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POSITION PAPER

TRAINING FOR THE FUTURE: PREPARING MEDICAL STUDENTS FOR THE IMPACT OF ARTIFICIAL INTELLIGENCE

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INTRODUCTION

Through the long arc of human history, technology has served as a driver for change. While the social role of a healer has existed for millennia (e.g. prehistoric shamans appealing to spirits), humans have only been able to apply technology to cure at scale over the last century owing to the invention and adoption of diagnostic investigations, pharmaceuticals, and modern surgical techniques. Today, emerging technologies of the such as artificial intelligence, gene editing, nanotechnology, and the blockchain are being explored as ways to fundamentally "disrupt" medicine and healthcare.

Despite the promises of such technologies, implementing this kind of disruption has presented countless unintended challenges. The large-scale adoption of electronic medical records in particular have tempered the expectations of health care providers of the transformative capacity of emerging technologies. Technology intended to empower better care for patients ended up achieving the converse: removing physicians from their patients. In his recent *New Yorker* piece, Atul Gawande outlines a rise in physician burnout linked with an increase in time spent interacting with computers doing clerical duties as opposed to caring for patients.[1] These sentiments fit within a broader societal backlash against "big tech", and points to the unique challenges of technological transformation in health. This backlash can be, in part, traced back to the technology industry's mantra to "move fast and break things." By seeking to 'disrupt' inefficiencies across various aspects of society without putting attention into social consequences, the industry has been accused of creating an epidemic of digital addiction, monopolizing access to information, and even compromising democracy.[2] Given, first and foremost, the Hippocratic duties of healthcare providers to 'do no harm', it is essential that the role of these emerging technologies in medicine is carefully scrutinized by practitioners that understand and can think critically about them.

Artificial intelligence (AI) presents itself as the new technology poised to transform healthcare. AI can be broadly defined as the ability for a machine to perform human-like tasks after learning from experience. The backbone of contemporary AI, known as machine learning, is the algorithmic training of a machine to predict appropriate outputs given an input, following training on large datasets.[3] AI models can be trained without explicit instructions, and their predictions can be generated without humanly-intelligible or rational explanation.[4] AI has been applied to medicine in a variety of categories, including natural language processing, signal processing, administrative task management, and computer vision. Several impressive AI applications have occurred in the area of computer vision, where machines trained to detect melanoma have demonstrated greater diagnostic accuracy compared to a team of expert

clinicians.[5] Elsewhere, AI has been used to more detect patterns in patients' electrocardiogram tests and cognitive decline through analyses of speech patterns.[6,7] These AI applications showcase the capability of these algorithms in identifying patterns in massive volumes of data, often outperforming human cognition alone.

The promise surrounding AI's application to medicine is evident among both practitioners and patients. In a 2018 survey of 500 Americans by the global analytics company SAS, 60% of respondents said they were comfortable with clinicians using AI to analyze their medical treatment to formulate treatment plans; 61% were comfortable with their healthcare providers accessing health data from wearable devices such as smart watches; and 52% of respondents over age 40 were willing to undergo AI-assisted surgery (interestingly, only 40% of respondents under 40 felt the same).[8] Despite the excitement, less than half of all respondents said they could explain AI to a friend or colleague.[8] This demonstrates the clear discordance between patient education and patient enthusiasm. In spite of this discordance, at the system level, US healthcare organizations have been quick to incorporate AI into many processes. According to a 2017 report by consulting company Accenture, 42% of surveyed US healthcare firms are using machine learning in their business workflows, thereby leveraging AI's suitability for administrative tasks.[9] Therefore, while AI may seem like a new force within medicine to some, it is already being widely explored.

However, patient and practitioner enthusiasm does not mean there is a lack of concern over data privacy. Patients worry about how safely their data are being stored and used. In the same SAS survey, only 35% of respondents felt confident that their personal data was being stored securely by industry.[8] Given major news stories regarding data breaches and abuse of consumer data, such as the Cambridge Analytica scandal, this reservation is understandable.[10] With the increase of public understanding on how their personal data is being used, it will become increasingly pressing to develop fair regulation surrounding data use for AI. If physicians are to use AI applications, it will be in the best interest of patients to share the responsibility of developing such systems.

