Building a Learning Health System for Canadians

Report of the Artificial Intelligence for Health Task Force

July 2020

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Key Messages

- Canadian scientists have been pioneers in the development of artificial intelligence (AI), and the AI field in Canada has benefited from substantial new public and private investment in the last three years.

- AI-powered technologies have particular promise in the health realm, broadly defined. In particular, responsible use of AI could:

    - Improve the effectiveness, efficiency and safety of ***health service delivery***;

    - Provide insights to inform both ***disease prevention*** and policies addressing broader ***population health determinants***; and

    - Underpin the ***discovery and development*** of new diagnostic tools and treatments.

- Canada has lagged behind many peer nations in its pace of uptake of digital healthcare innovations. This situation is impeding the development and scaling of AI applications in healthcare delivery and research.

- Many other nations have also made strategic investments in AI, and Canada's strongly competitive position in the field is at risk.

- The time is now for Canada to make strategic investments in a national AI for health strategy to leverage all of our strengths, foster collaboration and coordination across sectors and jurisdictions, and deliver better health for Canadians and the world.

- Government action relevant to AI for Health (AI4H) is urgently needed on three broad fronts.

    1. **Establishing AI4H infostructure that enables responsible access to health data while ensuring data are secure and privacy is protected**

       The types of comprehensive datasets that will optimize the impact of AI in the health sphere cannot be created without strong public engagement to help guide terms and conditions for their use. More generally, members of the public and patients should be included as active partners in the development, governance and evaluation of AI4H policies and strategies.

    2. **Accelerating the development of safe, high-performance AI4H applications by both public institutions and private enterprises, alongside deployment of incentives that promote strategic procurement and responsible scaling of these applications within Canada's healthcare systems**

       This involves two mutually reinforcing elements. One is smart development and procurement of AI within Canada's publicly funded healthcare systems. The other is an effective commercialization plan, supporting the growth of Canadian-led AI4H enterprises through both direct and indirect funding, targeted procurement, and facilitating access to international markets. Success in both domains depends critically on the implementation of the right set of incentives.

    3. **Ensuring that federal and provincial/territorial plans to advance digital health are coupled to an explicit AI4H strategy with the relevant policies, investments, partnerships, and regulatory frameworks**

       Such a plan should aim to ramp up research, enable improvements in healthcare delivery and population health policymaking, and facilitate the development of scalable AI4H innovations under the aegis of both private enterprises and public institutions. Without this alignment, Canadians will not reap the full health benefits of the opportunities available from responsible use of AI and machine learning more generally.

Further recommendations relating to these three fronts for action can be found in the body of the Task Force report.

These recommendations are intended to lay foundations for a national, coordinated, and integrated effort that will help Canada take full advantage of transformative new technologies that are rooted in Canadian research and have widely-recognized potential for use in every corner of the world and by people in every conceivable walk of life. Failure to seize these opportunities will have adverse consequences for the quality and efficiency of our healthcare systems, the health of our communities, and the prosperity of the nation. We call on the Government of Canada and all interested provincial/territorial governments to collaborate urgently in developing an AI4H strategy in lockstep with broader plans to accelerate digital healthcare innovation.

Building a Learning Health System for Canadians

Report of the CIFAR Task Force on Artificial Intelligence for Health

Context

The Global Competition for AI Leadership

Over the course of little more than a decade, AI has emerged as one of the most exciting and dynamic areas of global technological innovation. Five factors have converged to drive the ongoing revolution in AI and machine learning.

- Transformative improvements in computing power have enabled efficient processing of very large amounts of data.
- Capacity for mass data storage has undergone an enormous expansion both locally and at remote sites (the 'Cloud').
- A huge variety of fixed and mobile devices are now generating digitized inputs in every corner of the world, not least through the growth of so-called 'wearable' technology.
- Advances in statistical science have produced computer programs that can explore and learn from large datasets with limited intervention by humans.
- Last, and far from least, with powerful computers and big high-dimensional data sets, models of AI based on homology with human neural networks have surged into prominence. These 'deep learning' techniques have shown unprecedented capacity to process diverse data sources and build algorithms that recognize intricate patterns and predict outcomes with unusual accuracy [1, 2, 3].

A working definition of Artificial Intelligence

For the purposes of this report, we define AI to be any current or future machine learning approach to predictive analytics, decision-support systems and/or automated decision-making. Specific examples of today's AI technology that are being applied to health and health care include deep learning, reinforcement learning and robotics.

Leadership or Followership?

Canadian scientists — most prominently, pioneers such as Geoffrey Hinton, Yoshua Bengio, and Richard Sutton — have been major contributors to the development of modern AI. While these breakthroughs are a source of justifiable national pride, they offer no assurance that Canada will disproportionately reap the social and economic benefits of AI. Canadian scientists discovered stem cells in the 1960s. Since then, other nations have taken the lead in stem cell science and commercialization of regenerative medicine techniques. Canadians invented the smartphone in the 1990s, and the BlackBerry took the world by storm. Within a decade, however, American and Asian competitors had taken the lead in the smartphone market. Likewise, over the last few years, one country after another has made substantial investments to capitalize on Canadian advances in AI, as have all the largest multinational tech companies.

Canada has also started to raise its game. In 2017, the Government of Canada appointed CIFAR to develop and lead a $125 million Pan-Canadian Artificial Intelligence Strategy, the world's first national AI strategy. The Strategy enabled the establishment of new, independent research institutes in Edmonton (Amii), Montreal (Mila), and Toronto (the Vector Institute) in partnership with provinces and the private sector. In just three years, all three institutes have established themselves as the central hubs for research, training and innovation within their respective AI ecosystems. The cornerstone of the Pan-Canadian AI Strategy is the Canada CIFAR AI Chairs program, is designed to attract and retain top AI researchers in Canada by providing long-term, sustained support to their research programs. To date, 80 of the world's leading researchers have been named Canada CIFAR AI Chairs, appointed at partner universities and each affiliated with one of the national AI institutes. A full 30% of these world-class researchers are interested in advancing AI for health applications. This talent trove is multiplying as growing numbers of students and trainees enter the exciting realms of AI, data science, and machine learning.

These are very promising developments. Nonetheless, given Canada's comparatively small size and low density of large-scale digital technology companies, one might ask whether some strategic sub-specialization may be advantageous. This report answers that question in the affirmative. In particular, we believe the health realm is a high-yield focal point for convergent AI initiatives by the federal and provincial/territorial governments, by private enterprises and investors, and by a wide variety of non-profit institutions and civil society stakeholders.

The Health Connection

The general case for focusing on AI applied to the health realm rests on several general trends and on a fast-growing literature that illustrates the potential of these technologies in health-related applications. These trends and findings can be summarized as follows: [2]

- Modern healthcare makes increasing use of images of all types, along with myriad tracings and other digitized data sources. These data are highly amenable to analysis with machine learning methods, yielding interpretations at a level competitive with highly expert clinicians.

- AI has enormous integrative potential: it can assimilate information from a very wide range of sources. This is not only crucial to improve diagnosis, treatment, and prognostication at the level of individual patients. It also facilitates biomedical and health research by illuminating possible biological and pathophysiological mechanisms of disease and treatments, or by generating novel hypotheses from population data to help explain why some people are healthy and others are not.

- Forms of rule-based AI have been used to improve the efficiency and quality of healthcare delivery for many years. Modern machine learning has far wider applications in everything from pre-screening radiological images and biopsy material, to improving workflow and queuing practices or enabling early intervention to prevent admissions and readmissions to hospital. Future applications are likely to include image-guided robotic assistance for almost all major diagnostic and therapeutic interventions and dynamic adjustments to diet and medications based on continuous monitoring of data from individuals and environments.

- Although there is still justifiable anxiety that AI could be misused to 'dehumanize' healthcare, recent reviews have emphasized that AI tools can be viewed as "augmented intelligence" — enhancing decision-making capabilities, facilitating quality control and applied research, and accelerating the emergence of "learning health systems" [3]. Topol [4] and others [5] have further argued that AI could free overburdened health professionals from much routine drudgery, enabling a stronger focus on individuals and families, and facilitating more personalized and participatory decision-making. AI-enabled efficiency gains in time management by health workers could also mitigate shortfalls in the numbers and capabilities of diverse disciplines and professions within the health workforce.

For Canada, the healthcare case has special resonance. Canadians have a strong attachment to their universal healthcare systems as an expression of social solidarity and our shared commitment to inclusion and equity. Our 13 provincial/territorial systems have many strengths, but multiple reports have also emphasized the need for pan-Canadian improvements in the timeliness and scope of insured services for a variety of conditions [6] [7]. Moreover, with healthcare costs for 2020 projected to rise above 11% of GDP, and ongoing gaps in coverage, enhanced efficiency is imperative.

