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Artificial intelligence in healthcare: An essential guide for health leaders

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Abstract

Artificial Intelligence (AI) is evolving rapidly in healthcare, and various AI applications have been developed to solve some of the most pressing problems that health organizations currently face. It is crucial for health leaders to understand the state of AI technologies and the ways that such technologies can be used to improve the efficiency, safety, and access of health services, achieving value-based care. This article provides a guide to understand the fundamentals of AI technologies (ie, machine learning, natural language processing, and AI voice assistants) as well as their proper use in healthcare. It also provides practical recommendations to help decision-makers develop an AI strategy that can support their digital healthcare transformation.

Introduction

Artificial Intelligence (AI) is evolving rapidly in healthcare due to its potential to unlock the power of big data and gain insight for supporting evidence-based clinical decision-making and achieving value-based care. It is crucial for health leaders to understand the state of AI technologies and the ways that such technologies can be used to improve the efficiency, safety, and access of health services, supporting the digital transformation of healthcare.

It is evident that AI has begun to affect almost every aspect of healthcare, from clinical decision support at points of care, patient self-management of chronic conditions at home, to drug research in the real world. The development and deployment of AI technology, however, is challenging and costly. Health organizations need to overcome a series of challenges in order to bring AI to success. Such challenges include the following: (1) a lack of understanding about what a particular type of AI technology can or cannot do; (2) a lack of clear strategies for integrating different AI technologies into the existing care systems to effectively solve the most pressing problems that health organizations currently face; (3) a shortage of well-trained workforce for AI implementation; (4) the incompatibility of AI technologies with legacy infrastructure; and (5) a lack of access to good and diverse medical data for training Machine Learning (ML) algorithms.[1,2]

In this article, we will address the above issues by first describing the state of AI technologies and the potential of such technologies for transforming healthcare. We will also discuss issues related to the selection, development, and implementation of AI technologies for improving care quality, access, and cost. Finally, we will provide recommendations to help health leaders develop a strategy to support their AI integration and digital healthcare transformation.

The state of AI technology

Artificial intelligence, in a practical sense, refers to computer systems that simulate or exhibit specific aspect of human intelligence or intelligent behaviour, such as learning, reasoning, and problem solving.[3] As such, AI is not a single technology but a range of intelligent processes and behaviours generated by computational models and algorithms. Recently, refined computational models and algorithms, coupled with powerful computers and the availability of massive data, have accelerated the advancements of AI, particularly in ML, Natural Language Processing (NLP), AI voice technology, AI assistants, and robotics. New powerful solutions have been developed to solve complex real-world problems in image understanding, speech recognition, big data analytics, and healthcare. In the subsequent sections, we will look at the AI technologies currently available and discuss their proper use in healthcare.

Machine learning

Machine learning represents the dominant approach in AI, and it is responsible for most of the recent advancements in the field. Typically, ML refers to a system that trains a predictive model by identifying patterns of data from input, then uses such a model to make useful predictions from new, never-before-seen data. Machine learning algorithms can automatically learn and improve from experience without being explicitly programmed, and such "learnability" represents a key feature of AI. Machine learning is widely used in other types of AI technologies, such as NLP, voice technology, and robotics. Health leaders need to become familiar with the main ML algorithms as they are the foundation for understanding the potential and limitations of various types of AI technologies. Briefly speaking, the most common ML algorithms are supervised learning, unsupervised learning, Reinforcement Learning (RL), and deep learning.

Supervised learning uses a data set as input and some known, labelled outcomes as output, then identifies patterns that correlate the outcomes with input for making predictions. In

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this approach, the algorithm needs to know the conclusions it should come up with from a given data set. With enough data and correctly labelled answers, the algorithm eventually learns to make predictions from input data it has never seen before. Supervised learning has been widely applied to healthcare, providing data-driven clinical decision support for mapping input variables into discrete categories (eg, using medical imaging to diagnose cancer tumor, its subtypes, and severity) and predictive analytics within a continuous output (eg, using Electronic Health Record [EHR] data to make predictions about the recurrences, prognosis, and mortality of a disease).