In response to excitement from venture capitalists, entrepreneurs, researchers, patients, and politicians, physician leadership groups are recognizing the importance of AI. In 2017, the Canadian Medical Association (CMA) began overhauling its Code of Ethics to, in part, account for the impact of disruptive technologies such as AI.[11] In August 2018, the CMA hosted its inaugural Health Summit to convene stakeholders and discuss opportunities for innovating within the Canadian healthcare system. Like the American Medical Association (AMA), the CMA also adopted the term of "augmented intelligence", explicitly framing artificial intelligence as a method to complement human decision making capabilities.[11] The CMA also provided a set of action items for moving forward such as: involving clinicians in the design of technical solutions, seeking clinician feedback about the impact of AI in their clinical setting, making recommendations to governments and technology providers to address gaps and concerns, and to provide guidance to help uptake and regulate new technologies.[12] Finally, the CMA is actively conducting research around public opinion. Results of a survey regarding attitudes around health technology among roughly 2000 Canadians were released in August 2018. Notably, they found that 6/10 Canadians are excited about the impact AI can have in healthcare and trust these systems more when delivered by a physician.[13]

Despite interest from leadership bodies about the role of artificial intelligence in medical education, gaps exist. A study in NPJ Digital Medicine in September 2018 examining the number of papers in PubMed with MeSH terms such as "machine learning" and "medical education" found that while the number of machine learning papers has grown rapidly since 2010, a combined search for "machine learning" and "medical education" only returned sixteen papers. Upon further examination, none of those sixteen papers were focused on education around machine learning for medical professionals.[14]

Despite substantial academic interest and industry investment across sectors (see Figure 1 & Figure 2), the integration of AI into clinical medicine is still in its nascent state. In 2017, nearly 100% of healthcare delivered in the United States was done without any AI component.[15] But given the described breakthroughs in medical research, the public's willingness to receive AI-incorporated medicine, and the large amount of investment placed in AI applications in healthcare, it can be argued that we are on the

verge of an AI revolution in medicine. Accenture forecasted that the AI health market in the US will grow to $6.6 billion by 2021.[9] Even if one believes that we are headed towards more AI integration into healthcare, some may say that it is too early to begin training future clinicians to use such tools. We argue that given the long training path of Canadian medical trainees, with roughly fours years in undergraduate training followed by often five in residency, now is the time to begin training our future physicians to build AI competencies. Given the high number of hours required to build clinical expertise in clerkship and beyond, we argue that preclerkship education must include such competencies. Currently, there is a lack of education surrounding AI in medicine at medical schools across Canada, both at the curriculum and peer-to-peer level*. What follows is a framework by which this can be done.

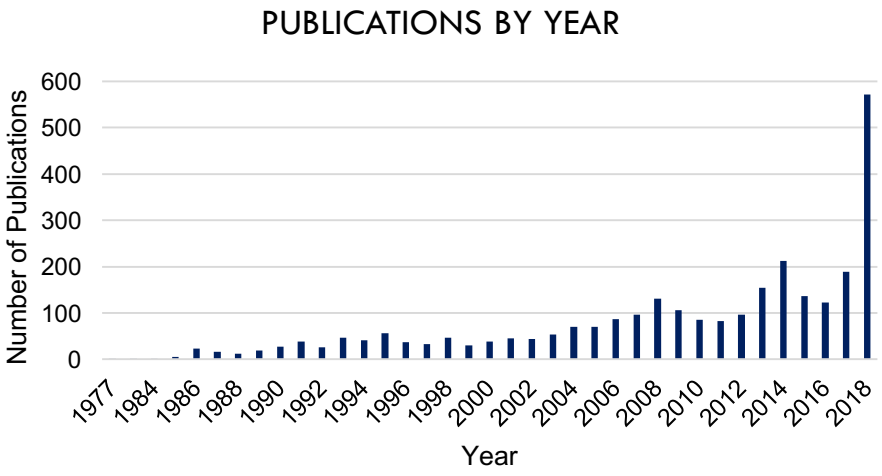

Figure 1. Pubmed searches for “artificial intelligence” AND “medicine” over time.

