Artificial Intelligence, Machine Learning and the potential impacts on the practice of Family Medicine: A briefing document.

Ross Upshur. BA(Hons.), MA, MD, MSc, MCFP, FRCPC

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Prepared by:

Ross Upshur. BA(Hons.), MA, MD, MSc, MCFP, FRCPC

Professor, Department of Family and Community Medicine and Dalla Lana School of Public Health
Dalla Lana Chair in Clinical Public Health
Head, Division of Clinical Public Health, Dalla Lana School of Public Health
University of Toronto
Scientific Director, Bridgepoint Collaboratory for Research and Innovation
Associate Director, Lunenfeld Tanenbaum Research Institute,
Sinai Health System, Toronto

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Doctors as we now know them will become obsolete eventually. In the meantime, we should expect stepwise introduction of AI technology in promising areas, such as image analysis or pattern recognition, followed by proof of concept and demonstration of added value for patients and society. This will lead to broader use of AI in more specialties and, sooner than we think, human doctors will merely assist AI systems. These systems will not be perfect, but they will be constantly perfecting themselves and will outperform human physicians in many ways.

Jörg Goldhahn, 2018 [1]

As with the EMR, there are legitimate concerns that artificial intelligence applications might jeopardize critical social interactions between colleagues and with the patient, affecting the lived experiences of both groups. But concerns about physician "unemployment" and "de-skilling" are overblown. In the same manner that automated blood pressure measurement and automated blood cell counts freed clinicians from some tasks, artificial intelligence could bring back meaning and purpose in the practice of medicine while providing new levels of efficiency and accuracy. Physicians must proactively guide, oversee, and monitor the adoption of artificial intelligence as a partner in patient care.

Abraham Verghese et al. 2017 [2]

Introduction

In 1996, the College of Family Physicians of Canada launched the Janus Project in part to assist family physician's meet the needs of "tomorrow's society". The College was concerned with transformation and providing practicing family physicians with appropriate skills and opportunities for growth. Remaining static and relying on established modes of practice and education would no doubt poorly serve the discipline.

Janus is an ancient Roman God, renowned for being represented as having two faces. The two faces are commonly interpreted as being forward looking to the future and backward facing to the past. Janus also symbolizes transitions, the passage of time and beginnings and endings. Janus represents duality, the way in which an entity can be two things simultaneously: a threat or an opportunity, a weakness or strength.

Modern information technology, in its multiple guises, represents precisely this type of duality. Claims have been made that it will liberate clinicians from drudgery and free them to focus on the humanistic elements of care thus putting clinical practice back in touch with its historical roots as a healing profession. Access to large volumes of data, spanning from molecular biology to population health will transform our capacity to accurately diagnose and prognosticate, uncover new treatments, risks for disease and ill health and inform new models of care. It is not difficult to find accounts in the popular media of the exceptional impact predicted for these new technologies. In this interpretation, the new technologies are seen as the dawn of new possibilities.

There is another side to this story, one that sees the potential for new technologies to displace human labour and initiate regimes of workplace surveillance and productivity measurement. Some technology developers are explicit in their ambitions to supplant human agents, particularly physicians, through modalities of virtual care supported with advanced artificial intelligence and machine learning. In this interpretation, we may be witness to the end of an era of a type of medical practice.

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[1] Goldhahn J. ***Could artificial intelligence make doctors obsolete?*** https://www.bmj.com/content/363/bmj.k4563
[2] Verghese A., et al. ***What this computer needs is a physician: humanism and artificial intelligence***
https://jamanetwork.com/journals/jama/fullarticle/2666717

At this stage, it is not possible to predict which direction the new technologies will take family medicine, but this paper is premised on the acknowledgement that current technology is very likely to effect a significant change in the practice of family medicine. The purpose of this paper is not to argue that this is necessarily a good or a bad thing but to set the stage for leaders in family medicine to prepare themselves, the profession and the patients and the communities they serve for the changes to come.

