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Task Force Report on Artificial Intelligence and Emerging Digital Technologies

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In collaboration with:

Council Task Force on Artificial Intelligence and Emerging Digital Technologies

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Executive Summary

Incorporated by a special act of Parliament in 1929, the Royal College of Physicians and Surgeons of Canada is an organization of medical specialists dedicated to ensuring the highest standards and quality of health care.

The Royal College sets the standards for the training, evaluation and certification of specialist physicians, and the accreditation of specialty postgraduate medical education programs. It also supports specialists' continuing professional development through its Maintenance of Certification (MOC) program and contributes to advancing the health system and its workforce.

Recognizing the importance of advanced technology in health care, the Royal College Council commissioned a task force to help the medical profession in Canada prepare for the profound changes that artificial intelligence (AI) and emerging digital technologies will bring to residency training and delivery of care. The Task Force on Artificial Intelligence and Emerging Digital Technologies was mandated to conduct extensive research into the current and future states of these technologies and to provide recommendations to Council about how to meet the challenges and opportunities these technologies present to the Royal College.

The task force further recognizes that the technology landscape will continue to evolve. As such this report is not the endpoint of exploration. The Royal College will have to ensure that it prepares and supports medical specialists to function appropriately in the unfolding world of AI and digital technology in health care.

Members of the task force include experts in AI and Fellows of the Royal College. The task force consulted widely with key stakeholders, reviewed the current literature, surveyed Fellows and Resident Affiliates, formally interviewed over 20 authorities in the field, and formally engaged a group of Fellows of the Royal College with expertise in AI and emerging digital technologies.

The task force's findings and recommendations are summarized below. Given the limitations of scope and fiscal considerations, the recommendations have been streamlined to align with achievable fiscal goals and foreseen resources.

Anticipated impacts on medical practice

Key findings:

- AI and emerging digital technologies will not replace a physician's presence, intuition, creativity, judgment and compassion.
- AI and emerging digital technologies will become more integrated into the practice of specialty medicine, supporting the daily routines of a health care team.
- AI and emerging digital technologies could liberate physicians from repetitive tasks, allowing time for more patient care, including compassionate care, and improving the safety and quality of patient care.

Recommendation:

- That the Committee on Specialties of the Royal College of Physicians and Surgeons of Canada continue to regularly monitor the health of individual disciplines, assessing the impact of AI and emerging digital technologies. At this time there are no recommendations to alter the number and complement of specialist physicians being trained in Canada.

A new fundamental competency

Key finding:

- AI and digital technologies will become fundamental to the practice of medicine. To continue to meet patient needs, physicians will need a basic understanding of the available technologies, a stronger background in mathematics and statistics, and the ability to find and understand health information from electronic sources.

Recommendation:

- Digital health literacy competencies should be integrated into the CanMEDS Framework.

Changes to physician practice

Key findings:

- Career transitions in the health workforce will become more common. It is unlikely that physicians will remain in the same area of practice for their whole careers.
- Frequent training and new skill acquisition will be required to adapt to the rapid pace of change imposed by emerging digital technologies.

Recommendation:

- As a matter of urgency, develop processes to address the current challenges faced by all specialties in developing new competencies or making career changes that may be needed as a result of the impact of AI and emerging digital technologies on specialty medicine.

Emerging careers

Key findings:

- New technology-oriented roles and specialties will emerge.
- Survey respondents expressed significant interest in this area of work either as early adopters, innovators or enrolment in a new technology-focused specialty.

Recommendations:

- Consider introducing a new discipline in the area of Clinical Informatics.
- Partner with Canadian medical schools to promote AI and MD/PhD programs and clinician investigator programs focused on digital technology to ensure opportunities for training in this area and encourage a cadre of "clinical innovators" in AI in health care.

AI in health is team science

Key findings:

- Responsible AI tools for medicine are co-developed by teams that include members of the health care team and specialists involved in the development of AI systems, such as computer scientists, engineers, mathematicians and professionals working in other technology-oriented disciplines.
- The majority of Fellows and Resident Affiliates of the Royal College who responded to a survey see themselves as adopting AI technologies now and would like to be more involved in the development, refinement, validation and deployment of AI technologies in the future.

Recommendation:

- Play an active role in supporting Fellows and Resident Affiliates to co-develop, refine, validate and spread AI-enabled technologies.

New products and advancements

Key findings:

- Approvals for the use of AI-based medical technologies in medical settings are increasing. These technologies, and new ones under development, hold great potential to assist in diagnosis, clinical decision-making, training, early prediction and prevention, treatment and personalized medicine.
- Physicians and other members of the health workforce must be up to date on advancements in these fields and understand the capabilities, limits and risks of AI and emerging digital technologies in medicine.

Recommendation:

- Working with individual disciplines and the Committee on Specialties, develop guidelines and principles for integrating the teaching of AI and emerging digital technologies across all residency training programs, and incorporate these teachings as a component of continuous professional development (CPD) for current Fellows.

A complementary addition to the medical team

Key findings:

- AI and emerging digital technologies will become a "member" of the future health care team by supporting its daily routines.
- Health care will become increasingly multidisciplinary. Teams will comprise individuals with diverse backgrounds, including engineering, robotics and data science.

Recommendation:

- Promote the development of new opportunities that support Fellows and Resident Affiliates in working with innovators in the public, not-for-profit and private sectors to co-develop, refine, validate and spread AI and emerging digital technologies and take into account considerations for conflict of interest.

AI – a potential democratizer of health care

Key findings:

- Given that patients will increasingly have access to health data, including their own, AI and digital technologies could have a positive impact on the physician–patient relationship, creating a data-centered partnership that further enables a patient-centered approach to health.
- More and more, physicians will need to embrace their new roles as guides and coaches to empowered patients.
- Despite its great potential for democratizing health care, AI could exacerbate the "digital divide" of marginalized, historically under-represented and other underserved populations if its implementation is not conducted responsibly and monitored.

Recommendation:

- Implement mechanisms to include patients' perspectives in all facets of AI-related decision-making to ensure that multiple, diverse perspectives are represented.

Ethical and legal considerations

Key findings:

- Current governance (legal, ethical, policy) of AI may not be agile enough to support the adoption of AI into health care systems, or to appropriately safeguard privacy, quality and safety and prevent discrimination against historically underserved populations.
- New regulatory frameworks are required that emphasize timely implementation of legal and ethical considerations, such as explainability and transparency, prevention of bias and discrimination, data-related matters, privacy and security, and liability and accountability.

Recommendation:

- Collaborate with partner organizations to develop, tailor, curate and distribute educational offerings related to privacy, discrimination, safety and other ethical and legal concerns arising from adopting AI into health care systems.

Social accountability

Key findings:

- Adoption of AI in health care is predicted to improve the efficiency and effectiveness of health care, leading to improved patient outcomes.
- Current health data, however, does not always include data from all patient populations.
- There is therefore a risk that the integration of AI into health care may pose a risk to the safety and quality of care of historically under-represented populations, or that these populations will be excluded from the anticipated benefits of AI, or both.

Recommendation:

- Promote, enable and extend scholarship, education and other forms of support to physicians that increase their knowledge of the social justice implications of AI-based technologies.

Institutional considerations

Key findings:

- The Royal College is a data rich organization. It generates and collects a large amount of data through its various programs, from accreditation and examinations to its Continuing Professional Development (CPD) and Maintenance of Certification (MOC) programs.
- Increases in data volume are anticipated in an era of competency-based medical education (CBME). The implications for standards of training and for examinations are profound.

Recommendation:

- Establish a working group to review how best to apply AI to support elements of the Royal College's operations, particularly in relation to its role as an examining body. The working group should also consider ways AI could improve the analysis of data collected by the Royal College and address issues pertaining to data governance and ownership.

Surveillance and monitoring of AI advancements

Key finding:

- The rapidly evolving nature of AI and emerging digital technologies will require adaptive action and ongoing monitoring from the Royal College.

Recommendation:

- Develop an ongoing monitoring and development strategy to address the need for further recommendations in the field of AI and emerging digital technologies.

Background

Context

Advances in AI and emerging digital technologies, and their application to medicine and health care, are becoming increasingly prominent. Many are predicting that specialty medicine may fundamentally change, and further, that no areas of medicine will remain untouched by the profound transformation these technologies are expected to bring. Although the pace and timing of these practice-altering changes are still being debated, most agree that changes will come soon.