Among the issues repeatedly identified is a digital health deficit. In particular, there is wide recognition that Canada has lagged many peer nations in development of health infostructure and in its uptake of digital healthcare innovations such as virtual care, home monitoring, and remote-control robotic interventions.

This situation is also impeding the development and scaling of AI applications in healthcare delivery and research. However, this lag creates an important opportunity for alignment. Work to enhance digital health in Canadian healthcare can be closely aligned with efforts to develop, adapt, and responsibly scale AI applications in the broad health sphere.

Canadian AI4H Case Study

An AI "Co-Pilot" for Physicians Interpreting Chest X-rays

Partners

1QBit, Saskatchewan Health Authority

Challenge

A new coronavirus, SARS-CoV-2, which causes severe respiratory illness in humans, emerged in late 2019, and by March 2020 was classified by the World Health Organization as a global pandemic. Even with the implementation of widespread states of emergency and the closure of schools, workplaces and cross-border travel, the virus has had an unprecedented toll in a few short months. While sinus swab and nucleic acid-based (PCR) testing is the standard test to confirm SARS-CoV-2 infection, it is not universally available, has limited throughput, and the global demand for testing is straining the supply chain for the necessary reagents.

Solution

Chest X-ray remains the gold standard for clinical confirmation of pneumonia, the primary symptom of COVID-19, and the respiratory syndrome associated with the virus. Over the last several years, 1QBit, a Vancouver-based software firm, has developed a computer vision and machine learning approach to diagnosing lung abnormalities on chest x-rays and has recently completed extensive clinical trials. They saw an important opportunity to apply their decision-support tool, XrAI, to COVID-19 and urgently began testing its accuracy in identifying lung changes associated with the infection.

Result

In a matter of days, XrAI demonstrated 100% accuracy in identifying COVID-19 infections, 1QBit applied for and received expedited regulatory approval by Health Canada, and XrAI was adopted by the Saskatchewan Health Authority as part of its COVID-19 pandemic response. 1QBit is now working with partners in Canada and around the world to deploy XrAI and support them in the fight against COVID-19.

Source: https://1qbit.com/news/1qbit-saskatchewan-health-authority-announce-xrai-chest-radiography-tool-deployment-unprecedented-health-canada-regulatory-approval/

Canadian AI4H Case Study

AI Early Warning for Patients at Risk of Needing Transfer to Intensive Care Unit

Partners

Vector Institute, Li Ka Shing Centre for Healthcare Analytics Research and Training (LKS-CHART), St. Michael's Hospital

Challenge

About one out of every 13 patients in the St. Michael's Hospital general internal medicine unit are critically ill and will ultimately need to be transferred to the intensive care unit (ICU) or will succumb to their illness in hospital. However, predicting which patients are likely to need ICU-level care is often difficult: that's where AI comes in.

Solution

The Early Warning System for General Internal Medicine uses a predictive risk model to make medical recommendations. The system uses machine learning to process regular feeds of health data and predict when a patient needs to be transferred to the ICU. Accurately predicting when patients need to be transferred 12 to 24 hours earlier may allow more time for potentially lifesaving early-intervention care, decreasing rates of cardiac arrest and mortality.

Result

The team has already demonstrated a proof of concept. The next step is addressing the challenges of integrating it into existing hospital systems in a way that it provides physicians with helpful and meaningful information in an environment where alarms go off regularly. A critical component of the approach and key to their success to-date is the access to frontline care workers. They bring doctors, nurses and patients together to first find out what they need and then work within those constraints. This approach and mindset are particularly effective because it allows them to focus on tailoring the algorithm to clinicians' workflows, rather than tailoring clinician behaviour to how an algorithm performs.

Source: https://vectorinstitute.ai/2019/05/06/vector-institute-kicks-off-series-of-pathfinder-projects-focused-on-health-ai-adoption/

Harnessing the Potential of AI4H

In brief, the Task Force believes AI-powered technologies could:

- Improve the effectiveness, efficiency and safety of ***health service delivery***;
- Provide insights to inform both ***disease prevention*** and policies addressing broader ***population health determinants***; and
- Underpin the ***discovery and development*** of new diagnostic tools and treatments.

Elaborating the potential outcomes of these effects in more concrete terms, we foresee the following:

- **Canadians will have better healthcare outcomes, and live longer, healthier lives.**

  AI can not only improve the patient experience, processes and outcomes of health services, but it can also transform our understanding of the complex array of risks to health across the biological, behavioral, social and environmental spheres. Addressing these latter issues has been a goal of Canadian health policy since the 1974 Lalonde Report[8]. A combination of tailored primary prevention strategies with broad community-level interventions may at last enable more tangible improvements in health equity and population health indices.

- **Provincial and territorial health costs can be significantly contained.**

  AI can help bend the cost-curve in Canadian health services in myriad ways. Medical errors are not only too frequent and fatal; they are costly. AI has major potential for enhancing the safety of medical care. As well, with virtual care and predictive algorithms combined with remote monitoring, more patients will avoid disruptive hospitalizations. Delayed care, too, can be wasteful. With AI-powered enhancements of workflows, facilities will be able to decrease wait times in emergency rooms and clinics, as well as for a wide variety of elective procedures. Indirect savings are even possible through environmental benefits. Hospitals worldwide are surprisingly large greenhouse gas emitters. Machine learning is increasingly used to design "green" buildings, enable energy conservation, and help enterprises reduce the carbon footprints of their diverse activities.

- **Canada can reap significant economic benefits as a leader in the commercialization of AI for Health solutions.**

  AI is already ushering in a new era of diagnostic and therapeutic technologies. In combination with existing technologies, convergent advances occurring in bioscience and data science have boundless potential to increase the precision and effectiveness of clinical care. The foregoing use-cases have also underscored that AI has wide applicability to current practices and techniques in health systems around the world. Thus, the market for AI4H innovations is truly global and staggering in size. Appropriately evaluated and responsibly used, AI has the potential to optimize many aspects of contemporary healthcare, even as it facilitates the development of new technologies that can radically enhance our capacity to prevent, treat, and cure illness.

  Canada has several brand advantages in this fast-growing market. First, Canada is globally recognized for seminal contributions to the development of AI. Second, Canada's major cities are among the most multicultural in the world. AI algorithms derived and validated in this context may have wide appeal because of their generalizability. Third, our universal healthcare systems mitigate potential biases related to differential access by socioeconomic status. And fourth, Canadians have shown a commitment to responsible and ethical use of AI, thereby fostering greater trust in services and products arising from our model of AI innovation.

  We alluded earlier to the need for Canada to meld its initiatives in digital health and AI. This represents a joint opportunity to develop and apply expertise in designing health data systems that will be better aligned, interoperable, amenable to real-time analysis, and managed responsively and ethically. The Task Force saw clear evidence that a new generation of digital entrepreneurs is working on both specific AI4H applications and broader innovations that will improve health data systems. There is enormous opportunity for new Canadian businesses to grow and scale internationally.

  Last, the surging global demand for AI experts and AI literacy offers different markets – those based on higher and continuing education. Indeed, global AI industry leaders are making unprecedented investments in nurturing and retaining talent — a situation that helps explain the recent dramatic growth in their Canadian operations and investments. Capitalizing on these opportunities, however, carries

an obvious risk: Canada's competitive position may be further eroded by exporting know-how and shaping the machine-learning work-force for other nations — unless Canada is resolved to stake a claim to leadership in one or more key realms for application of AI.

Make Haste, Avoid Hurry

Domestically, the imperative to improve health and healthcare is clear. The performance of Canada's healthcare systems now lags relative to some peer nations [9]. Inequities in health status have stubbornly persisted. Cost containment for the provincial/territorial public programs is vital given fiscal challenges facing several provinces, and widespread interest in expanding public coverage for, *inter alia,* prescribed drugs, dental care for children, and mental health services. And with the aging of our population, AI and related technologies have clear potential for helping people retain independence, as well as enabling them to receive health care and health care monitoring in their own homes.

Not only does AI have much to offer in the health realm; the single payer and other attributes of Canada's health system lend themselves well to AI development and deployment. The Task Force observed, however, that federal initiatives in AI have been inconsistently integrated with plans to accelerate digital health innovation that fall within provincial/territorial healthcare systems. Investments thus far have been fragmented, and funding levels at times mismatched with project aspirations. Moreover, data infrastructure development remains uneven, issues of public trust and social license need further attention, and there is no coherent plan for strategic procurement and scaling that would accelerate the emergence of Canadian 'gazelle companies' in the AI4H marketplace.