This paper is also premised on the fact that the situation is highly dynamic, poorly regulated and near impossible to keep abreast of. Evidence of the harms and benefits of these technologies is sparse. In what follows I will outline briefly some of the major types of technology that will likely impinge on family medicine. Specific focus will be placed on big data, artificial intelligence and machine learning. These are three related components that undergird the development of web-based and mobile applications in health care. Suggested readings are found at the end of the paper.

The approach taken in this paper is largely narrative. It is informed by a study funded by the Canadian Institutes for Health Research on ethical issues in artificial intelligence as well as wide reading of major reports published by reputable organizations. It is therefore not a systematic review, but closer to an evidence synthesis or rapid scoping review. The author takes full responsibility for all acts of omission and commission. The overarching objective of the paper is to stimulate thought among the leaders of the College of Family Physicians of Canada.

Types of Technology: Definitions

The early 21st Century has witnessed the advent of the digital age. Computer technology has rapidly evolved over the past few decades with increases in the volume of data production and increasing processing speed. An important element of the digital age is the creation of large volumes of data. Big data has been defined as "information assets characterized by such a high volume, velocity and variety to require specific technology and analytical methods for its transformation into value" The ability to link diverse data sets has produced the conditions under which artificial intelligence and machine learning (AI/ML) have become useful tools for the analysis and exploration of latent patterns in big data. Sometimes these terms are used interchangeably. For the purpose of clarity I will define some key terms.

AI – Artificial Intelligence :

Refers to a broad field of science encompassing not only computer science but also psychology, philosophy, linguistics and other areas. AI is concerned with getting computers to do tasks that would normally require human intelligence. [3]

Machine learning:

Machine learning is a branch of artificial intelligence that allows computer systems to learn directly from examples, data and experience. Through enabling computers to perform specific tasks intelligently, machine learning systems can carry out complex processes by learning from data, rather than following pre-programmed rules. [4]

Deep learning:

Deep learning is a class of machine learning algorithms that:

- use a cascade of multiple layers of nonlinear processing units for feature extraction and transformation. Each successive layer uses the output from the previous layer as input;
- learn in supervised (eg classification) and/or unsupervised (eg clustering) modes;

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[3] https://www2.deloitte.com/se/sv/pages/technology/articles/part1-artificial-intelligence-defined.html
[4] https://royalsociety.org/~/media/policy/projects/machine-learning/publications/machine-learning-report.pdf

- learn multiple levels of representations that correspond to different levels of abstraction; the levels form a hierarchy of concepts. [5]

Natural language processing:

Takes an advanced neural network to parse human language. When an AI algorithm is trained to interpret human communication it is called natural language processing. This is useful for chat bots and translation services, but it is also represented at the cutting edge by AI assistants like Alexa and Siri. [6]

Patient-generated data:

Health-related data created, recorded or gathered by or from patients (or family members or other caregivers) to help address a health concern. [7]

Wearables:

Designating or relating to a portable device (now especially one incorporating computer technology) that is designed to be worn on one's person. [8]

While few physicians are expert in the use of these technologies, virtually everyone has experienced them in their day to day lives. AI/ML power the engines of large data banks and underlie the operations of most social media applications, online commerce and web-browsers. Thus, AI/ML is not so much a thing, but a set of processes used to enable the use and analysis of large volumes of data.

Context

Medicine has long been shaped and reshaped by the influence of technology. The close relationship between science and technology has led to advances in virtually every aspect of clinical medicine. These technological innovations can be roughly divided into epochs coincident with medicine's increasing identification with empirical sciences as a means of differentiating itself from other health and healing traditions. From the stethoscope and the microscope, to the discovery of the nature of the infectious basis of major diseases and the development of antibiotics medicine has continuously integrated science and technological innovation to improve patient care and reduce morbidity and mortality.

The early 20th century saw medicine, particularly through the Flexner Report , firmly align itself with university based education and increasing professional identity premised on science based practice. This trend increased through the 20th century and medicine co-evolved with advances in pharmaceutical science, surgical and imaging technology and towards the late 20th century, the capacity to harness and sequence the genome. The early 21st century has witnessed the rapid integration of computer technology into healthcare. For most physicians the first substantial ingress of information technology into practice would be through internet access.

