Perspectives

# Artificial Intelligence in Health and Medicine: Progress, Challenges, and Recommendations

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## ABSTRACT

Artificial intelligence (AI) has broadly reshaped health and medicine, benefiting clinicians, patients, and health systems. However, technical, regulatory, and ethical challenges exist in the application of medical AI, ranging from data scarcity to fairness. We provide our perspective on how to address the major challenges facing widespread clinical adoption from both technical (e.g., building high-quality datasets, using larger and more diverse datasets for training, creating problem formulations that go beyond supervised learning, and combining human skills with AI tools) and ethical (e.g., using highly secure data platforms and strengthening governmental legislation) perspectives.

Artificial intelligence (AI) refers to "machines that mimic cognitive functions similar to the human mind such as learning and problem solving" (*1*). The promise of AI in health and medicine dates back to the 1960s, when ELIZA, one of the first chatbots, was developed to engage in simple dialogue with users (*2*). Owing to rapid advances in AI, an increasing interest in applying AI to medicine has emerged in the last decade (*3*–*4*). AI technology has achieved remarkable success in helping clinicians diagnose and treat diseases, enabling patients to process their own data to improve health, and optimizing health service delivery (*3*). Despite advances, healthcare is below average in the adoption of AI, compared with other industries (*5*), potentially owing to challenges such as bias, privacy and security, and lack of transparency (*6*–*8*). Recommendations have been proposed in the end for the use of AI in health and medicine to overcome these challenges.

## PROGRESS IN MEDICAL AI

Only a few years after the first landmark demonstrations of AI algorithms that could detect diseases from medical images, the landscape of medical AI has matured considerably (*4*). AI-enabled medical practice transforms clinical care in terms of medical knowledge, patient journey, and clinical practice (Figure 1). AI systems have been deployed in a wide range of clinical settings that benefit clinicians, patients, and health systems.

## AI FOR CLINICIANS

AI has been widely used among clinicians, ranging from specialty doctors to paramedics (*3*,*8*–*10*). This involves pattern recognition using deep neural networks (DNNs) that can help interpret, for instance, vital signs, electrocardiograms, medical scans, endoscopy, pathology slides, skin lesions, and retinal images (*3*). AI systems can serve as medical knowledge resources for clinicians (*9*), simplify clinical text summarization (*10*), and assist in decision-making and guideline adherence (*9*).

Radiology has garnered significant attention in the field of medical AI (*3*). AI systems have been widely used in various medical scans (*3*), including computed tomography scans for lung nodules, pancreatic cancer, and liver masses; echocardiograms; brain scans for evidence of hemorrhage, head trauma, and acute referrals; magnetic resonance imaging; mammography; and bone films for fractures and estimation of aging. AI has repeatedly shown to not only improve the accuracy and efficiency of disease diagnosis but also make more accurate risk predictions and guide treatment (*11*–*13*). For instance, Wang et al. proposed a triage-driven Chinese Lung Nodules Reporting and Data System and found that it achieved a state-of-the-art performance with an area under the curve (AUC) of 0.918 on an internal testing dataset, outperforming the single-dimensional approach (AUC=0.881) (*14*).

Owing to remarkable success in image classification, AI algorithms have then been applied in specialties that heavily rely on the interpretation of medical images

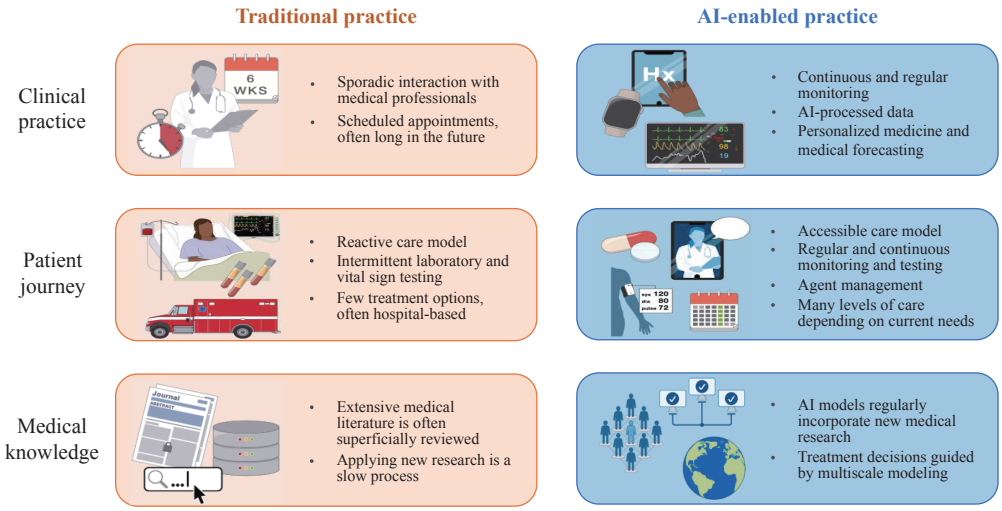


FIGURE 1. Comparison between traditional practice and AI-enabled practice in clinical care.
Abbreviation: AI=artificial intelligence.

such as pathology, ophthalmology, dermatology, cardiology, and gastroenterology (*3*–*4*). In the field of pathology, using whole-slide imaging, deep learning has made major strides in accelerating workflows for disease diagnosis (*15*) and providing new disease insights (*4*). DNNs have also made progress in gastroenterology, particularly in improving the sensitivity of colonoscopy (*16*).