Meanwhile, the US, UK, China, Israel and many other countries have taken substantial steps to build out major health data repositories and the analytic capacity essential to capitalize on their potential. Size is a substantial advantage for the US and China, and to a lesser extent the UK. The US technology ecosystem is still dominant, and America's technology giants are making enormous investments in AI. Google/Alphabet and Amazon, in particular, have big plans for health applications. Israel's tech sector is small but remarkably powerful. The UK intriguingly has the most advanced arrangements, with multiple data lakes, a strong AI/data science workforce and research ecosystem, and explicit plans for responsible scaling of what is sometimes called 4P medicine (personalized/precise, participatory, predictive, and pre-emptive/preventive) [10][11].

In short, if Canada does not raise its game rapidly, it will at best find itself playing catch-up in the AI4H realm, or at worst fall irreversibly behind. As matters stand, Canadian hospitals are currently spending billions on electronic health record systems purchased from US vendors. In future they could find themselves importing an ever-widening set of costly AI-powered health technologies that are, paradoxically, built on intellectual foundations laid by Canadians, but not fit for use in Canada because the AI models were tuned to the US health system.

The AI4H Task Force

In the spring of 2019, CIFAR convened AI and health innovation leaders from across Canada in a roundtable discussion to understand Canada's opportunity to advance AI for health. A strong consensus emerged that with a concerted effort to leverage Canada's world-leading AI research ecosystem, together with its extensive population-wide data holdings within the publicly funded health system, Canada could become a world-leader in the development and adoption of AI-based approaches to health and healthcare. However, **we need to act quickly.** The roundtable stakeholders supported the establishment of a Task Force to develop recommendations towards a national strategy on AI for health.

The Task Force was convened by CIFAR in September 2019 and comprised 17 leaders with diverse expertise and, including co-chairs Tim Evans (McGill University) and David Naylor (University of Toronto). The Task Force met on seven occasions through to February 2020.

The AI4H Task Force endeavored to align its work with both federal and provincial strategic priorities and activities. The Task Force has been in close contact with officials from both Innovation, Science and Economic Development Canada and Health Canada throughout the course of its work. The Task Force also took several opportunities to engage with officials from provincial and territorial Ministries of Health to ensure that their perspectives and priorities were understood.

The AI4H Task Force engaged Accenture Consulting to undertake an analysis of the AI for health landscape in Canada and globally and to consult with key stakeholders. The Task Force also engaged directly with stakeholders across sectors, and across the country as it developed its recommendations, culminating in a series of town hall consultations in Toronto, Montreal, Edmonton, and via webinar in January 2020 to share and receive feedback on a set of draft recommendations. See Appendix 1 for a list of key stakeholders consulted throughout the process.

In view of work related to AI being undertaken by other bodies (e.g. the Federal Government's AI Advisory Council, the Royal College of Physicians and Surgeons Task Force on AI, and CIHR's new Strategic Plan), and in view of a short-time frame for its deliberations, the Task Force focused on three critical areas of AI4H: i) accessible data; ii) development and deployment; and iii) strategic action. Given the urgent action required for Canada to capitalize on its strengths and to not fall behind other jurisdictions, the Task Force committed to acting quickly in order to deliver its recommendations within six months of convening.

Key Findings

AI4H Landscape

- AI4H represents an exciting "convergence" between well-established, quantitative methods emerging from biostatistics and epidemiology and the rapidly evolving analytic algorithms that make up machine learning. This convergence is being fueled by the growth of digital sources of information such as medical imaging, mobile phones and wearable health monitoring devices, together with new opportunities to link multi-level data arising from clinical records as well as genomics, metabolomics, microbiomics, and environomics.

  AI4H, as measured by trend lines in publications, is growing exponentially in the last decade (see Figure 1 for numbers of papers on AI4H 1963-2019). Canada ranks in fifth place amongst countries in terms of numbers of publications with about 4% of publications compared to 31% of publications for first-ranked United States and 8% of publications for China.

- The majority of all published work on AI4H focuses on diagnosis of conditions. (See Figure 2 for areas of greatest development in AI data-driven technologies). This pattern reflects both the degree to which imaging data lends itself to AI analytics, as well as the ease of access to this type of data. This skew in data availability and ready applicability may lead to a "looking under the streetlight" bias in the development of AI4H.

- Investments in AI4H are growing rapidly with the articulation of ambitious AI4H national strategies that are making "big bets" backed by "big bucks" [13]. Canada has several "established" hubs that are deemed amongst the global leaders in AI4H including Toronto and Montreal but we lag behind the leaders in the UK (London), the US (New York) and Israel [14].

- Projected growth in the value of the AI4H market over the next ten years is extremely rapid with very high anticipated rates of return [15].

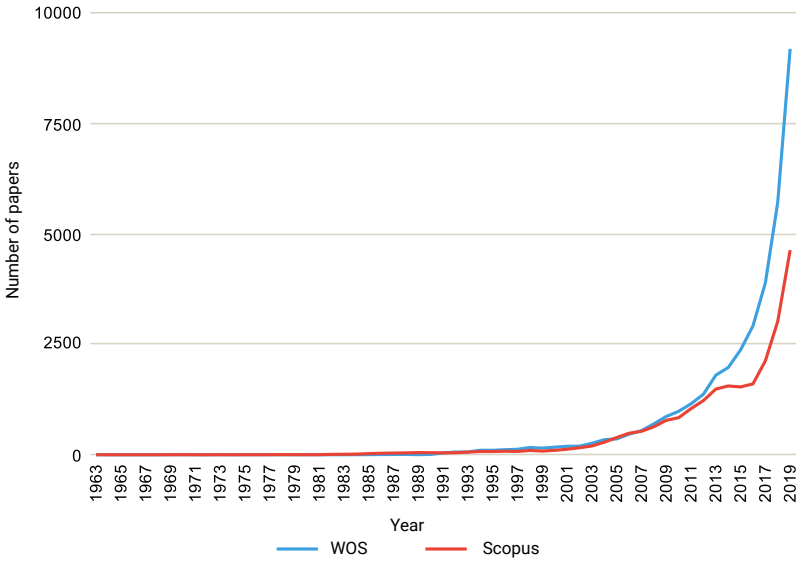

Figure 1: The number of AI4H papers by year in the Web of Science and Scopus databases, 1963–2019 (adapted from [12]).

Figure 2: Dimensions of data quality (from [17]).

Canadian AI4H Case Study

Bringing AI to home care for better patient outcomes

Partners

AlayaCare Partners: CBI Health Group, Bien Chez Soi, Integracare, Polytechnique Montréal, Scale AI

Challenge

As our population ages, we need to develop more efficient and effective ways to deliver care in the home.

Solution

AlayaCare, a Montréal-based SME that provides home health care software, is partnering with home care providers CBI Health Group, Integracare and Bien Chez Soi to launch a $1.8-million project to give caregivers better planning and management tools aimed at ensuring that home care agencies are able to meet the growing demands of our aging population.

Result

AlayaCare has established an innovative software platform that enables home care providers to deliver best-in-class services and improve patient outcomes. Using AI, optimization and machine learning technologies, the platform bridges the gap between client needs and what science can offer through planning, time management, clinical documentation, home patient monitoring and a mobile application.

Source: https://scaleai.ca/wp-content/uploads/2017/11/ScaleAI-Annonce-invest-2020-01-Communiquee%CC%8C-v09finalPLUS-EN.pdf

Data

- The Economist's bold statement that "the world's most valuable resource is no longer oil, but data" [16] certainly rang true in the context of this Task Force. From the very first meeting and throughout all of the consultations, the issue of data for AI4H garnered disproportionate attention that was anything but dispassionate!

- Canada suffers from a major data paradox. It should have a comparative advantage arising from a set of single-payer, universal healthcare systems. But that advantage has been elusive when it comes to the availability and accessibility of comprehensive datasets amenable to analysis using AI and other advanced machine learning methods. The difficulties of accessing data to train AI algorithms creates a risk that AI scientists in Canada will shift their research attention to countries where data resources are more easily accessible. It also means that far-sighted investments in personnel through federal-provincial AI initiatives could be squandered as scientists themselves move to jurisdictions without the excessive privacy protection restrictions that prevail today in most Canadian provinces.