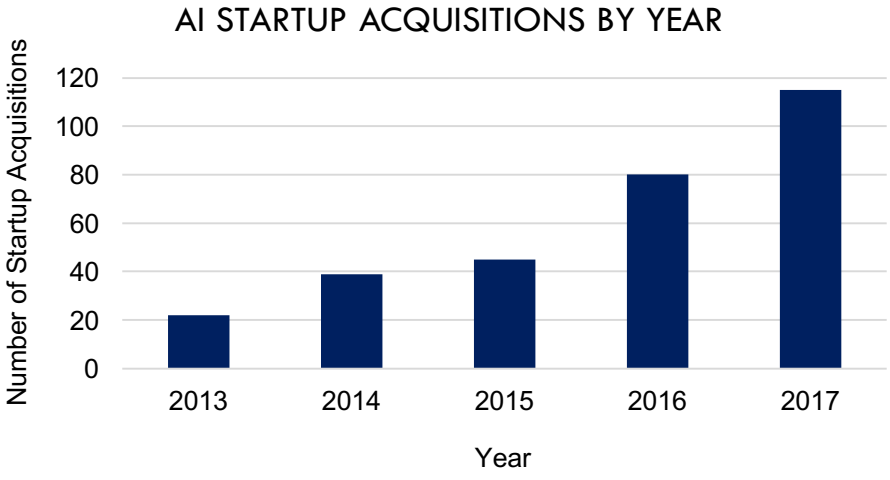

Figure 2. Increase in AI startup acquisitions over recent years. (Figure adapted from: CB Insights. *The Race for AI: Google, Intel, Apple In a Rush To Grab Artificial intelligence Startups.* 2018).[16]

PROBLEM STATEMENT

AI is poised to introduce significant changes to medicine and healthcare. Physicians will be expected to navigate these changes and utilize new technologies in a competent and ethical manner.[17] Currently, curricular and extracurricular opportunities addressing AI in medicine across Ontario medical schools are sparse or nonexistent. The Medical Council of Canada (MCC) does not have any objectives that specifically address AI and other relevant topics such as statistics, technology, and machine learning, which highlights the lack of formalized education pertaining to AI.[18] Failing to prepare future physicians to respond and adapt to novel AI applications in medicine may lead to dire consequences including but not limited to decreased quality of care, exploitation of patient data, and widened health disparities.[19,20] It is crucial that physicians, as patient advocates, are equipped with the skills and knowledge base to be a voice in the evolving dialogue surrounding the integration of AI into healthcare.

We characterize the shortage of AI education within Ontario medical education as an issue with three primary components. Firstly, there are no official curricular opportunities addressing the future impact of AI on the medical profession. Second, there are, as a result, no curricular opportunities to educate Ontario medical students on the ethical and societal implications of AI and prepare them to be future advocates of safe and ethical AI technologies. Finally, there are few designated extracurricular opportunities at Ontario medical schools for students to further explore and understand AI as an emerging force in healthcare.

PRINCIPLES

1. Given the significant and growing private and public investment in AI, as well as patient and physician enthusiasm to participate in AI-integrated healthcare, there is a pressing need to educate future physicians in AI competencies.

2. Given the long training of Canadian medical students prior to becoming licensed physicians, the diminishing time for activities outside of clinical practice in clerkship and beyond, and the high likelihood of AI applications to become increasingly present in healthcare, medical students should be educated in AI concepts in preclerkship training. This should be delivered through curricular and extracurricular pathways.

3. As future physicians accountable to their communities and patients, Ontario medical students should be prepared to become stakeholders in discussions on AI in medicine. They should be competent in understanding this space and confident in navigating it. The CanMED roles of Advocate, Leader, and Medical Expert need to be maintained as technology will inevitably change the field of medicine.

RECOMMENDATIONS

1. Introduce and advance education on how AI is impacting the medical profession.

Medical schools should adapt their curriculum to address the changing career landscape for future physicians. Students and medical educators alike should advocate to introduce AI application competencies within the existing curricula.

