Errors can occur from using earlier AI applications due to the absence of relevant articles as algorithmic sources and the absence of verification of output accuracy.

AI will likely improve workflows for infection preventionists, minimizing the countless hours spent in surveillance and reporting HAI events (Table 1). Although the primary motivator of surveillance programs is to monitor and reduce HAI incidence, these data are now increasingly utilized for benchmarking, public reporting, and pay-for-performance programs. A future use of AI in healthcare epidemiology may include predictive technology for emerging pathogens, transmission of extensively drug-resistant pathogens among hospitalized patients, and prediction of the onset of hospital outbreaks prior to traditional triggers.

Table 1. Applications of Artificial Intelligence (AI) in Infection Prevention and Healthcare Epidemiology, Antimicrobial Stewardship, and Public Health

Domains of Interest	Applications of Artificial Intelligence
Infection prevention and healthcare epidemiology	Predict healthcare-associated infections more accurately and quickly compared to traditional methods and can help hospitals prioritize infection prevention efforts ^{10,11} Improve workflow for infection preventionists, minimizing the countless hours spent in surveillance and reporting HAI events ³²
Antimicrobial stewardship	Help clinicians choose the right antimicrobial agent, dose, and duration of therapy for individual patients, and predict and prevent antimicrobial resistance ^{19–21} Support diagnostic stewardship and assist with validation of new molecular methodologies in the clinical microbiology laboratory that are essential to evaluate the accuracy and reliability of these tests before implementation in clinical care ²²
Public health	Identify false or misleading information by comparing to reputable sources of information. Synthesize and summarize literature to support optimal decision making ^{4,23} Improve disease surveillance, outbreak detection and efficiency of disaster response, and resource allocation ^{25,26,32}

Antimicrobial stewardship

AI focused on antimicrobial stewardship may provide individualized, real-time recommendations to providers on most appropriate antibiotic regimens (including antibiotic selection, dosing, duration).¹⁹ Such approaches can help ensure that patients receive optimal empiric and targeted therapy as early as possible.²⁰ One exciting potential use of AI is enabling faster prediction of antimicrobial resistance patterns directly from matrix-assisted laser desorption/ionized-time of flight (MALDI-TOF) mass spectra profiles from clinically relevant isolates, allowing more efficient optimization of therapy compared to traditional laboratory based antimicrobial susceptibility testing.²¹ However, this application may initially require oversight by infectious diseases pharmacists and physicians who must validate such models in their population and consider additional factors, such as social determinants of health that may affect a patient’s clinical outcome.

AI may revolutionize the way we track and compare outpatient antibiotic use across healthcare systems by accounting for patient-level information such as a diagnosis, severity, and important comorbidities. There is currently no standardized system in the United States assessing comprehensive antimicrobial use in the outpatient setting. The Centers for Disease Control and Prevention provides a metric for the percentage of visits resulting in antimicrobial prescriptions; however, this approach does not account for crucial information such as treatment duration, route of administration, the diagnosis for which antibiotics are prescribed, or multiple refills in single prescription, resulting in a potentially flawed evaluation of trends. An automated national system leveraging AI capabilities and incorporating individual-level information could address these limitations and provide a

more accurate and comprehensive understanding of outpatient antibiotic usage across healthcare systems in the United States and globally.

AI may also support diagnostic stewardship and assist with validation of new molecular methodologies in the clinical microbiology laboratory that are essential to evaluating the accuracy and reliability of these tests before implementation in clinical care.²² AI may be integrated with clinical decision support technology embedded in EHRs and computerized provider order-entry systems. For example, models may detect symptomatic versus asymptomatic states and fire EHR alerts to prevent inappropriate testing for asymptomatic bacteriuria, *C. difficile* colonization, and prevent antibiotic overuse. Finally, although EHR technology is already in place to detect pathogen–drug mismatches and inappropriate dosing in real time, further use of AI may speed up these processes, detecting harmful trends sooner and alerting the provider to the appropriate intervention (Table 1). With all aforementioned uses, it is clear that human oversight, expertise, and direct communication is still required, at least for now.

Public health

The accuracy of information provided by AI has the potential to be used to combat vaccine misinformation and other harmful medical inaccuracies. AI systems can be trained on large data sets of reliable information and can be used to identify false or misleading information. However, the reliability of AI in this context is only as good as the data inputs, so it is important to ensure that data are comprehensive and up to date. AI systems can also be vulnerable to biases and inaccuracies; therefore, public health agencies must monitor their performance constantly and correct any errors identified.^{4,23} However, during novel viral pandemics, such as that caused by SARS-CoV-2, disease transmission dynamics maybe unknown, especially early on, therefore, it is important to recognize that unknowns may affect the application of AI and predictive modeling. Transparency and nuanced communication by public health authorities are required concerning areas of uncertainty.