- Consistent with the observation above, Canada is underinvesting in its health data systems relative to international competitors. Key domains of the "infostructure" requiring attention include:

1. ***Scope:*** The range of data from diverse sources that can be brought together including structured, unstructured and simulated data;

2. ***Skews:*** Problems arise when data that are not representative of relevant populations or problems are used to build/train algorithms;

3. ***Standards:*** Although there exist robust criteria for assessing data quality and reliability (See Figure 2 for domains of data quality), they are not widely recognized or used;

4. ***Sharing and Ownership:*** There are many different data sharing and ownership models ranging from patient-owned, to public, private, not-for-profit data trusts, or federated learning models. The strengths and weaknesses of these models need to be better characterized with greater consensus on what constitutes good (and bad) practices; and

5. ***Trust and Privacy:*** Protecting the privacy of personal data requires continuous technical scrutiny as well as greater public engagement to build trust. Surveys suggest that the public is very supportive of availing health record data for opportunities to improve health and health care, whereas private sector efforts to make patient data a profit center are not supported (see Figure 3 for UK attitudes towards data sharing for specific purposes in health).

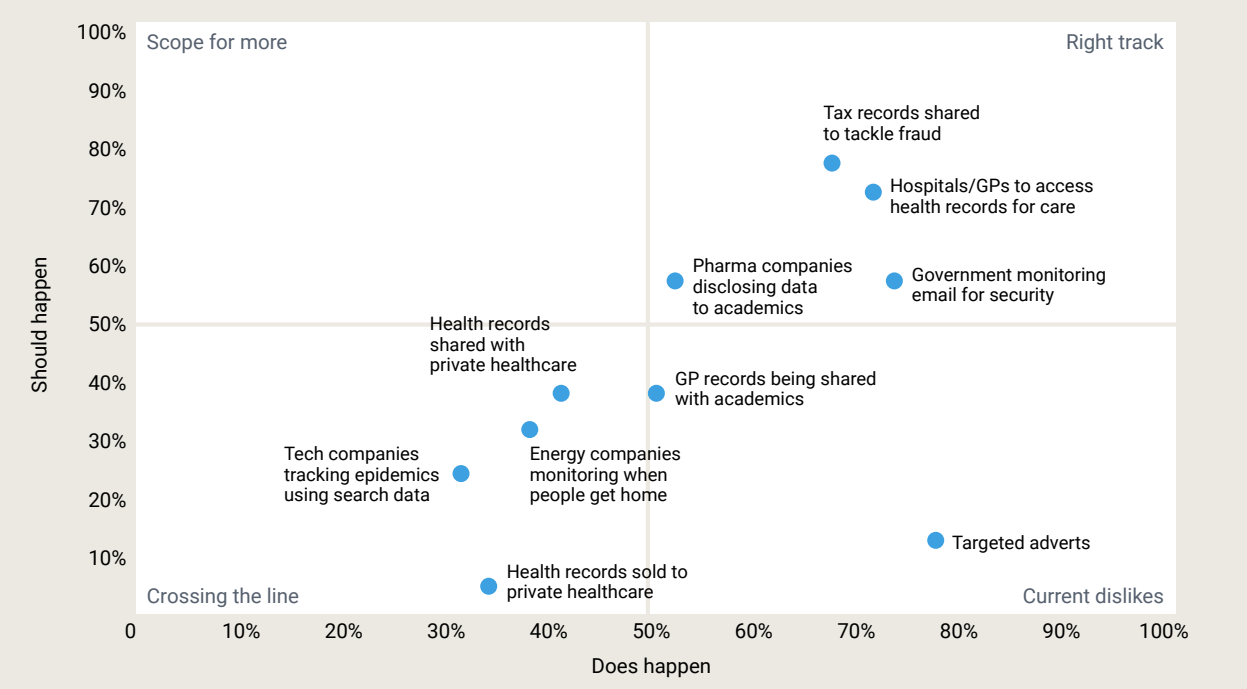

Figure 3: Public attitudes to the use and sharing of their data (UK, 2014) (from [18]).

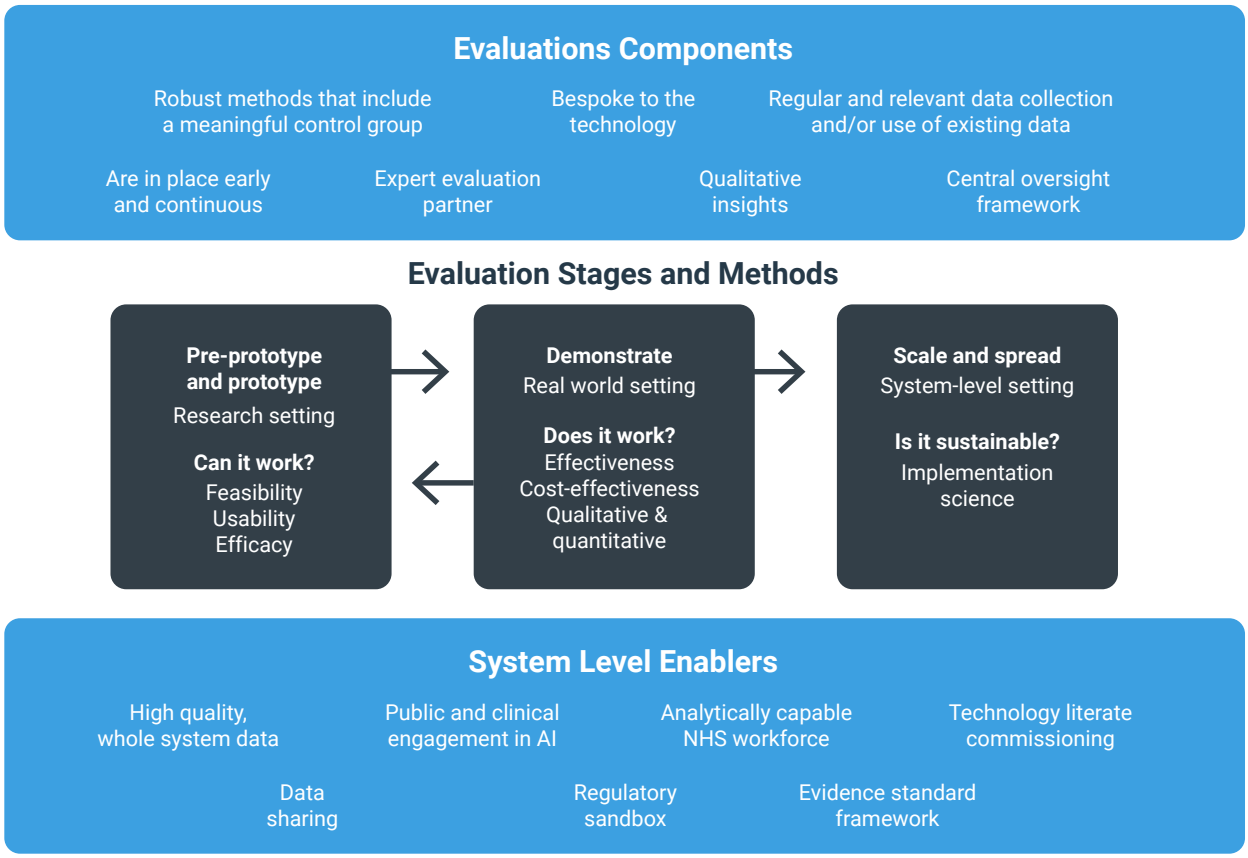

Figure 4: A framework for monitoring AI and assessing which products should be scaled for use within the NHS (from [19]).

Many countries e.g. UK, Israel, China have invested heavily in major reforms of their health infostructure that are enabling AI4H. For example, the UK's data hubs (see Figure 4 for how the UK's health data are being structured to make discoveries) have benefited from a carefully considered design with political and financial backing to support their implementation. While new initiatives like the Health Data Research Network and the Digital Health and Discovery Platform, both launched last year, are great steps in the right direction, Canada would do well to take inspiration from these international efforts and further develop these evolving ideas.

Development and Deployment

- The science of building AI4H algorithms is young and quickly evolving. Standard principles and criteria are emerging to guide: i) the construction of algorithms such that they are explainable, transparent and scientifically sound; and ii) the assessment of algorithm performance in terms of effectiveness, cost-effectiveness, biases, unintended consequences and accountability (see Figure 5 for a schematic outline of steps towards algorithmic explainability in health).

- A special problem is designing both evaluative studies and nimble regulatory regimens that acknowledge and capitalize on the "learning" nature of these tools. Current study designs and regulatory regimes reflect the dominance of the pharmaceutical model — where a single bespoke molecule, usually protected by a patent, is the intervention of interest. Closed algorithms are being marketed that are likely to be suboptimal in a large number of circumstances — in effect, needlessly replicating both the business model of the pharmaceutical industry and inherent limitations of current trial designs [20].