In light of these anticipated impacts, Council commissioned a task force to study the current and future influence of AI and emerging digital technologies on specialty medicine in Canada. The task force was requested to bring recommendations back to Council with reference to the implications for the role of the Royal College in overseeing the standards and practice of specialty medicine in Canada.

Activities of the Royal College

When the Royal College was proclaimed by royal charter in 1929, it recognized two specialties, Medicine and Surgery. Today the Royal College recognizes 67 disciplines covering the full range of medical, surgical and laboratory medicine specialties. The scope and content of these disciplines continue to evolve.

Among other activities, the Royal College sets standards for postgraduate medical education, assesses the competencies of graduates of residency training programs and accredits the various training programs in the 17 medical schools in Canada. Aspects of continuing professional development and maintenance of competence also fall under the domain of the Royal College. Further information can be found on the Royal College website at www.royalcollege.ca.

Role of the Task Force on Artificial Intelligence and Emerging Digital Technologies

The Royal College Council charged the Task Force on Artificial Intelligence and Emerging Digital Technologies with studying the impacts of AI and emerging digital technologies on the training of future medical specialists and the practice and professional development of current physicians and formulating recommendations to address these impacts.

Terminology

For the purposes of the task force and this report, "AI and emerging digital technologies" refer to such technologies that intersect with medicine. These include machine learning, augmented reality (AR), virtual reality (VR), health apps, omics, precision medicine, robotics, 3D printing, computer vision and intelligent medicine. Other terms used in this report are defined in Appendix A.

Responsibility and authority

Reporting to Council, the task force was convened to

- study, collate and form recommendations to inform the Royal College Council, standing committees and management on the implications of AI and emerging digital technologies for the training of future medical specialists;
- learn from other sectors that are anticipated to bring AI benefits to the health sector in the near future;
- explore and identify the innovations that will impact specialty medicine education;
- define the approaches, partnerships and sources of data required to continuously monitor emerging advances in AI-related technology and assess the impact on specialty medical education, training and delivery of care;
- define strategies to monitor and assess the impact of emerging digital technologies on specialty medicine;
- identify, engage and integrate with other internal and external initiatives, including other task forces, initiatives and national-level organizations working to develop AI strategies; and
- bring a focus on AI to other aspects of the strategic plan.

For the purposes of the task force and this report, "AI and emerging digital technologies" refer to such technologies that intersect with medicine.

Deliverables

This report is the main deliverable of the task force. Following delivery of this report to Council, recommendations will be considered and operationalized as appropriate by the management and staff of the Royal College.

The task force further recognizes that the technology landscape will continue to evolve. As such this report is not the endpoint of exploration. The Royal College will have to ensure that it prepares and supports medical specialists to function appropriately in the unfolding world of AI and digital technology in health care.

The Task Force

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Methods

The task force applied a range of methods in fulfillment of its mandate:

Literature review: The task force conducted a comprehensive analysis of more than 20 published reports and articles related to AI and emerging digital technologies in health care and adopted an ongoing monitoring strategy for new material in the field. This archive of materials created a rich basis for discussions and provided fundamental insights into how other organizations perceive AI from multiple perspectives.

In-person and virtual meetings: Members of the task force met in person five times and held seven teleconference meetings. During these meetings, members of the Research Unit team iteratively presented findings to the task force for discussion. Members of the task force, Royal College executives, invited members of the Royal College Ethics Committee, and Fellows and Resident Affiliates identified as early adopters and experts in AI, met in person to test the task force's draft findings and emerging recommendations. Members of the task force discussed the feedback received and incorporated it into this report (see Appendix B, Section 4).

Delphi method: The task force employed this structured communication technique to reach consensus on the draft recommendations.

Interviews: Using multiple sourcing approaches, the task force identified 22 international experts in AI and emerging digital technologies with whom to conduct key informant interviews. Interviews were recorded, transcribed and analyzed using a continuous content coding approach. Two independent reviewers identified emerging themes (see Appendix B, Section 1).

Surveys: Fellows of the Royal College were surveyed to explore their perspectives on a broad range of topics, including their level of familiarity, interest and willingness to learn about AI. Analysis of their responses identified educational and institutional gaps and opportunities (see Appendix B, Section 2, for the full survey issued to Fellows). Resident Affiliates of the Royal College received a similar survey that was adapted to inform the task force of any current shortcomings in the educational curricula; the results of this survey informed a number of the findings and recommendations (see Appendix B, Section 3, for the full survey issued to Resident Affiliates). Members of the task force also participated in multiple surveys to inform and prioritize recommendations.

Stakeholder engagement: To triangulate the data and to enrich discussions within the task force, multiple engagement methods were leveraged to provide members of the task force with opportunities to interact with the primary stakeholders of this report (see Appendix B).

Scoping review: To complement the work of the task force, efforts are underway to develop a protocol for a scoping review of AI and specialty medicine. This review will address an identified gap in the scholarly literature and could serve as an evidentiary base for this report and future monitoring strategies (see Appendix B, Section 5).

Using multiple sourcing approaches, the task force identified 22 international experts in AI and emerging digital technologies with whom to conduct key informant interviews.

Findings and Observations

Artificial intelligence, machine learning and deep learning

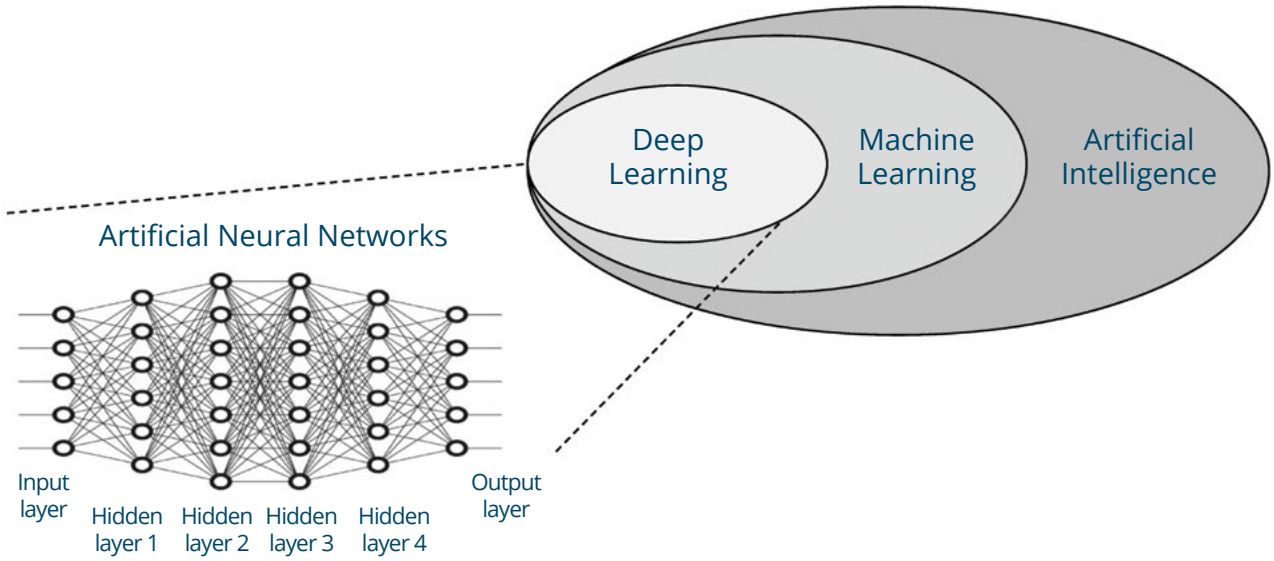
"Artificial Intelligence (AI) refers to computers that can learn about the world flexibly, make inferences about what they see and hear, and achieve human-like understanding of information."[1] By doing so, AI systems mimic the way humans appreciate information to perform tasks normally associated with humans. These tasks are programmed by human experts who encode explicit rules to enable AI systems to carry out specific tasks.

One important component of AI is machine learning (ML). Machine learning refers to the process of computers learning to recognize patterns in data directly from the examples provided and improve their performance using pattern recognition algorithms. ML algorithms identify patterns in the data to create and refine predictive models that are suited to that data, but which can also be generalized to future data. Examples of ML algorithms include artificial neural networks, decision trees (tree-like flowcharts automatically learned to model decisions) and support vector machines (algorithms discovering margins or hyperplanes separating classes of data).

