# Artificial Intelligence for healthcare applications

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**Abstract**

It is clear that artificial intelligence has huge potential to better human life and reduce error within a wide range of sectors, especially healthcare. In recent years, AI has become particularly relevant in the medical field as it offers a new hope for patients with many different illnesses because it has the ability to diagnose and cure people on a massive scale with greater efficiency than human medical practitioners. The implementation of these kinds of artificial intelligence-powered systems will allow patients more autonomy as well as more individualised treatment plans, and it will free up crucial resources in the industry, allowing physicians to focus their efforts elsewhere. While artificial intelligence shows great promise in the sector, there are risks associated with it, and some medical practitioners are opposed to its usage for a variety of reasons, including a lack of education on how they work as well as the potential legal and ethical ramifications of using these technologies. It is evident that there are a number of benefits to using AI in healthcare, but these concerns must be addressed before it can truly be unleashed on a global scale. We discuss a variety of potential and current applications of artificial intelligence in the medical sector and the pros and cons of each of these. We also consider the ethics of using AI and deep learning, specifically for monitoring and analysing patient information, and discuss the current law surrounding the use of an individual's data within the EU.

## Introduction

Artificial intelligence has many applications across a wide range of industries.AI is a massive industry with huge growth, projected to be worth over $200 billion dollars by 2026[1]. A study from Johns Hopkins University discovered that more than 250,000 people in the U.S. die every year from medical mistakes, which means that it is the third-leading cause of death in the U.S., behind heart disease and cancer[2]. Artificial intelligence in the healthcare sector will reduce human error, as it can collate and analyse data far faster than any human possibly could and it can also recall and use that information effortlessly, where humans may forget and mix up different patients - one study found that one error was reported per 1000 consultations per year for family practitioners, and about 70% of these errors were related to providing healthcare while 30% were due to knowledge gaps on the part of the physician[3].

AI can be given a list of symptoms and it will recommend cures or treatments for these ailments by utilising a large amount of data to make the suggestions. Using machine learning, the AI is able to build on a database of information to constantly keep up to date with the latest treatments and cures available. It can analyse data quickly and efficiently and can detect diseases such as cancer at a much earlier stage than any human doctor, as well as recognising symptoms earlier by analysing patient history. Medical records are incredibly important to patient diagnostics, but mistakes are often made, whether with digital or manual records, by doctors and nurses inputting incorrect medical information. For example, one woman in the U.S. was listed as having given birth to two children, when she had never given birth at all[4].

AI can also be used to allow people to keep track of their health through apps as well as allowing doctors to use this information and track patterns. AI is highly effective at recognising patterns, which can be used to determine when people are at high risk of developing certain diseases, or to see when these diseases are worsening due to various factors, such as lifestyle and environment. Artificial intelligence can review and analyse this medical information far quicker than any human, allowing it to make appropriate recommendations for diagnosis and treatment[5]. It clearly has a wide range of possibilities for use in the healthcare sector, as well as both advantages and disadvantages, which we will discuss in the following essay.

## Expert Systems

At first, medical expert systems were developed for academic areas but they were later designed for clinical uses as well[6]. Health care systems have enormous amounts of information on patient's including demographic, clinical, and billing data, all of which is suitable for analysis by intelligent systems. Medical expert systems can help clinicians in various ways, such as providing assistance with the diagnostic process, deciding what treatment to give, analysing data within laboratories and teaching medical students.

Medical expert systems are used for emulating the diagnostic decision making ability of human experts. Some of these systems include Mycin for infectious diseases[5], and Internist-1, QMR and DXplain for general internal medicine[7]. Mycin, developed by Shortliffe in 1976, is one of the most widely known medical expert systems. It was developed in Stanford University as a research project to aid physicians in diagnosis and treatment of meningitis and bacteremia infections. Medical expert systems mainly have two components, a knowledge base and a rule-based inference engine[8][9]. The knowledge base is curated by medical experts and uses evidence-based medical knowledge. Knowledge bases consist of diseases, gathering information on them such as symptoms, signs, history, lab results and their relationship. In most cases they lay out the findings and what causes them. The rule based inference operates with the knowledge base to give differential diagnosis, and this is also curated by medical experts[7][9].