Unsupervised learning is used to discover the structure of data and make predictions based on input alone. This learning algorithm is more applicable to situations in which the outcomes are unknown or the labelling of data is too costly. It is mostly used in an exploratory way for clustering, anomaly detection, and pattern recognition in a variety of data types. In healthcare, unsupervised learning is particularly useful for predicting individual disease risks using genetic biomarkers or for designing personalized treatments based on genomic variations. As unsupervised learning can automatically "learn" without human's labelling of outcomes, it is closer to "true AI" in some sense. However, without human teaching, unsupervised learning is more prone to errors because it may use trivial features of the data to make predictions. So, in practice, supervised and unsupervised learning are often used in combination by making use of a large amount of unlabelled data for training with only a small proportion of data labelled. This is called *semi-supervised learning* which takes the advantages of both learning algorithms.

Reinforcement learning is a more autonomous learning algorithm that allows a computer agent to take actions and interact with the environment using rewards and errors as the feedback to guide training. This can be seen as the ultimate self-learning approach because the agent learns from its own experience without either data or labelling; it produces very good results for sequential decision-making tasks or tasks that are well defined with clear rules and outcomes, such as abstract strategy board games like Go. It is also used successfully in self-driving cars and robotics. In healthcare, it can be used in situations in which an agent needs to continuously interact with the environment and adjust its actions based on the feedback from the environment, for example, for optimizing treatment designs and robotic-assisted surgery.

Deep learning discovers the intricate structure in large data sets by using a backpropagation algorithm operating on multiple levels of abstraction.[4] It is aimed at increasing the capacity of supervised and unsupervised learning algorithms for solving complex real-world problems by adding multiple processing layers based on artificial neural networks, including "hidden layers" that play a key role in breaking down the problem to be analyzed. Deep learning has brought breakthroughs in domains that rely heavily on feature detection and big data (eg, Go game, computer vision, speech recognition, NLP, drug discovery, and genomics).

Machine learning has been applied to many data types (such as images, speech, videos, and text) on complex tasks that involve massive data, producing results that are comparable to and sometimes superior to human experts in terms of both accuracy and efficiency. It has shown the potential to provide data-driven, evidence-based clinical intelligence for advancing medical diagnosis, treatment decisions, biomedical research, and service delivery across the full spectrum of healthcare.

Even though ML has achieved great successes in areas where medical imaging and big data are involved, ML is not an all-purpose solution. For tasks that require common sense reasoning or domain-specific knowledge, or situations that are outside of the ML training data set, ML is less applicable. This is because ML relies on computational power and massive data to identify superficial patterns and correlations. As such, it does not reveal the causal relations or clear understanding of the phenomenon under study. Consequently, it is difficult to explain the results of ML and fix the specific known errors produced by the ML algorithms.

Natural language processing

Natural language processing uses computational methods to automatically analyze and represent human languages, mostly in text format. Recently, ML methods have been applied to NLP, achieving impressive results in speech recognition, machine translation, text classification, question answering, sentiment analysis, information extraction, and search engine. In healthcare, there is a very large amount of unstructured textual data in the forms of doctors' notes, test results, lab reports, medication orders, and discharge instructions. Natural language processing tools can be used to extract critical information about patients from such rich descriptive data, helping improve diagnoses and treatment recommendations. The capacity for machines to digest huge amounts of imagery and textual data quickly through ML and NLP will enable physicians to make timely diagnoses and treatment decisions, which can have profound impact on health service delivery, particularly on the ways that patients are treated.

Artificial intelligence voice technology and assistants

Voice is the most intuitive, natural, and universal way for humans to communicate. Artificial intelligence voice technology is changing the nature of human-machine communication, making it much easier for people to obtain, understand, use, and store health information. Voice interface has the potential to optimize users' experience, helping them overcome barriers existing in text-based information exchange or complex system operation.