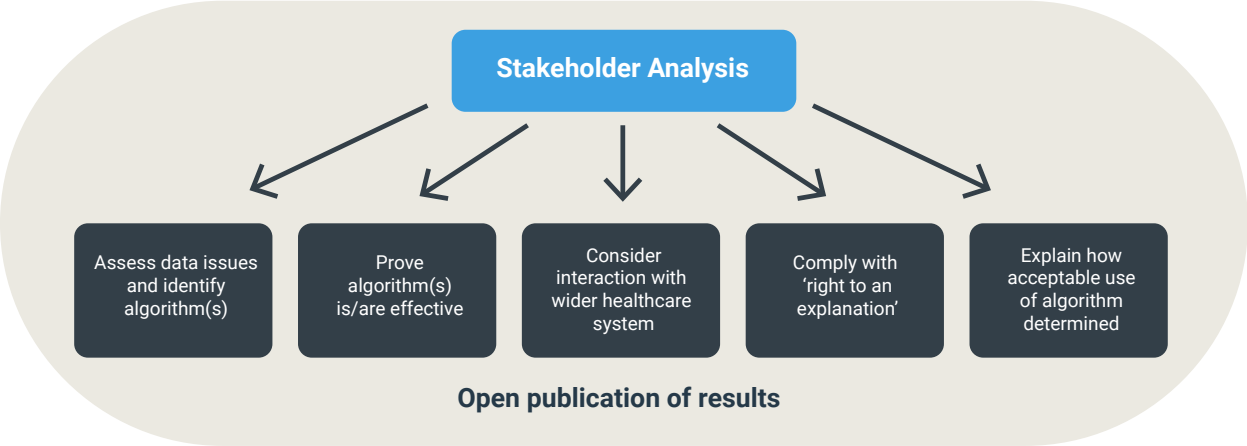

Figure 5: A schematic outlining steps towards algorithmic explainability in health (from [19]).

- Co-development is vital and is quickly becoming the industry standard. Where there is collaboration amongst developers, users, regulators and other stakeholders from the outset, AI solutions are more responsive to community health needs. "Innovation sandboxes" [21] are accelerating the development and deployment of innovations to improve health and health care at different Canadian sites (e.g. the Li Ka Shing Centre for Healthcare Analytics Research and Training at St. Michael's Hospital in Toronto, and the CAN Health Network, a national consortium of hospitals across Ontario, BC, Alberta and Manitoba). Multiplying the number of innovation hubs will be critical to Canadian AI4H development. Mapping the complex linkages between development and deployment is crucial for efficient scaling of the most promising AI-powered products and services (see Figure 4, above).

- Canada can only excel in AI4H if the nation trains and retains talent at a world-beating pace. New curricula and programs are fast emerging for data scientists and machine learning experts who are at the core of developing AI4H opportunities. More attention needs to be directed to the educational/training needs of users of AI including health professionals, administrators, and the public at large. And while the demand for training and retraining is surging — from entry-level orientation to deep learning experts — the growth supply of good quality training programs to meet this demand does not appear to be keeping pace.

- The current Canadian landscape for financing the development of AI can be characterized as lumpy and limited.
    - The Federal government has spawned several sizeable efforts that are helping both to secure the scientific foundations for development, via for example the 80 Canada CIFAR AI Chairs (~ 30% of whom have an interest and expertise in AI4H); and, to accelerate some "moonshot" development efforts in high yield areas such as imaging. As noted above with respect to ***data***, however, Canada's public investment in health data systems is woefully insufficient especially relative to other countries.

    - Incentives for start-up companies in the form of direct grants or tax-credits from the federal and provincial governments are helping the private sector pursue AI4H product development. As well, private financing of new AI4H businesses is growing through both dedicated and general venture funds that are backing early stage companies. Like other tech sectors, however, Canadian early-stage financing of AI companies is small relative to the availability in the US and China, and many international funds have a greater capacity to make follow-on investments. As a result, AI4H developers often seek international investors or are pursuing growth strategies with a view to being taken over by a bigger international company.

- Canada has longstanding problems with scaling homegrown healthcare innovations of any type. In theory, Canada's single payer systems represent a valuable opportunity for companies with new products and services to achieve early scale in AI4H markets. In reality, there are several barriers.

- First, although progress is being made, Canada has not established clear regulatory standards to assess effectiveness and cost-effectiveness of new AI4H products that can be used by provincial/territorial purchasers/payors. The US Food and Drug Administration has been moving faster and more creatively on this front, although Health Canada, to its credit, is now moving to catch up. However, Canada will only become a world leader in AI4H if it designs a novel regulatory regime suited to the unique features of this technology, and avoids cookie-cutter application of current technology assessment modalities.

- Second, as documented elsewhere, health sector entrepreneurs report that Canada's healthcare purchasers actually seem averse to buying Canadian, particularly if the company is headquartered out of province [6].

- Third, the weakly integrated nature of Canada's provincial/territorial healthcare systems means that incentives are poorly aligned to support the adoption of innovative technologies. An integrated system reconciles investment in one segment of healthcare with savings in another, to determine whether the net outcome is positive. Canadian healthcare budgeting largely lacks this clarity and alignment [6].

For all these reasons, AI4H products are having difficulty finding access to the Canadian market and companies are turning to international markets. On this front, fortunately, Canada's EDC and bilateral trade promotion efforts offer potential support to companies seeking to tap foreign markets.

Canadian AI4H Case Study

AI treatment plans for radiation therapy

Partners

Princess Margaret Hospital, UHN Techna Institute, RaySearch Laboratories.

Challenge

Radiation therapy is required in approximately 40% of cancer cases. Each patient receiving radiation therapy needs a treatment plan, which must carefully balance the delivery of radiation to the tumour while minimizing the dose received by nearby healthy organs. Each patient's body shape and cancer are unique, so creating the plan traditionally requires a team of professionals working for hours or even days.

Solution

An AI planning system developed by UHN researchers dramatically reduces the time and associated costs required to generate radiation treatments: it can create a high-quality treatment plan in just minutes. The system uses AI that compares patients' medical images with a database of previously high-quality treatment plans created by experts at Princess Margaret. It can then use the information contained in the previous treatment plans to generate a new plan that is personalized to the patient.

Result

A preliminary study found that AI treatment plans were preferred or found equivalent to human-generated treatment plans that had been used for patient care in 88% of cases according to a panel of clinical experts. Every patient with localized prostate cancer treated at the Princess Margaret Cancer Centre now has two plans created for them: one using the traditional manual system and another using the new machine-learning automated system. A physician reviews both plans and chooses one for further review and quality assurance before it is used to guide radiation therapy for the patient.

Source: https://www.uhnresearch.ca/news/ai-treatment-plans-used-patients

Canadian AI4H Case Study

Community-based ultrasound for reduced wait times and broader access

Challenge

Clinical 3D ultrasound is a widely available tool in hospitals and clinics for diagnosis and monitoring of many conditions, including cardiovascular disease, pregnancy, vascular issues and other soft tissue imaging. Patients must travel to specialized facilities to have their tests read by qualified radiologists, which limits access to this technology and increases wait times. It is safer, more cost-effective, and more portable than many other imaging modalities, and yet, millions of people around the world do not have easy access to ultrasound imaging.

Solution

MEDO.ai is an Edmonton-based start-up company that uses AI and cloud computing to bring ultrasound technology to underserved communities. By using MEDO's AI-augmented platform for 3D ultrasound, patients no longer need to travel to specialized clinics or hospitals for imaging, but instead can be imaged in their own communities, including the offices of their primary care physician or community clinics. The resulting scan can be uploaded onto MEDO's analysis platform and analyzed using AI, eliminating the need for radiology expertise to read the scan.

Result

By making ultrasound scans more accessible through the use of portable imaging and AI-based analysis, people in developed countries will see reduced wait times and will not need to travel from rural regions to access this important medical imaging tool, leading to faster diagnoses and reduced costs to the health system. In low-income countries, this approach has the potential to have an even greater impact, making ultrasound more accessible to those who may not otherwise be able to get a scan in a timely or affordable way.

Source: https://www.startupedmonton.com/medo

Canadian AI4H Case Study

Dermatology Point-of-Care Intelligent Network

Partners

Change Health Care, BC Cancer Agency, Careteam, MetaOptima, Providence Health Care, University of British Columbia, University of Victoria, Canada's Digital Technology Supercluster

Challenge

One in six Canadians will develop some sort of skin cancer during their lifetime. Each year in Canada there are 80,000 reported cases of skin cancer (melanoma). The annual cost of skin cancer to the healthcare system is over $500M coupled with immeasurable costs to families. Advanced cases of skin cancer can cost over $160,000 per patient to treat, whereas a timely intervention can cost as little as $50. Canada is facing a severe shortage of dermatologists leading to wait times of six months or more to see one. Melanoma can rapidly progress in as little as six weeks and patient survival declines from 98% to 15% if treatment is delayed.

