GOOD PEOPLE *for* GOOD HEALTH

## A HANDBOOK OF ARTIFICIAL INTELLIGENCE (AI) FOR DOCTORS

# HEALING *with* ALGORITHMS

### Advancing Medical Practice with AI Innovations


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The Therapy Bytes

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*To the dedicated healers in aprons,*
*who bring hope and healing with every touch -*
*this book is a humble expression of*
*gratitude for your selfless service and compassion.*
*Thank you, doctors, for your unwavering*
*commitment to the art of healing.*

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# *Foreword*

Medicine and healthcare touch everyone's lives. It is also a field that faces enormous challenges, such as global pandemics, rising costs, doctor and nurse burnout, lack of equitable access, and aging populations. Many researchers in the field of Artificial Intelligence and Medical Robotics view these challenges as golden opportunities to use technology to increase access to care, fill care gaps, and relieve medical professional burnout. These are commendable goals, especially in a country like India, while we await significant changes at the healthcare delivery systems, public health, and policy levels.

Doctors want to trust AI. The good news is we can get there, and it will take important decisions. Through our book "Healing with Algorithms- Advancing Medical Practice with AI Innovations", we aim to provide an excellent starting point for doctors to navigate current directions in Artificial Intelligence, including both possibilities and pitfalls. We admire the contributors' methodological investigation of the literature to help define and understand this continually evolving field, and thank them for their efforts to make this book real.

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# *Preface*

*"AI will not replace medical professionals.*
*However, medical professionals who use AI will replace those who don't."*

-Dr. Bertalan Meskó, MD, PhD
Director of The Medical Futurist Institute,
Professor at Semmelweis Medical School,
Budapest, Hungary

Welcome to the ever-evolving landscape of Artificial Intelligence (AI) in medicine! Here, stethoscope and scalpel meet algorithms, empowering clinicians with groundbreaking discoveries, diagnostic accuracy, and tailored treatment plans for revolutionizing patient care.

The roots of AI in medicine can be traced back to the earliest experiments in machine learning and pattern recognition, where innovators dared to dream of a future where algorithms would augment, if not surpass, human capabilities. Fast forward to the present day, we find ourselves standing on the cliff of a paradigm shift, where the promise of AI-driven medicine is no longer confined to speculation, but is realized in clinics, hospitals, and laboratories around the globe.

Amidst the excitement and promise of AI in healthcare, we also confront the ethical dilemmas and societal challenges that accompany its rise. From concerns about patient data privacy to questions about the impact of automation on the healthcare workforce, the journey ahead is undoubtedly fraught with complexity.

This book serves to cover topics ranging from drug design, medical imaging, and surgery to data privacy, law, and ethics. It is specifically written for those interested in advancing medical practice through AI applications including physicians and surgeons, other healthcare professionals, policy-makers, business leaders, and students.

Join us as we embark on this journey together– a journey into the transformative power of AI, where medical expertise, technology, and empathy converge to illuminate the path towards a brighter, healthier tomorrow.

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*Section 1*

# *Overview of AI in Medicine*

## 1.1. Introduction

The world we are living in today feels, in many ways, like a Wonderland! Robots, image recognition, smart speakers, and self-driving cars- all of this is possible due to advances in artificial intelligence (AI).[1] AI is the general name of the technology for the development of machines, which are created entirely by artificial means and can exhibit behaviours like human beings, without taking advantage of any living organism.[2] If a human needs a thinking process and a system could simulate the process into the expected solution, it means the system is leveraging AI. In a nutshell, AI is defined as a collection of processes in a system with the capability to learn and solve problems like humans.

## 1.2. History

AI was not formally established until 20th century. The concept of using computers to simulate intelligent behaviour and critical thinking was first described by Alan Turing in 1950. In his book "Computers and Intelligence", Turing described a simple test, which later became known as the "Turing test," to determine whether computers were capable of human intelligence. Six years later, in 1956, John McCarthy described AI as "the science and engineering of making intelligent machines" for the first time at a conference in Hanover, New Hampshire, at Dartmouth College. Cognitive scientist Marvin Minsky at MIT and other scientists participating in the conference were quite optimistic about the future of AI. From 1957 to 1974, AI flourished. Computers started storing more information and became faster, cheaper, and more accessible. There were significant improvements in machine learning algorithms, and people got better at knowing which algorithm to apply to solve their problem. Despite innovations in engineering, medicine was slow to adopt AI.

In the 1960s, the development of the Medical Literature Analysis and Retrieval System and the web-based search engine PubMed by the National Library of Medicine became important digital resources for the later acceleration of biomedicine. In 1971, Saul Amarel developed a computer-based framework for significant research in the biomedical sciences- The Research Resource on Computers in Biomedicine at Rutgers University. The Stanford University Medical EXperimental computer for Artificial

Intelligence in Medicine (SUMEX-AIM), a timeshared computer system, was created in 1973 and enhanced networking capabilities among clinical and biomedical researchers from several institutions. As a result of these collaborations, the first National Institutes of Health-sponsored AI in medicine workshop was held at Rutgers University in 1975. One of the first prototypes to determine the feasibility of applying AI to medicine was the development and demonstration of a consultation program for glaucoma using CASNET model at the Academy of Ophthalmology meeting in Las Vegas, Nevada in 1976. Moreover, a "backward chaining" AI system, MYCIN, was developed in the early 1970s. Based on patient information input by physicians and a knowledge base of about 600 rules, MYCIN could provide a list of potential bacterial pathogens and then recommend antibiotic treatment options adjusted appropriately for a patient's body weight. MYCIN became the framework for the later rule-based system, EMYCIN. INTERNIST-1 was later developed using the same framework as EMYCIN, and a larger medical knowledge base (570 diseases in internal medicine) to assist the primary care physician in diagnosis, was established.[3]

In 1986, DXplain, a decision support system that uses inputted symptoms to generate a differential diagnosis, was released by the University of Massachusetts. In 2007, IBM created an open-domain question-answering system named Watson with technology called DeepQA. This technology used natural language processing and various searches to analyze data over unstructured content to generate probable answers. By drawing information from a patient's electronic medical record and other electronic resources, users could apply DeepQA technology to provide evidence-based medicine responses. As such, it opened new possibilities in evidence-based clinical decision-making. In 2017, IBM Watson was used to successfully identify new RNA-binding proteins that were altered in amyotrophic lateral sclerosis. Natural language processing transformed chatbots from superficial communication (Eliza) to meaningful conversation-based interfaces. This technology was applied to Apple's virtual assistant, Siri, in 2011 and Amazon's virtual assistant, Alexa, in 2014. Pharmabot was a chatbot developed in 2015 to assist in medication education for pediatric patients and their parents, and Mandy was created in 2017 as an automated patient intake process for a primary care practice (Figure 1).[4]

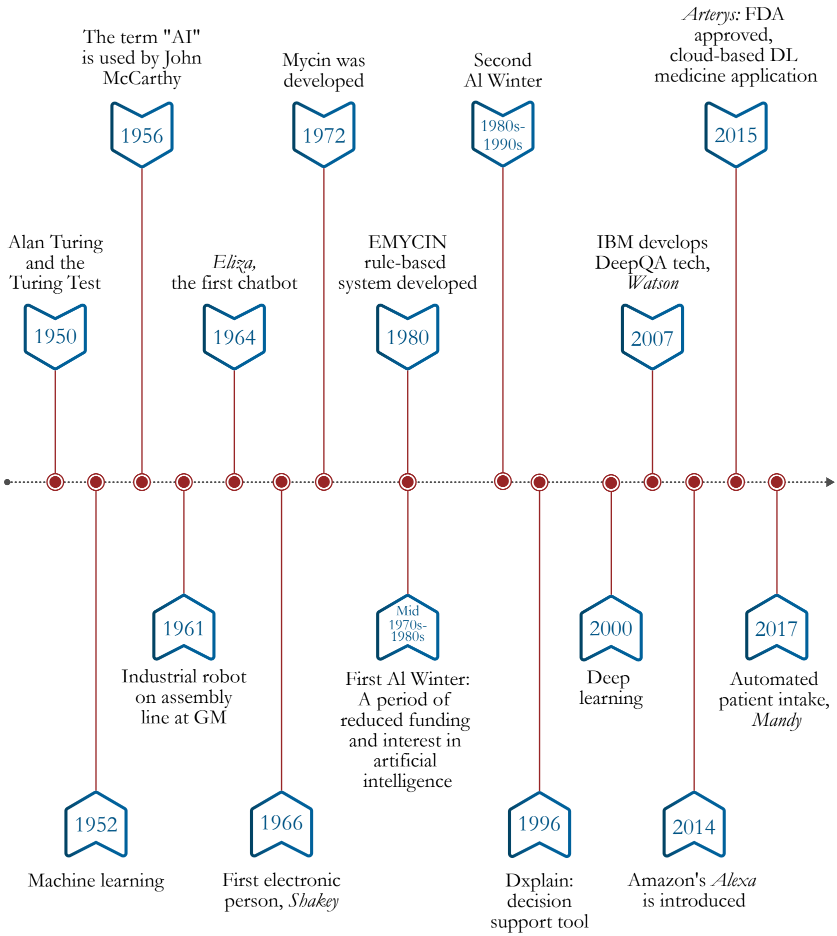


*Figure 1: Timeline of artificial intelligence*[4]

## 1.3. Applications in Medicine

AI applications have huge potential to augment clinician decision making, improve clinical care processes and patient outcomes, and reduce healthcare costs. Furthermore, studies have shown that a collaborative work effort between AI and doctors has led to improved performance in all the areas where collaboration happened. Today, the top 4 applications of AI in medicine include patient care, empowered physician, medical imaging and diagnostics, and research and development (Figure 2)[5]:

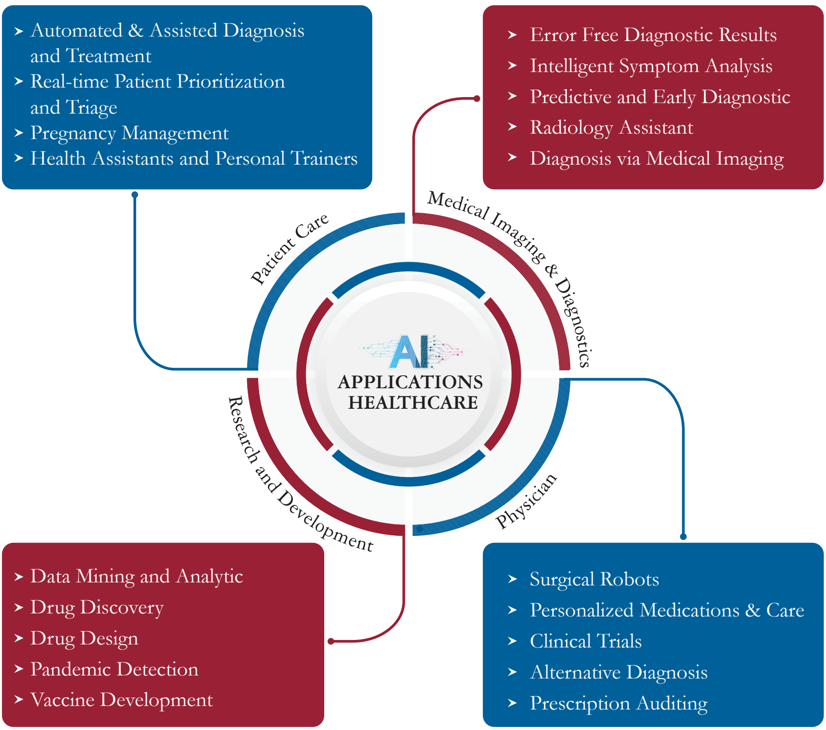


*Figure 2: Four pillars of AI applications in medicine[5]*

*Section 2*

# *Subsets of AI*

Several subsets of AI focus on various aspects of AI research and applications within the larger field of AI. Each subset has its distinct problems, approaches, and applications, and together they add to the rich and multifaceted field of AI. The 6 most common subsets of AI include: Machine Learning (ML), Deep Learning (DL), Natural Language Processing (NLP), Expert System, Robotics, Machine Vision (MV), and Speech Recognition (SR) (Figure 3). Among all of these, ML plays a crucial role in AI.[6]

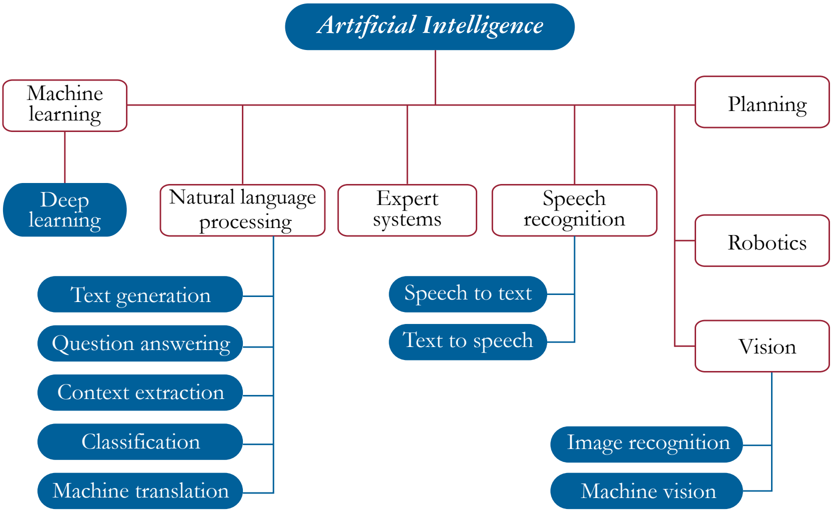


*Figure 3: Six common subsets of AI*[6]

## 2.1. Machine Learning (ML)

ML is a subset of AI that involves building computer models that are capable of learning and making independent predictions or decisions based on the provided data. These models continually improve their accuracy through learned data. ML can be subdivided into two main types- supervised learning and unsupervised learning. For example, Adaboost is a supervised ML algorithm widely used in computer-aided diagnosis (CAD) and can support medical practitioners to make critical decisions regarding disease conditions, such as Alzheimer's disease, diabetes, hypertension, and various cancers. Furthermore, it can help to improve the accuracy in classifying diseases, predicting patient outcomes, and detecting abnormalities in medical images. XGBoost is another supervised algorithm that has been successfully applied to a wide range of tasks, such as disease diagnosis, prognosis, treatment selection, and patient outcome prediction. One of the key strengths of the XGBoost is its ability to handle diverse types of medical data, including structured data (e.g., patient demographics and laboratory results) and unstructured data (e.g., medical images and clinical notes).[7]

## 2.2. Deep Learning (DL)

DL is a subset of ML which provides the ability to machine to perform human-like tasks without human involvement. It provides the ability to an AI agent to mimic the human brain. DL can use both supervised and unsupervised learning to train an AI agent. It is the primary technology behind self-driving cars, speech recognition, image recognition, automatic machine translation, etc.

DL is implemented through neural networks architecture hence also called a deep neural network (DNN). The largest number of recent studies report the use of DNNs in the analysis of radiological images, among which include: models detecting apparent and non-apparent scaphoid fractures using only plain wrist radiographs, algorithms for COVID-19 detection from CXR images, models for mammography screening, and tools for the segmentation of intracerebral haemorrhage on CT scans.[7]

## 2.3. Natural Language Processing (NLP)

Natural language processing (NLP) is the ability of computers to understand and process human speech and text in human language such as English. It is used in everyday technology, such as email spam detection, personal voice assistants and language translation apps. Without NLP, AI agent cannot work on human instructions.[6,8]

It is a known fact that although medical field is one of the richest in terms of big unstructured data, NLP in medicine is still in its early stages. However, there are no limits to how NLP can support the healthcare system. Here are few important applications of NLP tools in medicine:[9]

**1. Refining Clinical Records and Documentation**

Rather than wasting valuable time manually reviewing complex electronic health records (EHR), NLP uses speech-to-text dictation and formulated data entry to extract critical data from EHR at the point of care. This not only enables doctors to focus on providing patients with essential care but also ensures that the clinical records are accurate and kept up to date.

**2. Improving Clinical Trials**

Using NLP techniques, healthcare providers can automatically review massive quantities of unstructured clinical and patient data and based on that can identify and select eligible subjects for clinical trials. This could not only expedite patients' access to experimental care but could also improve their medical condition and quality of life.

3. **Supporting Clinical Decisions**

   NLP makes it fast, efficient, and easy for doctors to access health-related information exactly when they need it, enabling them to make more informed decisions at the point of care.

4. **Review Management and Sentimental Analysis**

   NLP can also help healthcare organization to manage online reviews. It requires gathering and evaluating thousands of reviews on healthcare using NLP techniques. They can even rapidly examine human sentiments along with the context of their usage. This helps to understand the patient attitude and helps to decide on further treatments.

5. **Root Cause Analysis**

   NLP systems are used to assess unstructured responses and know the root cause of patients' difficulties or poor outcomes. One classic *case example* is the proposed utilization of NLP and ML to assist with the assessment and rehabilitation for acute and chronic conditions. Alberta Health Services (the healthcare authority for the province of Alberta, Canada) has launched a novel telehealth service to address the rehabilitation needs of those with acute and chronic musculoskeletal, neurological, and other conditions impacted by the pandemic. This Rehabilitation Advice Line (RAL) is first of its kind telephone service in Canada that allows patients and caregivers to speak directly with rehabilitation clinicians and professionals (Figure 4).


*Figure 4: NLP case example- Rehabilitation Advice Line launched by Alberta Health Services*

When a patient or caregiver phones into the RAL, clinical notes are entered into an online charting platform by the occupational therapists and physiotherapists. These clinical notes contain key information about the patients, such as their age, location, and gender along detailing the patient's rehabilitation concerns. Currently, AI researchers at the Departments of Medicine, Electrical and Computer Engineering, University of Alberta, are looking at the use of NLP and ML technologies to assist with analysing the information contained in these clinical notes (after anonymization- a data processing technique that removes or modifies personally identifiable information). The call notes consist of unstructured data that can be classified into three categories: 1) *History* including previous patient diagnoses, medications, and existing symptoms; 2) *Action* taken by the RAL advisor during the call including discussion of current symptoms (including pain, weakness, or difficulty performing ADLs, etc.), subjective over-the-phone assessment, and cause of the condition (if it was caused through injury); and 3) *Disposition*- detailing the advice provided or service referrals given to the patient. By capturing this information, the RAL provides a means of monitoring and assistance to individual patients.

The NLP-ML system designed by University of Alberta is thought to provide deeper insights into the data collected by the RAL. These insights include: automatically capturing demographic data; categorizing the reason for the call as resulting from musculoskeletal, neurological, COVID, or other conditions; analysis of the disposition to better understand the patient care plan; and predictive modelling of areas where rehabilitation services will be needed in the future. As shown in Figure 5, the NLP-ML system consists of two main components: the NLP-based preprocessing of clinical notes and an AI/ML-based system for modelling and analysing the collected data. Apache cTAKES (clinical Text Analysis and Knowledge Extraction System is a NLP system that extracts clinical information from electronic health record unstructured text) is being used for NLP processing of the clinical notes to convert them to a machine-readable format. cTAKES can process and provide context from these notes, including highlighting the patient's condition and medical history (including any injuries or medications), subjective assessment results, and the advice provided to them. Preliminary work has shown that the NLP system is capable to correctly identify salient keywords within the clinical notes (e.g., total knee replacement, multiple sclerosis, fractures, etc.).[10]