MEDICAL SCHOOL LEARNING OBJECTIVES FOR AI IN MEDICINE

With numerous potential roles for AI in medical practice, it is important to determine a set of core learning objectives that will be most beneficial for students.[21] The emphasis should not be on training medical students to have a deep understanding of the computer science underlying AI algorithms, but rather upon developing understanding of the impacts these tools will have on the delivery of healthcare. It is important to have a practical awareness of the ways such tools may integrate into

healthcare teams, and an understanding of their conceptual strengths and limitations.[22] Research has shown that "centaurs" (integrated teams incorporating both artificial and human intelligence) can outperform humans or machines alone in cognitive tasks.[23] A central focus of AI-conscious medical education should be placed around ensuring that students can work effectively in concert with - rather than adjacent to - these tools, in order to improve performance and patient outcomes.

AI COMPETENCIES FOR COMMUNICATION

It is crucial for physicians to have an adequate understanding of the tools they are working with. In addition to having the ability to effectively use these tools, physicians must be able to effectively communicate with patients about the impact of emerging technologies upon care. With increasing adoption of artificial intelligence within healthcare upon the horizon, medical education must adapt to ensure that future physicians can adequately fulfil this aspect of the communicator role.[21] Many physicians already express discomfort with their understanding of statistics, and their ability to accurately and adequately communicate the meaning of predictive risk and benefit values to their patients.[24] Given the central importance of statistical methods to both the inputs and outputs of AI-based prediction machines, this deficit could be amplified if it is not adequately addressed. A physician must not only be able to explain to the patient what the AI-based tool says, but they must further be able to clarify its meaning in the context of the patient's situation and care.

PREPARE FOR A CHANGING PROFESSIONAL LANDSCAPE

It is the role of medical education to not only impart clinical knowledge but also prepare future physicians for the societal issues that will most directly impact their careers. AI applications shaping up to be a pertinent discussion AI applications have outperformed experienced physicians in diagnostic tasks spanning dermatology, ophthalmology, pathology, oncology, and radiology.[21] This can easily lead to an attitude of anxiety amongst medical students towards AI as a threat to their careers. A comprehensive analysis by the Oxford Martin School of 700 professions, physicians and surgeons are ranked as the 15th least likely jobs to be automated.[25] Even specialties purported to be more susceptible to AI applications, such as radiology are low on the list, at 218 out of 700. On the contrary, AI offers a myriad of benefits including lowering healthcare costs and decreasing administrative burden. Navigating this interface between medicine and technology ethically and effectively is not straight forward. Healthcare will become increasingly dependent on large data sets from a multitude of sources and various AI tools.[24] Future physicians must be able to screen and utilize these tools as well as extract and communicate the meaning behind large data sets to patients. Some even conceptualize the formation of a new data-science medical specialty, or the evolution of radiology or pathology training pathways to fill this role.[26] In a multi-centered survey of medical students, students educated in technology were more confident in the benefits of AI and less fearful of its risks.[27] Thus, it is crucial for medical education to dispel the unproductive fears and myths surrounding AI technology in healthcare and prepare future physicians to harness its benefits and become competent practitioners in a data-rich environment.

2. **Introduce and maintain the uptake of education on the ethical and societal implications of AI, especially as they relate to healthcare**.

Schools of medicine, which all bear a commitment to promoting health equity, ought to be active agents endorsing the safe and ethical development of AI in medicine. As such, they must empower students to advocate for the equitable development and distribution of these technologies.

DATA AND ALGORITHMIC BIAS

It is essential to ensure that the performance of AI applications is equitably effective for all patient populations. Due to aspects of algorithmic structure, or the desire of developers to protect trade secrets, certain AI applications function as "black boxes", processing inputs and generating outputs without a clear explanation of the "Point A to Point B" process. Such algorithms may act to perpetuate

existing implicit biases, or introduce new biases of their own, in subtle ways that are not easily interrogated or understood. For programs that incorporate machine learning - the ability to "learn" from data and improve their performance on specific tasks in ways that are not explicitly programmed - the representativeness of input data is important. For example, a melanoma detection AI application primarily trained on lighter-skinned images may demonstrate poorer performance when used on darker-skinned patients.[27] The issue of non-representative data informing decision making has permeated medicine before- clinical trials have often included homogenous populations and been applied, perhaps inappropriately, to broader populations.[28] AI raises this concern once again, and as AI applications come to influence clinical decisions these tools may serve to propagate historical biases.