Solution

The new cloud-based Dermatology Point-of-Care Intelligent Network will use MetaOptima's tele-dermatology and Change Health Care's tele-pathology imaging, augmented by artificial intelligence. The project will also offer the possibility to not only expedite urgent cases faster through e-referral and e-triage but will train AI models on real-life clinical data, to create algorithms for clinical decision support and medical education.

Change Health Care's imaging division, with its decades of experience in radiology and cardiology imaging, will develop an enterprise-wise Intelligent Imaging Network (IIN) to manage multiple kinds of images and associated complex clinical workflows. MetaOptima will apply its revolutionary DermEngine platform to be used by medical professionals and integrated into TELUS Health electronic medical records and the patient-centered collaboration platform of Careteam Technologies. The project will apply the exceptional care backbone and integrated research expertise of Providence Health Care and the advanced research capabilities of a BC post-secondary research institution.

Result

The project is expected to roll out in different regions of British Columbia in multiple phases in 2019 and 2020. Once proven to address the needs of British Columbians, the intent is to expand coverage of the system to other parts of Canada and the world, particularly those with increased solar exposure and higher incidences of skin cancer.

This project will also help the medical community accelerate early diagnosis of skin diseases and substantially improve skin cancer patient survivability by earlier diagnosis and intervention. Additionally, it will serve as a basis for building similar end-to-end processes in other image-intensive service lines such as Cardiology, Radiology, Pathology, Ophthalmology.

Source: https://www.digitalsupercluster.ca/programs/precision-health/dermatology-point-of-care-intelligent-network/

Call to Action

For Canada to harness the opportunity that AI can bring to health and health systems, the AI4H Task Force recommends that our governments act urgently on three fronts.

1. **Establishing AI4H infostructure that enables responsible access to health data while ensuring data are secure and privacy is protected**

   The types of comprehensive datasets that will optimize the impact of AI in the health sphere cannot be created without strong public engagement to help guide terms and conditions for their use. More generally, members of the public and patients should be included as active partners in the development, governance and evaluation of AI4H policies and strategies related to data sharing.

   Work on this front has other elements, including:

   - Establishing the computational capacity necessary to handle massive high-dimensional datasets.
   - Enriching and sustaining large-scale health data sets that are high quality and appropriately representative of target subpopulations of interest. This would include both the common practice of using **population-wide** (unconsented, de-identified) data holdings for public health and research purposes under the appropriate oversight and ethical and scientific review, as well as emerging models that preserve meta-data and enable wider linkages with even more stringent controls, including total containment of all data within a surveilled and curated environment that precludes removal of any data. A third modality, already well established, involves maintaining very large (consented) **cohort studies**.
   - Ensuring that all public health data assets are governed and managed responsibly to enable collaboration, coordination and integration **across jurisdictions**, accessibility, trust, and appropriate accountability/traceability to prevent and police unauthorized access.

2. **Accelerating the development of safe, high-performance AI4H applications by both public institutions and private enterprises, alongside deployment of incentives that promote strategic procurement and responsible scaling of these applications within Canada's healthcare systems**

   This involves two mutually reinforcing elements. One is smart development and procurement of AI within Canada's publicly funded healthcare systems. The other is an effective commercialization plan, supporting the growth of Canadian-led AI4H enterprises through both direct and indirect funding as well as targeted procurement. Success in both domains depends critically on the implementation of the right set of incentives.

   Again, work on this front has other elements. One bridges back to responsible use of data:

   - Reviewing extant Canadian legislation and regulations as well as international policies and practices that govern interchanges of patient data between publicly funded institutions and private enterprises.

   Others follow:

   - Determining whether and how public funds should be used to seed new private capital investments in AI start-ups.
   - Customizing some of the current federal supports for mid-size companies in the AI4H 'space' to scale and reach global markets.
   - Ensuring the applicability of existing tax incentives for companies focused on made-in-Canada AI4H solutions.
   - Expanding innovation-friendly talent/immigration policies and growing the Canadian talent pool in AI and machine learning so that both public and private enterprises can progress rapidly in AI4H innovations.

- Extending the concept of 'regulatory sandboxes' to networks of collaborators focused on AI4H innovation, evaluation and scaling. These virtual col-laboratories should engage a range of domestic stakeholders with international partners as appropriate: e.g. academic researchers, entrepreneurs, venture capitalists, provincial and territorial health ministries, health assessors and regulators, hospitals, clinical networks.

3. **Ensuring that federal and provincial/territorial plans to advance digital health are coupled to an explicit AI4H strategy with the relevant policies, investments, partnerships, and regulatory frameworks**

   Without this alignment, Canadians will not reap the full health benefits of the opportunities available from responsible use of AI and machine learning more generally. Such a plan should aim to foster more research, enable improvements in healthcare delivery and population health policymaking, and facilitate the development of scalable AI4H innovations under the aegis of both private enterprises and public institutions.

   Yet again, work on this front has other elements, including:

   - Mobilizing expert advisory capacity to support a national, coordinated AI4H strategy. This could take many forms, ranging from term-limited task forces to the establishment of a multi-stakeholder national AI for Health Leadership Council.
   - Mandating the AI for Health Leadership Council with the identification of AI use cases across the full spectrum of health in Canada, from health service delivery and disease prevention to population health determinants, to the discovery and development of new diagnostic tools and treatments, as an urgent first priority.
   - Ensuring that policy development involves not only members of the general public and patients, but from the outset draws in as full partners those provinces and territories that are prepared to make tangible commitments to this joint effort.
   - Ensuring that Health Canada and both federal and provincial health technology assessment bodies work together to develop a regulatory and evaluation framework for AI4H applications that is responsible, innovation-friendly, and meets, or better still, becomes an international standard. As noted earlier, it is essential that these processes be nimble; algorithms evolve and cannot be regulated in exactly the same way as prescription drugs and devices.
   - Working with educational partners to ensure the elaboration of integrated AI4H curricula that will expand the relevant talent pools for both the development and use of AI4H across diverse healthcare professions, institutions, and enterprises. This effort is crucial to the long-term success of any Canada-wide AI4H initiatives.

Conclusion

These recommendations are time sensitive. They are the result of the deliberations of a CIFAR-convened Task Force of expert volunteers who have all been engaged with AI4H in diverse ways. They are intended to lay foundations for a national, coordinated, and integrated effort that will help Canada take full advantage of transformative new technologies that are rooted in Canadian research and have widely-recognized potential for use in every corner of the world, and by people in every conceivable walk of life. Failure to seize these opportunities will have adverse consequences for the quality and efficiency of our healthcare systems, the health of our communities, and the prosperity of the nation.

We call on the Government of Canada and all interested provincial/territorial governments to collaborate urgently in developing a AI for Health strategy in lockstep with broader plans to accelerate digital healthcare innovation.

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References

[1] G. Hinton, "Deep Learning—A Technology With the Potential to Transform Health Care," *JAMA,* p. 320(11):1101–1102, 2018.

[2] C. D. Naylor, "On the Prospects for a (Deep) Learning Health Care System," *JAMA,* p. 2018;320(11):1099–1100, 2018.

[3] M. Matheny, S. Israni, M. Ahmed and D. Whicher, "Artificial Intelligence in Health Care: the Hope, the Hype, the Promise, the Peril," National Academy of Medicine, Washington, 2019.

[4] E. Topol, Deep Medicine: How Artificial Intelligence Can Make Healthcare Human Again, New York: Basic Books, 2019.

[5] A. Fogel and J. Kvedar, "Artificial intelligence powers digital medicine," *NPJ Digital Medicine,* p. 1:5, 2018.

[6] C. D. Naylor, N. Fraser, F. Girard, T. Jenkins, J. Mintz and C. Power, "Unleashing Innovation: Excellent Healthcare for Canada — Report on the Advisory Panel on Healthcare Innovation," Government of Canada, Ottawa, 2015.

[7] E. Schneider and D. Squires, "From Last to First — Could the U.S. Healthcare System Become the Best in the World?," *New England Journal of Medicine,* vol. 377, no. 10, pp. 901-904, 2017.

[8] M. Lalonde, "A new perspective on the health of Canadians," Minister of Supply and Services Canada, Ottawa, 1974.

[9] B. Barua and D. Jacques, "Comparing Performance of Universal Health Care Countries, 2018," Fraser Institute, Vancouver, 2018.