The advent of information technology has been hailed as the fourth industrial revolution information. This industrial revolution has been noted for its twin capacity for innovation and disruption. Much speculation has been offered in the popular press and academic literature regarding the potential of these new technologies.

But the most significant contribution has been the electronic medical record, hailed for its transformative capacity to improve clinical management and ease the workload of physicians. The lived reality has been one of mixed effects. Now a suite of developments are pushing forward to convergence: mobile technologies such as smartphones, wearable applications

[5] https://en.wikipedia.org/wiki/Deep_learning
[6] https://thenextweb.com/artificial-intelligence/2017/09/10/glossary-basic-artificial-intelligence-terms-concepts/
[7] https://www.healthit.gov/topic/scientific-initiatives/building-data-infrastructure-support-patient-centered-outcomes-research
[8] https://www2.deloitte.com/uk/en/pages/technology/articles/wearables.html

with health data potential such as Fitbit and Apple watches, health related apps that can be accessed across a wide variety of platforms (smartphone, tablet, desktop, laptop etc) and accessed from virtually anywhere. While it might make sense to see each of these developments in isolation and address each one separately this would be in my estimation a mistake. Rather I would propose that we reflect upon how these technologies are converging. The chief means by which their convergence will take place is through the growing capacity of big data and its analysis through artificial intelligence and machine learning.

David Naylor has argued that seven factors are driving the introduction of AI/ML into the health care field. [9]

These are:

- Digital imaging in all its forms is becoming more powerful and more integral to medicine and health care
- Digitization of health-related records is accelerating, as is sharing of high-quality fully labeled and specialized data sets.
- Deep learning is highly adaptable for integrative analysis of heterogeneous data sets assembled from diverse sources.
- Deep learning has enormous capacity to inform the process of discovery in health research and to facilitate hypothesis generation by identifying novel associations.
- Deep learning shows promise for streamlining routine work by health care professionals and empowering patients, thereby promoting a safer, more humane, and participatory paradigm for health care.
- Deep learning is diffusing rapidly through a combination of open-source and proprietary programs.
- None of these developments depend on improvements in the basic technology of deep learning.

The combination of these factors and their rapid emergence is at the center of discussions on the impact of new technologies in clinical practice and may have dramatic implications for the practice of family medicine. There is, in principle, the possibility of detailed data on patients, their context, their family their data and integrating these later data sources into what I have termed the linkome. Artificial intelligence and machine learning require big data in order to optimally function. Artificial intelligence and machine learning increase their sensitivity, specificity and accuracy by processing large volumes of data and seeking out latent patterns. It is argued that artificial intelligence has the capacity to harness the collective intelligence of medical history and practice, the sum of the published research literature. It is claimed that these approaches are able to perform as or more accurately than experienced clinicians in the diagnosis of selected conditions. Image based diagnostic practices, particularly radiology and anatomic pathology are seen to be particularly well suited to AI based approaches and evidence is emerging on the effectiveness of AI/ML in these fields.

What is known about how family physicians/general practitioners view AI/ML?

AI/ML has attracted attention only comparatively recently so there is limited literature regarding its impact on family medicine. Blease et al. [10](2019) conducted a cross sectional survey of British general practitioners to determine their perspectives on whether new technologies

[9] Naylor C.D. **On the prospects for a (Deep) learning health care system**
https://jamanetwork.com/journals/jama/fullarticle/2701667?resultClick=1
[10] Blease C. et al. **Computerization and the future of primary care: a survey of general practitioners in the UK**
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0207418

would be able to perform tasks foundational to clinical practice as well or better than primary care physicians. The authors note a divergence of views between primary care physicians and AI health researchers. They note that physicians were skeptical about the impact of AI/ML in clinical practice and believed that care from empathic physicians will always be preferred by patients. The expected benefits of the new technologies, from their perspective, will likely be limited to reducing administrative tasks and improvements in practice management.