The benefits to these systems are huge. They provide answers for decisions and tasks that are repetitive, they can hold huge amounts of information, they minimize the cost of training, and they give a more efficient system as they reduce the time needed to solve problems. One of the most important things they do lies in their ability to combine the knowledge of multiple human experts so that they can consider strategies that human experts may not even think of. This gives the systems an advantage as they'll know the same amount of information as if five, ten, or even twenty doctors were standing in the same room trying to diagnose the patient, and due to this wealth of knowledge, human error will be reduced. These systems are also used to look for inconsistencies and omissions within treatment plans already developed.

They can create their own treatment plan based on the patient's specific condition and the accepted treatment guidelines.

Even though there are huge advantages to these systems, there are always some disadvantages too. These include that these systems cannot use common sense in making their decisions as they have none, and this also means that they won't have a creative response that a human might have in doing a procedure. When a system makes its decision it won't be able to explain why it made that decision and the reasoning behind it. This could cause problems if a procedure goes wrong or does not work out as planned, as the patient and family will want justification for why this procedure was undertaken instead of a different option. The systems, unlike humans, don't have the flexibility to adapt to a changing environment. This can be an issue if there is a procedure being carried out and something goes wrong, as the system won't know how to deal with the situation. Sometimes, there is just no answer to a medical problem and these systems will not know what to do in this case, as it will constantly try to find a solution even when there is none[10]. This could result in the system recommending a procedure that is not viable, which will waste resources and could put the patient at risk for no good reason.

The children's hospital in Ottawa is one of the few children's hospitals that use these systems to gather information about newborns with critical illnesses[10]. This data aids the choice of treatments and can also help in predicting their health outcomes. These systems were exclusively used within adult hospitals and this example is one of the few approaches used on newborns. The systems are hooked up to each baby to both collect and store various data. The monitors collect data continuously which allows doctors to assess the newborns and if any complications arise they can act on them quickly. The data they collect ranges from respiratory rates to heart rates to heart rhythms, and, using this information, the systems can then predict the chances of survival and the length of the stay the newborn will need in the hospital. These systems have a 95% accuracy rate and have consistently performed well for the hospital, preventing multiple possibly fatal outcomes, and they are much more efficient than human observation twenty four hours a day. In the near future hundreds of additional cases will be added to this database, and an increasing number of diagnostics and procedures will take place as a direct result of this.

## Development of new medicines

One of the most hopeful applications of AI in healthcare is the development of new drugs. While it is not yet widespread, some experimental cases have shown great promise in this area. In particular, a drug used to treat Obsessive Compulsive Disorder (OCD) was invented using machine learning by two companies working in cooperation, namely Exscientia and Sumitomo Dainippon Pharma[11][12]. While drugs take about five years on average to

develop, this one took a mere twelve months, causing it to be labelled a “key milestone in drug discovery”. The drug will be entering the clinical trial stage in only nine months[11] [12]. Should these clinical trials be successful, the use of AI in drug development may rapidly become more widespread, ushering in a new age of prosperity in the drug industry.

Between the research, discovery, testing and development of drugs, the average cost is regularly as high as $2.6 billion to create a new drug[13][14]. The approval rate for drugs, as of 2019, is roughly 12%[13][14]. Not only does AI have the potential to drastically reduce the price of drug development, it also offers companies the chance to speed up the rate at which these drugs are being designed and developed. This advancement would benefit the companies who stand to save billions in the development as well as the consumers whose lives may well depend on the production of these drugs, and in many cases they do.

Studies are being carried out at the Swiss Federal Institute of Technology in Zurich in relation to the use of AI in drug development. According to Gisbert Schneider, the head of the research team, while AI can speed up drug creation, machine learning requires large amounts of data to be efficient and accurate[15]. After feeding the software this data, the system was trained to recognise important characteristics of known drugs. As a result of this, the software was able to assemble new molecules with the desired properties.

