Medical Students' Osler Society and the Board of Curators of the Osler Library of the History of Medicine Essay Contest:

On the Cutting Edge: Artificial Intelligence in Medicine

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Introduction

In a world where computers have been integrated into daily life, we cannot exclude the prominent role they play in the medical field. The possible applications of technology in medicine are growing exponentially, as is the scope of what those technological innovations can accomplish; computers now possess the ability to store, process and analyze data on a scale beyond the abilities of individual clinicians, making diagnoses and providing prognoses of patients world-wide (3)(5)(14)(17). So how can physicians transform impersonal data into individualized service? The answer to this question is the key to converting data into practical knowledge.

Medicine is a field that nurtures meaningful connections between people as they grapple with profound life changes and challenges, and it is thought that artificial intelligence in medicine (AIM), will be a great asset to practicing professionals (3)(14). AIM is technology that uses data-science and mathematical algorithms to recognize patterns in order to generate meaningful predictions and outputs in medical practice (5)(14). However, many people believe that using these tools prevents the patient from forming a trusting relationship with their physician (2)(3). This essay will explore the history of Artificial Intelligence in Medicine (AIM) as it applies to various elements of medical practice, including determining diagnoses, providing prognoses, assessing clinician performance and, most importantly, ensuring quality of patient care and outcomes.

Applications of AIM

Larry Smarr, a leader in scientific computing and super-computing applications, states that it is essential to "go from a 'data poor' world to a 'data rich' world (17)." One person's body may

produce up to 1 trillion points of usable data; going from information as simple as weight, blood test results, personal DNA and data from the microbiome genome present on the human body. Dr. Smarr is building a platform dedicated solely to patient data, creating a data freeway system in which all information can be shared by hospital and academic facilities in the state of California; he hopes that one day, this system will expand to the rest of the United States, North America and the world (17). This would make AIM the primary source for retrieval of patient information (i.e. family history, medical history, existing conditions, results of previous tests, etc.), enabling the treating physician to access this information from anywhere in the world and rendering the healthcare system more efficient.

How can we effectively use this data if this information platform has been set up? AIM machines excel at logic, arithmetic and pattern recognition, using training data and historical results to create predictive outputs (17). The machines then use available data to allow for personalized medicine for both diagnosed and undiagnosed patients. For instance, when patients display symptoms of a certain disease, such as Inflammatory Bowel Disease or Crohn's disease, patterns shift in their genomes; machinery can analyze and compare these patterns to those in the genomes of healthy individuals, providing information for a diagnosis in a timely manner and without having the patient undergo invasive endoscopic procedures (17). Similarly, genomic pattern data can be applied to diagnosing conditions such as cancers, heart disease, infectious disease, and respiratory disease (3). This aids the physician in making important decisions regarding patient care and generating treatment plans.

Medicine uses an array of image- and graph-generating techniques such as X-rays, magnetic resonance imaging (MRI), ultrasound, computerized tomography (CT), positron emission tomography (PET), electroencephalography (EEG), and electrocardiography (ECG) (3)(6)(19).

AIM has the capacity to instantly recognize a pathological area on a scan or immediately interpret the graphs on an EEG or ECG. Sometimes, imaging data is complicated and certain pathologies can be easily missed by a physician; however, machines can be designed to process specific data and taught to reach appropriate conclusions. For this reason, AIM would make the processing of imaging data faster, easier and more reliable.

AIM can formulate new treatment plans or implement existing treatment plans (3). The machinery can be used in day-to-day care, by monitoring a patient's physiological condition or reminding a patient of when to take medication. Lastly, AIM can assist the clinician in making diagnoses, where an expert system can generate a list of diagnoses, ranking them from most probable to least probable, based on a patient's family history, medical history and symptoms. Through clinical trials, Lifecom, a medical information technology company, demonstrated that medical assistants using a diagnostic knowledge engine were 91% accurate *without using lab results, imaging, or exams* (10). So, if combined with supplementary tests, accuracy rates of AIM-based diagnosis can conceivably be even higher, presenting an advantage to both the patient and the treating physician.

Ethical and Social Challenges

Apprehension, worry and unease are a few words to describe a population's attitude towards utilizing AIM technology with patients, and so AIM, albeit promising, is controversial (2)(3). From a humanistic perspective, one could argue that medicine, a field embedded in the relationship between patient and physician, will lose its personal touch. The patient, rather than being treated as an individual, will increasingly be perceived as a sort of 'data point' from which information needs to be extracted and entered into a computer system for analysis. A more technical objection is that a patient data hub requires the existence of complete and up-to-date electronic medical

record systems, but many institutions around the world have yet to collect and compile all their data in an accessible online platform (17). From a research and medical ethics standpoint, AIM machines will face the added challenge of making their data reproducible and open to auditing while maintaining patient privacy (2). These many legitimate concerns may lead one to think that it is preferable to continue relying on health professionals than to apply AIM in healthcare settings.