The authors note that AI health researchers share the belief that AI/ML will improve administrative function of practices, but also point out the potential to outsource clinical decision making to computer based systems. They also suggest "...not all AI experts are sanguine about the future role of physicians, or indeed of people, in overseeing humanistic aspects of care. Although many AI experts appear to agree with this outlook, we suggest that this shared viewpoint does not yet future-proof the role of GPs in overseeing this task: conceivably, if informaticians predictions are borne out, nurse practitioners, or a new occupation of medical empathizers, may emerge to undertake humanistic tasks."

The authors recommend that physicians lead and engage broadly in discussions about the role of AI/ML in primary care medicine. They note that the questions posed are far reaching and have significant implications for future of family medicine. As they conclude: "Perhaps foremost among these questions is the adequacy of current medical education to inform future physicians about the scope as well as the current limitations of artificial intelligence, and data science. Retooling, we argue, is necessary if the profession is to manage and deeply influence foreseeable change, including in the delivery of primary care."

These studies raise two important issues. First is the need for a similar study in the Canadian context to ascertain Canadian family physician's perspectives and readiness to integrate the new technologies and their potentially disruptive effects on practice. Second, it raises the important issue of training residents and providing professional development opportunities to maximize digital literacy in family practice.

Application of AI in primary care.

It should be noted that efforts to introduce AI enabled primary care are taking place. Babylon AI has partnered with the UK National Health system first in London, and now in Birmingham to create a digitally based service called GP at Hand. This program has over 41,000 enrollees who have 24/7/365 access. It employs a combination of virtual appointments through cell phone apps as well as face to face consultations. A similar initiative, Babylon by Telus health, has recently been introduced in British Columbia. [11]

Potential Responses

To reiterate: no one knows with any certainty how the new technologies will impact family medicine. That there will be an impact is certain. How these impacts play out could be influenced by a vast number of factors. Policy contexts, political considerations, commercial interests and increasing consumer demands will intertwine in non-linear ways. These forces could put family physicians in a reactive and defensive stance.

Given that no policy decisions have yet been made, there is time for leaders in family medicine to be proactive in their efforts to engage with the potential impact of these technologies in practice. Leaders in family medicine must be strategic in their engagement with the introduction of new technologies into clinical care.

[11] See: https://www.telus.com/en/on/health/personal/babylon?INTCMP=VAN_babylon

There are many hyperbolic claims concerning the benefits that will accrue to both patients and clinicians that fuel the expectations and shape demand and preferences for such technologies. The early 20th Century has witnessed the growth of evidence based medicine and evidence informed approaches in clinical medicine and health policy. Enthusiasm for the new technologies must be tempered by sober and systematic evaluation of the utility, the benefits and harms as well as costs of the implementation of these into clinical practice. Specific attention should be devoted to the critical evaluation of claims for these.

There is a parallel to the pharmaceutical industry that is worth considering. Over time, a large number of critical appraisal frameworks, regulatory processes and other checks and balances have evolved to ensure that new pharmaceutical agents are safe and effective and beneficial in practice. Similar close scrutiny should be paid to the integration of new technology into family medicine. The economic power and influence of the pharmaceutical industry on the medical profession has been well documented. We would be unwise to ignore the potential similar economic influence of the large information technology corporations or the allure of the large number of startup health enterprises. We would be extremely naive not to recognize the obvious economic value represented by the data held by family physicians or the importance of accessing and using these data from our patients.

Unlike the pharmaceutical industry there are no regulatory requirements, set of critical appraisal frameworks, agreed upon standards or safeguards when it comes to the new information technologies. If consumer behavior is a reliable guide there is considerable appetite to subscribe and to and use apps and wearables for a large number of health related activities. It is important to note that there are few rigorously designed interventions studies that measure clinically relevant outcomes. Given the vast proportion of health apps will be devoted to chronic disease management, careful scrutiny is called for. Early indications suggest the benefits are not as substantial as initially thought. [12] It is unlikely, in the short term, that any data related to meaningful clinical outcomes will be available. A host of proxy outcomes or process variables will be touted as evidence of benefit

So of necessity this process must be negotiated in the context of high expectations fueling consumer desire and a paucity of informative data.