Voice technology has been widely used in various industries and it has started to be incorporated into healthcare to address some of the information challenges faced by both health professionals and patients. Current EHR systems are complex and hard to use, so many EHR vendors and health providers are incorporating voice technology into their EHR systems to simplify the clinical documentation process. On the consumer

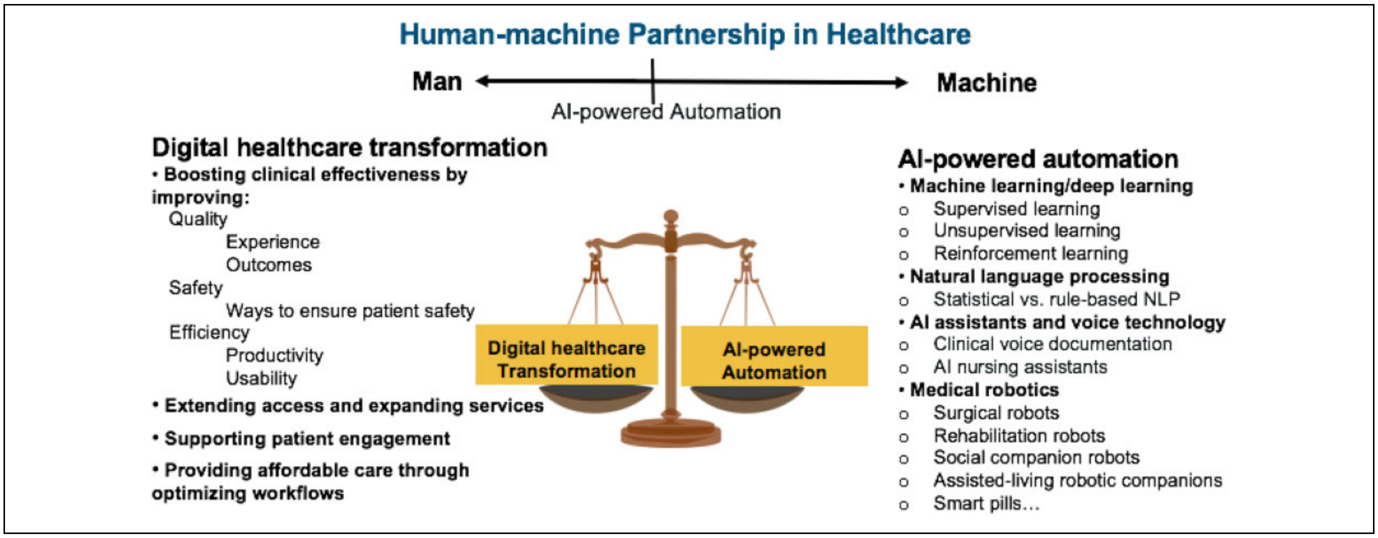

Figure 1. Human-machine partnership in healthcare.

front, AI assistants like Alexa, Siri, Cortana, and Google Assistant have gained the "skills" to perform specific routine and simple tasks in the healthcare context such as reminding patients when to take their medication and scheduling appointments. At this moment, such AI voice assistants have limited capacity in terms of providing reliable answers to health-related questions.[5] It seems that text-based chatbots are more reliable, thus have enjoyed a greater commercial success (eg, Babylon, Ada, and Buoy). However, the reliability of such text-based chatbots is often achieved at the cost of restricting user input to predetermined words and phrases, not allowing users to take the initiative in the dialogue.[6] With the high expectation of investors and the efforts from both big tech companies and start-ups, it is certain that more advanced AI voice health assistants that are capable of unconstrained language input and human-like natural conversations will soon be developed.

Medical robotics

Medical robots showcase the capabilities of all AI technologies described previously. Medical robots can help with surgical operations, rehabilitation, social interaction, assisted living, and more. One of the most commonly used medical robots is AI-assisted surgical robots, which can analyze data from pre-operative medical records to physically guide a surgeon's instrument in real time during a procedure. Such surgical robots are frequently used in neurologic, orthopedic, and laparoscopic procedures, being operated both locally and remotely. Compared to traditional surgery, robot-assisted surgery is minimally invasive, and it can reduce hospital stay, complications, and errors. Robots have also been used to help the rehabilitation of patients with stroke, to assist in the care of the elderly individuals, and to deliver medical supplies and equipment.[7] It is reasonable to anticipate that one day robots will be able to monitor a patient's vital signs and take proper actions when needed.

How can AI transform healthcare?