The algorithm that garners the most attention in the literature today is artificial neural networks. Artificial neural networks draw inspiration from the connectivity of the human brain. They consist of an input layer, hidden layers and an output layer. Each layer contains multiple neurons or "nodes," and the nodes from adjacent layers have connections between them. The nodes have a weight associated with them that denotes the relative importance of the information from each node (see Figure 1). At first, the weights are assigned at random, but as the learning algorithm is fed data, it learns which nodes are most important and adjusts the weights accordingly to optimize prediction accuracy.

The tremendous increase in scale of computation coupled with innovations in algorithms and availability of large data drove the rise of Deep learning. Deep learning is a type of artificial neural network that contains multiple hidden layers.[2] With the addition of hidden layers, more complex relationships can be analyzed. Training the algorithm can also be supervised or unsupervised. Deep learning is the most frequently used ML algorithm in medical applications and has been the most successful to date. While deep learning is the

Figure 1. Sample deep neural network



underpinning technology driving the resurgence of AI today, it is important to note that deep learning is a machine learning paradigm, and machine learning is a subfield of artificial intelligence.

Although a computer's learning process is designed to replicate that of the human brain, there is one fundamental difference: the computer's perception of information. For example, a computer does not see an image as the human eye would; instead, it requires that image to be translated into digital information before it can analyze it. Once the image is in digital representation, the computer can use human-designed pattern recognition algorithms to identify patterns within data. Identifying these patterns and trends in given data allows the computer to create a predictive model that predicts relations between a cause and event (input and output). The predictive model is not necessarily interpretable by a human. The computer can then extend this predictive model to new data it has not previously encountered. This logic is the general process of supervised machine learning, and any system that uses such a process for performing tasks and that continuously updates its learning algorithm can be called an AI system.

AI in health is team science

As noted in Dr. Eric Topol's 2019 article published in *Nature Medicine*, "High-performance medicine: the convergence of human and artificial intelligence,"[3] the generation of data in massive quantities – from sources such as high-resolution medical imaging, biosensors with continuous output of physiologic metrics, genome sequencing and electronic medical records – means we have clearly exceeded the limits of analyses that humans can do alone. This requires an increased reliance on machines; yet, as Dr. Topol notes, "the integration of human and AI for medicine has barely begun."

Early applications of AI in medicine, such as predicting mortality in the emergency room and applying computer vision to medical images, have focused on readily available data, regardless of whether the AI solution is needed or desired by physicians, patients or other stakeholders. More recently, physicians and other health stakeholders have been involved from the beginning of the process, when the problem to be addressed through AI support is first identified. A helpful roadmap for deployment that outlines steps for engaging stakeholders can be found in "Do no harm: a roadmap for responsible machine learning for health care."[4] Like all medical interventions, AI interventions will also need to be thoroughly validated by knowledgeable users before being released for widespread implementation.[5] Treating AI in health care as team science is much more likely to result in useful, responsible and high-impact AI that adds something essential to patient care, rather than making it marginally better.

Saying AI in health care is team science does NOT imply that all physicians need to learn how to code and develop AI models. There is, however, a tremendous opportunity for physicians to be deeply involved in the co-development, refinement, validation and spread of AI technologies in health applications.

Consistent with diffusion of innovations theory,[6] there can and should be multiple roles for physicians in the development and spread of AI technologies. Roles envisioned by the task force are presented in Table 1.

Respondents to our engagement surveys suggest their orientation toward AI is generally positive. Both Fellows and Resident Affiliates are keen to engage as partners early in the innovation process.

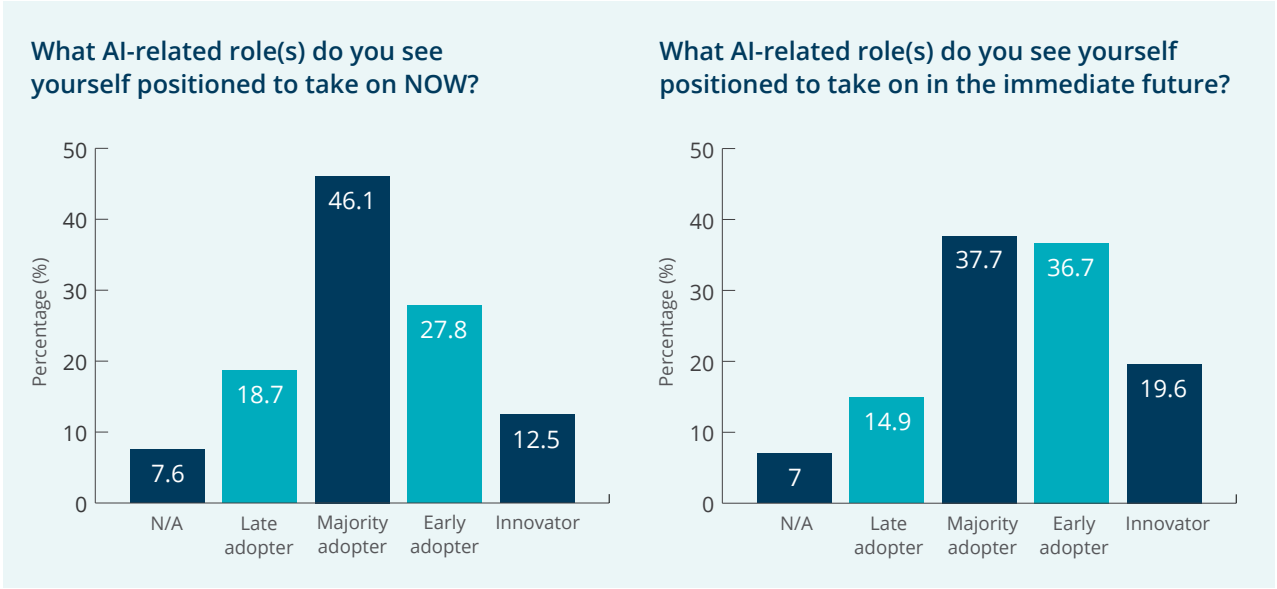
Survey results show that

- most Fellow respondents see themselves as adopting AI now and in the future;
- less than 20% of Fellow respondents see themselves as, or want to be, "late adopters";
- Fellows want to be involved earlier in the innovation process; for example, many "early adopters" want to become innovators, while many "majority adopters" want to be more engaged and become "early adopters" (see Figure 2);
- Resident Affiliates have an even more positive attitude toward AI than Fellows, with 90% of responding residents indicating they want to be innovators, early adopters or majority adopters (roughly one third in each category, respectively); and
- both Fellows and Resident Affiliates lack a deep understanding of the application of AI in medicine and strongly support the Royal College's role in providing AI-related education.

Table 1. Physician roles and their corresponding needs and activities

Role	Needs and Activities
Innovator Physicians who develop or co-develop AI technologies	**Innovators need** • opportunities to direct their entrepreneurial interest in developing new technologies and (where applicable) sharing profits, • opportunities to build their computer science expertise and work directly with computer scientists on cutting-edge science that tests the ability of AI to address important opportunities and gaps in health care, and • to be able to hand off rough innovations to an expert or group of experts who will refine them until they are ready to be spread widely.
Early adopter Physicians who refine and validate AI technologies	**Early adopters need** • confidence the technology they are testing is safe, • information about best practices and standards for testing and refining interventions (e.g., when and how to do a silent trial), and • to be acknowledged (and compensated) for the time and effort they put into translating AI prototypes and ideas into practice.
Majority adopter Physicians who use validated AI technologies	**Majority adopters need** • to be able to distinguish between promising but unproven applications of AI from validated, ready-to-use applications, • sufficient knowledge about AI and other emerging digital technologies to be able to explain to patients how they use them in their practice, • enhanced metacognition skills to integrate the outputs of AI into practice, and • opportunities to present their priorities for new technology development to ensure the sector moves in directions that are helpful for physicians versus "toy tasks" or applications that might pit humans against machines.
Late adopters Physicians who do not plan to adopt AI into their practice	**Late adopters need** • to know which colleagues they can refer patients to in cases where they do not have sufficient knowledge or experience to use AI and related technologies with confidence in their practice, and • the option of continuing to practise medicine in traditional ways.