In 1989, the Agency for Health Care and Research quality described numerous crisis points in the field, including "ceaselessly escalating healthcare costs, wide variations in medical practice patterns, evidence that some health services are of little or no value, and claims that various kinds of financial, educational, and organizational incentives can reduce inappropriate utilization (4)." However, more than 25 years later, the same problems still exist.

In 1990, the term 'Evidence Based Medicine' (EBM) was coined at McMaster University. EBM by definition is the application of scientific methodology to determine the optimal management of an individual patient, and so it falls under the umbrella of AIM (18). EBM has been incorporated into medical practice, but it does not exist without its challenges. In order to employ EBM properly and efficiently and ensure accurate data collection, strict clinical guidelines need to be followed, beyond the biases of individual researchers and influence of biomedical companies. Furthermore, quality evidence is either lacking or non-existent in many domains, so practicing clinicians often depend either on low quality evidence or expert opinion, both of which are suboptimal (4). Steven Hatch, in his book *Snow Ball in a Blizzard*, states that "in reality, doctors are just making guesses based on evidence they have—a measuring of risks and benefits and probabilities that are easily influenced by perceptions (8)." For this reason, if our data collection skills are optimized, patients can be treated in an efficient manner according to their condition, while minimizing adverse effects.

Machines and technology can be unpredictable: computers are vulnerable to internal malfunctions and external infiltration (2). Hence, both the treating physician and the patient are susceptible to identity theft. Precautions and proper protocols need to be put in place for any hardware glitches or hacking incidents. As computers and algorithms begin to diagnose patients, assuming some of the physician's traditional roles, questions about liability emerge (2). It becomes unclear who, or what, can be held legally responsible for the decisions made: is it the machine that supplies the data or the medical professional who interprets it? Such legal and ethical conundrums need to be resolved, and corresponding regulatory bodies and laws need to be introduced, *before* these technologies are implemented. As a prime example, Arvind Narayanan and Vitaly Shmatikov at the University of Texas were able to de-anonymize data provided from Netflix (12). In this case, the de-anonymized data revealed political affiliations, sexual orientation, BMI, market data and other such personal information that current legal standards would deem unacceptable to be released without consent (12). Nayanan mentioned "given a user's public IMDb ratings, which the user posted voluntarily to selectively reveal some of his (or her; but we'll use the male pronoun without loss of generality) movie likes and dislikes, we discover all the ratings that he entered privately into the Netflix system, presumably expecting that they will remain private (12)," This shows that data anonymity cannot be guaranteed and that any online receptacle is vulnerable to invasions of privacy (1)(12)(15).

Threats to the integrity of the data are another danger of electronic data banks. In the field of medicine, the smallest inaccuracy may cost the health and lives of many, and error can be introduced into the system by even the best trained and most well-intentioned users. If this error goes unnoticed, the consequences can accumulate. Mistake can build upon mistake, resulting in adverse effects for both the patient and treating physician.

The possibility of user error raises a third point: the need for continuous and comprehensive training (2). This requires the participation of trained professionals willing to teach and receptive medical practitioners willing to learn and change their way of practicing medicine. Additionally, institutions must have the funding and infrastructure to maintain and upgrade equipment, as well as monitor and test the software.

Lastly, one must overcome the medical culture present now in order to be able to apply AI in healthcare (4). The technology is present, but it is not yet being utilized in hospitals. Once there is a willingness to use AI in healthcare, then next-generation medicine will be born.

Impact on Patients

Approximately 98,000 patients die per year from in-hospital preventable harm, and in 2008-2011, more than 400,000 patients died of preventable harm in the United States (9)(11). These numbers are alarming, especially when these patients are lost mostly due to iatrogenic harm such as nosocomial infections, diagnostic errors, surgical complications, decubitus ulcers and even falls. Disturbingly, it is even stated that "the average U.S. patient is expected to be harmed by diagnostic errors at some point in [his or her] treatment (4)." If these errors can be minimized by having reliable data, then many patients can be protected from unnecessary harm; for if there is a better way of being able to collect, measure and store data, then there is a better way of improving EBM and, ultimately, a patient's quality of treatment.

Moving forward with this technology will reduce the chance of unnecessary diagnoses, the number of complications, and time spent in hospitals, while providing personalized medicine treatment options and increasing the healthcare system's efficiency (4). AIM can leverage large data sets from previous patients with similar conditions to help decide how to properly treat a patient, thus

providing personalized medicine to each patient. Machines provide consistent performance, without the fatigue, preconceived notions, and subjective emotional states that may affect a person's day-to-day judgement.