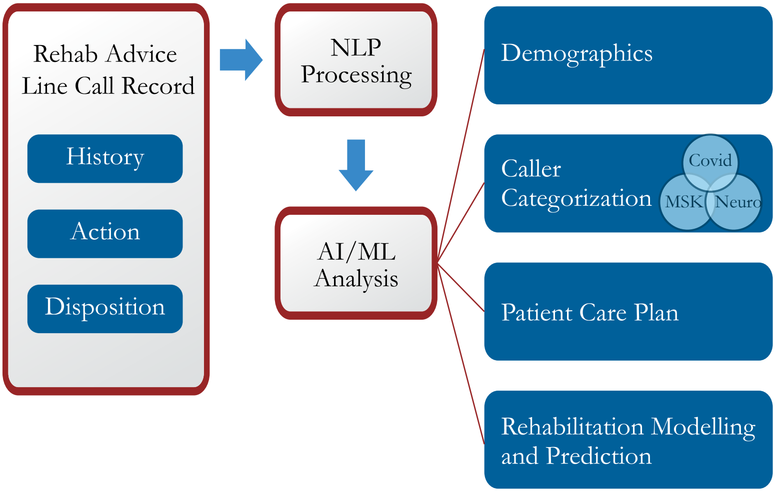


*Figure 5: NLP-ML system for Alberta Health Services rehab advice line call records*

## 2.4. Expert System

An expert system is a computer program that is designed to solve complex problems and to provide decision-making ability like a human expert. It performs this by extracting knowledge from its knowledge base using the reasoning and inference rules according to the user queries. One of the common examples of an expert system is a suggestion of spelling error while typing in the Google search box.[11]

Medical expert systems (MESs) aim to provide computerized clinical decision support to clinicians, patients, and other individuals with suitable information and knowledge at appropriate times to improve the quality and safety of healthcare. The most prolific application of MESs till date has been in medical diagnosis. A classical medical diagnosis expert system (MDES) is the MYCIN. It was developed to capture the knowledge of medical experts in infectious blood diseases. MYCIN captured the expertise of clinicians on blood diseases to provide accurate and quick diagnosis of the present disease and the proper therapeutic recommendation.[12] It worked with a knowledge base of about 600 rules and a simple inference engine. It would ask the doctor running the program a long list of easy yes/no or text-based questions. MYCIN ranked possible culprit bacteria from high to low based on likelihood, confidence, reasoning, and drug treatment (Figure 6).[13,14]

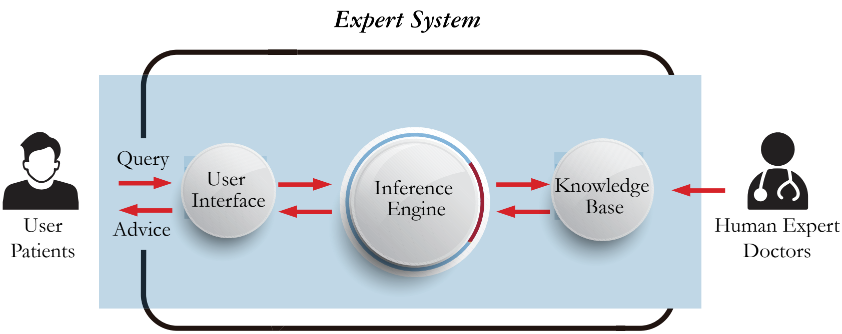


*Figure 6: MYCIN expert system architecture*[14]

Another feature that made MYCIN valuable apart from its ability to diagnose infectious blood diseases, is its contributions to the understanding of introducing a MES into the workplace.

## 2.5. Robotics

Medical robots are poised to revolutionize the practice of medicine. They had their start about 34 years ago when an industrial robot and computed tomography navigation were used to insert a probe into the brain to obtain a biopsy specimen. Today, medical robots are well known for their roles in surgery, specifically the use of robots, computers and software to accurately manipulate surgical instruments through one or more small incisions for various surgical procedures.[15]

The development of a wide range of robots serves a variety of roles within the medical environment. At present, below are six uses for medical robots:[16]

1. **Telepresence**

   Physicians use robots to help them examine and treat patients in rural or remote locations, giving them a "telepresence" in the room. Specialists can be on call, via the robot, to answer questions and guide therapy from remote locations. The key features of these robotic devices include navigation capability within the ER, and sophisticated cameras for the physical examination.

2. **Surgical Assistants**

   These remote-controlled robots assist surgeons with performing procedures, typically those that are minimally invasive. The ability to manipulate a highly sophisticated robotic arm by operating controls, seated at a workstation out of the operating room, is the hallmark of surgical robots. Additional applications for these surgical-assistant robots are continually being developed, as more advanced 3DHD technology gives surgeons the spatial references needed for highly complex surgery, including more enhanced natural stereo visualization combined with augmented reality.

### 3. Rehabilitation Robots

Rehabilitation robots play a crucial role in the recovery of people with disabilities in areas such as improved mobility, strength, coordination, and quality of life. These robots can be programmed to adapt to the condition of each patient as they recover from strokes, traumatic brain or spinal cord injuries, or neurobehavioral or neuromuscular diseases such as multiple sclerosis. Virtual reality integrated with rehabilitation robots can also improve balance, walking, and other motor functions.

### 4. Medical Transportation Robots

Medical transportation robots deliver supplies, medications, and meals to patients and staff thereby optimizing communication between doctors, hospital staff members, and patients. Most of these machines have highly dedicated capabilities for self-navigation throughout the facility. There is, however, a need for highly advanced and cost-effective indoor navigation systems based on sensor fusion location technology in order to make the navigational capabilities of transportation robots more robust.

### 5. Sanitation and Disinfection Robots

With the increase in antibiotic-resistant bacteria and outbreaks of deadly infections like Ebola, more healthcare facilities are using robots to clean and disinfect surfaces. Currently, the primary methods used for disinfection are UV light and hydrogen peroxide vapours. These robots can disinfect a room of any bacteria and viruses within minutes.

### 6. Robotic Prescription Dispensing Systems

The biggest advantages of robots are speed and accuracy- two features that are very important to pharmacies. Automated dispensing systems have advanced to the point where robots can now handle powder, liquids, and highly viscous materials, with much higher speed and accuracy than before.

One classic example of robotic surgical system is the Da Vinci surgical system that has gained good acceptance in clinical practice. It is a telemanipulation system composed of a surgical arm cart, a master console, and a conventional monitor cart. The patient side-placed surgical arm cart is a manipulator unit with two instrument arms and a central arm to guide a two-channel endoscope. At the master console, the surgeon handles telemanipulators and optical controls using three-dimensional vision. His intuitive hand movements are transmitted from the handles to the tips of the laparoscopic instruments on the surgical arm cart.

*Figure 7A: The 3 components of Da Vinci robotic system*[18]

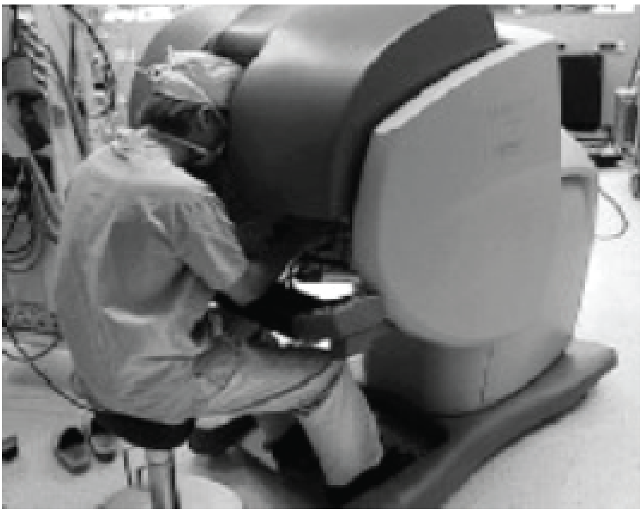

*Figure 7B: A surgeon sitting at the master console handles the robotic instruments on the surgical arm cart via telemanipulation*[18]

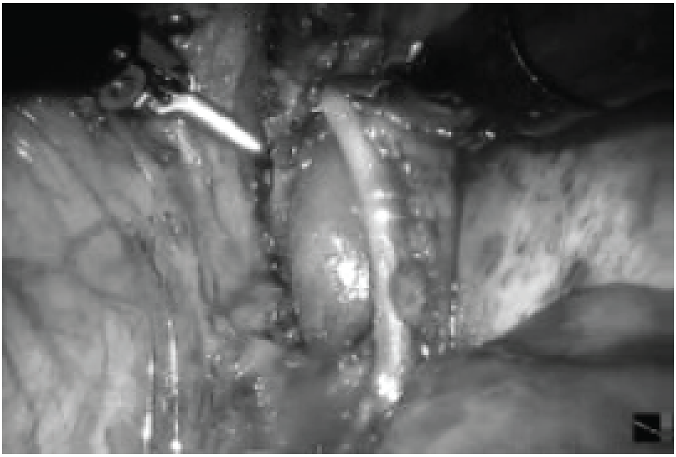

*Figure 7C: Da Vinci's robotic instruments allow for precise manoeuvring within tiny areas of difficult access*[18]

The main technological advances of the Da Vinci surgical system are realistic 3D imaging, motion-scaling, and tremor filtration. Thus, it facilitates more precise and accurate endoscopic surgery.[17] It is widely used in various surgical specialties such as general surgery, urology, gynaecology, and cardiac surgery, among others (Figures 7A-7C).[18]

## 2.6. Machine Vision (MV)

Machine vision (MV) is known as the practical realisation of image understanding, or more specifically computer vision techniques, to help solve practical industrial problems that involve a significant visual component. The introduction of machine vision to industrial processes is inspired by a desire to reduce costs by increasing efficiency (and so productivity), reduce errors (and so improve quality) or gather data.[19]

In medicine, 7D Surgical System- the first machine vision navigation system designed for spine surgery, can be an appropriate example to understand machine vision in depth. It consists of a small, mobile computer workstation with an attached, movable arm (Figure 8). The arm is connected to the system head which consists of a surgical light source, two stereoscopic video cameras, a structured light projector, and an infrared camera system for tracking navigation tools.

*Figure 8: The 7D Surgical System surgical light head contains navigation optics as well as LED lights used for standard lighting*[20]

The application of machine vision for spinal surgery navigation uses structured light imaging. Combining a light projector with two stereoscopic video cameras, this version of machine vision captures a precise and detailed three-dimensional image of the exposed surface anatomy and co-registers it to a pre-operatively or intra-operatively acquired image (e.g., fluoroscopy, CT) data set. This application of machine vision has been successfully applied to both cranial and spinal surgery.[20] A unique feature of the 7D Surgical System is the option of using augmented reality (AR) to facilitate accuracy and safety. When a navigated trajectory has been selected, a virtual line along that trajectory can be projected onto the system's video monitor and preserved during screw insertion (Figure 9).