Figure 2. Survey results indicating the roles Fellows see themselves fit to take on now and in the future



Data considerations

Data is a key component for training ML algorithms; a high-performing AI system depends on access to a large amount of high-quality data. To train an ML algorithm, the data is generally split into three sets:

- a training set used to train the algorithm to create prediction rules based on the accurately annotated data the algorithm is provided,
- a validation set used to evaluate the performance and tune the parameters of the trained algorithm, and
- a test set used to evaluate the performance of the final algorithm and estimate how it would perform with new data.

The process of training an algorithm in this way is referred to as *supervised learning*, which is the most common algorithm used in medical applications.[7] Data used to train the algorithm must be accurately annotated for the algorithm to be properly trained. It must also be all-encompassing to ensure the algorithm is trained on all types of data and to prevent algorithmic bias. This method is primarily used for classification problems, such as analyzing retinal images and differentiating between the retinas of diabetic and non-diabetic patients. Conversely, *unsupervised learning* primarily deals with clustering or grouping the data based on detected patterns. For this method, the data does not need to be annotated.

The ML algorithm learns patterns in the data even when such patterns originate from bias, noise, idiosyncrasies or other sources. Therefore, the data collection process requires significant care and some level of expertise and knowledge. The main issue with medical data sets today is that they were not collected for AI use. As a result, they often contain a range of deficiencies:

- **Missing data:** Vital information that could inform the algorithm may not always be recorded, such as family history of a disease.
- **Problematic de-identification:** The de-identification process may not adequately protect patient safety or may degrade the usefulness of the data.
- **Poor data quality:** The data may include inconsistencies such as typos or use of different abbreviations for the same terms, or the context may not be recorded.
- **Bias:** The data may reflect differences in treatment based on socio-economic status, race, gender or other elements.[8]

To address these issues, the health workforce should be trained on how to properly collect and assess data that can be used for AI algorithms. Ideally, all medical data would be collected in unified, standardized, and analysis-ready formats. Implementing this process would require training on what aspects of data are important for an AI system.

Virtual visits will also likely play an important role in future data collection. With an increasing number of physician–patient interactions poised to be taking place virtually, a large amount of patient data will be collected through this means. Just like data collected during in-person visits, data collected through virtual visits must be collected in a standardized manner to facilitate AI development.

New products and advancements

Applications of AI in health care are not a future consideration; they are here today. Starting with only a single FDA-approved algorithm in 2014, 23 algorithms were endorsed by the FDA in 2018.[9] This exponential growth has seen the FDA approve 35 AI algorithms in health care to date, and this number may well be outdated by the time this report is published. Recognizing the rapid emergence of AI technology, the FDA has proposed a framework for modifications related to AI- or ML-based software used as a medical device. This framework aims to facilitate continuous improvement to such devices and hence patient care.[10]

Many machines have also received the CE mark of approval as a medical product in Europe. Among them is the Apple watch, which was officially approved by the FDA in September 2018 following studies suggesting it can detect atrial fibrillation in some patients.[11] Not only is AI-based medical technology here, but many of us are already using it without even knowing it.

While AI-based medical devices may assist in the delivery of care in various ways, they have been making headlines for their high performance in clinical decision-making.[12] One of the earliest examples of a high-performing AI algorithm was a deep learning algorithm that could identify diabetic retinopathy in retinal fundus photographs with over 96% accuracy.[13] This algorithm's robust performance led to its implementation in ophthalmology clinics in India. Other high-performing AI algorithms have been developed since, many of which have performed either at the same level or above the performance of clinicians.[14] To keep track of AI's rapid advancements in clinical decision-making applications, the Institute of Electrical and Electronics Engineers (IEEE) designed a database[14] to track the most recent algorithms developed. The database is populated and frequently updated with published clinical decision-making research in areas such as breast cancer, heart scans and skin cancer. According to the IEEE, AI algorithms are either matching or outperforming physicians in 13 of the 17 clinical decision-making fields considered.

AI for health care and research purposes can be leveraged in the following fundamental categories.

Diagnosis

Given its ability to process large amounts of data quickly, AI can absorb entire patient records and data, consider hundreds of different factors and recognize patterns within the patient's data that are not comprehensible to the human mind. By doing so, AI can find detailed connections between cause and effect – many of which cannot be determined by human intuition – and thus can produce more accurate, faster diagnoses.

An example of the feasibility of AI-based diagnosis is an AI system developed by Stanford University (see https://www.nature.com/articles/nature21056?foxtrotcallback=true) that recognizes skin cancer in seconds from photos of skin lesions uploaded onto a mobile application.[15] The application's accuracy was on par with diagnoses by dermatologists. Another example is a cardiology algorithm developed by Rajpurkar P., et al,[16] that was trained using deep learning on 64,121 ECGs from 29,163 patients. The model can classify a patient's ECG into 13 different arrhythmias and demonstrated superior performance when compared to six cardiologists.

Decision-making and decision support

The practice of medicine will always involve decision-making; the key to making a good decision is summoning as much information and evidence possible around the case that is being judged. By parsing enormous data sets of medical information with ease, AI can help detect information and facts that are relevant to the situation, many of which would have gone unnoticed within the sea of information.

Many AI tools have been created to analyze data and provide information and guidance to physicians to help them make the best possible decision. These tools have increased accuracy in decision-making and helped determine priorities in the process. For example, IBM Watson has developed

an AI-based system called Watson for Oncology that recommends treatments for cancer patients using a combination of patient medical record data and data extracted from medical guidelines and literature.[17]

Training

Virtual reality (VR) and augmented reality (AR) are tools that can simulate clinical environments and place residents in similar-to-real-life situations to train them and enhance their skills. When coupled with AI, these technologies can serve as a live medical tutor,[18] observing every action the trainee takes and providing real-life feedback, mimicking a senior physician training residents.

There are numerous examples of such tools being used for training and simulation. For example, a Canadian medical device company developed a VR training simulator that provides real-time feedback on real-life surgical procedures.[19] Another example in the same domain is a VR surgical training and assessment platform used in orthopedic hospitals. A study involving 50 medical experts, published in the *Journal of the American Medical Association* (JAMA) in August 2019, concluded that VR simulators guided by machine learning can accurately evaluate the skills of neurosurgeons during virtual surgery and help improve their expertise in preparation for the operating room.[20] Using such technologies, training requires less supervision and fewer resources such as operation rooms and utilities.

Early prediction and prevention

Analyzing large patient data sets, both patient-specific and global, will enable AI systems to browse through numerous events of disease occurrences, look at the state of a patient before the occurrence of an event, and identify common early symptoms of disease, which may lead to early prediction. Data governance and the national and international sharing of data sets, along with the growing availability of data from wearables and sensors, are significant contributing factors toward predicting the likelihood and prevention of disease. An example of a predictive AI system is the early predictor of sepsis being developed at Johns Hopkins University. The system collects 44,000 days of data from the electronic medical records of 7,852 patients to train the model.[21, 22] The tool is still under development, but it has shown promise in predicting sepsis hours before it occurs.

Treatment

AI will play a large role throughout the entire journey of future patients, from prevention through to diagnosis and treatment. By scanning through patient data and medical records, AI can facilitate the treatment process by helping physicians with disease management and treatment planning. AI is currently being used in treatment planning for radiation therapy at the Princess Margaret Cancer Centre in Toronto.[23, 24] Radiation treatment planning involves positioning the body, making marks on the skin to define critical organs and tumours, and calculating the appropriate dose of radiation to the tumour that will minimize the dose to healthy tissue and prevent acute damage to critical organs. While these steps originally took hours to accomplish, AI has reduced the planning time to a few minutes.[25, 26]

Robotics is another treatment area that will be enhanced by AI, specifically robotic surgical assistants. Although not all robots need AI to function, the newer generations of robots will likely be equipped with computer vision and real-time motion feedback, which would result in greater precision and accuracy.[27]

Capabilities and limitations ("It's just math")

As we have seen with the emergence of other technologies, public hype and excitement may result in misleading information and unrealistic expectations about AI. Therefore, it may be just as important to understand what AI cannot do as it is to understand what it can.

