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EDITORIAL

The role of artificial intelligence in precision medicine

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1. Introduction

The essence of practicing medicine has been obtaining as much data about the patient's health or disease as possible and making decisions based on that. Physicians have had to rely on their experience, judgement, and problem-solving skills while using rudimentary tools and limited resources.

With the cultural transformation called digital health, disruptive technologies have started to make advanced methods available not only to medical professionals but also to their patients. These technologies such as genomics, biotechnology, wearable sensors, or artificial intelligence (AI) are gradually leading to three major directions. They have been (1) making patients the point-of-care; (2) created a vast amount of data that require advanced analytics; and (3) made the foundation of precision medicine.

Instead of developing treatments for populations and making the same medical decisions based on a few similar physical characteristics among patients, medicine has shifted toward prevention, personalization, and precision.

In this shift and cultural transformation, AI is the key technology that can bring this opportunity to everyday practice.

2. The dawn of practicing medicine

In previous centuries, healthcare has focused on working out generalized solutions that can treat the largest number of patients with similar symptoms. If cough syrup was good for the majority of the coughing masses and only a few people had a rash as an allergic reaction to it, there was no question about treating sore throat with cough syrup. Obtaining experience and empirical evidence on a generalized basis was the working method of the medical community since Hippocrates until around the beginning of the twentieth century.

With the refinement of diagnostic tools, the detection of viruses or bacteria, the development of new pharmaceuticals and medical methods, healthcare has been going through sweeping changes since the start of the last century. The experience-based and somewhat 'trial-and-error' approach of medicine made place for evidence-based medicine. As a consequence, physicians not only prescribed treatments because their ancestors also used the same methods, but they proved the efficacy of treatments and diagnostic methods in scientific papers and clinical studies. They mapped extensively why sore throat is best treated with cough syrup and started to analyze the side effects of it. People with an allergic reaction got to know that they should rather not use it, but turn to an alternative solution.

The challenge the twenty-first century has brought upon medicine is based on disruptive technologies [1]. Cheap genome sequencing, advanced biotechnology, health sensors patients use at home, and the collection of information about patients' journey in healthcare with hand-held devices have all been producing a vast amount of data. With the smartphone and health tracker revolutions under the name of digital health [2], it has become impossible for a physician to analyze all those data or simply to be up-to-date.

3. There is no precision medicine without AI

As the National Institutes of Health described it, precision medicine is 'an emerging approach for disease treatment and prevention that takes into account individual variability in genes, environment and lifestyle for each person.'[3] This approach allows doctors and researchers to predict more accurately which treatment and prevention strategies for a particular disease will work in which groups of people.

It requires significant computing power (supercomputers); algorithms that can learn by themselves at an unprecedented rate (deep learning); and generally, an approach that uses the cognitive capabilities of physicians on a new scale (AI).

The computing power of supercomputers has become a battleground for countries demonstrating their power through them [4]. Deep learning algorithms have been shown to make diagnoses at least as well as physicians in cardiology [5], dermatology [6], and oncology [7]. However, we need to emphasize the importance of combining such algorithms with the knowledge of physicians. In the grand challenge of the International Symposium on Biomedical Imaging, competitors created computational systems for detecting metastatic breast cancer in whole slide images of sentinel lymph node biopsies. The winner algorithm had a 92.5% success rate. When a pathologist independently reviewed the same images, the success rate was 96.6%. Combining the deep learning system's predictions with the human pathologist's diagnoses increased the pathologist's success rate to 99.5%, an approximately 85% reduction in human error rate [7].

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Table 1. A list of companies using a form of artificial intelligence to improve health care and/or medicine.

Company	Main area of research
Google DeepMind	Mining medical records
Verily	Wearable sensors
IBM Watson	Mining medical records
Careskore	Quality of care
Zephyr Health	Identifying therapies
Sentrian	Remote patient intelligence platform
3Scan	Radiology
Enlitic	Radiology
Arterys	Radiology
Atomwise	Drug development
Deep Genomics	Genomics

AI is divided broadly into three stages: artificial narrow intelligence (ANI), artificial general intelligence, and artificial super intelligence [8]. ANI is the most likely to appear in the next decade. ANI could analyze data sets, draw conclusions, find new correlations, and support physicians' job. There are companies that have demonstrated how supercomputers, deep learning, and ANI could support precision medicine (Table 1).

4. AI in clinical practice

A major application of AI in healthcare is collecting, storing, normalizing, and tracing data. The AI research branch of the search giant, Google, launched its DeepMind Health project, which is used to mine the data of medical records in order to provide better and faster health services. In 2016, they launched a cooperative project with the Moorfields Eye Hospital NHS Foundation Trust to improve eye treatment [9]. To investigate how technology could help to analyze eye scans, Moorfields shared a set of one million anonymized eye scans with DeepMind and some related anonymous information about eye condition and disease management.