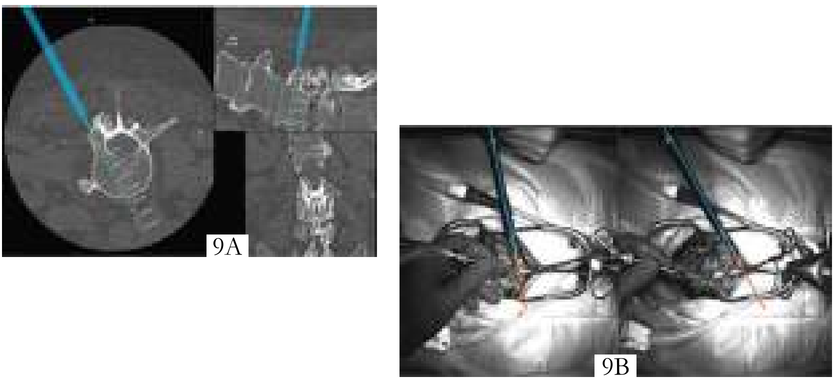


*Figure 9: Display of the navigation screen of the 7D Surgical System (A) showing the tracked tool in blue and the intended trajectory in green. The surgeons overhead view of the standard surgical site (B) with the trajectory created by AR displayed*[20]

## 2.7. Speech Recognition (SR)

Speech recognition (SR) systems compose of microphones (converting sound into electrical signals), sound cards (that digitalise the electrical signals) and speech engine software (that convert the data into text words).[21] In essence, it is defined as understanding voice by computer and performing the required task.

In medical field, speech recognition systems are extensively useful in maintaining electronic medical record (EMR), medical transcription, and many more. Medical professionals are always looking for ways to improve efficiency. Less time spent taking notes and filling out charts means more time to help patients. Using speech recognition software, doctors can dictate notes much faster than typing them. This allows more time spent diagnosing and treating patients. It also creates a digital record of a patient's history which can be later searched instead of spending time in searching countless paper documents.[22]

*Section 3*

# *AI in Clinical Practice*

## 3.1. Diagnostics

Diagnostics is the first frontier for artificial intelligence in medicine. Much of what happens in medicine is about collecting patient data (signs and symptoms, labs, genetics, etc.) and interpreting it to make determinations about a patient's health or medical issues. Let us see few key applications of AI in the medical diagnostic space:

1. **Automated Disease Diagnosis**

   The objective of automated disease diagnosis (ADD) is to support doctors by performing an initial examination of symptoms. It also diagnoses disease from the conversation between the patient and the doctor. First, the user reports their problems and symptoms (called explicit symptoms) in their self-report, and then the agent enquires about additional symptoms (called implicit symptoms) to diagnose the disease. Hence, an ADD can be summarised as a system where an agent enquires about symptoms step by step and then can diagnose disease based on implicit and explicit symptoms. For instance, in online communication with doctors, patients first inform their chief complaints, known as self-reports to doctors. Based on the chief complaint, a doctor is assigned, who conducts a detailed symptom investigation and extracts relevant symptoms through chat. An example is shown in Figure 10. Some ADDs, such as Mayo Clinic, Babylon Healthcare, and GMAN, are already deployed and extensively used by both hospitals and patients.[23]

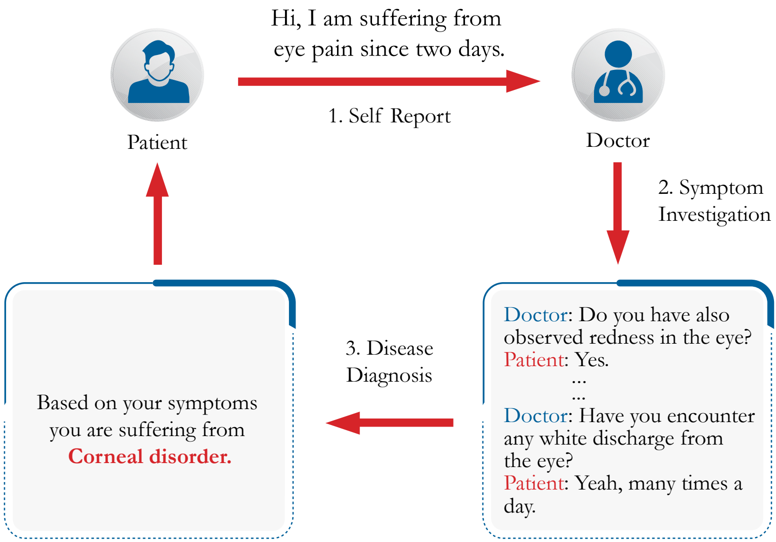


*Figure 10: Understanding ADD- Online symptom investigation and disease diagnosis*[23]

## 2. Remote Patient Monitoring

Remote patient monitoring (RPM) is one of the common healthcare applications that assist doctors to monitor patients with chronic or acute illness at remote locations, elderly people in-home care, and even hospitalized patients. The role of AI in RPM ranges from physical activity classification to chronic disease monitoring and vital signs monitoring in emergency settings. This is achieved by incorporating new Internet of Things (IoT- network of devices, appliances and other physical objects that are embedded with sensors, software, and network connectivity) methodologies such as telehealth applications, wearable devices, and contact-based sensors. Figure 11 explains remote patient monitoring architecture utilizing AI to help support medical professionals in visualizing the health status of patients based on vital signs and activity recognition.

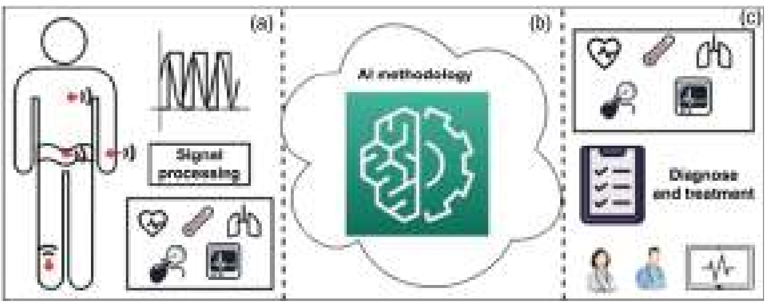


*Figure 11: Remote patient monitoring architecture utilizing AI methodology*[24]

The architecture breaks down into three sections- Section A illustrates the wearable devices connected to patients to collect vital signs such as heart rate, pulse rate, respiratory rate, breathing rate, body temperature, and so on. In Section B, the collection will be stored in cloud services for further analysis using machine learning methodologies that could predict or classify the patient data. The process could then estimate any abnormal events based on known threshold values of the vital signs and update medical professionals in Section C of the architecture.[24]

## 3. Sound-Based Diagnosis

Sound-based disease detecting system involves collecting diverse audio samples capturing specific human sounds related to diseases or health conditions. These samples encompass coughs, breath sounds, heart murmurs, or speech patterns indicative of various ailments. Through sophisticated signal processing techniques and feature extraction methods such as spectrograms, significant patterns and features are abstracted from the audio data. Machine learning (ML) algorithms are then trained on these extracted features to recognize correlations between sound patterns and specific diseases. The model undergoes rigorous validation and refinement to ensure its accuracy and robustness, or indicate potential diseases or health conditions. Collaboration among medical experts, data scientists, and ethical considerations are pivotal in developing and deploying this system responsibly, potentially revolutionizing early disease detection and enabling accessible remote healthcare.[25] Here is an example of spectrograms of heart sounds from normal subjects (a) and patients with ventricular septal defects VSDs (b) (Figure 12). The spectrums of sounds or other signals as they vary with time is shown. S1 (empty triangle) and S2 (solid triangle) are observed in the spectrogram of the normal heart sound. Systolic murmur (white arrow) is observed in the spectrogram of the VSD heart sound.[26]

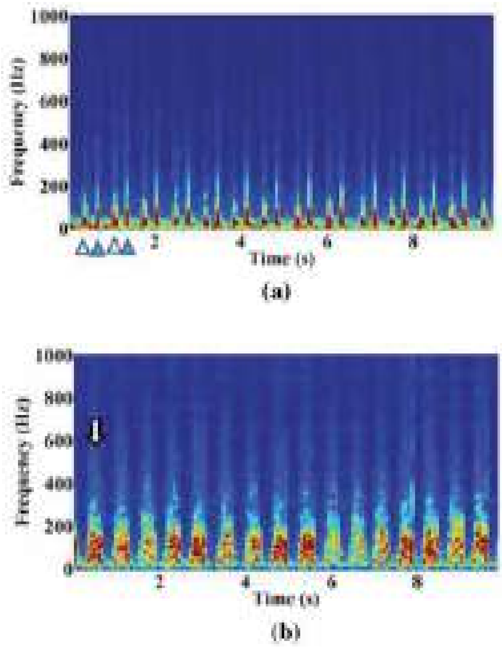


*Figure 12: Spectrograms of heart sounds from normal subjects and subjects with VSD[26]*

## 3.2. Therapeutics

In the realm of therapeutics, AI is already making significant strides in several key areas including precision medicine and personalized treatment plans and AI-assisted virtual reality (VR) therapy. Let us understand in depth the role of AI in these key areas:

1. **Precision Medicine and Personalized Treatment Plans**

   Precision medicine facilitates a clinician's delivery of care personalized for each patient and is enabled by several data collection and analytics technologies. It has the potential to yield more precise diagnoses, predict disease risk before symptoms occur, and design customized treatment plans that maximize safety and efficiency. AI and precision medicine are converging to assist in solving the most complex problems in personalized care. Figure 13 depicts five examples of personalized healthcare dogma that are inherently challenging but potentially amenable to progress using AI.