While AI has gained considerable profile in recent years, it is not a new concept. Its introduction dates to the 1950s, and we have used AI in various ways for years without noticing. Recently, however, the growth of available data and the exponential increase in the computational power of modern computers have considerably increased AI's prominence. The current form of AI is referred to as "narrow intelligence," meaning it is designed to perform a single task very well.[28] An AI system designed to detect sepsis at an early stage, for example, would not be able to predict or detect heart arrhythmia or do anything other than detect sepsis. AI systems cannot create knowledge; they can only implement the rules they have been programmed to execute.

"Artificial intelligence is only artificial intelligence until some critical mass understands how it works. Then it's just a computer program. It's nothing more."

Daniel Silver, Director, Acadia Institute for Data Analytics, Acadia University[29]

To summarize, AI systems can

- process and interpret data sets larger than the human brain can handle,
- find complex relationships between data, and
- predict cause and event, if programmed to do so and given sufficient data.

While these capabilities are beneficial and compelling, current AI technologies cannot yet

- create intelligence,
- learn on their own without rules and programming to perform specific tasks, or
- predict or detect patterns without sufficient and valid data.

Deeper understanding of these capabilities and limitations will be essential to differentiating between fact and myth in AI-related literature. This knowledge will become fundamental in most work settings, but it will be especially critical for physicians and the health workforce. As more and more AI-based health care tools become available, and with numerous studies being published about novel AI-based medical approaches, physicians will be expected to be aware of these different assistive options and implement the most appropriate ones for the better health of their patients. Physicians should also be able to distinguish between scientific, evidence-based studies and technologies and those that have not had rigorous scientific scrutiny and would not benefit or could even harm patients. To do this, physicians will need a basic understanding of AI and some of its underlying concepts, as well as a strong background in statistics and math.

Widespread impacts on medical practice

According to a 2017 report by the Standing Senate Committee on Social Affairs, Science and Technology, "42% of all current Canadian jobs are at risk of being automated, or 7.5 million jobs."[29] The health workforce, including physicians and specialists, is not exempt from this risk. As a recent report suggests, around 17% of the jobs in health care may be automated by 2030.[30] This prediction does not, however, necessarily mean a loss of health care jobs, but likely a change in the current workflow. Based on the evidence, the task force has come to the consensus that AI will affect every specialty in some way; the functions of all future physicians, including all specialist communities, will change.

The timing of these changes will likely vary across specialties. Given that machine learning algorithms such as neural networks perform better on image data sets, visual and digitally intense specialties are expected to experience significant implications first. However, the unavailability of valid, comprehensive sets of purposefully collected data are still a decelerating factor. Apart from its expected direct and immediate effect on specific specialties, AI may also indirectly affect the workflow of physicians.

"Machines will not replace physicians, but physicians using AI will soon replace those not using it."

Antonio Di Ieva, Associate Professor, Neuroanatomy and Neurosurgery, Macquarie University[31]

Expert opinions vary widely on when physicians can expect to see significant changes in their practice. In 2016, Dr. Geoffrey Hinton stated it is "quite obvious that we should stop training radiologists." Dr. Hugh Harvey disagreed, stating "I say train more; there aren't enough. We have a workforce crisis here in the U.K. This stuff is not going to be replacing what a radiologist or pathologist will do anytime soon." Despite these disparate views on the timing of AI-based changes, experts agree *the emerging technology will NOT replace physicians*. Based on the evidence, the task force does not foresee fewer jobs in any given specialty in the foreseeable future. While the number of jobs may not change, future physicians will be impacted by the development of AI and emerging technologies in other ways. They will need to be highly adapted to the emerging technologies and be able to use and interpret them in their practice for the benefit of their patients.

"The gift of time. To give that back to patients and their physicians – that is critical. That has been lost … the relationship has deteriorated."

Dr. Eric Topol, Executive Vice-President, Scripps Research Institute (Stakeholder engagement interview, July 8, 2019)

Although experts agree machines will not replace physicians, machines will significantly change what a physician does every day. The constant improvement in AI's abilities to recommend diagnoses and contribute to clinical decision-making means physicians will have a multi-functional assistant at their disposal. Future physicians will no longer need to spend most of their appointment times with patients on administrative tasks such as taking notes and searching through multiple documents about the patient's medical history. AI is anticipated to free them from many of these repetitive tasks and allow them to focus on important aspects of the physician–patient relationship, including compassionate care. In our increasingly rushed and constrained system, physicians will have more time to connect with patients, explain their treatment process, express empathy and compassion and build the human bond of which machines will never be capable.

"I think there's an opportunity for physicians to spend more of their time around considerations of empathy and care and shared decision-making with patients and using all of those tools and that data to help provide interpretation around that."

Dr. Brad Wouters, Executive Vice-President, Science and Research, Princess Margaret Cancer Centre (Stakeholder engagement interview, July 10, 2019)

Considering the significant potential of AI algorithms in predicting and providing early identification of disease, as well as in helping physicians to provide more accurate procedures and diagnoses, the practice of medicine is expected to shift toward prevention and management. Novel medical technologies will accompany and accommodate patients throughout their journeys, with the promise of better outcomes and faster recovery. Technology will also help patients before they become ill through more disease prevention strategies and timely intervention. To realize these anticipated benefits, physicians will need to embrace a wide range of skills and technologies.

"There's going to be increasing inter-disciplinarity, I think, to the workload. You're going to see more computer scientists – people who are not traditionally involved in health care – populating the clinical environment. And with all the interdisciplinary work, there's going to be some culture differences, differences in the technical language. So I think that is something that is going to be a real challenge."

Dr. Tom Chau, Vice-President, Research, Holland Bloorview Kids Rehabilitation Hospital (Stakeholder engagement interview, July 17, 2019)

Wider use of AI technologies in health care is also expected to affect the composition of medical teams. Medical teams of the future will likely become multidisciplinary teams that incorporate a much greater scope of expertise, including biomedical engineers, bioinformaticians, data scientists and others. Future physicians will need to acquire the necessary skills and competencies to work in such multidisciplinary teams, across boundaries such as specialties, and with individuals who have expertise in data analysis. Physicians will also need to be aware of the impacts these technologies will have on patients so that they can better understand what patients are experiencing during each phase of care. All of these implications will require adjustments to current training and education regimes, changes in focus and a broader range of skills among residents and future physicians.

A complementary addition to the medical team

The physician–patient interaction is at the heart of good patient care. In addition to its broader communicative function to establish a relationship and to build rapport, it helps the physician and the health care team to obtain detailed and pertinent data about the patient's complaints, signs and symptoms. This data is used to deduce the possible causes of the patient's problem (which could be a clinical disease, a psychological issue or a social problem), and to decide how to provide the best assistance, and where possible, treat and manage the problem. This interaction can be summarized

The Royal College is a data rich organization. It generates and collects a large amount of data through its various programs, from accreditation and examinations to its Continuing Professional Development (CPD) and Maintenance of Certification (MOC) programs.

as an effort to use data and reasoning to generate decisions about future action, a process that in many ways mirrors how an AI system works. This comparison may give a better view of how AI systems can be integrated into the roles of the physician and the health care team. The key factor is how much data can be validly and accurately obtained from the patient through a digital system.

According to IBM, "each person creates 1 million gigabytes of medical data throughout their lifetime, the equivalent of more than 300 million books."[32] Due to the fast-paced adoption of biosensors and trackers such as smartphones, watches and other wearables, health care data doubles every three years.[33] Considering the limited nature of the human brain, which allows it to only reason well when seven or fewer variables are involved, it would be impossible for the human mind to take advantage of all this information and find links between cause and effect. Inevitably then, an interaction based on the presence of a human health care professional alone may mean that the majority of patient data remains unused and that diagnostic predictions are made based on a very limited set of data. As scientific discoveries are proving every day, valuable information is hidden in this data; being able to extract all the relevant information may be critical for a more accurate diagnosis. Unlike the human brain, AI algorithms can process thousands of variables at the same time and detect patterns within these variables using machine learning algorithms. The effects of incorporating the new information extracted by AI algorithms into current medical practice will revolutionize the field of medicine and human health.