In my opinion, technology can also help engage patients in their personal care. How many of us have lifted our phones or opened our computers to google our symptoms and figure out what's wrong with our health? How many of us have needed instantaneous access to a medical professional's opinion during a time of mental or physical distress? How many of us have wished we didn't feel so helpless when a loved one experienced some kind of a crisis? With this technology and data made available, such information can be accessed instantaneously via secure and certified apps. If patients feel in control of their health, they will take on a more proactive role in their personal care.

Impact on Physicians

Sholom Glouberman, president of the Patients Association of Canada, has commented that "The instruments have got so powerful that doctors don't talk to patients, they order tests (16)." This is quite an alarming thought. Technology and medicine are fields that intersect on many different levels, but one must not forget that a healer's primary role is to make a patient feel genuinely cared for. There is a fear that with fast access to a patient's complete medical record, physicians will no longer strive to cultivate connections with their patients. Hence the main challenge to overcome is for doctors to maintain their caring disposition while learning how to work with new technologies.

With the presence of technology capable of diagnosing and treating a patient's symptoms, doctors may feel inadequate or superfluous and lose confidence in their own judgement and abilities.

Medical training requires considerable time, effort and resources. If the medical professional only feels like an extension of the technology, and not as the main care provider, then he or she will lose passion for their work. However, it is my opinion that technology will create a new niche for doctors with a new kind of training. Medical professionals will still fulfill their calling to help heal patients, but it will be in a different way. It is my belief that new technologies will make doctors more efficient in their jobs. In the future, greater reliance on computer-based diagnostics may relieve physicians of considerable time and stress, leaving them with more, rather than fewer, opportunities to express their care and empathy for their patients.

Final Words

Atul Gawande wrote "The important question isn't how to keep bad physicians from harming patients; it's how to keep good physicians from harming patients (7)." This has been the goal of AIM, to develop knowledge using the aid of experts and machines (5). What began as a simple aid to clinical encounters has since evolved into specific functions used in clinical laboratories, educational institutions and clinical surveillance. However, with medicine and technology becoming intimately attached, it must not be forgotten that medicine is a field strongly anchored in humility and empathy towards the self and all others, and it must remain that way. Healing patients does not occur solely through machine-aided diagnoses or drug prescriptions; it must also encompass the healing power that only human interaction can provide. As the future brings this technology to hospitals, schools, clinics and hospices, doctors must remember to only use the information provided as an aid to help prevent them from making mistakes or overlooking symptoms. Even though these machines can often provide a justification for their decision trees and recommendations, they are only tools in the hands of the practitioner; ultimately, as enshrined in the Hippocratic Oath, it is the physician who is responsible for the patient's health and

wellbeing. Moving forward, this will become more and more important as platforms such as Lifecom appear and technology increasingly mediates the patient-doctor relationship. Even though this technology is powerful, there are some drawbacks. First and foremost, there is not a large enough dataset at present to equip machines with comprehensive decision-making capability. In the future, this may change, but for now it must be noted that doctors cannot rely on these machines until more information becomes available. Computer literacy may also be an issue: staying on the bleeding edge of scientific advances in the medical field while trying to master a machine learning interface, in the midst of full-time practice, is a tall order (2)(3)(14). Computer literacy in hospital clinics and other locations is important, but the time for this training may not be available and it will be increasingly challenging to be the best possible doctor while trying to keep up with patients, scientific advances and shifting moral and cultural landscapes. While a harbinger of many benefits, AIM also carries the risk of privacy invasion on a massive scale. This data will be vulnerable to attacks, leaks and general de-anonymizing. Even though measures can be taken to protect the public, it should be expected that these security systems will fail (1)(12).

If used correctly, I believe AIM can allow a physician more time to be in touch with his patients, informed on the newest medical techniques and observations all the while increasing the quality of health care. Patients need to have a close relationship with their physicians in order to properly heal, and physicians need to have a close relationship with their patients in order to know how to alleviate their health struggles. We must accept that as our lives are becoming more integrated with technology, they become more exposed as well. As Scott McNealy, co-founder of the computer technology company Sun Microsystems, put it, "You have zero privacy, get over it (13)."

Medical practitioners should not forget that they are treating people who are struggling with difficult life situations, and always keep in mind the profound words of Dr. William Osler: “The

good physician treats the disease; the great physician treats the patient who has the disease." We have now arrived at a point where we can make it easier to treat the disease, while the practicing physician can focus on treating the patient.

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