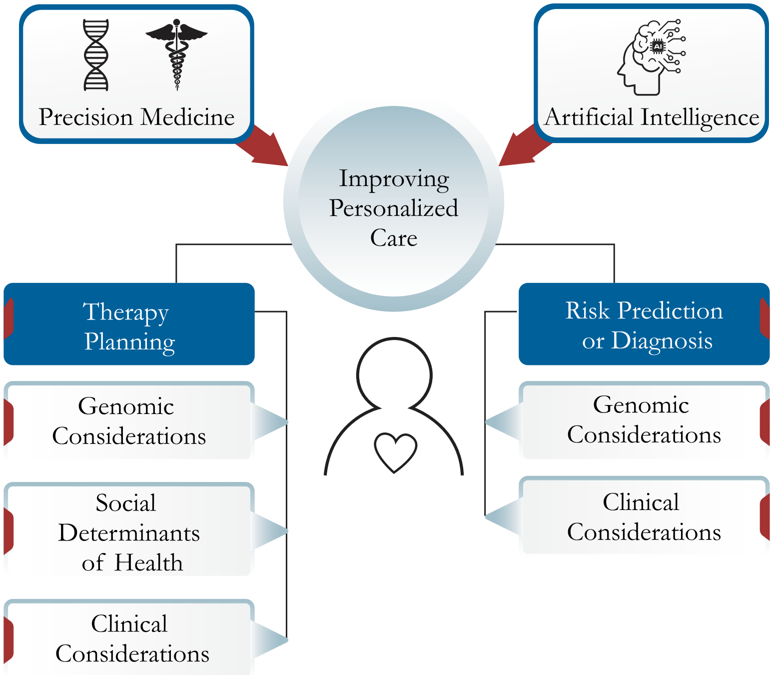


*Figure 13: Dimensions of synergy between AI and precision medicine. Both precision medicine and artificial intelligence (AI) techniques impact the goal of personalizing care in five ways: therapy planning using clinical, genomic, or social and behavioural determinants of health, and risk prediction/diagnosis, using genomic or other variables*

For example, AI has improved diagnostic capabilities in resource-poor locations, translating into better patient classification and therefore more personalized therapy planning. This includes the use of deep learning to identify patients with malaria and cervical cancer, as well as predicting infectious disease outbreaks, environmental toxin exposure, and allergen load.[27] One well known case example is that of

Oncora Medical, a radiation oncology analytics company, that has created a patient care platform for oncologists to address the challenges of collecting, extracting, and using clinical real-world data as well as enable personalized treatment recommendations. It integrates electronic health records (EHRs), cancer registries, and other software used in oncology clinics. Radiology and pathology reports and diagnostic tests are all in one tool. It provides doctors with information about each patient's condition in a structured way. With ML, the solution identifies patients with the highest risk of adverse events. Moreover, the solution undertakes routine data documentation tasks. This means clinicians can focus on treating patients. The MD Anderson Cancer Center (Figure 14) uses this tool. Since they do not need to enter the same patient data into different platforms, data documentation takes them 67% less time.[28]

*Figure 14: Case example- Patient care platform for oncologists launched by Oncora Medical*[28]

## 2. AI-Assisted VR Therapy

Virtual reality (VR) is a computer technology that uses VR headsets or multi-projected environments, sometimes in combination with physical environments or props, to generate realistic images, sounds and other sensations that simulate a user's physical presence in a virtual or imaginary world.[29] It can ameliorate few time-consuming and costly therapies, because it effectively reproduces stressful environments, and is mobile enough to be used at home. VR solutions can be enhanced by AI, particularly computer vision and natural language processing. Moreover, use of AI in VR technology serves to enable customization and adaptive training while maintaining the ease-of-use and comparatively low cost over traditional therapeutic strategies.[30]

One good example of utilizing transformative potential of AI-powered VR therapy lies in creating immersive and controlled environments for the gradual exposure and desensitization of individuals with phobias, promising a new frontier in mental health treatment. AI algorithms analyze extensive datasets to understand each patient's unique phobia profile. This includes severity of fear, personal triggers, and physiological responses. The data is then harnessed to craft personalized virtual environments that precisely cater to the individual's needs. Whether it's fear of heights, flying, spiders, cockroaches (Figure 15) or social situations, AI ensures that the VR experience is finely calibrated to the individual's unique phobia. Another key advantage of AI-powered VR therapy is its ability to adapt dynamically to an individual's responses. AI algorithms continuously monitor physiological indicators such as heart rate, skin conductance, and respiratory rate during therapy sessions. By analysing this data, the system can adjust the intensity of virtual scenarios in real-time. This adaptive progression ensures that exposure is gradual and tailored to the patient's comfort level, preventing overwhelming anxiety and fostering a sense of control.[31]

*Figure 15: AI-powered VR therapy for Katsaridaphobia (fear of cockroaches)[32]*

## 3.3. Clinical Decision Support

Clinical decision support (CDS) systems provide clinicians, staff, patients, and other individuals with knowledge and person-specific information, intelligently filtered and presented at appropriate times, to enhance health and healthcare. The most common use of CDS is for addressing clinical needs, such as ensuring accurate diagnoses, screening in a timely manner for preventable diseases, or averting adverse drug events. CDS can also potentially lower costs, improve efficiency, and reduce patient inconvenience. The table 1 below provides examples of CDS that address a range of target areas.[33]

| Target Area of Care | Example |
|---|---|
| Preventive care | Immunization, screening, disease management guidelines for secondary prevention |
| Planning or implementing treatment | Treatment guidelines for specific diagnoses, drug dosage recommendations, alerts for drug-drug interactions |
| Follow-up management | Corollary orders, reminders for drug adverse event monitoring |
| Hospital, provider efficiency | Care plans to minimize length of stay, order sets |
| Cost reductions and improved patient convenience | Duplicate testing alerts, drug formulary guidelines |

*Table 1: Examples of CDS interventions by target area of care*[33]

## 3.4. Clinical Workflows

The integration of artificial intelligence (AI) into clinical workflow requires operationalization, performance monitoring, and quality control. In general, advantages of AI integration into clinical workflows include enhanced and automated disease detection and patient risk stratification, identification of guideline concordant and discordant therapy, and recommendations for personalized treatment regimens. Specific examples such as determination of optimal statin treatment based on individual patient risk factors or increase in statin use demonstrate the potential promise of AI integration into clinical workflow.[34]

Let us consider an example wherein authors Zhai K *et al.* have proposed a healthcare fusion model (Figure 16) that can be applied to optimize clinical workflows. A healthcare fusion model utilizes a centralized, cloud-based information management system (IMS) as its one-stop health information exchange (HIE). Consequently, the burden of health record management shifts from individual healthcare providers and patients to a centralized system that contains patient and population data. In this workflow, no record gathering is required from the patient prior to the visit, as the patient's complete medical records are stored in the IMS. Instead, before the visit, the specialist retrieves the patient's medical profile from the IMS and can consider not only clinical records, but any available family, genetic, omics, demographic, and socioeconomic data, as well as population-level patterns and internet "buzz" that the patient may be exposed to. This enables the provider to devote more time during the encounter itself to problem-solving, as only a few aspects of the patient's history must be elicited. More importantly, diagnoses and therapeutic plans can be precisely tailored to the patient's individual medical, demographic, and socioeconomic context. After the patient-specialist encounter, relevant data are uploaded to the IMS and made available to insurance companies, pharmacies, and primary care physicians as needed; health records are therefore updated without any need for action by the patient.[35]

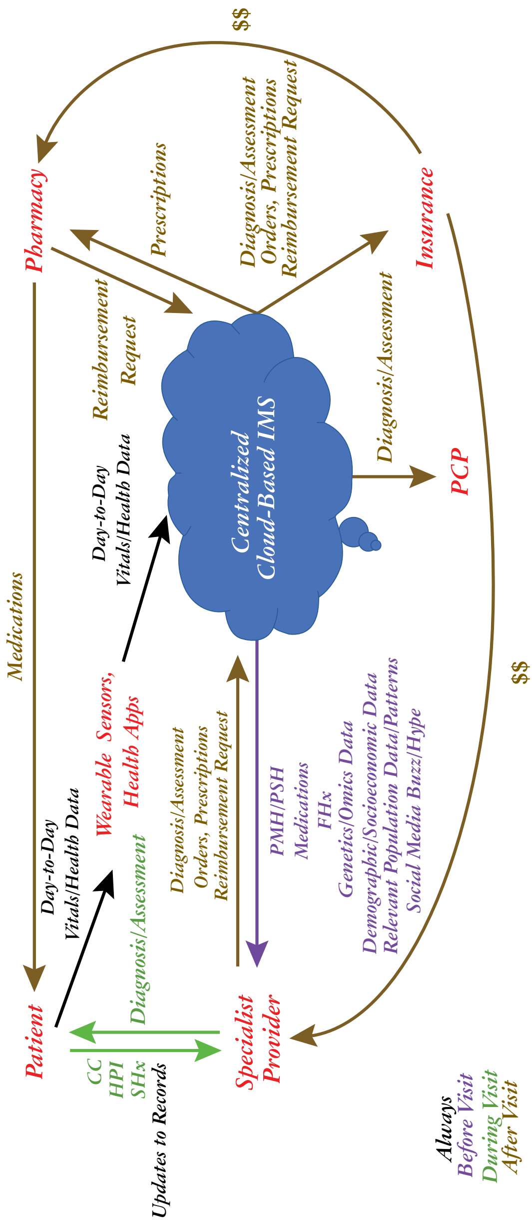


*Figure 16: A clinical workflow optimized for a fused healthcare system*[35]