Companies such as Atomwise, Phenomics AI and Arpeggio Biosciences are all at the forefront of this field, each offering valuable insights into the industry[16][17]. Atomwise focuses on the development of new active molecules and the prediction of bioactivity of small molecules, Phenomics AI has made breakthroughs in discovering new therapies against cancer, and Arpeggio Biosciences works on machine learning and data mining in relation to novel drug creation[17]. While humans are able to create, test and perfect drugs, computers can produce and mine molecules much, much faster than any human would ever be capable of[12]. In large part, this is due to active learning algorithms, which prioritise the experimental synthesis of the most informative compounds.

Currently, AI is being used in an attempt to tackle the infamous Covid-19 virus[18][19]. In cases of new viruses and bacterial infections, scientists traditionally attempt to develop a treatment using a combination of different drugs[19]. This tedious process wastes precious resources such as money and time, which, in a pandemic, are already in short supply. Haste is most certainly of utmost importance in situations like this and may be obtained with the help of AI.

While using artificial intelligence in drug design is undeniably one of the more promising applications of Intelligent Systems and machine learning, it has downsides as well. The aforementioned start-up Atomwise is indeed accelerating the development of this exciting field but they also use their funding and intelligent systems to develop more effective pesticides, which, while profitable, can be harmful to wildlife and their surrounding ecosystem[16]. However, it would seem that on this particular subject, the pros far outweigh the cons. Drug development using AI appears to be one of the most profitable and beneficial applications of AI in healthcare.

## More accurate diagnoses

In 2015, misdiagnosing illness and medical error accounted for 10% of all U.S. deaths[20] [21]. Human error is a big factor in many accidents and deaths across a wide range of sectors.

Imagine the reduction there could be in misdiagnoses, accidental injuries and deaths if an AI was capable of diagnosing people with illness with a much lower error rate. Artificial intelligence can predict and diagnose disease and illness with an accuracy far beyond that of a human. Additionally, it is possible for AI to collate massive amounts of data and use all the information it has in its repertoire to make decisions and it would not be limited by the amount of patients it had or what it can remember at that moment[22].

AI can also be used to allow people to keep track of their health and medication intake through apps as well as allowing doctors to use this information and track patterns. It is highly effective at recognising patterns, which can be used to determine when people are at high risk of developing certain diseases, or to see when these diseases are worsening due to various factors, such as lifestyle and environment. Artificial intelligence can review and analyse medical information quicker than any human[22]. It can index every journal, and every article available to it in a matter of seconds and make accurate recommendations based on all the information it has, while human doctors and nurses are simply unable to keep with all the new information that is forthcoming on a daily basis about new treatments and research.

## Watson - the AI that became a doctor

IBM's Watson, an AI with many capabilities including Natural Language Processing, was used to assist physicians in diagnosing cancer for many years[5][23][24]. Watson was never intended to replace human medical practitioners but instead to guide them and speed up the time it takes to review a patient's symptoms and think of a diagnosis, while avoiding human problems such as cognitive bias. A doctor can type, for example, "My patient has fluid coming from their ears" and within seconds Watson will provide a list of possible treatments, with degrees of confidence in their effectiveness, as well as the medical research to back up these suggestions[23]. However, Watson has been found lacking in recent years, and many doctors who initially were vocal supporters of it have been dismayed at its lack of progress in recent years[25]. While Watson is still a fantastic example of the progress that has been made in Natural Language Processing, it was perhaps hyped up a little too much by IBM - they made it seem as though Watson would become a doctor, when it is really a tool to assist medical practitioners rather than replace them.

## Detection of illnesses and diseases

Currently, artificial intelligence is used in the early detection of atrial fibrillation via remote ECG monitoring, intelligent seizure detection, glucose level monitoring as well as gait, posture and tremor assessment. Deep learning algorithms can help to collate data from the various sources that it is gathered from today - wearables and smartphones all tracking fitness levels, sleep, heat rate. This information can be analysed and monitored by AI.