Critical appraisal has been has been a longstanding competency required of clinicians. Critical appraisal guidelines for a wide range of clinical practice have been widely available since the 1980s. A similar extension to health technology, adapted to family medicine, is needed urgently. Vollmer et al. have provided a template of 20 questions to guide decisions on the introduction of machine learning/deep learning to into clinical practice. These questions and a link to the paper are included below.

The report was created by stakeholders from data national data holders and academics clinicians in the UK US. The report emphasizes the development cycle of machine learning and artificial intelligence solutions for clinical care from its research and development phase through assessment and adoption, its integration into clinical care and monitoring and evaluation through the cycle. They emphasize the importance of engaging patients, clinicians and the broader public.

The most thorough treatment of the potential of the new technologies in health care was the Topol report, commissioned by the NHS. The commission had a wide remit to investigate *"how technological and other developments (including in genomics, artificial intelligence, digital medicine and robotics) are likely to change the roles and functions of clinical staff in all professions over the next two decades to ensure safer, more productive, more effective and more personal care for patients".* [13]

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[12] See Lum et al. **An analysis of diabetes apps indicated numerous missed opportunities to optimize care**
https://jamanetwork.com/journals/jama/fullarticle/2730605
[13] The Topol Review **Preparing the healthcare workforce to deliver the digital future** https://www.hee.nhs.uk/our-work/topol-review

The commission looked at the implications of the introduction of new technologies across a wide range of issues with a particular emphasis on the required skills for health professions including primary care medicine. It emphasized the need to anticipate changes required for *"the selection, curricula, education, training, development and lifelong learning of current and future National Health Service staff".*

 As the report states:

"We are at a unique juncture in the history of medicine, with the convergence of genomics, biosensors, the electronic patient record and smartphone apps, all superimposed on a digital infrastructure, with artificial intelligence to make sense of the overwhelming amount of data created. This remarkably powerful set of information technologies provides the capacity to understand, from a medical standpoint, the uniqueness of each individual – and the promise to deliver healthcare on a far more rational, efficient and tailored basis."

Ethical concerns on machine learning and artificial intelligence

AI/ML and related technologies raise a host of ethical issues. Not surprisingly these have gained increased attention as the full possibility of these technologies has become increasingly apparent in the last few months. I will not comprehensively discuss the ethical issues in this document but will direct interested readers to thoughtful and comprehensive reports.

Common concerns arising from AI/ML focus on issues related to the privacy and confidentiality of health information and ownership of data. The implications of extensive linkage to other data sources, the use of such data for both public health and workplace surveillance, as well as the possibility of embedding systematic and structural bias into algorithms raise concerns for increasing health inequalities. Such concerns not theoretical as there has been such occurrences documented. The possibility to stigmatize and worsen the disadvantage of vulnerable groups would impair trust and violate norms of fairness and justice.   It would also be contrary to the social justice mission as articulated by the College of Family Physicians.

The fact that the results stemming from the use of some forms of artificial intelligence, particularly unsupervised deep learning with neural networks, cannot be fully scrutinized and explained raises issues of transparency. Issues relating to liability and accountability for acting on the results of such models have yet to be established and are urgent issues requiring clarity.

Will the new technologies change the physician patient relationship?

The introduction of electronic medical records has been a mixed blessing for family physicians and other clinicians. Data indicates that clinicians are spending more and more time at screens often at the expense of relationships with peers and time spent with patients. [14] The advent of the iPatient and the 4000 keystroke day has been linked with increasing rates of burnout and more physicians questioning the meaning of the physician's life. [15] Information technologies have already altered the physician patient relationship and the new technologies promise even more changes. Easy access by the public to vast amounts of medical information through the Internet is already well established. Often physicians will have to spend time on undiagnosing patients who have formulated beliefs about their symptoms from using Internet search engines such as Google. Patients also have access to a wide range of apps and wearables that provide health