[10] M. Flores, G. Glusman, K. Brogaard, N. Price and L. Hood, "P4 Medicine: How systems medicine will transform the healthcare sector and Society," *Per Med,* vol. 10, no. 6, pp. 565-576, 2013.

[11] R. Horne, J. Bell, J. Montgomery, M. Ravin and J. Tooke, "A new social contract for medical innovation," *Lancet,* vol. 385, no. 9974, pp. 1153-1154, 2015.

[12] B. Tran et al., "Global Evolution of Research in Artificial Intelligence in Health and Medicine: A Bibliometric Study," *Journal of clinical medicine,* vol. 8, no. 3, p. 360, 2019.

[13] J. Kung, "Building an AI World: Report on National and Regional AI Strategies," CIFAR, Toronto, 2020.

[14] Ernst & Young, "Positioning Montréal to attract quality foreign direct investments in the AI Life Sciences Sector," Montreal International, Montreal, 2019.

[15] Accenture, "Artificial Intelligence (AI): Healthcare's New Nervous System," Accenture, 2020. [Online]. Available: https://www.accenture.com/fi-en/insight-artificial-intelligence-healthcare. [Accessed 6 March 2020].

[16] "The world's most valuable resource is no longer oil, but data," 6 May 2017. [Online]. Available: https://www.economist.com/leaders/2017/05/06/the-worlds-most-valuable-resource-is-no-longer-oil-but-data. [Accessed 6 March 2020].

[17] E. Harwich and K. Laycock, "Thinking on its own: AI in the NHS," Reform Research Trust, London, 2018.

[18] IPSOS Mori, "Public attitudes to the use and sharing of their data," Royal Statistical Society, London, 2014.

[19] I. Joshi and J. Morley (eds.), "Artificial Intelligence: How to get it right," National Health Service (UK), London, 2019.

[20] D. Angus, "Randomized clinical trials of artificial intelligence," 17 February 2020. [Online]. Available: https://jamanetwork.com/journals/jama/article-abstract/2761468. [Accessed March 2020].

[21] C. Pralahad, "Innovation Sandbox," *Strategy+Business,* Reprint No. 06306, Autumn 2006

Appendix 1: List of Key Stakeholders and Organizations Consulted

Key Stakeholders Consulted

Last Name	First Name	Position	Organization
Ainslie	Peggy	Executive Director, Health Care Strategies Directorate	Health Canada
Akshay	Mohan	Doctoral Student	University of Toronto
Alberga	Hannah	Journalist	Ryerson University
Alhasani	Rehab	PhD Candidate	McGill University
Angus	Helen	Deputy Minister	Ontario Ministry for Health
Arbel	Tal	Professor and Canada CIFAR AI Chair	McGill University
Arancibia	Rodrigo	Director	Innovation, Science and Economic Development Canada
Arbuthnot	Andrea	Director, Communications & Engagement	Vector Institute
Auger	Louise	Director, Professional Affairs	Fed. Medical Regulatory Authorities of Canada
Awadalla	Philip	Director, Computational Biology	Ontario Institute for Cancer Research
Ba	Jimmy	Assistant Professor and Canada CIFAR AI Chair	University of Toronto
Baclic	Oliver	Medical Advisor	Public Health Agency of Canada
Baillet	Sylvain	Professor & Associate Dean (Research)	McGill University
Barr	Jennifer	National Sales Training Neuroscience	Novartis
Basu	Sanjana	Associate	Radical Ventures
Basu	Sumana	PhD Student	Mila
Beed	Janet	Former President and CEO	Markham Stouffville Hospital
Bendahmane	Farah	Director, Enterprise Development	Montréal InVivo
Bengio	Yoshua	Scientific Director and Canada CIFAR AI Chair	Mila
Bertin	Paul	Intern	Mila
Bhavsar	Amit	Assistant Professor	University of Alberta
Boudreau	David	Acting Director General, Medical Devices Bureau	Health Canada
Bramwell	Anthony	Policy Analyst	Health Canada

Last Name	First Name	Position	Organization
Brockstedt	Ulrike	Researcher	University of Alberta
Brooks	Rupert	Senior Research Scientist	Nuance Communications
Buckeridge	David	Professor	McGill University
Buckley	Jenny	Senior Improvement Lead	Canadian Foundation for Healthcare Improvement
Caesar	Michael	Executive Director, Data & Implementation Science	University Health Network
Campbell	Jennifer	A/Manager, Major Initiatives	CIHR
Casselman	Mark	CEO	Digital Health Canada
Chandar	Sarath	Assistant Professor and Canada CIFAR AI Chair	Polytechnique Montreal and Mila
Chowdhury	Biswajit	Researcher	Self employed
Cloutier	Réal	President and CEO	Winnipeg Regional Health Authority
Cohen	Joseph Paul	Postdoctoral Fellow	Mila, University of Montreal
Côte	Pierre	Medical Affairs Manager	Boehringer Ingelheim Canada
Crichlow	Monique	Director, Strategy & Policy Development	Compute Ontario
Cross	Justin	Chief Digital Health Officer	Jewish General Hospital
Davidson	Janet	Board Chair	Canadian Institute for Health Information
Davies	Mitch	Senior Assistant Deputy Minister	Innovation, Science and Economic Development Canada
De Montigny	Simon	Research Assistant Professor	University of Montreal
DeCaria	Jennifer	Senior Director Business Development	Unity Health Toronto
Decelle	Barbara	Health Research Advisor	IVADO
Diemert	Lori	Project Manager	University of Toronto
Dolatabadi	Elham	Technical AI staff scientist	Vector Institute
Doyle	Stéphanie	Director, Business Development, Life Sciences & Health Technologies in English	Montréal International
Epstein	Shelley	Vice President, Corporate and Public Affairs	Imagia
Fascione	Clotilde	Innovation Advisor	Health Canada
Finley	Rita	Senior Policy Advisor	Public Health Agency of Canada
Forbes	Cindy	EVP & Chief Analytics Office	Manulife Financial
Fortier	Francis	Analyst	Conseil Interprofessionel du Québec
Frey	Brendan	CEO	Deep Genomics
Fuhrer	Rebecca	Professor	McGill University
Gapanenko	Katerina	Manager, Analytic Techniques and Tools in English	Canadian Institute for Health Information
Ge	Jenny	Senior Sector Advisor, Life Sciences	Government of Ontario

Last Name	First Name	Position	Organization
Ghassemi	Marzyeh	Assistant Professor and Canada CIFAR AI Chair	University of Toronto
Gibson	Garth	President and CEO	Vector Institute
Gibson	Jennifer	Sun Life Financial Chair in Bioethics and Director, Joint Centre for Bioethics	University of Toronto
Giguère	Sébastien	Co-founder	InVivo AI
Giroux	Philippe-Olivier	Policy Analyst	Innovation, Science and Economic Development Canada
Graili	Pooyeh	Principal Consultant	Quality HTA
Greenshaw	Andrew	Professor and Associate Chair (Research)	University of Alberta
Greiner	Russ	Professor of Computer Science	University of Alberta
Grimm	Christine	Senior Executive Director, Digital Health, Analytics and Privacy	Nova Scotia Department of Health and Wellness
Hashmi	Owais	Senior AI Specialist	IBM
Herst	Stephen	Chief Operations Officer	Terry Fox Research Institute
Hitti	Yasmeen	Research Intern	Mila
Horsley	Tanya	Associate Director, Research	Royal College of Physicians and Surgeons of Canada
Hu	Pingzhao	Assistant Professor	University of Manitoba
Ingram	Katrina	Student Researcher	University of Alberta
Jabet	Carole	Scientific Director	Fonds de la recherche en santé du Québec
James	Deborah	Associate Vice-President, Innovation; Co-lead	University of Alberta; Precision Health Signature Area
James	LLana	PhD Student	University of Toronto, Faculty of Medicine
Jankowicz	Damian	VP & CIO	The Centre for Addiction and Mental Health
Joanette	Yves	Directeur	Consortium Santé Numérique — Université de Montréal
Johnson	Tracy	Director, Health System Analysis and Emerging Issues	Canadian Institute for Health Information
Kandel	Rita	Chief of Pathology and Laboratory Medicine; Professor, Laboratory Medicine and Pathobiology	Mt. Sinai Hospital; University of Toronto
Kennedy	Simon	Deputy Minister	Innovation, Science and Economic Development Canada
Kim	Eugene	Associate Director, Privacy and Data Governance	Sidewalk Labs
Kingsford	Douglas	Chief Medical Information Officer	British Columbia Ministry of Health
Kong	Arthur	Head of Science, Innovation, and Policy	British Consulate-General Toronto
Krishna	Sai	Machine Learning Researcher	99andBeyond
Kurji	Naheed	President & CEO	Cyclica

