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How Can AI be Used to Minimise Medical Errors?

Artificial Intelligence (AI) is autonomous software designed to learn to solve complex problems with minimal human supervision. Medical errors are the preventable failures of any part of the healthcare system in improving the health of its population. Avoiding errors is difficult both because of the diversity of health conditions and because healthcare operators and users are people. Therefore, errors occur as inefficiencies at a systems level and mistakes at a human level. AI can benefit patients at each part of their medical journey through diagnosis, monitoring and treatment by making systems more efficient and freeing clinicians to operate at their safest.

Diagnosis

Early machine learning research used ideas from neuroscience to develop the artificial neural network (figure 1). This is an algorithm that combines multiple numerical inputs to give a numerical output. The output can then be compared to a desired output. Depending on the difference between the output and the desired output the weighting of each input can be gradually changed until the network has learned to map a specific pattern of inputs to an output. For example, in image recognition problems each input is a pixel in a picture and the network can be trained to map the histology of a melanoma to the diagnosis of melanoma[1]. Clinical diagnosis is fundamentally a similar process. Signs and symptoms (inputs) are recorded and compared to a criterion to form a diagnosis (output). Medical errors can occur both when there are mistakes in identifying signs and symptoms and in comparing them to diagnostic criteria. An AI doctor's assistant based on an artificial neural network could relieve the burden on doctors to keep up to date with diagnostic criteria. This gives doctors more time to take a history and examine the patient, while the AI integrates the signs and symptoms automatically and near instantaneously. Furthermore, the AI could be facilitated by up-to-date numerical weighting from large-scale population studies. Diagnosis would be improved because the AI has the memory capacity to learn to integrate many more risk factors as inputs to direct its diagnosis. For example, a doctor will know that hypertension, smoking and hyperlipidaemia are significant risk factors for heart disease. There are also less significant and unknown risk factors that may have little diagnostic utility on their own but in summation can usefully inform the AI's diagnosis.

There are already consumer facing apps such as Your.MD[2], that will ask for a list of symptoms and compare it to diagnostic criteria, and like Ada[3] who will use their preliminary diagnosis to suggest a referral to a doctor. However, these systems are not truly autonomous as they first require a clinician to take a history and do clinical examinations. Furthermore, an app cannot give a diagnosis itself without the company responsible for producing the app claiming liability for an incorrect diagnosis. Therefore, it is likely that diagnostic apps are best placed as gatekeepers for referrals to clinicians before a formal diagnosis is given.

Many diagnoses also require image analysis from X-rays, histology, CT scans and MRIs. In this area AI can be as accurate as expert clinicians, even in three-dimensional optical scans as shown by De Fauw et al Moorfield's Eye Hospital[4]. This requires large datasets of correctly annotated diagnostic images to train the algorithm. Even with vast datasets the algorithms are restricted to diagnoses sufficiently similar to what they have been trained on. They need to be used alongside expert clinicians to correctly identify unusual presentations[4].

Besides more detailed image recognition, genome sequencing stands to significantly increase information available to clinicians thus avoiding the error of misdiagnosis. Many diseases correlate with genetic risk factors but the large volume of the data available requires computational analysis. The NHS' 100,000 Genomes Project is paving the way for increased use of genomic data and someday genetic sequencing may become routine[5]. Already companies like 23andMe are offering consumer tests that include disease risk factors[6]. This empowers patients, democratises medical expertise and promotes patient autonomy. However, it risks unnecessary distress when diagnostic information is miscommunicated, misunderstood or when people are misled by internet searches that select attention-grabbing reporting. With increasing numbers of rare diagnoses available even algorithms that have a 99.9% correct diagnosis rate can cause unnecessary alarm. For example, if only 1 person in 10,000 has the disease they will likely be correctly diagnosed, but 10 healthy people may also be falsely diagnosed with disease (figure 2). It is unclear what ratio of true positive diagnoses to false positives should be ethically allowed. If diagnostic apps and genetic testing are freely available to all, doctors further relinquish their control over diagnostic testing. The responsibility of acting in people's best interest then falls to the designers of the apps and their consumers.