IBM Watson launched its special program for oncologists to provide clinicians with evidence-based treatment options. Watson for Oncology has an advanced ability to analyze the meaning and context of structured and unstructured data in clinical notes and reports that may be critical to selecting a treatment pathway. Then by combining attributes from the patient's file with clinical expertise, external research, and data, the program identifies potential treatment plans for a patient [10].

IBM launched another program called Medical Sieve. It aims to build the next-generation 'cognitive assistant' with analytical, reasoning capabilities and a range of clinical knowledge. Medical Sieve is qualified to assist in clinical decision-making in radiology and cardiology. The 'cognitive health assistant' is able to analyze radiology images to spot and detect problems faster and more reliably [11]. In the future, radiologists might only have to look at the most complicated cases where human supervision is necessary.

A Dutch company, Zorgprisma Publiek, analyzes the digital invoices of hospitals and insurance companies and uses IBM Watson in the cloud to mine the data. They can tell if a doctor, clinic, or hospital makes mistakes repetitively in treating a certain type of condition in order to help them improve and avoid unnecessary hospitalization of patients [12].

Deep Genomics aims to identify patterns in large data sets of genetic information and medical records, looking for mutations and linkages to disease. They are working on a new generation of computational technologies that can tell physicians what will happen within a cell when DNA is altered by genetic variation, whether natural or therapeutic [13].

Regarding the development of pharmaceuticals, clinical trials take sometimes more than a decade and cost billions of dollars. Speeding this up and making it more cost-effective would have an enormous effect on today's health care and how innovations reach everyday medicine. Atomwise uses supercomputers that root out therapies from a database of molecular structures. In 2016, Atomwise launched a virtual search for safe, existing medicines that could be redesigned to treat the Ebola virus. They found two drugs predicted by the company's AI technology which may significantly reduce Ebola infectivity. This analysis, which typically would have taken months or years, was completed in less than 1 day [14].

Although the directions seem promising, all these companies need to demonstrate the efficacy of their method and the safety of ANI with peer-reviewed research, which many companies have still failed to do.

5. Is precision medicine the end of the human touch?

With advantages will also come ethical considerations and legal issues. Who is to blame if an AI system makes a false decision or prediction? Who will build in safety features? How will the economy respond to the appearance of AI when it starts making certain jobs useless? With driverless cars, there is a global debate about what decisions the algorithms would make in tricky situations. When it comes to health, this becomes a vastly bigger ethical challenge. There are more unanswered questions today than we can deal with and hopefully, with public discussions worldwide, this will clear up as AI is becoming a reality.

AI also has serious limitations in healthcare. Forecasting and prediction are mediated based on precedence in the case of machine learning, but algorithms can be underperforming in novel cases of drug side effects or treatment resistance where there is no prior example to build on. Hence, AI may not replace tacit knowledge that cannot be codified easily.

Nevertheless, precision medicine requires a myriad of disruptive technologies to be implemented into developing treatments, practicing medicine, and delivering care. However, data analysis, no matter how advanced it is, should support the skills of physicians and is not meant to replace the traditional physician–patient relationship. In order to keep the human touch in medicine in a way that the opportunities of treating the right people with the most personalized therapies are augmented, certain preparations might be useful:

(1) The creation of ethical standards about the use of AI which are applicable to and obligatory for the whole health-care sector. A similar example is how the German government created the world's first ethical guideline for the makers of autonomous cars. The

rules emphasize that human safety is always needs to be prioritized over protecting animals or property and always allow the human driver to supersede the program's decisions. However, the guideline admits that not every ethical decision can be standardized [15].

(2) The incrementally gradual development of AI, meaning that every step can be clearly evaluated before proceeding to the next level of development, to give time for mapping of the possible downsides and to build in fail-safe systems to prevent an AI apocalypse [16]. Independent bioethical research groups and institutions could monitor the process.

(3) For medical professionals, acquiring basic knowledge about how AI works in a medical setting in order to understand how such solutions will help them in their everyday job. While no AI is meant to replace physicians, those physicians who use AI might replace those who do not.

(4) For patients, getting accustomed to AI and discovering its benefits – e.g. with the help of CogniToys which supports the cognitive development of small children with the help of AI.

(5) For companies developing AI solutions, peer-reviewed research and clear communication toward the general public about the potential advantages and risks of using AI in medicine are needed.

(6) For decision-makers at healthcare institutions, doing all the necessary steps to be able to measure the success and the effectiveness of the system. It is also important to push companies toward offering affordable AI solutions since it is the only way to bring the promise of science fiction into reality and turn AI into the stethoscope of the twenty-first century. The US FDA already approved certain AI solutions with medical purposes [17].

Through the cultural transformation called digital health, the hierarchy of traditional medicine is transforming into an equal-level partnership between patients and caregivers. Besides many disruptive technologies, AI has the biggest potential to support this transition by analyzing the vast amounts of data patients and healthcare institutions record in every moment. By taking away the repetitive parts of a physician's job, it might lead to being able to spend more precious time with their patients, improving the human touch. However, AI can only fulfill its mission if it remains a safe, efficient, and proven aid in treating patients and improving healthcare.

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Declaration of interest

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