Humans and machines each have their unique strengths and weaknesses, and they can complement each other in providing and optimizing healthcare. The American Medical Association recently defined the role of AI in healthcare as "augmented intelligence," stating that AI will be designed and used to enhance human intelligence rather than replace it.[8] American Medical Association's view emphasizes the partnership between man and machine, which has important implications for the use of AI in healthcare. Below are our perspectives on the role of AI and how AI should be designed, implemented, and integrated to support human performance and foster digital healthcare transformation.

Artificial intelligence as a powerful tool and partner

The AI technologies described above can be used as powerful tools and partners to enhance, extend, and expand human capabilities, delivering the types of care patients need, at the time and place they need them. Figure 1 shows how man and AI can form a partnership to improve clinical effectiveness (ie, quality, safety, and efficiency), access, and affordability of care.

It is important to indicate that a human-machine partnership by no means implies that the machine cannot be used alone. For tasks where machine has surpassed human performance (eg, screening cancer, diabetic retinopathy, and certain heart conditions), tasks where mistakes do not lead to serious consequences (eg, flagging an at-risk population group for vaccination), or for situations where human doctors are unavailable but machine can do a good job (eg, using a chatbot to show a patient how to give an insulin injection), complete AI automation is possible. The key in man-machine partnership is to keep the delicate balance between the types of care we value and the levels of automation that AI technologies offer (see Figure 1).

Embedding AI features into workflows to support clinical decision-making

The best AI integration in healthcare requires AI technologies to be embedded into the workflows to support clinical decision-making at the point of care. By integrating AI into the workflows, AI can help us accomplish the following:

- Unlock the power of big data and gain insight into patients;
- Support evidence-based decision-making, improving quality, safety, and efficiency, coordinate care and foster communication;
- Improve patient experience and outcomes;
- Deliver value and reduce costs; and
- Optimize health system performance.

As EHRs serve as the backbone of digital healthcare systems, the preferable approach to integrate AI in healthcare is to embed useful AI features directly into EHR systems. Currently, most EHRs are "systems of records and storage" with limited capabilities. Machine learning, NLP, and voice technologies and AI assistants can transform EHRs from "systems of records" to "systems of intelligence" and "systems of engagement." Regardless of whether a health organization plans to purchase a new EHR system, adds AI features to an existing EHR system, or builds a brand-new AI-powered next-generation digital healthcare system, it is necessary to consider certain AI features. Table 1 shows the different system capabilities supported by specific AI features.

Knowing the key platforms, products, and services for developing AI in healthcare

There are three main types of companies that are providing a wide range of AI platforms, products, and services for developing AI-enabled healthcare systems. The first type is EHR vendors such as Epic, Cerner, Allscripts, Athena, which have started to add some AI capabilities in their EHR systems,[9] incorporating ML, voice dictation, and NLP to support clinical decision-making, workflows, and patient engagement. The second type is big tech companies such as Google, Microsoft, Amazon, Apple, and IBM, which are providing AI cloud platforms, services, and ML algorithms for health organizations to build, manage, and deploy various AI applications with massive data. They also offer specialized healthcare products that can be used by health organizations. The third type is specialized healthcare AI firms. There is a fast-growing number of companies, particularly start-ups that are producing various kinds of AI healthcare applications. Such applications usually fall in one of four categories: patient-facing, doctor-facing, research, and telehealth.[10] Table 2 is a summary of the key AI players, their platforms, products, and services available for developing AI applications.

The development and implementation of AI in healthcare

Using a wide range of AI platforms, tools, and services available, many health organizations have been collaborating with technology companies to build their AI capabilities. They usually combine the following approaches in such development: hiring external talent, building capabilities in-house, licensing capabilities from large technology firms, buying AI-focused start-ups or other companies, partnering with other institutions, and retaining internal talent. Currently, there seem to be three trends in developing healthcare AI:

1. *Machine learning is a dominant approach, proven to be reliable for disease detection, diagnosis, and management*. In recent years, ML algorithms have been proven reliable for detecting and diagnosing diseases. Many such algorithms have received approvals from the US Food and Drug Administration (FDA) for their safe use in healthcare. Meskó[11,12] has offered a good overview of such FDA-approved algorithms and indicated that most of them are developed in the areas of radiology, pathology, cardiology, oncology, endocrinology, and dermatology . Besides disease detection and diagnosis, many hospitals in United States and Canada have started using ML for predictive analytics for hospital management purposes (eg, predicting adverse events, mortality rates, the number of patients to the emergency department). Such predictability enables hospitals to take proactive measures for the foreseen events days in advance. Following are some ML highlights worth mentioning:
    - Stanford researchers have developed an AI algorithm that can diagnose up to 14 types of medical conditions simultaneously from medical images.[13]
    - Mayo Clinic neuroradiologists are using AI to find molecular biomarkers in magnetic resonance imaging scans instead of testing samples collected during surgery.[14]
    - Researchers from Memorial Sloan Kettering Cancer Center have developed a deep learning model and system that uses only the reported diagnoses as labels for training on whole-slide images, thereby avoiding manual annotation of big data sets other deep learning models require. Their study shows that their system has the ability to train accurate classification models without annotated data sets, thus overcome a great challenge for deploying computational decision-support systems in clinical practice.[15]
    - Massachusetts Institute of Technology (MIT) has recently developed a new deep learning-based AI prediction model that can anticipate the development of breast cancer up to 5 years in advance. More importantly, this AI model is specifically designed to ensure it is equally accurate for white and black women.[16]
    - Several hospitals in Canada are using AI to predict the number of patients to the emergency department 2 or 3 days in advance, allowing the hospital to take proactive action in staffing and resource allocation.[17,18]

Table 1. Embedding AI features into EHRS to support clinical decisional-making and workflows

System capabilities	AI features
Providing clinical decision support at the point of care to improve diagnostic accuracy and treatment recommendations	• Diagnostic analytics using medical imaging (eg, CT-scan, X-rays, MRI, ECG/EKG, pathological images) or genomic, behavioural, and other clinical data (eg, symptoms, family history) • Predictive analytics (eg, predicting high-risk patients and outcomes to a treatment) • Personalized treatment recommendations based on clinical, genomic, and behavioural data • Prediction and prevention of adverse events • Medication safety and reconciliation • Routine integration of medical imaging with other clinical data for triage and critical care monitoring, diagnostic interpretation, and treatment modification • Precision medicine and drug discovery
Extending access and expanding services	• Access to on-line services (on-line consultation, appointment booking, drug renewal)
Providing patient engagement technology to support self-care	• Patient empowerment via access to their health data • Patient engagement tools (eg, chatbots, wearables, and mobile devices) for supporting patient education, informed decision-making, self-monitoring, and self-management of chronic conditions • Channels for patients to interact with healthcare providers, systems, and services • Integration of crucial patient data from wearable, mobile devices and health apps into EHR
Optimizing workflows and resource allocation, improving operational efficiency	• Predictions of the number of patients during a specific period and resources needed (staff, equipment, and facility) • Integrated voice technology in EHR for clinical documentation, data entry, voice interface, question asking and answering • Integrated NLP capacity for processing narrative health data (doctor's notes, clinical reports) and providing critical summaries of key patient information • Smarter search algorithms • Simplification of operational processes through AI automation • Detecting fraud, waste, and abuse via machine learning
Facilitating population health monitoring and management, improving wellness	• Population health monitoring • Identification of high-risk population groups • Prioritization of at-risk patient populations and management of proactive interventions • Investigation of social determinants on healthcare and management of population wellness
Supporting real-world clinical research and evidence-based medicine	• Collection and storage of real-world data for clinical research and care improvement • Precision medicine and clinical trial matching

Abbreviations: CT, computed tomography; ECG, electrocardiographic; EHR, electronic health record; MRI, magnetic resonance imaging; NLP, natural language processing.

The ability for the machine to digest huge amounts of information and provide needed insights quickly will have a profound impact on the ways that medical health services are delivered and managed. It will also equalize healthcare by paying attention to patients who are typically left out.