[14] See Atul Gawande **Why Doctors Hate Their Computers** https://www.newyorker.com/magazine/2018/11/12/why-doctors-hate-their-computers
[15] Schulte and Fry **Death by 1,000 clicks: Where electronic health records went wrong** https://khn.org/news/death-by-a-thousand-clicks/

related data and advice. The number of these products is already large and growing. There is an increasing need for the technologies to be certified and approved by medical professions. But movement on this has been slow in Canada and much work still needs to be done. Information technology expands the means and speed by which physician- patient communication can take place. Text messages, video links, e-mail, patient portals, patient specific mobile applications are all means by which patients can be in contact with their family physician. Besides phone and face to face contact, it is likely that technologically mediated real time communications from patients to physicians will become an increasing reality. This will put pressure on setting standards and best practices. Regulatory authorities, as well as medical protection groups, will play an important role in guiding family physicians in what can and cannot be done with these technologies.

While the new communications technologies will no doubt be appealing to patients in terms of convenience and potentially increasing access, the effect on family physicians may not be salutary. The technologies create 24/7/365 capacity. Family physicians already experience long work hours and the technologies threaten further incursion into non-work time and blur the work/non-work balance. Given the general high level of conscientiousness found in family physicians, the stress associated with this blurring should not be underestimated.

There is also the possibility of increasing inequity. Many of the new tools are data rich and require access to highly functioning internet or mobile data streams. Not all patients then will have the resources to access and use some of the technologies. Rural areas in particular with low bandwidth and patients of lower socioeconomic status may therefore be further disadvantaged.

Some claim that artificial intelligence robots may eventually replace physicians. This is unlikely to occur for multiple reasons, some technical some more fundamental to the meaning of medical practice. The technical barriers to replacing physicians are substantial. I will not dwell on them here. Family medicine rests on principles of care that are holistic and play close attention to context and relationship. Even if chat bots can be programmed to reflect empathy or robots to smile they will never be fully embodied persons (perhaps in science fiction but not in the immediate future).

AI/ML sharpens our attention and focus on what it means to be a family physician. There is no question that computers can process vast volumes of data far more quickly and efficiently than any individual clinician. There is no doubt that computer support can bring the most relevant clinical evidence in a rapid and timely manner for a clinical decision making. Artificial Intelligence may even succeed in diagnosing certain conditions or predicting/prognosticating with equal or greater accuracy than an individual clinician. After all, artificial intelligence simply builds upon thousands of years of clinical observation, distills the outcome data of millions of patient encounters and the research literature with potential to link to a staggering array of data sources. All of this should be welcomed by family physicians but only to the extent that it demonstrates benefits to patients and communities.

The most important piece of advocacy work for family physicians is to insist upon the evidence of benefit from the new technologies arising from family medicine not imposed upon it. This means advocacy on the part of the College of Family Physicians of Canada for the resources to foster not only digital literacy, but the capacity to evaluate the impact and outcomes of the new technologies on patient care in family medicine with alertness for unintended consequences. This is a potentially very large but urgent undertaking. Partnerships will need to be forged between experts in artificial intelligence and machine learning, digital health technology and frontline clinicians. Promise of benefit in advance of evaluation should not be considered persuasive. We only need to remember the introduction of electronic medical records.

 More fundamentally machines lack something that is constitutive of physicianhood: the willingness to accept responsibility for the care of another human. Medicine is fundamentally

a moral undertaking, reflected in the responsibilities that physicians assume when entering a physician-patient relationship. This role entails accepting the fallibility and frailty of both parties.

Clinical medicine is premised on the understanding that our diagnosis, treatment plan and prognosis are uncertain and may not always work out for the best. Machines lack the sense of moral responsibility and reciprocity as they can be turned on or off, reboot, freeze and crash. No computer behavior entails responsibility and accountability. The willingness to assume responsibility and try to help a person with issues related to their health and well-being is as ancient as the healing arts.

This twin capacity for beneficence nonmaleficence and the fiduciary responsibility of physicians for the well-being of others is something that cannot easily be deferred to machines. As we move forward in the co-evolution of medicine with the new technologies we should be in a constant mode of questioning, evaluating and strive to be wise enough to step away when there is no clear evidence that it is working, despite the desire to see it work.

Key questions

Several key questions emerge from this analysis for discussion.