## AI FOR PATIENTS

AI-driven tools can provide patients with accessible conversational interfaces to interact with general medical information and their individual health data in electronic health records (*17*), thereby offering more accessible, proactive, and personalized healthcare (*9*). Medical AI has been employed throughout the human lifespan (Figure 2).

AI algorithms are poised to provide timely and personalized feedback through continuous monitoring (*9*). AI-enabled wearable sensors have shown the ability to identify high-risk individuals (*18*) with high diagnostic accuracy (*19*). Hence, patients are empowered to manage their health and wellbeing in a timely manner (*9*). Furthermore, AI systems promise to revolutionize medical forecasting with multiscale capacity (*9*). Due to the pattern-matching strengths of computers and large data input, forecasting can be applied to the entire context of health, from the molecular level to the cellular, cell/tissue, individual, population, and global levels (*20*). For instance, Li et al. proposed a framework that leverages large language models (LLMs) to estimate individual aging using only health examination reports and found that LLM-predicted ages had superior performance in predicting aging-related diseases than other aging proxies, such as telomere length and frailty index (*21*). The use of AI has enabled more accessible, proactive, and individualized healthcare.

In addition to continuous monitoring, advanced medical screening, and multiscale medical forecasting, the use of AI algorithms has been described in mental health settings. Machine learning can help characterize depression, predict suicide, predict bouts of psychosis in patients with schizophrenia, and predict successful antidepressant medication use through the digital tracking of depression and mood via keyboard interaction, speech, voice, facial recognition, sensors, and interactive chatbots (*3*). In particular, mental health chatbots have demonstrated great potential for reducing the stigma about mental health care and increasing referral rates (*22*).

## AI FOR HEALTH SYSTEMS

In addition to these applications, AI algorithms have been integrated into healthcare delivery, making it more precise and efficient (*3*,*9*).

AI-powered scribes have been reported to record patient histories, generate medical notes, handle pre-authorization requests for medications or tests, schedule follow-up appointments, and manage laboratory test results and scans (*9*–*10*), thereby lowering the potential for medical errors. Moreover, powerful AI models enable earlier diagnoses and interventions, which can improve health outcomes and

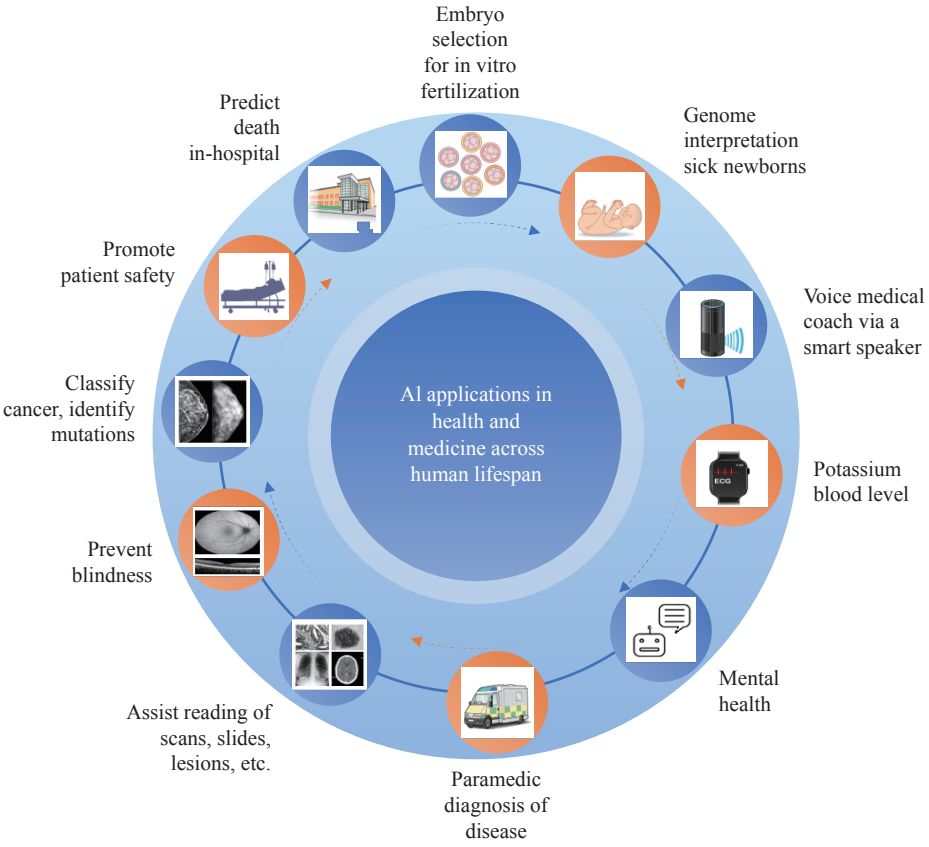


FIGURE 2. Examples of the breadth of AI applications in health and medicine across human lifespan.
Abbreviation: AI=artificial intelligence.