2. *Cross-sector collaborations are vital for advancing AI in healthcare.* Currently, most major AI firms are all working with partners in life sciences or sensor manufacture to develop their healthcare AI capabilities. For instance, Apple has partnered with over 100 hospitals and clinics for its health records project, allowing consumers to exchange their health data with healthcare providers. Similarly, IBM has developed partnerships with many hospitals, enabling them to make cancer diagnosis and treatment recommendations using Watson Health. The collaboration across sectors provides a leverage for both AI firms and health organizations, enabling them to manage the multi-faceted complexity of AI and healthcare. Such an approach will have a significant impact on the advancement of AI in healthcare.

Table 2. Key AI players, their AI platforms, products, and services for healthcare

Technology providers	AI platforms, tools, and services
EHR vendors (eg, Epic, Cerner, Allscripts, Athena, and others)	EHR vendors have started to add some AI capabilities in their EHR systems,[9] such as: • Natural language processing • Machine learning for clinical decision support • Integration with telehealth technologies • Automated imaging analytics • Voice dictation • On-line tools for engaging patients.
Big tech companies (eg, Google, Microsoft, Amazon, Apple, IBM, NVIDIA, Nuance, OpenAI, and others)	Big tech companies are providing AI cloud platforms, services, and machine learning algorithms for health organizations to build, manage, deploy various AI applications with massive data, including capabilities for: • Image recognition • Natural language processing • Voice recognition • Question-answer matching • Predictive analytics • AI voice assistants: Alexa, Siri, Cortana, and Google Assistant These companies have also developed specialized products for healthcare: • IBM Watson can learn from new data and make diagnosis and treatment recommendations for cancer • Nuance offers NLP tools that can be integrated into commercial EHRs to support clinical documentation and data entry • Apple Health Records app enables consumers to enter their health data, import such data from mobile apps and devices, then exchange with their healthcare providers • Amazon offers its Comprehend Medical, a NLP tool for analyzing unstructured clinical text • Amazon's Alexa HIPAA can be used for building compliant healthcare chatbot "skills" • Google DeepMind has built a system for making diagnosis and treatment recommendations for over 50 different eye diseases • Microsoft Azure API for FHIR enables health providers to connect their existing EHR data for analytics, machine learning, and actionable intelligence • Microsoft Healthcare Bot provides healthcare intelligence, including language models to understand healthcare information and content from credible sources
Specialized AI firms in healthcare	A fast-growing number of companies, particularly start-ups, are producing both patient-facing and doctor-facing AI applications: (a) Patient-facing application: Meskó has provided an overview of such chatbots,[11] below is a list of some well-known chatbots: • Text-based chatbots: Woebot, Babylon health, Buoy health, Your.Md, Molly, Eva, Ginger, Replika, Florence, Izzy, Safedrugbot, Sensely, GYANT, Bots4Health, and others • Voice-activated chatbots: Ada health, Infermedica, Avaamo • Platforms for developing voice chatbots in healthcare: Orbita (b) Doctor-facing AI applications: • Voice dictation tools for clinical documentation: Dragon Medical Practice by Nuance • Medical NLP tools: Optum by United Health Group, MetaMap by NLM, cTakes by Mayo Clinic, Inguamatics, and CLAMP Toolkit by University of Texas

Abbreviations: API, application programming interface; EHR, Electronic Health Record; FHIR, fast healthcare interoperability resources; HIPAA, Health Insurance Portability and Accountability Act; NLP, natural language processing.

3. *The partnerships between governments and AI industry become common*. To overcome the healthcare challenges that they face, governments in many countries have formed strategic coalitions with the private sector. For instance, the UK National Health Service has developed several partnerships with AI firms to improve its healthcare services. It is partnering with Babylon Health to provide on-line medical diagnosis and tele-consultation to make healthcare more accessible; it is collaborating with DeepMind, the Google-owned UK AI research firm, to develop deep learning model for continuously predicting the likelihood of patients developing life-threatening conditions, and it has recently formed a partnership with Amazon to provide people with reliable answers to their medical questions through Alexa.