It is crucial that safety, quality, and performance of AI-enabled devices and softwares used in clinical practice are compliant with the rigorous requirements set by regulatory bodies. Following are few examples of AI/ML-enabled medical devices and softwares as medical devices (SaMD) approved and regulated by United States Food and Drug Administration (USFDA) and Central Drugs Standard Control Organization (CDSCO), India:[36, 37, 38]

| Sr. No. | Device/SaMD/ Algorithm name | Therapy areas | Use | Approving regulatory body |
|---|---|---|---|---|
| 1. | Aurora ventilatory effort recorder | Anaesthesiology | Breathing frequency monitor used to measure patient's respiratory rate | USFDA |
| 2. | Air Next | | Diagnostic spirometer used in pulmonary function testing | USFDA |
| 3. | PMD-200 | | Adjunctive pain measurement device that includes software algorithms to analyze physiological sensor data and measure response to painful stimuli in patients under general anaesthesia | USFDA |
| 4. | Eko Low Ejection Fraction Tool (ELEFT) | Cardiology | Reduced Ejection Fraction machine learning-based notification software to suggest reduced ejection fraction for further referral or diagnostic follow-up | USFDA |
| 5. | LINQ II Insertable Cardiac Monitor | | Arrhythmia detector and alarm (including ST-segment measurement and alarm) | USFDA |
| 6. | ECG Software for home use | | Creates, analyses, and displays ECG data, and provides information for identifying cardiac arrhythmias | CDSCO |
| 7. | Angiographic Coronary Vascular Physiologic Simulation Software | | Identification of functionally significant cardiovascular disease | CDSCO |

| Sr. No. | Device/SaMD/ Algorithm name | Therapy areas | Use | Approving regulatory body |
|---|---|---|---|---|
| 8. | Guardian Connect System Algorithm | Diabetology- Endocrinology | Predicts blood glucose changes | USFDA |
| 9. | DreaMed Algorithm | | Management of Type 1 diabetes | USFDA |
| 10. | Continuous Glucose Monitor Secondary Display Software | | Notifies another person, the follower, of the patient's continuous glucose monitoring system sensor glucose information in real time | CDSCO |
| 11. | Insulin Pump Therapy Adjustment Calculator Software | | Recommends insulin pump therapy parameter adjustments (e.g., basal rate, insulin to carbohydrate ratios, insulin sensitivity factors) based on data from external devices, including continuous glucose monitors | CDSCO |
| 12. | X-Guide Surgical Navigation System | Dentistry | Provides real-time guidance on the orientation and location of the dental instrument relative to the patient's anatomy for general dentistry procedures | USFDA |
| 13. | CEREC Ortho Software | | Orthodontic software for the diagnosis and treatment planning of orthodontic patients and conditions | USFDA |
| 14. | Dental Abutment Design Software | | Restoration of chewing function by allowing a dental laboratory or dental clinician to design the patient-specific component of a dental abutment (i.e. abutment collar and abutment post) and CAM or create that component at dental office or dental laboratory following the directions of dental implant system | CDSCO |

| Sr. No. | Device/SaMD/ Algorithm name | Therapy areas | Use | Approving regulatory body |
|---|---|---|---|---|
| 15. | SKOUT® gastrointestinal lesion software detection system | Gastroenterology | Computer-assisted detection device used in conjunction with endoscopy for the detection of abnormal lesions in the gastrointestinal tract | USFDA |
| 16. | Colon Computed Tomography System, Computer Aided Detection Software | | Assists radiologists in the review of multi-slice computed tomography (msct) exams of the colon and highlights potential polyps that the radiologist should review | CDSCO |
| 17. | SurgiCount+ System | General and Plastic Surgery | Image processing device for the estimation of patient's external blood loss | USFDA |
| 18. | Burn Resuscitation Decision Support Software (BRDSS) | | Prediction of hourly fluid volume during initial 24 hours of burn resuscitation in patients who have greater than 20% total body surface area burn | CDSCO |
| 19. | Athelas Home | Haematology | Automated differential cell counter | USFDA |
| 20. | X100HT with Slide Loader with Full Field Peripheral Blood Smear (PBS) Application | | Automated cell-locating device | USFDA |
| 21. | LensHooke X1 PRO Semen Quality Analyzer | | Semen Analysis Device to evaluate one or more human semen parameters including semen volume, sperm concentration, total sperm number, sperm motility, sperm morphology, sperm vitality, WBC concentration, and pH | USFDA |

| Sr. No. | Device/SaMD/ Algorithm name | Therapy areas | Use | Approving regulatory body |
|---|---|---|---|---|
| 22. | EpiMonitor | Neurology | Physiological signal-based seizure monitoring system to identify abnormal physiological activity that may be associated with a seizure | USFDA |
| 23. | EarliPoint | Neurology | Pediatric Autism Spectrum Disorder diagnosis aid | USFDA |
| 24. | Index Generating EEG Software | Neurology | Analyses electrical activity of the brain by transformation of EEG signals into a dimensionless index number for use and interpretation | CDSCO |
| 25. | Computerized Cognitive Assessment Aid Software for Concussion | Neurology | Assessment aid software in the management of concussion | CDSCO |
| 26. | OTS Hip | Orthopaedics | Orthopedic Stereotaxic Instrument for stereotaxic guidance during orthopaedic surgery procedures. Indicated for orthopaedic joint or spine surgery | USFDA |
| 27. | Radiological Computer Assisted Detection/Diagnosis Software for Fracture | Orthopaedics | Detection, localization, and/or characterization of fracture on acquired medical images (e.g. radiography, MR, CT) | CDSCO |
| 28. | PAPNET Testing System Algorithm | Obstetrics-Gynaecology | Rescreening of negative Pap test | USFDA |
| 29. | Fertility Diagnostic, Contraceptive, Software Application | Obstetrics-Gynaecology | Monitors and provides fertility information to prevent pregnancy (contraception) | CDSCO |

| Sr. No. | Device/SaMD/ Algorithm name | Therapy areas | Use | Approving regulatory body |
|---|---|---|---|---|
| 30. | ReSET-O Algorithm | Psychiatry | Adjuvant treatment of substance abuse disorder | USFDA |
| 31. | Computerized Behavioural Therapy software-based mobile app for Psychiatric Disorders | | Provides cognitive behavioural therapy to treat substance use disorder | CDSCO |
| 32. | Critical Care Suite Algorithm | Pulmonology | Chest X-Ray assessment of pneumothorax | USFDA |
| 33. | Lung CT System Software, Computer Aided Detection | | Assists in the review of multi-slice computed tomography (msct) exams of the chest and highlight potential nodules | CDSCO |
| 34. | Overjet Charting Assist Software | Radiology | Automated radiological image processing and analysis | USFDA |
| 35. | Software for film-recorded digital radiography | | Processes data obtained from film-recorded digital radiography. The resultant data are provided for diagnosis | CDSCO |
| 36. | ACR/LAB Urine Analysis Test System Algorithm | Urology | Diagnosis of urinary tract infection | USFDA |
| 37. | Software for urodynamic measurement system | | Processes data obtained from a urodynamic measurement system | CDSCO |

*Section 4*

# *Existing Regulatory Landscape for the Use of AI*

Regulatory authorities play a crucial role as AI systems in medicine make critical decisions that directly impact individuals' health, safety, and well-being, and regulations help to prevent errors or malfunctions that could potentially harm patients. Additionally, regulations provide a framework for the ethical use of AI in medicine. They address issues such as patient privacy, consent, and the responsible handling of sensitive medical data. Standardisation is another key aspect. Regulations help to establish common guidelines and standards for AI applications in medicine, promoting interoperability and compatibility among different systems, which is essential for seamless collaboration and communication within the healthcare ecosystem. Furthermore, regulations can foster trust among healthcare professionals, patients, and the public.[39]

Here are leading global regulatory authorities that have been identified for regulating AI in medicine:

## 4.1. United States Food and Drug Administration (USFDA)

In January 2021, USFDA published the "Artificial Intelligence and Machine Learning Software as a Medical Device Action Plan" or "AI/ML SaMD Action Plan", which outlined the following five actions based on the total product life cycle (TPLC) approach for the oversight of AI-based medical devices (AI-MDs):[39]

i. Specific regulatory framework with the issuance of draft guidance on "Predetermined Change Control Plan"
ii. Good machine learning practices
iii. Patient-centric approach, including the transparency of devices to users
iv. Methods for the elimination of ML algorithm bias and algorithm improvement
v. Real-world performance monitoring pilots

Later, in October 2021, the USFDA, Health Canada, and the United Kingdom's Medicines and Healthcare products Regulatory Agency (MHRA) jointly identified 10 guiding principles for the development of Good Machine Learning Practice (GMLP) (Table 2). These guiding principles are intended to help promote safe, effective, and high-quality medical devices that use artificial intelligence and machine learning (AI/ML).[40]

| **Guiding Principles**<br>Good Machine Learning Practice for Medical Device Development |
|---|
| Multi-disciplinary expertise is leveraged throughout the total product life cycle |
| Good software engineering and security practices are implemented |
| Clinical study participants and data sets are representative of the intended patient population |
| Training data sets are independent of test sets |
| Selected reference datasets are based upon best available methods |
| Model design is tailored to the available data and reflects the intended use of the device |
| Focus is placed on the performance of the human-AI team |
| Testing demonstrates device performance during clinically relevant conditions |
| Users are provided clear, essential information |
| Deployed models are monitored for performance and re-training risks are managed |

*Table 2: Guiding principles for GMLP*[40]

## 4.2. National Institution for Health and Care Excellence (NICE)

In 2019, UK's NICE collaborated with the National Health Service (NHS) England and published the "Evidence Standards Framework (ESF) for Digital Health Technologies (DHTs)" document.[39] The NICE ESF has been designed for the evaluation and regulation of most DHTs that are likely to be commissioned in the UK health and social care system. These DHTs include:

- Smartphone apps
- Standalone software
- Online tools for treating or diagnosing conditions, preventing ill health, or for improving system efficiencies
- Programmes that can be used to analyse data from medical devices such as scanners, sensors, or monitors

The ESF is not intended to be used for evaluating the following types of DHTs:

- Software that is integral to, or embedded in, a medical device or in vitro diagnostic (IVD), also called software in a medical device (SiMD)
- DHTs designed for providing training to health or care professionals (such as virtual reality [VR] or augmented reality [AR] surgical training)
- DHTs that facilitate data collection in research studies

Further, the ESF classifies DHTs by intended purpose (Figure 17) to allow them to be stratified into tiers A, B, and C based on the ascending order of potential risk to service users and to the system.[41]