PRIVACY AND DATA OWNERSHIP

Machine learning depends heavily upon the presence of large volumes of input data, incorporating as many relevant factors about a patient as possible, often gathered from electronic patient records. Existing challenges related to the recording and use of patient data are compounded in the environment of AI projects. Vulnerable populations with stigmatized conditions - such as HIV positive individuals - may be particularly likely to fear the prospect of a data breach (accidental or malicious) or the failure of anonymization methods.[29] Sensitive information in the hands of employers, insurers, etc may carry significant consequences for patients, specifically those from vulnerable populations.[30] Health inequities can thus be furthered by the self-exclusion of such populations from datasets.[29] Physicians have the responsibility of effectively communicating the implication of patients' participation in the development and use of artificially intelligent healthcare tools. Existing health sciences research curricula can be extended to encompass this new field of research, and include the specific considerations that AI research might entail for research participants. More broadly, medical professionals must act as stewards of this data, recognize and declare conflicts of interest, and advocate for enforcement and enhancement of data privacy and protection within their institutions and health systems.

DISPARITIES IN ACCESS TO AI APPLICATIONS

As the integration of AI in medicine advances, it is important to remain vigilant regarding who benefits from these technologies and which populations may be excluded resulting in the deepening of existing health inequities. This phenomenon has been identified and discussed previously as the 'digital divide', which AI may serve to exacerbate.[30] There are several mechanisms by which this may occur. First, AI applications themselves require significant infrastructure, such as internet access, electronic medical records, and computing power, all of which have significant associated costs.[31,32] This may make them inaccessible to those in regions of lower income, such as developing nations, or where there are environmental limitations, such as rural and remote areas. Next, AI applications require a degree of computer and health literacy to operate, both on the part of health care providers and patients (such as in the case of direct to patient applications like chatbots). There is concern that this might leave out populations with less opportunities to acquire computer and health literacy from successfully using AI applications, such as the elderly or those without access to education.[31] Finally, one of the most common applications of AI in healthcare are clinical decision support systems. These systems, however, rely on complete electronic medical record data to make accurate predictions. People from vulnerable populations may be disadvantaged by incomplete records, either due to a lack of consistent providers, loss to follow-up, or withholding information from providers due to lack of trust.[29] This lack of trust in the medical system may be due to historical precedent (e.g. indigenous populations) or a lack of comfort in sharing information (e.g. some trans populations, people with mental health conditions).

Medical students have a responsibility to advocate for the equitable distribution of these technologies to prevent adverse downstream impacts of AI on population health equity. Learning about potential disparities in access to AI applications in the classroom will raise awareness of these issues, and allow medical students to advocate for vulnerable populations now and as they progress through their training. In addition to learning about these disparities, they should also be provided with strategies to

mitigate them. For example, it is important to be able to explain to patients the importance of a complete electronic medical record for CDS systems to provide the best predictions. This can be complemented by counselling around the importance of not withholding information or missing appointments, and creating spaces where patients are comfortable to share information.

3. **Form student groups that facilitate exploration around the design and implementation of AI in healthcare**.

Speaker series, discussions, and other forms of peer-to-peer knowledge transfer can develop meaningful bridges between technical and medical communities (e.g. AI research institutes, health technology startups, etc.). These efforts should (1) foster conversation in medical schools on the challenges and opportunities of AI in medicine, and (2) develop hubs for personal and professional opportunities for students.

STUDENT GROUPS OFFER STUDENTS OPPORTUNITY TO DISCUSS THE FUTURE OF MEDICINE

The profession of medicine in Canada is self-regulated in that physicians take ownership of their profession. We are a part of a "social contract" where we must uphold our duty to our patients and profession. With technological improvement and rapid innovation that may change the practice of medicine, physicians must ensure that this remains the case. Innovation led by industry may lead to unacceptable risks, as the free-market may not prioritize patient interests. Involvement at early-stages of training will empower future physicians to stay informed and ensure that new technology upholds our responsibilities towards our patients. Considering recent examples where corporations are involved in health, there are clear cases where maintaining patient rights and ensuring an evidence-based approach are forgone for profit-seeking. Theranos is a former blood-testing company that is infamous for defrauding investors with technology that did not do what it promised.[33] Not only was this a corporate crime, but it led to patient agony, as patients were given false blood results that led to changes in treatment and were not told about this for months.[33] Student groups will empower students to be critical about new technology. This type of knowledge is necessary because as future practitioners, we must build and think for the future.