1. What resources do front line family physicians need in order to engage with both the new technologies and manage patient's expectations of these for their care?

2. Should CFPC consider developing competency based "digital literacy" educational programs?

3. At what groups should these programs be directed?

4. Who should CFPC partner with to pursue these goals?

5. What role should CFPC play as the AI/ML agenda unfolds in health care?

6. Is there a need for a national forum on AI/ML/ technology in health?

7. How best can CFPC support and encourage research into family physician perspectives on AI/ML and the impact of AI/ML on clinical care?

Recommended Readings

Two reports have been particularly informative in the preparation of this report

1. *Machine learning and AI research for Patient Benefit: 20 Critical Questions on Transparency, Replicability, Ethics and Effectiveness*
Sebastian Vollmer, Bilal A. Mateen et al. https://arxiv.org/abs/1812.10404

This quotation is worth heeding:

"Furthermore, nearly all biomedical research publications using ML/AI are reported in a 'positive' light, however, **there are currently few examples, if any, of health-related ML/ AI algorithms that have conclusively demonstrated improved patient outcomes***. So how do we (i.e. clinicians, methodologists, statisticians, data scientists, and healthcare policy maker), identify and critique relevant ML/AI research to assess its suitability for translation from the 'computer-bench' to the bedside? Currently, such assessments are difficult because we lack guidance on what differentiates good from bad at the different stages of the healthcare-related ML/AI development pipeline, from design and data analysis, through to reporting, and evaluation of effectiveness/impact on health. Producing such guidance is a major undertaking due to the ever-growing battery of ML/AI algorithms and the multifaceted nature of assessing performance and clinical impact.* **Not taking action is unacceptable, and if we wait for a more definitive solution, we risk wasting valuable work, whilst allowing futile research to continue unchecked, or worse, translation of ineffective (or even harmful) algorithms into clinical practice"**

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20 Critical Questions for Health-related ML/AI Technology

Overall Project-specific Question

1) How is the ML/AI model embedded in feedback loops as part of a learning health system?

Inception-specific Questions

2) What is the health question relating to patient benefit?

3) When and how should patients be involved in data collection, analysis, deployment, and use?

4) Is there organisational transparency about the flow of data?

Analysis-specific Questions

5) Is the data suitable to answer the clinical question, i.e. does it capture the relevant real-world heterogeneity, and is it of sufficient detail and quality?

6) Does the methodology reflect the real-world constraints and operational procedures associated with data collection and storage?

7) On what basis are data accessible to other researchers?

8) What computational and software resources are available, and are they sufficient to tackle this problem?

9) Are the reported performance metrics relevant for the clinical context in which the model will be used?

10) Is the reported gain in statistical performance with the ML/AI algorithm clinically justified in the context of any trade-offs?

11) Is the ML/AI algorithm compared to the current best technology, and against other appropriate baselines?

12) Are the different parts of the prediction modelling pipeline available to others to allow for methods reproducibility, including: the statistical code for 'pre-processing', and the modelling workflow (including the methods, parameters, random seeds, etc. utilised)?

13) Are the results reproducible in settings beyond where the system was developed (i.e. external validity)?

Impact Evaluation-specific Questions

14) What evidence is there that the model does not create or exacerbate inequities in healthcare by age, sex, ethnicity or other protected characteristics?

15) What evidence is there that clinicians and patients find the model and its output (reasonably) interpretable?

16) What evidence is there of real world model effectiveness in the proposed clinical setting?

Implementation-specific Questions

17) Is the model being regularly re-assessed, and updated as data quality and clinical practice changes (i.e. post-deployment monitoring)?

18) Is the ML/AI model cost-effective to build, implement, and maintain?

19) How will the potential financial benefits be distributed if the ML/AI model is commercialized?

20) How have the regulatory requirements for accreditation/approval been addressed?

2. ***The Topol Review: Preparing the healthcare workforce to deliver the digital future*** https://www.hee.nhs.uk/our-work/topol-review

Recommendations for Training:

For data-driven and autonomous technologies to flourish the following are required:

- the digitisation and integration of health and care records;
- the provision of a binding 'code of conduct' (a core set of ethical principles and commitments) for those designing and implementing data-driven health and care technologies into the NHS
- guidance of 'evidence for effectiveness' which helps regulators, commissioners, procurers, managers and clinicians in the NHS to evaluate, regulate, purchase and use data-driven technologies.