The Canadian government has also started to develop a coalition called the Digital Health and Discovery Platform (DHDP), with a network of 100 partners across Canada. The network engages the Canadian Association of Radiologists as well as healthcare institutions, private firms, and universities across Canada in developing a cutting-edge, pan-Canadian health data platform for advancing precision medicine. The DHDP will integrate diverse sources of data, including genomics, imaging, and electronic medical records from multiple hospitals across Canada to discover new therapeutic interventions, such as AI-derived biomarkers, for personalized diagnoses and treatments on cancer and eventually on other diseases. Canada has a public-funded universal healthcare system, world-renowned ML scientists, and top-notch researchers in both medical science and health informatics, so it shall be able to develop a cutting-edge, AI-powered digital healthcare ecosystem to improve healthcare for all Canadians.

The US federal government has been slow in forming a coalition with the private sector on healthcare AI. In February 2019, the US government announced the American AI Initiative, promoting a whole-of-government strategy in AI collaboration targeting explainable healthcare systems, systems that are "reliable, dependable, safe, and trustworthy." In spite of the slow action taken by the federal government, the United States still shows dominance in AI due to the great efforts from its private sector (particularly large tech companies, EHR system vendors, and innovative start-ups), top-notch universities, and very active federal department agencies. So far, the majority of FDA-approved ML algorithms are developed by US companies or universities. Most AI-enabled EHR systems and consumer AI applications are the products of the United States, some of which are listed in Table 2.

China is becoming a global powerhouse in AI,[19]thanks to its comprehensive national AI strategies, decisive action to support AI industry with generous central government funding, state-owned hospital networks, big population data, less restrictive data governance, and aggressive start-up culture. China now publishes more scientific papers on AI than any other country. Its AI brain imaging system has beat human expert physicians in diagnosing brain tumors and predicting hematoma expansion.[20] Robots are commonly seen in hospital, greeting and directing patients; many private firms are teaming up with hospitals to offer experimental AI-powered diagnosis services. For instance, Tencent's AI medical imaging software that has over 90% accuracy in diagnosing preliminary esophageal cancer is now used in more than 100 hospitals across China.[21] Clearly, China is gaining global leadership in AI research, technology innovation, and AI-enabled healthcare services. With its newly developed 5G connectivity, China surely will gain more advantages, showing a convergence of AI and other advanced technologies in its healthcare.

Discussion and recommendations

The development and implementation of AI in healthcare is complex and costly, so health organizations need to make smart decisions and develop strategic plans that enable them to bring real value to their organizations. Below are some considerations for the successful development, deployment, and integration of AI in healthcare.

Considering both short-term and long-term goals of your organization

As decision-makers, it is essential to consider both the short-term and long-term goals when you develop an AI strategy for your organization. In the short term, you need to build a use case by identifying the most pressing problems that your organization is facing and determine how such problems can be solved by cost-effective AI technologies and methods available. In the long term, you need to envision the future of your organization, considering how your organization may evolve and how the existing and emerging AI technologies can be scaled to effectively transform your organization, building a hospital of tomorrow.

Many health organizations are currently focused on ML on hospital EHR data. As the 5G super-fast connectivity becomes available, there will be a convergence of technologies of AI, sensors, voice chatbots, virtual/augmented reality, and other interactive media. Real-time monitoring, diagnoses, and treatment optimization based on historical and current data of both individuals and the population will become possible. This will allow the development of an intelligent, integrated, and connected nationwide digital health ecosystem that will not only support medical decision-making and clinical research but will also improve patient education, participation, and care at home. So, health leaders need to design their AI strategies and infrastructure capacities with a view on both the present and the future.

Establishing the leadership, team, culture, and collaboration for successful implementation

Technology alone will not transform healthcare; it needs people who derive value from AI and who create impact across your organization. Senior leaders can make a difference in their AI projects by providing the funding, talent, and resources required. In addition, it is crucial to build a team of people who possess the diverse expertise required for AI development, technology integration, data migration, and medical service integrations. It is equally important to develop a corporate culture for organization-wide participation in AI innovation. Health organizations should be prepared to collaborate with partners across the industry, working with partners to make smart decisions and bring the AI implementation and integration to success.