Atrial fibrillation increases a patient's risk of stroke as well as other cardiac complications. Artificial intelligence has the ability to detect when a patient's heartbeat is irregular and beating rapidly[26][27]. Devices can use AI to determine whether someone is currently experiencing atrial fibrillation and it can also use a patient's history to reveal whether they've had an irregular heart rhythm in the past. Using this information, the AI can determine if they will experience it again in the future, as it can recognise patterns in a way that humans can't[26]. Even if a patient has a normal heart rhythm, it is still possible for an AI to detect atrial fibrillation as it detects minute changes in electrical rhythm. A human doctor would not be able to detect this by looking at an Electrocardiogram, for example, as an ECG can only detect atrial fibrillation while the abnormal rhythm is occurring making diagnosis of atrial fibrillation expensive and inefficient[27]. In patients with episodic atrial fibrillation, this can make identifying the problem difficult, and using AI to detect it will allow them to get life saving treatment and fatal prevent strokes and heart failure[26].

According to the World Health Organisation between 4 and 10 in every 1000 people suffer from epilepsy-related seizures [28] but from various studies it has been found that the vast majority of these have symptoms that could be mitigated with medication. However, this is only effective when patients are in the preictal stage, which is right before the seizure occurs, and it is incredibly difficult for most patients to determine when they are in this phase[29]. As a result of this, many researchers have set out to develop an artificial intelligence capable of detecting when seizures will occur to a high degree of accuracy.

The problem, however, is that every individual experiences seizures in a different way, with different levels of brain activity shown before, during, and after the seizure occurs. Due to this fact, it is not an easy task to create an AI that can accurately detect when a seizure is going to happen[30]. While it is relatively straightforward to train an AI to, for example, recognise cats by simply showing it millions of photos of them, the AI needs personal patient data, such as multiple cranial Electroencephalograms (EEG), in order to get an accurate baseline for brain activity and predict abnormal electrical activity[29][30]. In the future, this type of technology could be embedded into smart watches which would allow patients to track their seizures and be prepared for when they will occur.

Artificial intelligence is also being used to help measure and monitor blood glucose levels[31]. Currently, most patients with diabetes around the world have to prick their fingers multiple times per day in order to check the glucose levels in their blood or have to wear a continuous glucose monitor[32]. This can be painful for patients and causes them to be less likely to check their glucose levels as often as they should, particularly when talking about paediatric patients[31], leading to potentially fatal outcomes like hypoglycaemic shock. Researchers have shown that they can use artificial intelligence to detect hypoglycaemia using electrocardiogram signals, which can be obtained from patients using wearable sensors, and is naturally much less invasive than finger pricks[31].

## Image recognition / Medical Imaging

In order to function in almost any medical field, an intelligent system needs to be able to perceive the world the way a doctor would, via a sense of sight, which is artificially created for these systems using image recognition. The development of this ability in AI systems was not an easy one, as computers will never see images the way humans do. Instead, they see the bare math behind the image. However, through machine learning and high quantities of data, computer scientists can train a system to recognise images. While work on image recognition began in 1959 with the transformation of images into grids of numbers, it was not until 2001 that two researchers in MIT developed the first real time face detection image recognition system[33].

Companies like Google and Facebook later came on the scene, bringing massive amounts of funding and new ideas for the application of this type of technology. Today, mobile phones use facial image recognition as a safety measure, self-driving cars use it to plan a path, and it now has promising applications in the field of medicine. Using image recognition, an intelligent system can detect tumours or interpret X-ray scans with relative ease[34], two tasks that every doctor spends years in a higher learning institute to learn.

On the more trivial side of this technology, applications like Snapchat and Facebook use image recognition to apply filters to faces. Smartphone galleries can recognise faces and accurately sort photos of certain individuals into separate folders on the device. In 2010, Google released Goggles, an app that performs searches based on photos taken by a mobile phone[33]. On a more serious note, similar software to that which was developed by Facebook was used to confirm the identity of Osama bin Laden, showing the value of such technology in a more real world scenario[33].

Due to these investments, image recognition in healthcare has a variety of applications today. Medical imaging is a mechanism of developing visual representations of the inside of a body. Using this, medical professionals can create an accurate representation of what internal organs and tissue should look like. Endoscopies, X-rays, MRI and CT scans are all types of medical imaging[34]. In cooperation with image recognition, medical imaging can be used to predict diseases, find tumours and diagnose broken bones without the need for human input. It is even conceivable that routine check-ups may be done through this medium in the future.