Another advantage that student groups provide is that they allow for extensive interdisciplinary thinking and cross-pollination of ideas. Interdisciplinary research is on the rise with more and more disciplines citing work outside of their fields.[34] Health research has grown to be very interdisciplinary due to the incorporation of broad fields such as public health and social aspects of health. At the University of Toronto alone, eight new AI research chairs have been appointed in the fields of computer science, statistical science, medicine, molecular genetics, and rehabilitation sciences.[35] Our nation's leading AI institutes all boast faculty members with cross-appointments across their affiliated universities. This speaks to the interdisciplinary nature of AI and the importance of bringing together perspectives from multiple disciplines. Starting this process early in training is critical. At the University of Toronto, for example, the Artificial Intelligence in Medicine Student Society (AiMSS) organizes multiple speaker sessions throughout the year. The events aim to bring together people from a variety of different disciplines within and outside of clinical medicine. The role that students can play in preparing their peers has largely been neglected, but student-led interprofessional collaboration can yield significant benefits.[36] Student groups such as AiMSS provide opportunities for interprofessional and interdisciplinary collaboration in this space. Not only can ideas be exchanged, but they can be launching pads for innovation.

STUDENT GROUPS CAN SERVE AS HUBS FOR PERSONAL AND PROFESSIONAL OPPORTUNITIES FOR STUDENTS

Beyond student groups as a means of exchanging ideas, medical student groups can actively participate in guiding the development of AI applications in the best interest of patients. As venture capital funding given to teams working on healthcare problems has increased exponentially over the

last year, there is an increasing opportunity for medical students to get involved.[37] In fact, media sources have taken note of the growing number of medical students and physicians in the United States who conduct some form of consultory or management work for startup businesses.[38] Here in Canada, the MaRS Discovery District in Toronto currently houses a total of 51 ventures in health targeted towards solutions in biotech and pharma, wellness, digital health, and medical devices and diagnostics.[39] We believe that while medical students are engaging in experiences outside of clinical medicine, this kind of intellectual and cultural crosstalk is critical for the development of improved medical technology. There is a growing body of evidence in various domains, mainly in policy-development, suggesting the importance of front-line staff in agenda-setting in systems change.[40] Whether this be in the public policymaking realm, or in the world of technological development, there is an opportunity for medical students to shape the agenda of medical technology towards clinically-relevant products.

Additionally, through student groups, medical students may facilitate opportunities to build management, leadership, and organizational experience critical for future professional success. In Canada, great emphasis has been placed in the last few years on the growth and development of "non-medical expert" CanMEDs competencies, such as the "Leader" competency. Practical experiences in organizations working towards medical problems can help support students in developing critical leadership competencies, particularly in working with interdisciplinary teams to produce a product. There has been growing interest in similar kinds of programs offered through medical schools in innovation & entrepreneurship in the United States that lead us to believe the value of practical industry experience in undergraduate medical education.[41] Some students have also outlined their experiences in building these skills practically in startups.[42] Overall, this is an opportunity for students at scale to guide startups, and build these experiences in tandem.[39] Student groups can source these opportunities for medical students to support one another's personal and professional development.

CONCLUSION

In conclusion, we believe that the role of AI in undergraduate medical education is not about specific forecasting or training around a single tool. It is about providing an understanding of a set of technologies and design mindsets that stand to permeate many dimensions of the healthcare landscape. As Dr. David Naylor, Interim CEO of The Hospital for Sick Children, and former Dean of the University of Toronto Faculty of Medicine recently noted, AI will "have the capacity to learn from hundreds of thousands of [cases] and correct over time as more information comes in...That's pretty hard to beat in terms of its capacity to improve health care".[43]

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