Last Name	First Name	Position	Organization
Ladner-Keay	Carol	Director of Clinical Research	University of Alberta
Lang	Michael	Academic Associate	McGill University
Leprêtre	Sacha	Director, Innovation, Development and Technologies	Mila
Létourneau	Stéphane	Vice-President, Partnerships and Corporate Affairs	Mila
Lewis	Charles	Vice-president TELUS Health and Payment Solutions and Chief Technology Officer	TELUS Health
Linke	Cam	CEO	Amii
Loiselle-Boudreau	Josiane	Partnerships Scientific Adviser	National Institute of Public Health of Quebec
Lourenco	Celia	Director General, Biologics and Genetic Therapies Directorate	Health Canada
Lucas	Stephen	Deputy Minister	Health Canada
Luo	Lewis	Advisor / Global Affairs Consultant	CBERN / ANI Networks
MacIntyre	Georgina	Director of Trainee Professional Development, Office of Research	University of Alberta
Mah-Fraser	Tammy	Executive Director, Health Platforms	Alberta Innovates
Malikov	Kamil	Director, Health Data Science	Ontario Ministry of Health
Marchand	Maëlle	Improvement Lead	Canadian Foundation for Healthcare Improvement
Mardis	Nicole	Senior Business Partner	Alberta Innovates
McMahon	Meghan	Associate Director	CIHR-Institutes of Health Services and Policy Research
Ménard	Caroline	Senior Ecnomist	Innovation, Science and Economic Development Canada
Milburn	Jocelyn	Manager	Government of Canada
Modaresi	Farhang	VP	Concinto
Moreno	Laurent	Director, Health AI Application	Vector Institute
Morgan	Ed	Director General	Health Canada
Motulsky	Aude	Assistant professor	Université de Montréal
Mussa	Fatima	Project Coordinator	CIHR-Institute of Population and Public Health
Najjar	Bahareh	Senior CRA	Medpace
Nemer	Mona	Chief Science Advisor	Government of Canada
Nikiema	Jean-Noël	Post-doctoral Fellow	Centre de recherche du CHUM
O'Donnell	Maureen	Executive Vice President, Clinical Policy, Planning and Partnerships	Provincial Health Services Authority, British Columbia
O'Toole	David	President & CEO	Canadian Institute for Health Information
P	Brian	Sr. Consultant	Bpintl

Last Name	First Name	Position	Organization
Pajek	Daniel	Product Manager	Panaxium
Pariseau	Jean-François	Co-Founder and Partner	Amplitude Ventures
Pellerin	Martine	Vice dean Research and Innovation	University of Alberta
Petitgand	Cécile	Postdoctoral fellow	Université de Montréal
Pineau	Joelle	Professor / Researcher and Canada CIFAR AI Chair	McGill University, Facebook
Pisano	Valérie	President & CEO	Mila
Polsky	Sharon	President & CEO	The Privacy and Access Council of Canada
Prawdzik	Sally	Sr. Advisor	Health Canada
Rahemtulla	Alisha	Independent Consultant	Shoppers Drug Mart
Rahimi	Samira	Assistant Professor	McGill University
Reznick	Richard	Professor	Queen's University
Richer	Etienne	Associate Scientific Director	CIHR Institute of Genetics
Rogers	Susan	Project Lead, Aging Institute Initiatives	CIHR
Ronen	Raphael	Senior Commercialization Manager	Sunnybrook Research Institute
Rosen	Lorna	Deputy Minister	Alberta Health
Rosychuk	Rhonda	Professor	University of Alberta
Roy	Denis	Vice President, Science and Clinical Governance	Institut national d'excellence en santé et en services sociaux
Rylett	Jane	IA Scientific Director	CIHR
Saleh	Shems	Member of AI Technical Staff	Vector Institute
Saulnier	Marcel	Associate ADM	Health Canada
Scherer	Stephen	Director, The Centre for Applied Genomics; Senior Scientist, Genetics & Genome Biology	Hospital for Sick Children
Schoffer	Carter	Sr. Manager of Science, Medical & Education, & Business Affairs	Arthrex
Schull	Michael	President & CEO	The Institute for Clinical Evaluative Sciences
Serpe	Michael	Professor	University of Alberta
Shah	Prakesh	Pediatrician	Sinai Health System
Sheremeta	Lori	Researcher/consultant	University of Alberta
Sinnatamby	Nila	Senior Policy Advisor	Ontario Ministry of Health
Smith	Kevin	President and CEO	University Health Network
Sohi	Shelly	Program Manager	Alberta Innovates
Song	Melodie	Postdoctoral fellow — equitable AI for public health	Public Health Ontario
Strug	Lisa	Senior Scientist	SickKids
Taylor	Mark	Senior Director of Research	University of Alberta

Last Name	First Name	Position	Organization
Thomas	Karam	CEO	99andBeyond
Tsang	Tyler	Director	Shoppers Drug Mart
Vallières	Martin	Assistant Professor and Canada CIFAR AI Chair	Université de Sherbrooke
Viviano	Joseph	Student	Mila
Williams	Christine	Deputy Director and Head, Clinical Translation	Ontario Institute for Cancer Research
Wilson	Laure	Senior Analyst	Western Economic Diversification Canada
Wright	Martin	Assistant Deputy Minister, Health Sector Information, Analysis and Reporting	British Columbia Ministry of Health
Yang	Kathleen	Team lead	Canadian Institute for Health Information
Yiu	Verna	President & CEO	Alberta Health Services
Zaïane	Osmar	Professor	University of Alberta

Key Organizations Consulted

Sector	Organization	Geographical Representation
Clinical Practice & Research	Centre for Addiction and Mental Health	ON
	Institut national d'excellence en santé et en services sociaux (INESSS)	QC
	Markham Stouffville Hospital	ON
	Medpace	International
	Sinai Health System	ON
	St. Michael's Hospital	ON
	Sunnybrook Research Institute	ON
	The Hospital for Sick Children (SickKids)	ON
	Unity Health Toronto	ON
	University Health Network	ON
	Winnipeg Regional Health Authority	MB
Government	Alberta Health Services	AB
	British Columbia Ministry of Health	BC
	British Columbia Provincial Health Services Authority	BC
	British Consulate-General Toronto	International
	Canadian Institutes of Health Research (CIHR)	National
	CIHR — Institute of Genetics	National
	CIHR — Institute of Population and Public Health	National
	Health Canada	National
	Nova Scotia Department of Health and Wellness	NS
	Innovation, Science and Economic Development Canada	National
	Ontario Ministry of Health and Long-Term Care	ON
	Public Health Agency of Canada	National
	Public Health Ontario	ON

Sector	Organization	Geographical Representation
Industry	ANI Networks	International
	Arthrex	National
	Boehringer Ingelheim (Canada) Ltd.	ON
	Manulife	National
	Novartis	Multinational
	Nuance Communications	International
	Shoppers Drug Mart	National
	TELUS Health	National
Innovation & Startup	99andBeyond	QC
	AltaML	AB
	Dialogue Technologies	QC
	Cyclica	ON
	Deep Genomics	ON
	Imagia	QC
	Imagine Canada	National
	InVivo AI	QC
	MetaOptima Inc.	BC
	Panaxium	International
	Winterlight Labs	ON
Not-for-profit	Canadian Institute for Health Information (CIHI)	National
	Conseil Interprofessionel du Québec	QC
	Digital Health Canada	National
	Montreal International	QC
	Montreal InVivo	QC
	Royal College of Physicians and Surgeons of Canada	National
Patient Partnership & Advocacy	Canadian Foundation for Healthcare Improvement (CFHI)	National
	Patient Advisors Network	National
	Patient Critical Co-Op	National

Sector	Organization	Geographical Representation
Research & Training	Alberta Innovates	AB
	Amii	AB
	CIFAR	International
	Compute Ontario	ON
	Fonds de Recherche du Québec	QC
	Institute for Clinical Evaluative Sciences (ICES)	ON
	Institut de valorisation de donées (IVADO)	QC
	Institut national de santé publique du Québec (INSPQ)	QC
	McGill University	QC
	McMaster University	ON
	Mila	QC
	Ontario Institute for Cancer Research (OICR)	ON
	Queen's University	ON
	Polytechnique Montreal	QC
	Simon Fraser University	BC
	Terry Fox Research Institute	BC
	Université Laval	QC
	Université de Montreal	QC
	Université de Sherbrooke	QC
	University of Alberta	AB
	University of Toronto	ON
	Vector Institute	ON
Venture Capital	Amplitude Ventures	QC
	Radical Ventures	ON