Selecting the right AI platform, tools, and approaches for implementing your AI strategy

Healthcare providers vary in their sizes, types, challenges, priorities, and resources. For providers that have already installed a sound EHR system, adding AI capabilities into the EHR system is possible as many EHR vendors have opened their platforms to allow data exchange and system connection. In addition, many vendors are adding AI features into their EHR systems. For most hospitals, working with the EHR vendor and other AI technology firm to develop the solutions they need is perhaps the best option. For organizations that have the expertise and resources to build their own AI capabilities or that want to become an AI player in the healthcare industry, they can do so by using commercial AI cloud platforms and service currently available (see Table 2). To keep business as usual, they can build their new AI infrastructure and process independently, then link it to the old infrastructure. This gives health organizations complete control in instantiating a new process while avoiding interfering with the ongoing operations.

Forming a good data strategy to derive patient insights

Successful ML relies on the access to large volumes of quality data; the source, size, and quality of data can dramatically impact the ML models developed. Collecting large-scale data that are complete, accurate, up-to-date, and representative of typical populations is a big challenge for analytics professionals.[22] Part of the bias in AI is due to the lack of diverse data available for training the algorithms. So the capacity to collect, store, and learn from data is crucial for AI success and often AI workers spend a large part of their time to clean up data in order to ensure the quality of the ML models they are developing. Some data scientists believe that collecting new data that meet the current data standards is better than cleaning up old messy data. This is a valid perspective because the old data in EHR systems often contain noises, biases, errors, and unusable data.

Retraining ML algorithms and validating AI applications with data and patients from the local organizations

Not including enough meaningful and representative data during training and validation is a common problem in ML. Health organizations need to understand such limitations and provide adequate, balanced, diverse, and representative data from its population for retraining and validating ML models when they deploy them. Decision-makers need to be aware that most AI technologies are not "out-of-the-box" products that you can simply plug into your digital system for it to work. Small-scale on-site pilot testing is a good way to validate any AI application.

Determining the context and protocols for the safe use of AI technology

Ensuring the safety, privacy, and well-being of patients requires one to conduct a hazard analysis, evaluate the consequences of potential false positive and false negative, and develop hazard prevention protocols. For crucial clinical processes that can lead to serious consequences (eg, making medical diagnosis and treatment decisions), a dual safety mechanism is required. In such cases, doctors are the ones who make the calls, using data-generated insights as references. Furthermore, for any AI product to be deployed, an on-site pilot implementation and validation is needed. Finally, it is important to collect real-world evidence and develop a mechanism to continuously monitor system performance, ensuring the safety and effectiveness of the deployed AI product on an ongoing basis. In all these processes, it is important to establish policies and protocols to ensure the privacy, security, and ethics of AI use. However, we must keep a balance between patient privacy and data sharing, and between regulation and innovation. Artificial intelligence professionals need to work with a large volume of real patient data to ensure the accuracy and safety of the ML models, so patients need to know that AI can only be advanced when they share data more freely, and this can be done in a secure environment. Meanwhile, health organizations need to ensure that their AI approaches are lawful, ethical, and robust, showing complete transparency about what they do with patient data.

Establishing performance standards to measure AI success

Assessing AI approaches takes time but it will enable health organizations to discover problems and fix them before it is too late. Before implementation, it is essential to define performance evaluation metrics, then measure AI success accordingly at different stages of the development and implementation (eg, pilot testing, scaled implementation, and validation). Such performance metrics should reflect the values, priorities, and vision of your organization. There are many ways to assess AI technologies. Generally speaking, things to consider in the evaluation should include improved clinical effectiveness (quality, efficiency, and safety), extended access and expanded services to patients, improved patient experience and outcomes, optimized operational processes, improved staff satisfaction with the work environment, and reduced costs and increased revenue.

Developing nationwide AI-powered digital healthcare ecosystems

Given the high complexity and costs involved in developing the various types of AI technologies needed for improving the effectiveness, access, and affordability of healthcare, each country needs to have a national AI strategy for building a nationwide AI-powered digital healthcare ecosystem that benefits both health organizations and patients. Currently, the majority of funding is used for developing ML on big EHR data, mostly for the benefits of health professionals. As the total health can only be achieved through jointed efforts between health professionals and patients, patients need to have AI-powered tools for self-monitoring and self-managing their chronic conditions.

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