Using an Intra-Tumour Classification Network for region labelling, a system reviewed by Hindawi was able to accurately localize a brain tumour from MRI images[35]. Another paper proposed a DBN-DS based multi classifier for the pathologic prediction of prostate cancer, early tests of which showed promisingly high accuracy, with a rate of 81.27%, as opposed to the more mainstream Partin table, which has an accuracy rate of 64.14%[36]. Both of these are massive advancements that have the potential to revolutionise medical imaging, if they can be utilised on a large scale. In the long term, it would save hospital's huge amounts of money, as they would not need to employ specialist doctors capable of reading each scan.

Image recognition also has applications in areas like blood testing. Given a blood sample, an intelligent system could use image recognition to recognise diseases in the blood, pick up on abnormal blood cell counts and even recognise pathologic distributions of leukocytes in blood[37]. Scientist Robert Debre theorises that automated microscopy analysers may well replace manual microscopy due to its reliability, though he also believes that it will never totally replace the eye of the cytologist[37]. Image recognition stands to be one of the biggest advancements in medicine in recent history. It has the potential to cut down on medical costs for both patients and hospitals and save doctor's time, freeing them to work on non-automated aspects of their profession.

## End of life care

AI has the potential to revolutionise end of life care, allowing people to live independently for longer with conditions such as dementia. It can also be used to combat loneliness and social isolation by providing an opportunity for conversation especially as natural language processing develops further. In the US 46% of patients who die use palliative health care services[38], but frequently these services are used too late or not at all. Sometimes doctors are overly optimistic about the prognosis for their patient, or simply make an inaccurate judgement call. It is possible for AI to identify patients who are in need of palliative care as well as to accurately predict the mortality of patients, which will not only prevent unnecessary, aggressive, and potentially painful treatments for people who are in the final days of their lives but will also reduce medical costs for patients, which is a real worry for many people in many countries such as the USA, as well as the costs for hospitals[38][39]. The Chief Technical Officer of Optellum, which has created an AI system that can diagnose lung cancer much earlier than doctors currently can, has suggested that AI could cut industry costs by $13.5 billion[39].

One program, created by Tech company Kensci, produced an AI capable of predicting mortality within three to twelve months with 90% accuracy, and 95% of those it assessed as having a low probability of dying lived past twelve months[38][40]. It does this by comparing the patient's medical history with that of millions of other patients and considering a variety of factors including hospital admissions. Recognising when patients need end-of-life care sooner than we currently do would allow patients to take control of their surroundings, including giving them the chance to pass in their preferred environment. Studies have found that around 80 percent of Americans would rather die at home than in a hospital, yet 60 percent of them end up dying in acute care hospitals[39][40]. Identifying these patients who are critically ill at an earlier stage would offer them more control and get them needed treatment sooner, as well as allowing them the opportunity to stay at home.

# Ethical Considerations of Artificial Intelligence in Healthcare

For healthcare advice to be heeded and followed the source must be trusted. Artificial Intelligence does not yet have that trust as throughout popular culture it is held with more than a degree of skepticism. In all forms of media, AI is purported to be steps away from the complete destruction of humanity, and it is often portrayed as having developed an ability to actually think like a human being as well as having a conscience. In reality, this form of Artificial General Intelligence is thought to be entirely unrealistic and unlikely to ever come to fruition at this point. Very few researchers are delving into this area anymore as it has been found that it is far easier to create a specialised artificial intelligence, one that excels in one particular area such as playing a game of chess, rather than trying to literally recreate human intelligence in artificial form.

Using AI within the healthcare sector would allow for greater autonomy and more personalised treatment as the AI has the ability to look at all aspects of a patient's history that is supplied to it and make judgements based on that. However, it is not advocated for by all physicians[41]. In the same way that many people are not interested in autonomous cars, some physicians object to the use of AI in healthcare for a variety of reasons, for example, there are ethical considerations to be thought of where continuous monitoring and analysis is concerned as data is mined from personal wearable devices[41].