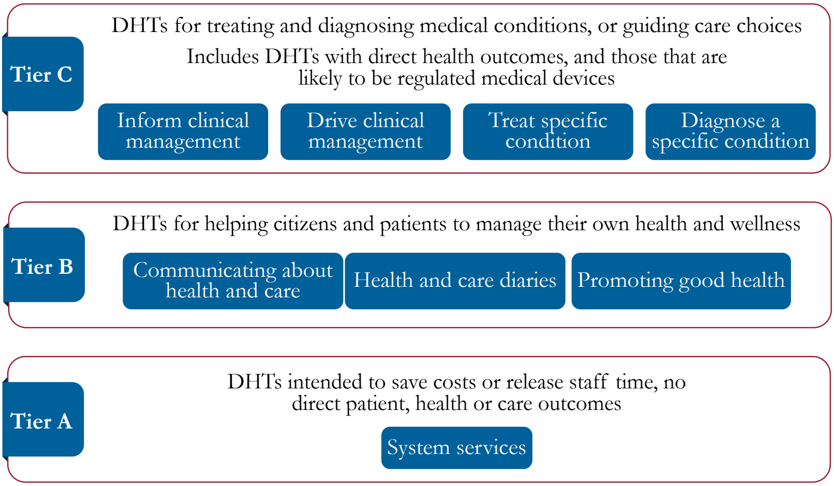


*Figure 17: DHTs classified by intended purpose and stratified into risk tiers*[41]

## 4.3. European Union (EU)

The EU began to establish its approach to AI with non-binding guidelines, including the "Ethics Guidelines for Trustworthy AI" and the "Policy and Investment Recommendations," which were published in 2019. In April 2021, the EU proposed the AI Act, which laid down a harmonised legal framework for AI products and services, from the development phase to their application. In that framework, Articles 9 to 15 address the requirements for AI systems with respect to risk management, data governance, human oversight, transparency, accuracy, robustness, and cybersecurity. In addition, the obligations of providers to users of such AI systems are provided in Articles 16 to 29. The AI Act uses a risk-based approach to regulate AI systems. High-risk AI systems include those that utilise biometric identification, sort patients based on their medical history, and use software for the management of public healthcare services and electronic health records. The main requirements for these high-risk AI systems under the AI Act are data governance and risk management, which need to be addressed by the manufacturer. For low/limited risk and minimal/no risk AI systems such as chatbots that may interact with humans as part of healthcare service, a voluntary code of conduct for safe and reliable service needs to be in place[39] (Figure 18).


*Figure 18: 4 levels of risk for AI systems defined by EU AI Act Regulatory framework*[42]

## 4.4. Therapeutic Goods Administration (TGA)

The regulation of SaMDs falls under the Australian government's TGA. In August 2021, the Therapeutic Goods (Medical Devices) Regulation 2002 was amended, and a guideline entitled "Regulatory changes for software-based medical devices" was published to explain the amendments. This guidance includes a risk-based classification approach. Areas exempt from the guidance are consumer health products for prevention and management; enabling technologies for telehealth, healthcare, and pharmaceutical dispensing; certain electronic medical records; population-based analytics; and laboratory information management systems.[39] Moreover, the guidance furnishes information about the new classification rules for software based medical devices that:[43]

- Provide a diagnosis or screens for a disease or condition
- Monitor the state or progression of a disease or condition, or the parameters of a person with a disease or condition
- Specify or recommend a treatment or intervention
- Provide therapy through the provision of information

## 4.5. Indian Council of Medical Research (ICMR)

In 2023, ICMR released "Ethical Guidelines for AI in Healthcare and Biomedical Research" applicable to AI-based tools created for all biomedical and health research and applications involving human participants and/or their biological data. The document outlines 10 key patient-centric ethical principles for AI application in health sector. As shown in Figure 19, these principles include accountability and liability, autonomy, data privacy, collaboration, risk minimisation and safety, accessibility and equity, optimisation of data quality, non-discrimination and fairness, validity, and trustworthiness (data security and trustworthy).[44]

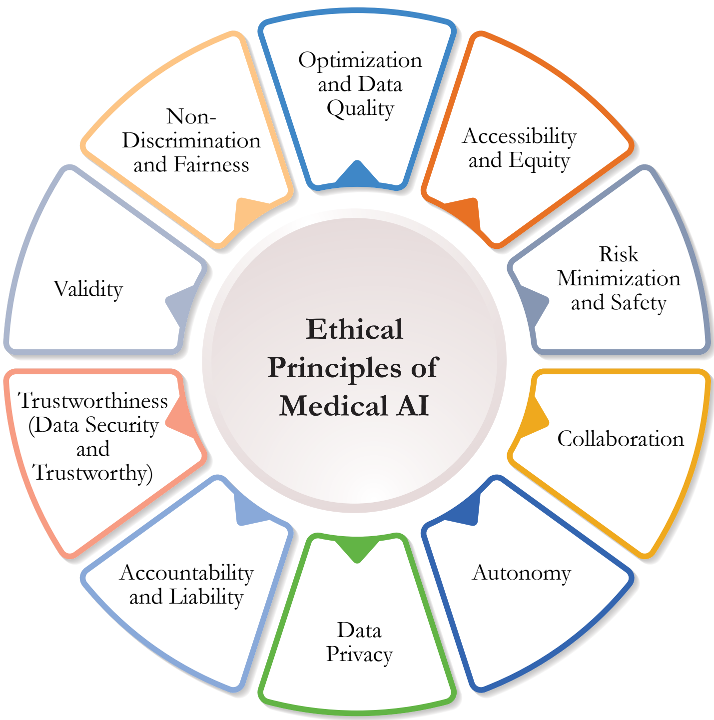


*Figure 19: Ethical principles in AI for health*[44]

*Section 5*

# *Current and Future Applications of AI in Medical Specialties*

The following list provides a fundamental synopsis of current and future applications pertaining to AI within the major domains of medical practice:[45,46]

| Sr. No. | Medical Specialties | Current AI Applications | Future AI Applications |
|---|---|---|---|
| 1. | Cardiology | • Advancing CT and MRI techniques for measuring lumen diameter, recognizing coronary calcium score, and identifying obstructive coronary disease<br>• Digital stethoscopes with wireless ECG device, automated murmurs & AFib detection | • Continuous monitoring and prevention of development of cardiovascular diseases<br>• Enhancing diagnostic precision with ECG<br>• Creating digital twin of the heart |

| Sr. No. | Medical Specialties | Current AI Applications | Future AI Applications |
|---|---|---|---|
| 2. | General Surgery | • Use of AI/ML models in preoperative phase, accurately diagnosing pancreatic conditions, and postoperative phase, evaluating prognosis and predicting complications<br>• Assisting bariatric surgeries | • Management of pharmacotherapy, hemodynamic optimization, neuromuscular block monitoring, and anaesthesia depth assessment<br>• Augmented and wireless surgeries |
| 3. | Gastroenterology | • Use of computer-aided diagnosis (CAD) in diagnosing premalignant and malignant gastrointestinal lesions, predicting treatment response in patients with inflammatory bowel disease, conducting histopathological analysis of biopsy specimens | • Early detection and prevention of esophageal cancer<br>• Gastric sensors nanotechnology to detect the causes of overlapping gastric symptoms |
| 4. | Radiology | • Image analysis, diagnosing conditions, and predicting outcomes | • Virtual Assistants for drafting radiology reports<br>• Unified radiology workstation, with image display, reporting, and AI integrated into a cloud-based cockpit |

| Sr. No. | Medical Specialties | Current AI Applications | Future AI Applications |
|---|---|---|---|
| 5. | Pediatrics | • Modeling of extensive datasets related to childhood neurologic disease, including radiologic, biological, and clinical data<br>• Categorization of children into normal or hypoxic-ischemic brain injury groups, based on the measurement of corpus callosum widths | • Utilization of Decision trees for analysis of data in pediatric neuroimaging<br>• Wearable devices to monitor mother's and child's vital signs |
| 6. | Ophthalmology | • Automated analysis of retinal images for the identification and diagnosis of diabetic retinopathy<br>• Automated detection of drusen, fluid, and geographic atrophy, leveraging fundus images and spectral-domain optical coherence tomograph to enhance diagnosis and treatment of age-related macular degeneration<br>• Efficient classification of glaucomatous and healthy eyes | • Enhancing comprehension of diabetic retinopathy predictions<br>• Early and efficient assessment of fundus images<br>• Addressing challenges in glaucoma screenings |
| 7. | Dermatology | • Prompt diagnoses of skin diseases, facilitating a wider range of treatment options and enhancing accessibility<br>• Improvements in facial recognition and aesthetic analysis<br>• Identification of skin lesions using 360-degree walk-through whole body skin scanner | • 3D-printed living skin with blood vessels for people with burn injuries or other skin issues like diabetic or pressure ulcers<br>• Development of models and devices to replicate dermatologists' sensory inputs such as touch and visual examination under various skin conditions |

| Sr. No. | Medical Specialties | Current AI Applications | Future AI Applications |
|---|---|---|---|
| 8. | Oncology | • Predicting prognosis based on patient's genetic background and tumour's molecular makeup, precision medicine and targeted treatments<br>• Utilization of softwares for in-depth oncology data results and imaging for operational improvements and positive health outcomes | • Enhancing comprehension of tumors and designing personalised treatments for any cancer type or patient<br>• Development of fluid biopsies for analysis of tumor cells from blood samples to detect all types of cancer from a very early stage |
| 9. | Neurology | • Enhancement of neuroimaging to investigate brain and its functionality<br>• Algorithms for non-invasive identification of investigational molecular markers from diagnostic imaging and determination of mutational status of several markers<br>• Automated segmentation of tumors for enhancing the efficiency of radiation therapy treatment planning | • Enhancing comprehension of clinical management of brain tumors<br>• Accurately differentiating central nervous system malignancies without the need for invasive procedures, especially in resource-constrained environments that lack access to specialized neuroradiologists |
| 10. | Pulmonology | • Identification of respiratory illnesses in chest radiographs and CT scans<br>• Identification of malignant pulmonary nodules by analyzing chest CT images to enhance the accuracy of lung cancer screening | • Enhanced comprehension of image analysis, decision-making processes, and prediction of prognoses for early detection of lung cancer |

| Sr. No. | Medical Specialties | Current AI Applications | Future AI Applications |
|---|---|---|---|
| 11. | Orthopaedics | • Severity evaluation of orthopaedic diseases, triage, diagnosis, treatment, and rehabilitation<br>• Classifying individuals into distinct pain phenotypes based on predictive models | • Personalized implants based on patient's anatomy and physiology to improve the fit and functions of implants and reduce complications<br>• Personalized pain management plans based on patient's need and response to treatment |
| 12. | Urology | • Predicting the outcomes of prostate biopsies, with a specific focus on prostate cancer<br>• Analysis of recurrence-free probability and diagnostic evaluation for bladder cancer<br>• Identifying risk factors and co-variates that contribute to the failure of renal transplantation | • Enhanced comprehension of genitourinary malignancies, stones and functional urology<br>• Cost effective alternative to expensive laboratory and ultrasound tests for diagnosing urinary tract infections |

| Sr. No. | Medical Specialties | Current AI Applications | Future AI Applications |
|---|---|---|---|
| 13. | Haematology | • Characterizing qualitative and quantitative variations within specific cell lineages, such as morphology of erythrocytes and textural alterations observed in sickle cell disease<br>• Diagnosing multiple myeloma solely using mass spectrometry data obtained from peripheral blood | • Enhanced comprehension of diagnostic peripheral blood analysis, leukemia classification, as well as chemical and genomic information to identify synergistic drug combinations<br>• Automated interpretation of bone marrow specimens |