Monitoring

With an ageing population healthcare systems increasingly have patients with chronic co-morbid conditions receiving polypharmacy. Patients also have more medical notes. This means when they see a new clinician more time is spent reading and writing notes with more opportunity for error. Electronic health records (EHR) were marketed as a way to free-up clinician time by allowing them access from any health centre at the same time and reducing the risk of notes getting lost[7]. However, a metanalysis by Poissant et al showed physicians spend significantly more time documenting when using EHR than using paper[8]. Natural language processing services like Amazon's Comprehend Medical[9] might be able to automatically record a consultation and greatly reduce manual note taking. This would also reduce errors caused by forgetfulness and fatigue. The algorithm could also provide a transcript to the patient as a memory aid. However, these AIs may miss other forms of communication including body language and tone of voice resulting in a new set of errors.

Treatment

Intelligent computer systems are already aiding prescribing such as by drop-down menus for correct drug doses. As before this reduces the memory burden for clinicians. Reminders of patient drug allergies and interactions can also appear in order to prevent harmful prescribing. These algorithms are simple to implement and augment clinicians rather than seeking to replace them. Furthermore, automating small, repeatable tasks has the advantage of largely avoiding creating new types of errors.

Advances in robotics concomitant with AI could also reduce errors in the operating theatre. Just as car manufacturing has become faster, cheaper and more efficient through automation, surgical robots may one day displace surgeons to a supervisory role. Shademan et al showed their autonomous robot was superior to manual laparoscopy and robot-assisted surgery for suturing of porcine intestinal anastamoses[10]. Robot surgeons do not suffer fatigue or stress, have no hand tremor and can work and be ready 24 hours a day. Even if robot surgeons become demonstrably and routinely less prone to errors than humans, they may still be underused due to the legal system not allowing liability to fall on machines. If a serious adverse complication occurs patient have a right to seek compensation: should this be from the robot, the supervising surgeon or the manufacturer? Patients may not be comfortable putting their lives in a robot's "hands" and surgeons may not accept responsibility for complications that they have not directly caused.

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Artificial intelligence has the potential to revolutionise healthcare and reduce many forms of medical error. Addressing systemic inefficiencies allows clinicians to spend more time with patients. This could best utilise clinicians and reduce attrition[7]. Intelligent systems work best alongside clinicians and in roles they are specifically designed for such as data storage and pattern recognition. Doctors will remain essential for the relational side of healthcare; taking a history and physical examinations. Moving beyond this to truly autonomous AI doctors is likely far off as it requires first addressing who is liable for errors and other legal problems as well as the technological advancement.

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Figure 1

An Artificial Neural Network

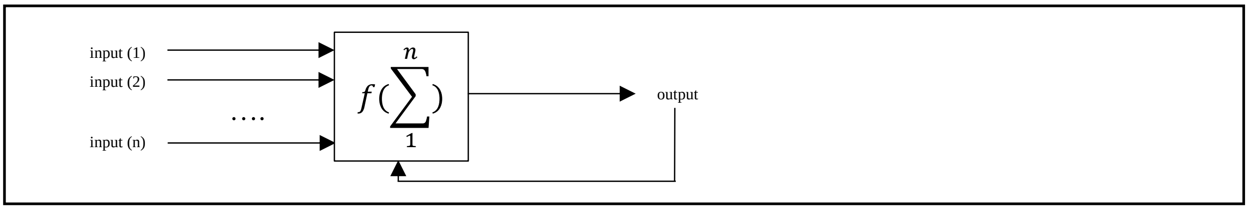

Figure 2

A population of 10,000 with disease x and diagnostic test 99.9% accurate will likely result in 10 false positive diagnoses and 1 true positive diagnosis.

True Positive (1)	False Positive (10)
True Negative (0)	False Negative (9989)

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