reduce the burden on health systems (*9*). For instance, Du et al. introduced and applied PandemicLLM, a framework with multimodal LLMs that reformulates real-time forecasting of disease spread as a text-reasoning problem to the coronavirus disease 2019 (COVID-19) pandemic, and observed that PandemicLLM performed better in forecasting one-week and three-week hospitalization trends compared with the CDC ensemble model (*23*). In addition to infectious disease prevention and control, AI has been used for immunization. For instance, Hou et al. assessed the effectiveness of a vaccine chatbot in improving human papillomavirus (HPV) vaccination among female middle school students aged 12–15 years and observed that 7.1% of the intervention group had received or scheduled appointments for the HPV vaccine for their daughters versus 1.8% of the control group over a two-week intervention period (*24*).

## CHALLENGES IN MEDICAL AI

Notwithstanding striking advances, medical AI faces major technical challenges, particularly in composing training datasets and building model trust (*3*–*4*). Questions also remain on the regulation of AI in health and medicine and shifts in responsibility throughout the health system (*3*–*4*). Ethical concerns regarding data privacy, security, and fairness also exist (*3*–*4*).

Various qualities are desired in AI systems, including reliability, convenience, and ease of integration into clinical workflows (*25*). However, the usefulness of AI relies heavily on how humans provide inputs and interpret the outputs (*4*). Medical data used to train AI systems are limited and possibly erroneous, and the devices required to obtain the input for AI are costly (*4*), impeding both the data collection and deployment of AI systems. Bias in the training data is likely to limit output accuracy and cause major harm to patients (*26*). Numerous AI models now function as uninterpretable black boxes (*3*–*4*). The data used for training, model performance on any task or population, and variation of the output according to the nondeterministic nature of AI remain unclear (*9*). Accordingly, explaining the predictions of AI models poses a serious technical challenge and their reliability in novel clinical settings remains unclear.

Medical AI poses additional challenges from a regulatory perspective. Regulatory challenges may arise from continual learning (AI models learn from new data over time and adjust to shifts in populations) (*27*), which may contribute to overwriting previously learned patterns or generating new errors (*4*). Moreover, as medical AI takes on more responsibilities, clinicians may become overly reliant on AI systems, leading to a gradual decline in their skills or personal connections with patients (*4*). Hence, a serious concern is that if AI makes mistakes, it remains unclear whether developers, regulators, sellers, or health providers should be held accountable (*4*).

Even further, ethical concerns also exist regarding the application of AI in health and medicine. An overriding issue in medical AI is how well data privacy and security can be assured (*3*,*9*). Bad actors interested in identity theft and other misconduct may take advantage of medical datasets (*4*) containing sensitive information about real patients (*3*). An individual's identity is likely determined by facial recognition or genomic sequences from large datasets (*3*). A risk of deliberate hacking of AI algorithms to harm people on a large scale also exists (*3*). Furthermore, although AI can make healthcare more accessible to underrepresented groups, the disproportionate use of AI systems may reinforce existing inequities in health (*3*–*4*). Intertwined with the concern of widening the present gap in health outcomes is the embedded bias in numerous AI algorithms owing to the lack of inclusion of minorities in datasets (*3*).

## RECOMMENDATIONS FOR MEDICAL AI

To build trustworthy AI tools for health and medicine, their design, development, evaluation, and deployment should follow FUTURE-AI, an international consensus guideline based on six guiding principles: fairness, universality, traceability, usability, robustness, and explainability (*28*). Moreover, the applications and optimizations of AI in health and medicine should be based on the complex adaptive systems (CAS) theoretical framework (*29*); that is, AI should adjust its behavior through multi-agent interactions between AI, patients, clinicians, public health practitioners, the public, and decision-makers to achieve continuous learning and adaptive optimization and meet the complex health needs of the population. In practice, in terms of technical challenges, it is necessary to advance AI algorithms by building high-quality datasets through implementing data standardization protocols, multi-institutional collaboration frameworks, and annotation quality control measures; using larger and more diverse datasets for training, such as text, chemical, and genomic sequences (*4*,*9*); creating problem formulations that go beyond supervised learning (*4*); and combining human skills with AI tools (*4*,*30*). Furthermore, new models of health data ownership with rights to individuals, use of highly secure data platforms, and strengthening of governmental legislation are warranted to counter regulatory and ethical issues in medical AI (*3*).

## CONCLUSION

The use of AI in health and medicine has made substantial progress: for clinicians, predominantly via rapid and accurate image interpretation and decision-making; for patients, by enabling them to access their own data to promote health; and for health systems, mainly by optimizing healthcare delivery. Despite the major advances in medical AI, challenges related to accuracy, bias, privacy, and ethics persist. These challenges must be addressed before medical AI can be realized to make health systems more accurate, efficient, and accessible to the public worldwide.

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