AI can monitor public health by analyzing large amounts of data from social media and other sources.²⁴ This allows public health organizations to identify and respond to health threats in real time, improving their ability to protect public health. An improved understanding of situational risks will optimize the delivery of humanitarian aid in disaster-stricken areas by analyzing data on population density, infrastructure, and resource availability (Table 1). Recently, humanitarian teams in Turkey and Syria used AI technology to identify buildings and infrastructure damage during the devastating earthquake to strategize rescue efforts.²⁵ This approach ensures that aid is delivered to the individuals who need it most, improving response times and reducing waste.²⁶

The CDC uses AI for its Syndromic Surveillance System, which collects and analyzes emergency department data in real time to detect potential outbreaks.²⁷ It was used heavily during the 2022–2023 “triple-demic” of COVID-19, influenza, and RSV. The CDC is also using AI to analyze genomic data and track new SARS-CoV-2 variants.²³

Ethics and safety concerns of new biotechnology

AI has rapidly evolved in recent years, with AI becoming increasingly advanced and capable of carrying out complex tasks.

However, this progress has also raised ethical concerns about the impact of AI on society. It is important to consider these ethical concerns and to develop responsible guidelines and regulations for the development and use of AI technology.

Although it does not involve AI, another groundbreaking example of medical technology raising significant ethical and safety concerns is gene-editing technology like Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR), which are DNA sequences derived from bacteriophage genomes. CRISPR resulted in experimental treatments for Huntington’s disease and sickle cell anemia, as well as certain cancers. CRISPR raises numerous ethical concerns, including the possibility of creating “designer babies” and unintended consequences of genetic modifications. In response, various national and international organizations enacted guidelines and regulations to govern its use. The World Health Organization established a global registry to track all CRISPR-related research and its effects.²⁸ Currently, there is no similar framework for regulating application of AI; however, it is an active area of discussion and research.^{3,4} Another major difference is that CRISPR developed from a predominantly scientific community, which may have a more clearly defined code of ethics and conduct versus the more diffuse and broad AI community, which may have less defined ethical standards.²⁸

Data privacy and bias challenges in the adoption of AI

Another challenge with the widespread adoption of AI in medicine is data privacy because sensitive medical information is used to train AI algorithms. AI uses a combination of anonymized and other data, such as ZIP code, which may threaten the privacy and security implicit in the term “protected health information (PHI).” Therefore, widespread AI adoption and acceptance by patients and healthcare providers will require transparent and reliable protections of PHI and checks on implicit biases which may harm minoritized communities. AI biases occur because human beings choose the data that algorithms use and decide how the results of those algorithms will be applied. For example, facial analysis technologies had higher error rates for nonwhite minorities, particularly minority women, potentially due to unrepresentative training data. Without extensive testing and diverse teams, it is easy for unconscious biases to enter machine-learning models. AI systems then automate and perpetuate those biases in models.^{29,30}

One proposed solution would be for patients themselves to control their data and then provide consent for their data to be used to develop AI applications.⁹ However, if these concerns are thoroughly addressed by AI platforms and federal agencies, and at-risk communities are empowered to assert control over their data, then numerous potential uses in scientific research, infection prevention, public health, and stewardship should be explored.

Future directions and warnings

Although the future state of healthcare may involve greater automation and elimination of certain routine functions, which may be viewed by some as a threat, we encourage providers to embrace the positive implications. These include the improvement of workflows, the implementation of nudges that enhance safety and the elimination of excess time spent at the computer to maximize time spent with patients, families, and care team members. Moreover, the ability of AI to operate in multiple languages can serve as a tool to bridge linguistic gaps and promote global collaboration. With the growing body of literature in the fields of infection prevention and control, antimicrobial

stewardship, and public health, AI will play an emerging role in identifying and synthesizing such evidence to answer clinical questions quickly and accurately.

AI-mediated instruments enhance human performance as observed with Smartphones, computers, the Internet, GPS, etc. Various initiatives are underway at the federal and international level to regulate and deploy advanced technologies in a manner that ensures safety and ethics.⁴ In conclusion, AI is here to stay and will continue to expand. The healthcare community must proactively explore how to best integrate it and develop a framework for use while appreciating its benefits and limitations.^{11,31} Scientific originality and transparency must prevail. AI may improve patient outcomes but must be used responsibly and with proper safeguards in place to ensure patient privacy and the accuracy of medical decisions without biases.

Despite these benefits, we must recognize that AI currently lacks originality, thoughtfulness, nuance, innovation, and the ability to function in “gray zones.” With this, AI should prompt us to verify the accuracy of outputs using our own expertise and should drive us to focus more on humanistic factors such as deliberation, reflection, interpersonal communication, and empathy, that which makes medicine meaningful. A “human touch” remains essential to uphold the passion and humanity of medicine and should not be taken for granted.

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