To better understand the potential outcomes of using this technology in health care, it may be valuable to look at two recent experiments. A company has recently developed an AI system that uses natural language processing and deep learning to extract data from patient medical records and contribute to data-driven decisions.[34] After being trained on sufficient data, the model was tested on a mock medical exam, and its performance was compared against two groups: a group of physicians from a top medical university in the U.S. and a group of physicians combined with the AI system. In the combined group, the AI system recommended a "best answer choice" to the physicians, which they either accepted or rejected and selected another answer. A multiple-choice exam was used to evaluate the accuracy of diagnosis. The exam consisted of 100 questions, in which patient scenarios were described and data such as symptoms and medical history was provided. The results demonstrated an average score of 75% for the human physicians, 85% for the AI system alone and 91% for the combined group of physicians and the AI system.[34]

In another study published in *Nature Medicine Letters* in February 2019, an AI tool was developed to analyze electronic health records and diagnose pediatric diseases, once again using natural language processing and deep learning techniques.[35] This model was trained on data extracted from 11,926 medical records collected over the course of 1,362,559 visits from 567,498 pediatric patients. The AI tool and 20 pediatricians with diverse levels of experience were both tested using the same medical data. Results demonstrated that of the participating pediatricians, all those considered junior (three to 15 years of experience) were outperformed by the AI tool, whereas the senior pediatricians performed better than the model.

The above studies are examples of AI's complementary role in the medical workflow and its potential to serve as an assistant, training tool or even safety measure as part of a health care team. Despite improving every day, algorithms still depend on physician-created data such as electronic health records and clinical notes, without which they would not be able to function. Apart from this dependency, algorithms such as artificial neural networks, although designed to mimic the human mind, also do things very differently than humans do.

The differences between human and artificial intelligence bring different strengths in the analysis but also different types of errors. As suggested by the aforementioned studies, collaboration between the two may therefore lead to more accurate or comprehensive analyses and fewer errors. Machines will always lack human qualities such as creativity, intuition and judgment that arise from years of experience. It seems clear that for the safe and effective use of AI in health care, significant physician involvement will be essential at all stages, from design, testing and refinement to validation and implementation.

"So, the touted benefits – I call them touted because no one has proven them yet – is that we're going to see massive efficiency scaling of repetitive tasks that normally take human cognition a few seconds to do and we can do them instantly and indefatigably with machines."

Dr. Hugh Harvey, Managing Director, Hardian Health (Stakeholder engagement interview, July 11, 2019)

According to the World Health Organization, the global average life expectancy at birth was 72 years in 2016, indicating that life expectancy has increased by 5.5 years between 2000 and 2016.[36] Many countries in the world, including Canada, are also facing aging populations due to low birth numbers and longer life expectancy. The number of seniors in Canada is forecasted to comprise 23% to 25% of the population by 2036.[37] The increase in average life expectancy, coupled with the aging population, means there will be a growing number of patients and higher demand for health care resources in the future.

Physicians already face exhausting workloads, leading in many cases to burnout and early retirement. According to the World Health Organization, the global needs-based shortage of health care workers is projected to reach more than 14.5 million in 2030.[38] Adding this to existing problems such as long waiting and travel times, shortage of staff, long delays for patients seeking specialist appointments and the limited number of specialists, there seems to be an ever-increasing demand on physicians. The benefits of integrating AI systems into the medical team become more apparent when we consider the forecast for medicine in the coming years. AI will be able to help physicians organize and scan large amounts of data and take care of repetitive tasks. AI assistance could save physicians and other health professionals time and energy so they can focus on the more important matters and only intervene when there is a specific need for human involvement.

As physicians' workloads increase, they become more prone to medical error. Unlike humans, AI is not prone to fatigue or time limitations. It can tirelessly complete repetitive tasks such as administrative data analysis, basic classification and diagnosis, and data and information management. We could therefore expect this new addition to the team to help overcome problems of overwork and lessen the burden on physicians caused by repetitive tasks.

"We simply won't have enough doctors to deal with the rising population in the next 10 years in countries like Canada, the U.S. and the U.K."

Dr. Lionel Tarassenko, Head of the Department of Engineering Science, Oxford University (Stakeholder engagement interview, July 16, 2019)

Having underlined the importance of future technologies in medicine and introduced the notion of AI as a potential addition to the health care team, it is important to underscore one dimension: the human health care professional must always remain in charge. Machines will serve as assistants, performing tasks such as drawing the attention of a busy clinician to important facts about the patient, doing administrative tasks, suggesting clinical decisions and providing information to help make an informed diagnosis.

The task force does not imagine a machine ever making a final decision about the care a patient receives without human supervision. Although AI and related digital technologies hold great potential to assist humans, these technologies are not a replacement for human skills and competencies. Physicians' core skills and competencies must remain robust so that they and other health professionals can intervene as needed. Human vigilance and skills will be more important than ever to monitor the function of AI systems, detect any risks of error and intervene immediately. Just as a GPS system can stop working or even mislead its user, AI-based medical tools will be prone to biases, analytic errors and machine failure. Physicians need to be prepared for situations in which they will have to take full control of an autonomous task performed by an AI-based tool.

"The danger is if you become too reliant on technology, you lose the basic common sense that comes with the skill you were taught."

Dr. Bernard Meyerson, Chief Innovation Officer, IBM Corporation (Stakeholder engagement interview, June 25, 2019)

As we have seen with other technologies, the introduction of AI into health care will also bring unique and unforeseen risks and safety concerns. Ensuring the safety of AI systems will require a joint effort between AI researchers and clinicians. AI researchers will need to inform clinicians on what data is most useful for algorithms to learn, what information to report, how to interpret an algorithm's output and other related matters. Clinicians, for their part, will need to convey to AI researchers the factors that are important for patient evaluation, what AI-generated information is most valuable to them, and what areas of AI function and the human–machine interface need to be improved. There may also be disruptions in data patterns that are not comprehensible to AI specialists, but may be understandable for health care specialists because of their sophisticated skills in pattern recognition developed over years of experience. This skill will be important to ensure that AI systems are safe. Regulatory standards for medical device safety need to change to further enhance patient safety in environments employing AI technologies. New safety regulations should also aim to define parameters for the safe use of technology, including how patients may positively or negatively be affected by the use of AI technology at scale and comparing these numbers to the effects (including error rates) using current, standard approaches.

Changes to physician practice

As discussed, AI will not replace physicians. Many aspects of the practice of medicine will, however, significantly change. Given the anticipated impact of AI and emerging digital technologies, the task force predicts future specialists will no longer stay in one area of competence for their entire careers, and career transitions will become more common. This means that unlike the traditional medical setting, it is unlikely that the Fellows of the future will enter a discipline and continue to do the same tasks within their 30–40 year span of practice. AI is already recognized as a significant "game changer," and many other fields are becoming increasingly important such as genomics, proteomics, robotics and others that could fundamentally change what future physicians do and how they do it.[39–41] Unlike some of these other innovation categories, the lower barrier to entry to the development and deployment of AI-based tools may alter the rate of innovations and clinical practice transformations.

The implications of this scenario for retraining and recertification will be significant. It will be difficult to change the current mindset of residents expecting to spend five years of training on a specialty and then the next 40 years of their practice working in the same discipline. To prepare for these career transitions, it is the task force's opinion that changes to the CanMEDS Framework will be required. Fundamental changes in the training of physicians may be required to prepare them to adapt to a more fluid field of practice.

> ***"Could be that specialists are trained in such a way that they could switch to another specialty if needed."***
> Dr. Yoshua Bengio, Founder and Scientific Director, Mila (Stakeholder engagement interview, July 15, 2019)

The goal of the Royal College has always been to support Fellows throughout their learning, from their days as a junior resident to their final practice period and retirement. The Royal College's Continuing Professional Development (CPD) program has been designed to help Fellows with their transitions throughout this continuum by

- guiding and supporting their learning during their transition to a specific discipline,
- supporting them in learning the foundations of that discipline,
- preparing them to transition into practice,
- helping them to maintain their competence and advance their expertise, and
- supporting their transitions out of professional practice.

With career transitions expected to become more frequent and common, the Royal College will need to prepare Fellows for additional transitions in practice. To continuously enhance physicians' expertise to meet the evolving workplace requirements resulting from technology changes, the Royal College will have more responsibility to support the lifelong learning strategies of Fellows and Resident Affiliates.

AI – a potential democratizer of health care

The task force believes AI will level the playing field of the physician–patient hierarchy and will fundamentally alter the health provider relationship. The physician–patient relationship is transforming such that patients are becoming partners and drivers in their own care.[42] Patients now have access to medical technology and information that was historically only available to physicians; for the first time in the history of medicine, patients will become the point of care, empowering them more than ever. The patient empowerment movement will further intensify given rapid advancements in emerging digital technologies, and physicians will need to adapt, understand, embrace and prepare for this new reality.