In addition to concerns about all of this data being stored remotely, there are also issues relating to the security of this data. It would be imperative that this information is kept securely and is protected in the best manner possible from any attacks by hackers, for example, which would undoubtedly increase if it was known that such patient information is kept there. Separate to this is the fact that collating all of this data about people in one place is a gold mine for companies that mine and sell data for advertising purposes as well for more nefarious ones. For example, if personal medical information about a patient was leaked it could cause employer's to doubt their ability to do their job or cause an insurance company to increase a patient's premium if they are predisposed to an illness or disease. In recent years, there have been many scandals where large companies have mined the data of millions of people, by tracking websites and search terms, and they sold and used this information for the purpose of generating large amounts of revenue. It would be crucial that if artificial intelligence was used in the healthcare sector, personal patient information would, first and foremost, be protected.

Within the European Union, we have the General Data Protection Regulation, which regulates how companies can collect, process, store, and use personal data. This naturally has the effect of severely limiting the data set which companies can use to teach AI, as they now require the consent of every EU resident in order to process their data and to allow an AI to make decisions that affect a person, as per Articles 13-15 of the GDPR[42]. Article 22 of the GDPR states that data subjects have the right not to be subject to a decision based *solely* on automated processing. This means that EU citizens have the right to object to their data being processed without human involvement[42]. As a result, artificial intelligence within the

healthcare sector will learn using a reduced data set within EU countries, which may decrease its accuracy in predicting diseases and illnesses as well as its ability to recommend appropriate treatment as it makes such decisions based on the data it has been exposed to.

At the moment there is accountability for doctors and their actions, however, if an A.I solution is implemented in the medical sector to diagnose, prescribe, and perform medical procedures, there is room for a defence of blaming the machine and the technology rather than the medical practitioners using it, and the designers of the machine would claim zero accountability for such an outcome. These legal issues would have to be considered and accounted for completely before we could consider implementing AI in healthcare on a broad scale.

There is also the human factor that must be taken into account. AI in healthcare can ultimately only go so far - it lacks human empathy and compassion, and cannot completely replace a human doctor[22]. Patients must perceive warmth from their physician in order to feel heard and that their concerns are being taken seriously, especially when they are expected to divulge personal information. Many people feel uncomfortable at the idea of providing their data to a machine and naturally worry about privacy concerns and data leaks, There are also real worries from pharmaceutical and medical device companies about AI showing bias in choosing or recommending healthcare treatment from certain companies over others, and there would be no clear and obvious way of making it fair and transparent without leaving the system at risk of exploitation.

# Conclusions

It is clear that there are many possibilities for artificial intelligence to improve the healthcare sector, but the pros and cons of implementing A.I are significant and daunting. It's important to balance the benefits and risks of artificial intelligence to ensure the best care is provided for all patients. Artificial intelligence is more reliable and far faster than any human and can review vast amounts of information from various sources in a matter of seconds. However, an AI will never replace real human contact[22], which is important for many patients, and while it is very good at accurately suggesting treatments based on a provided set of information, it does not yet, and possibly won't ever have, the ability to read through multiple sets of notes from various medical practitioners that are not in chronological order and accurately give a diagnosis or recommend treatment. It has been found that it frequently falls short in real world scenarios where it is expected to do so.

We must also consider that in order to introduce AI into the sector, medical practitioners of all kinds would need to be educated on how it works and what it can do, as well as what it cannot. Additionally, it is important that the AI is considered a tool and a source of a second opinion[22], perhaps confirming what the physician thought or providing an insight that they hadn't considered, but ultimately the physician should still be confirming these diagnoses and treatment recommendations rather than blindly following whatever the technology says. This

will prevent the aforementioned issues of doctors and other medical practitioners abdicating responsibility on account of any misdiagnoses or maltreatment being the fault of the machine.

While artificial intelligence will never completely take over the healthcare industry, it is clear that it has a place within the sector and that it could vastly increase efficiency and reduce cost as well as human error. At present, it is in its infancy in this area but with time and a greater understanding of the place that artificial intelligence has in the medical community, it could become a key player in saving human lives and increasing the quality of care provided to patients, whether in diagnosing illnesses early enough to treat or in recommending end-of-life care in time to let people make their own decisions on how they pass. Without a doubt, we think artificial intelligence will eventually inhabit an irreplaceable role in the healthcare industry.

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