There is also the need for specific workforce learning in three key areas:

- knowledge and skills in data provenance, curation and governance;
- knowledge and understanding of the ethical considerations in using data-driven and robotic
- technologies for healthcare;
- critical appraisal of digital healthcare technologies – understanding how the technology works, including the statistics underpinning machine learning

Recommendations for health professional education regarding AI.

Educational resources should be developed to educate and train all healthcare professionals in: health data provenance, curation, integration and governance; the ethics of AI and autonomous systems/tools; critical appraisal and interpretation of AI and robotics technologies.

Additional Readings

AI/ML and Future of Clinical Medicine

These two articles provide a generally positive interpretation of the impact of AI/ML in clinical medicine. The articles contain examples of application, but the examples are not particularly relevant to family medicine.

Rajkomar A., et al. **Machine learning in medicine**. New England Journal of Medicine 2019; 380:1347-1358
https://www.nejm.org/doi/full/10.1056/NEJMra1814259

Topol, E.J. **High-performance medicine: the convergence of human and artificial intelligence**. Nature Medicine 2019; 25:44–56
https://www.nature.com/articles/s41591-018-0300-7

Ethics and AI/ML

These documents speak to the ethical challenges associated with AI/ML. The Montreal Declaration was released in December 2018. It is a proposed set of principles for all developers and users of AI/ML

Montreal Declaration
https://www.montrealdeclaration-responsibleai.com/the-declaration

Ethical Issues of AI/ML in healthcare
The Nuffield Council is a U.K. based independent organization that provides insightful analysis on ethical issues in health care.
http://nuffieldbioethics.org/project/briefing-notes/artificial-intelligence-ai-healthcare-research

AI/ML and Primary Care Diagnosis

This study compared Babylon AI's Triage and Diagnostic System algorithms against UK MRCP trained GP's. It concludes that the system was comparable and perhaps safer in recommendations. Worth a read to sharpen one's critical appraisal skills!

Raazaki S. et al. **A comparative study of artificial intelligence and human doctors for the purpose of triage and diagnosis**
https://arxiv.org/pdf/1806.10698.pdf

A critical look at AI/ML in clinical medicine

Chin-Yee B. and Upshur R. **Clinical Judgment in the era of big data and predictive analytics**. Journal of Evaluation in Clinical Practice 2017; 25:638-645
https://doi.org/10.1111/jep.12852

Doing AI/ML

The ability to work with AI/ML generally requires skills in coding and computer science. These skills have not traditionally been regarded as necessary prerequisites for a medical career. The advent of the new technologies may change this as the need for data scientists with an understanding of clinical realities will be pressing. There are many online tutorials available to explain how to use AI/ML techniques. Familiarity with a computer language such as Python or R is a necessary first step. Python is the most commonly used language.

Python
https://www.python.org/about/

Many online courses are available to learn the principles of AI/ML. Universities such as the University of Toronto, Oxford University and M.I.T. all offer online courses. Coursera has a large range of offerings as well.

Potential effects of AI/ML on Clinical Care

The lists below summarize the potential benefits and harms of AI/ML in clinical medicine. I have not included the potential societal impacts.

Physicians

Benefits:

- Reduced administrative burden
- Increased access to point of care personalized evidence
- More accurate diagnosis, treatment and prognosis
- New learning opportunities

Harms

- Loss of professional autonomy
- Loss of professional respect and authority
- De-skilling
- Hollowing of cognitive labour
- Reduction/disappearance of the profession of primary care

Patients

Benefits:

- Empowerment: better self-management, independence and self–efficacy
- Ease of access: 24/7/365 capacity
- More precise and personalized care
- Less need for office visits

Harms:

- Loss of relationship, human contact
- Increased isolation
- Potentially restricted choice
- Potentially less autonomy
- Potential inequitable treatment through biased algorithms