"When I arrive to my physician saying that look, I measured most of the health vital signs and health parameters I could, I got my genome sequenced, I used an advanced algorithm in the cloud to get some meaningful outcomes of it, but I can't deal with this alone … this puts physicians in a new situation where they have to deal with an immense amount of data and they will need skills and knowledge that they don't get in medical education."

Dr. Bertalan Meskó, Director, The Medical Futurist Institute (Stakeholder engagement interview, July 11, 2019)

Empowered patients will have full control over an abundance of personal medical information available to them – information the physician will need.[43] Patients may well have their genome sequenced, use numerous sensors and wearables that collect their data such as sleep sensors and heart rate trackers, and have multiple health monitoring apps at their disposal. As these technologies advance and people become more aware of digitally detected changes to their physiology, they will likely interact more frequently with the health care system, even before the onset of symptoms or physical signs of medical conditions. With increased access to these advanced digital technologies, patients will have much more data and information to inform their choice of treatment and will contribute and bring their own data to the table. The current health workforce will need to be prepared for this new reality.

AI and emerging digital technologies may also level the playing field for patients in terms of geographical, economical and social health inequalities. Despite nationwide efforts to minimize such inequalities, their presence can still be felt in the health care domain. With more power in the hands of patients and their increased ability to contribute to their own care, such inequalities could be further reduced.

"It's now going to become pervasive where a patient's going to walk in and say, "Look, you know, I think I'm having arrhythmia – let me show you my watch."

Dr. Bernard Myerson, Chief Innovation Officer, IBM Corporation (Stakeholder engagement interview, June 25, 2019)

The cultural component of this digital health transformation – defining how physicians will work with empowered patients – may well have the biggest impact on medical practice. The modern empowered patient will want to communicate with their specialists through digital technologies and have access to their own data, and the future physician will need to accept and embrace this.[43] To support patients in this way, future generations of physicians will need to be trained to work with these newly empowered patients. They will have to acquire the necessary skills, knowledge and approach to digital technologies to work with the data and tools that patients bring to them. To address the needs of empowered patients, the task force recommends the Royal College include patients' perspectives in all facets of AI-related decision-making to ensure that multiple, diverse perspectives are represented.

"Increasingly, physicians are going to have to play this role around interpretation, guidance, coaching, steering … understanding their patients and working together with them."

Dr. Brad Wouters, Executive Vice-President Science and Research, Princess Margaret Cancer Centre (Stakeholder engagement interview, July 10, 2019)

Despite the transformative potential these technologies promise, inappropriately interpreted data from wearables and other personal devices could harm patients. The avalanche of data that will be generated by new devices further underscores

the role of physicians as active partners with patients. Physicians will have greater opportunity to apply their years of education and training in the fundamentals of medicine to appropriately guide patients – in an evidence-based manner – to use patients' data in a safe way that promotes their health and autonomy. Physicians, along with regulators, will also have a role as supervisors of the emerging technologies since not all available tools would necessarily benefit patients. It is the responsibility of organizations, governments and medical professionals to support patient empowerment and ensure it happens in a safe and trustworthy manner.

Ethical and legal considerations

As the field of medicine becomes increasingly mediated by digital technologies such as AI that will supplement human presence and function, values and ethics in decision-making will become ever more important. With any advancement in innovation and technology, ethics and legal matters tend to lag behind technology development, and AI is no exception. Some current legal and regulatory frameworks for patient protection, safety and privacy are not ready to address these emerging technologies. The Royal College can play a supporting role in monitoring ethics in a controlled and timely way to help inform the appropriate adoption of these new technologies. To this end, the task force believes there are a number of areas that need specific focus and attention.

Timing is everything

Timing will be the most important factor in addressing the ethical and legal implications of emerging technologies. The task force believes ethics must be considered in the design phase of new technologies. Many ethical decisions must be made early in the technology's development, such as in data selection and collection.

The task force believes that ethics relating to the adoption of AI must be incorporated into the training of all physicians. Similarly, ethical considerations need to infuse the curricula of future engineers, research scientists and software designers who will work in the domain of AI and health. For medicine specifically, the task force stresses the importance of integrating ethics as a sub-competency in the CanMEDS Framework for residents.

Explainable, transparent AI

As the complexity of AI models such as deep learning increases, their explainability tends to decrease, leading to them being referred to as "black boxes." The output of a deep learning model with hundreds of hidden layers becomes almost impossible for the human mind to track back and follow, therefore making the decision-making logic incomprehensible and thus unexplainable for us. This may not seem like a problem when dealing with daily uses of AI such as face recognition tools on our cellular devices, but when human life and safety is at risk, decisions without explanation and justification may be problematic.

The inability to explain a model's results leads to further issues regarding transparency, which would be a significant dilemma in the medical setting. Furthermore, if physicians themselves do not understand how the AI-based tool has reached a result and recommendation for a patient, they will not be able to explain it to patients who will surely be asking for a detailed pathway of how the physician ultimately arrived at their decision. In such a scenario, accountability, liability and patient consent for further action based on the results of the model will be questionable.

This challenge can also be extended to indirect uses of AI in the health care setting, such as managing appointments or transplant queues based on patient priority.[44] If a patient is suddenly moved down to a lower order of priority for an appointment or intervention by an AI system based on their current medical records, they may want an explanation. AI systems are also constantly learning models and thus require correction along their learning path. So, in case of an error, the physician should understand what caused the error so that they can correct the model.

To address these issues, the Royal College should consider support for research into transparent, explainable AI models. This work would include providing sufficient training for all those collaborating in the development of models so they understand what aspects of the models should be explainable in a medical setting. The Royal College could consider advocating for standard evaluation and auditing of AI tools to ensure standard levels of transparency in the models and should also support public evaluations of such tools.

Bias and discrimination

Although emerging technologies have been widely praised for their potential to democratize the health care system and reduce systemic health discrepancies, their mismanagement could lead to the opposite outcome and further disadvantage under-represented and vulnerable groups. AI-based medical systems heavily depend on patient data, and the performance of a model is only as good as the data it is given. If the data itself is biased, this will lead to inherently biased and discriminatory algorithms. A major source of bias can be the data sets chosen to train the models, which may be dominated by data collected from patients of a certain gender, race or socio-economic status and under-representative of others. The divide in access to technology and mobile services could also result in biased data sets over-representing specific populations. Considering the uneven access to data across Canada, with around 20% of Canada's population living in remote communities that may have less data to offer, this becomes a serious concern.[45]

One example of under-representation is Indigenous communities. Cultural values may also cause some communities to avoid certain technologies, eventually leading to their further misrepresentation or under-representation in data sets. To address this issue, a different approach must be taken. Communities must be engaged to share their perspectives, and residents and physicians should be educated on how to behave within this context.

"Some of the struggles are still around lack of infrastructure, particularly around appropriate internet and telecommunications infrastructure that is not in place."

Dr. Carrie Bourassa, Scientific Director, Institute of Indigenous Peoples' Health, Canadian Institutes of Health Research (Stakeholder engagement interview, July 11, 2019)

Apart from data selection, biases can also be incorporated during the data collection process, such as differences in clinician–patient encounters and biases in treating patients. In addition to the risk of the data or model being biased, there is also concern about distributive justice and whether all people, regardless of their socio-economic status and location, would have equal access or benefits from these technological services. These same issues exist for current technologies where demographics and socio-economic status affect access to technology. However, we must keep in mind that AI systems are constantly learning from data, so not only should we be aware of the initial bias in data and models, but we must also take the extra step of continuously ensuring that the new data refining the model's learning is also not biased.

Another factor that distinguishes bias in AI from other technology is its opaque nature. The complexity of the models often masks the origins of bias, making it close to impossible to identify the source of the biased output.[44] This makes it ever more challenging to address biases since it would not be clear whether it originates from systematic and structural bias in the algorithm itself, bias in data collection, bias in training data selection or a combination of all factors. One example of such biases in algorithms is the Correctional Offender Management Profiling for Alternative Sanctions (COMPAS) tool that predicted African Americans to be at a higher risk of recidivism than they actually were, demonstrating a misclassification rate twice that of the white offenders.[46] Another is Google's targeted advertising system, which proved to be less likely to show women in highly paid jobs compared to men.[47] It is therefore necessary to integrate appropriate auditing and evaluation procedures to the current ethical and legal framework to ensure the algorithm and its data selection and collection steps avoid bias or discrimination.