*Section 6*

# 10 AI Tools Every Doctor Should Know About

The development of AI tools has improved patient care, minimized workload of huge data and information sets, eliminated medical errors, increased efficiency, reduced costs, and boosted safety. Here is a list of 10 AI tools that can be of good assistance to the doctors, help enhance patient care and build medical practice:

| Sr. No. | AI Tool | General Information | Applications |
|---|---|---|---|
| 1. | ChatGPT | Website: https://chatgpt.com/ Pricing: Free | ChatGPT is a commercial natural language processing (NLP) tool known as a large language model (LLM). It assists with administrative functions, such as generating office notes, responding to documentation requests, and generating patient messages. Additionally, it can be used as clinical decision support to provide differential diagnoses and assist in treatment planning. It may also be useful in creating patient education materials.[47] |

| Sr. No. | AI Tool | General Information | Applications |
|---|---|---|---|
| 2. | Google Gemini (Bard) | Website: https://gemini.google.com/app Pricing: Free | Google Gemini processes patient data and medical literature, providing doctors with insights and recommendations. This helps them make more informed decisions about treatment and operations. It provides educational material that answers the patient's question clearly and concisely. Moreover, it automates routine tasks by scheduling appointments, managing patient data, and generating reports.[48] |
| 3. | DeepScribe | Website: https://www.deepscribe.ai/about Pricing: Paid | DeepScribe is used to generate automated medical notes and documentation from physician-patient conversations. It excels at recognizing and complex scientific terminology, enhances documentation efficiency, saves time, and lessens physician burnout.[49] |
| 4. | Merative (IBM Watson Health) | Website: https://www.merative.com/ Pricing: Paid | Merative uses AI in the cloud to store, manage, and analyze medical data in real time. With its help, doctors can access patient records more quickly and accurately diagnose patients with a significantly higher level of accuracy. AI algorithms can help identify meaningful trends in health at an early stage. Moreover, a comprehensive electronic health record system as well as treatment plans that are tailored to the individual needs of patients are made available.[50] |

| Sr. No. | AI Tool | General Information | Applications |
|---|---|---|---|
| 5. | Viz.ai | Website: https://www.viz.ai/ Pricing: Paid | Viz.ai is a cloud-based patient record management system that allows doctors and patients alike to access and share information more quickly and effectively. Furthermore, it provides alerts when a patient encounters a medical problem or takes medication, which can allow doctors to take the appropriate action quickly.[50] |
| 6. | Suki | Website: https://www.suki.ai/ Pricing: Paid | Suki is a voice assistant for doctors that mechanically generates medical notes from provider-affected person conversations.[49] |
| 7. | Freed | Website: https://www.getfreed.ai/ Pricing: Free trial + Paid subscription | Freed is a scheduling tool designed to automate administrative obligations like appointment reserving and patient outreach. It uses superior NLP to recognize and generate human-like responses.[49] |
| 8. | Augnito | Website: https://augnito.ai/spectra Pricing: Free trial + Paid subscription | Augnito is a voice assistant specifically designed for clinical documentation and physician productivity. Their Clinical Speech Recognition and Natural Language Understanding technologies help streamline clinical workflows and make healthcare intelligence securely accessible. With Augnito's speech recognition software, doctors can create accurate and comprehensive medical reports in real-time, ensuring compliance and efficiency.[51] |

| Sr. No. | AI Tool | General Information | Applications |
|---|---|---|---|
| 9. | Phreesia | Website: https://www.phreesia.com/ Pricing: Paid | Phreesia helps patient intake and fee platform that includes AI-pushed patient self-service gear. It uses gadget mastering to affirm affected person insurance eligibility and automate workflow.[49] |
| 10. | Kyruus | Website: https://kyruushealth.com/ Pricing: Paid | Kyruus helps health sufferers with the right vendors throughout a health system. It automates patients get the right of entry to and referral control workflows. Patients can schedule appointments through Kyruus.[49] |

*Section 7*

# *Challenges and Future Directions*

## Challenges

Despite striking advances, AI in medicine faces major technical challenges, particularly in terms of building user trust in AI systems and composing training datasets.

## 1. Implementation challenges

### Dataset limitations

Although it is hoped that AI will reduce medical costs, the devices required to obtain the inputs for AI systems can be prohibitively expensive. For instance, the equipment needed to capture images of whole slides is costly and unavailable in many health systems, impeding both data collection for and deployment of AI systems for pathology. Additional concerns arise from large image sizes, because the amount of memory required by a neural network can increase with both complexity of the model and number of pixels in the input. Problems also arise when technological factors lead to bias in datasets. For example, single-source bias occurs when a single system generates an entire dataset, as when all the images in a collection come from a single camera with fixed settings.

**Model trustworthiness**

Because many AI systems currently function as uninterpretable 'black boxes', explaining their predictions poses a serious technical challenge. Moreover, proving the reproducibility and replicability of AI studies raises unique challenges. Datasets, code and trained models are often not released publicly, making it difficult for the wider AI community to independently verify and build on previous results.

## 2. Regulatory challenges

Recent work highlights regulatory issues regarding the deployment of AI models for healthcare. Specific regulatory challenges arise from continual learning, where models learn from new data over time and adjust to shifts in patient populations, as this may come at the risk of overwriting previously learned patterns or otherwise causing new mistakes.

## 3. Ethical data use

There are concerns about identity theft and taking undue advantage of medical datasets, which often contain large amounts of sensitive information about real patients. Further, there remains the risk that AI systems will face privacy attacks.[52]

### Future Directions

The future of AI in medicine is promising and shows that AI has the potential to improve healthcare delivery. While AI currently has a relatively limited role in direct patient care, its evolving role in complex clinical decision making is foreseeable.[53] Although early efforts at providing diagnosis and treatment recommendations have proven challenging, it is expected that AI will ultimately master that domain as well. Given the rapid advances in AI for imaging analysis, it seems likely that most radiology and pathology images will be examined at some point by a machine. Speech and text recognition are already employed for tasks like patient communication and capture of clinical notes, and their usage will increase.[54]

The greatest challenge to AI in medicine is not whether the technologies will be capable enough to be useful, but rather ensuring their adoption in daily clinical practice. For widespread adoption to take place, AI systems must be approved by regulators, integrated with EHR systems, standardised to a sufficient degree that similar products work in a similar fashion, taught to clinicians, paid for by public or private payer organisations and updated over time in the field. Hence, it is important for the medical community and regulators to monitor the explainability of AI technologies and consider how their use in different healthcare contexts is impacted. Guiding principles relating to the scope of AI, communicating the use of AI with patients to obtain informed consent, and assessing the use and application of AI is a pivotal step in establishing a standard practice. Proactive leadership from professional bodies may help foster public confidence in the safety and utility of medical AI, and fuel future innovation in this promising field.[53]

**AI in India- Current challenges, impact on medical practice, and way forward**

India's vast and diverse population strains its healthcare system, giving rise to a plethora of challenges such as inadequate healthcare infrastructure, shortage of skilled medical professionals, and a growing burden of diseases. Amidst these complexities, AI emerges as a beacon of hope.[55]

As we step into the third decade of the 21$^{st}$ century, India is already witnessing a significant surge in AI-driven healthcare applications, from diagnosis to treatment and beyond. According to recent statistics, the Indian healthcare AI market is expected to reach USD 1.6 billion by 2025, with a CAGR of 40.5% from 2020 to 2025.[56] More than 50% of

Indian healthcare organisations have bundled generative AI solutions with productivity tools to enhance efficiency and enable faster decision-making by leveraging AI algorithms for tasks like data analysis, prediction, and automation. For instance, generative AI-powered 'virtual chatbots' are providing 24x7 real-time interaction, offering instant personalised responses and tailored health advice to Indian patients.[57]

The ability of AI to process vast amounts of data and derive meaningful insights at unprecedented speed presents an opportunity to expedite the diagnostic process, enabling earlier detection of diseases and consequently facilitating timely therapeutic interventions in India. Such advancements have the potential to save countless lives and improve the quality of life for millions. Moreover, AI can bridge the gap between urban and rural areas by empowering doctors to remotely diagnose and monitor patients, provide health advice, and manage chronic conditions efficiently. This is especially valuable in a country like India, where many people reside in remote or underserved regions with limited access to medical facilities.[55] For example, while rural India has already been dealing with scarcity of radiologists (1 radiologist for every 1 lac people), COVID-19 pandemic witnessed the birth of XraySetu- an innovative AI tool to support doctors and health workers with chest Xray interpretation over WhatsApp during times when diagnostic tests were taking more than a week to get administered.

XraySetu analyses chest Xrays using machine learning algorithms and generates a patient report showing suspicious abnormal regions in the lungs and detects if the person is likely positive for COVID, pneumonia or other lung abnormalities.[58]

In summary, AI in medicine is one of the more powerful and consequential technologies to impact human societies. As a result, it will require continuous attention and thoughtful policy for many years.

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