Data considerations

Artificial intelligence is most effective when there is abundant data available to work with. In genomics, population health and epidemiology, national and international data sharing enables algorithms to detect patterns across a large, diverse data set. This capability could lead to significant new findings and help monitor public health. There are many barriers to data sharing, such as the reluctance of some nations and organizations to share data, differences in how data are defined (coding systems), data quality and collection methods and differences in privacy legislations.[48,49] These barriers also raise ethical concerns regarding how data is collected and shared.

The first step toward data collection is obtaining consent, yet the patient giving consent must be aware of all future uses of their data. With large data sets, the data is often reused multiple times, by different parties and in different formats, whereas the patient may have only given consent for a single use of their data to a specific organization. Another issue is the anonymization of data. A standardized method and specific policy on safe patient data de-identification are needed. If not performed correctly, de-identification can both cause privacy concerns and devalue the data. There is also the risk that without proper de-identification, the data can be re-identified. This was the case for the Washington State hospital discharge data set, where de-identified data was later found to be re-identifiable when combined with other publicly available data.[50]

Another important legal matter to consider is data ownership.[51] When a patient shares their data with a private or public organization, it is unclear whether that organization is permitted to share it with third parties. Legally, in Canada there is no data ownership in health care (see www.cigionline.org/publications/data-ownership). This raises a conflict between the efforts to allow data access for the means of research that can benefit the public in the long term versus protecting the data of patients. All these issues highlight the importance of guidelines and regulations that ensure data collection takes place in a standardized manner and with standard permission, consent, encryption and anonymization. Addressing such data sharing concerns can help facilitate research on international and interprovincial data sets.

Privacy and security

Privacy and security are the principal concerns when talking about data collection and sharing. The privacy and security of patient data must be protected in all stages of medical system design, starting from data collection and storage all the way to the modelling and deployment of the system. At the data collection step, to ensure patient privacy, clear information toward understanding must be provided on how the data will be used upon asking for consent. Although current privacy laws require consent for the collection, use and disclosure of personal health information, the consent is only intended for the specific group that is taking care of the patient's health. With AI systems being integrated into the medical team, discussion is needed on whether the consent for data sharing also applies to the AI system.

Exposure to personally identifiable information must also be minimized when collecting data. The collected data must then be stored in a secured manner, and patients must have the right to withdraw consent or ask for their data to be masked any time upon request. A clear explanation of how data will be handled after use is the right of each patient and the data must be disposed of safely. At the modelling phase, the algorithm must not be susceptible to any information leak or privacy faults that can jeopardize patient data. Finally, at the deployment stage, the model should be monitored to ensure it is being used for its intended purpose, and that there is a strategy to immediately recall or retrieve the model in case of a privacy or security harm.

The task force suggests the Royal College advocate for the education of physicians on the privacy risks of AI systems, so that they will be able to identify whether the system is handling information in keeping with security regulations. Ideally, physicians should be trained so that their understanding of these systems is deep enough to judge the performance of the system and decide whether patient data is safe and secure.

Liability and accountability

Liability for harm and accountability caused by AI-driven decisions is a significant issue raised with AI systems involved in clinical decision-making. Laws currently do not clearly identify who will be held accountable for physical and emotional harms, privacy harm or discrimination harm caused by AI-driven medical decisions. As the people responsible for overseeing AI systems, it may be intuitive to hold physicians accountable in such situations. However, potential legal liability should not only be targeted toward physicians, but also a larger group of stakeholders, including manufacturers, programmers and developers of the systems. Any AI-informed decision is a by-product and combination of the actions of all of the above groups; the initial algorithm design and training data is provided by manufacturers and developers, input and evaluation of AI-based results and recommendations are done by physicians, and patient behaviour and self-reporting play a part in the algorithms' learning. If physicians were held solely responsible, they could refuse to use

the technology that may offer many benefits to patients. In such a scenario, a further topic to be considered is whether physicians refusing to use AI should be held liable for harm caused to a patient as a result of not using the technology.

A new fundamental competency

The task force believes the pervasiveness of the impact of AI and emerging digital technologies is so profound that the Royal College must rethink its fundamental competency framework. Specifically, the task force believes the framework should include as a fundamental competency, and possibly as the eighth component of the CanMEDS Framework, "digital health literacy." According to the World Health Organization, "digital health literacy (or eHealth literacy) is the ability to seek, find, understand, and appraise health information from electronic sources and apply the knowledge gained to addressing or solving a health problem."[52]

"If I had to assign a percentage to how much of physician time will be spent on each of these very important skills, I would say the use of technology, and not even digital literacy, would take up at least 80% … I can't imagine that medical professionals, in not even 15, 10 or five years, will not be pushed, requested or asked to deal with technologies, the data from health sensors, the analytic platforms that they will look at when they want to find the right treatment for their patients."

Dr. Bertalan Meskó, Director, The Medical Futurist Institute (Stakeholder engagement interview, July 11, 2019)

Data from our Fellow survey suggests that 41% of Fellow respondents self-assessed as having no or very little familiarity with AI and its related concepts. In a similar survey conducted of Resident Affiliates, 42% self-assessed in the same way. When asked to describe the extent to which they felt exposed to AI-related conversations in their work or education environment, nearly 70% of residents indicated they have had no exposure or very limited exposure. Unsurprisingly, most (85%) resident respondents believe they have not received adequate information or teaching to prepare them for using AI and emerging digital technologies in their future practice. This data suggests there may be an important curricular gap in both undergraduate and postgraduate medical education. This gap may present an important opportunity for the Royal College to ensure that the education of current and future generations of physicians prepares them for the technological advances that will transform medical practice.

Our data also demonstrates that nearly half (48% of Fellows and 59% of residents) of our survey respondents have expressed high levels of interest in participating in AI-related education relevant to the practice of speciality medicine. Also, 55.6% of Fellows and 63.2% of residents have voiced interest in becoming innovators or early adopters of AI in health care if given the opportunity. These results demonstrate great potential and interest among health care professionals, and even more so among residents who will be the future workforce in medicine.

To this end, task force members suggest digital literacy be a requisite competency for all specialists in training as well as those in practice. Through consultation with experts, the task force has concluded that this knowledge would include at least

- a common understanding of how the technologies and AI systems work, including knowledge on the input to algorithms, how an AI-based decision is derived and the ability to meaningfully interpret outputs;
- common taxonomy and language;[53] and
- fundamental statistical knowledge such as linear regression.

Furthermore, medical specialists should be able to understand available literature and have the critical thinking skills to analyze the published literature and methods, identify methods that are of statistical significance and determine a significant finding from the plethora of published literature. They should also be able to select the best practice for their patients among the new techniques, methods and knowledge arriving at an ever-increasing rate. Although it is debatable how much depth of knowledge is required, experts agree that knowledge of statistics would be crucial. The way machine learning is used in medicine can be seen as an extension of statistics, requiring a strong mathematical statistical foundation.

Preparing for the future of AI today

Canada has hosted several leading AI research laboratories, stored digital health data for more than two decades and invested in modern information and communications technologies. Given these efforts, Canada is already at a significant advantage when it comes to using AI in health care.[53] However, the rapid pace at which AI and emerging technologies are changing the practice of medicine requires prompt action to keep pace. Significant gaps still need to be addressed to keep us on top of the game. We need to address deficiencies in the development of data gathering strategies, refine policies for anonymization and de-identification of data, address data sharing and ownership issues, develop a common framework for sharing AI models, address the lack of experts in translating technology to clinical use, and create opportunities for collaboration between academic research laboratories and industrial partners.[53,54]

Addressing such challenges requires collaboration among all key players. Canadian physicians can play their part by becoming more involved and contributing to research into AI applications in health care and supporting and adapting to the upcoming changes in their practice for the benefit of their patients. The Royal College could play an important role in facilitating this involvement and collaboration.

One significant factor that may act as a barrier to these changes is the economic burden that incorporating such technologies will have on the health care system. Integrating novel technologies into health care systems has always come at a high cost, with the attempts of digitizing patient records being a clear example. Canada is already among the top countries globally when it comes to health spending.[55] With a forecasted growth of 3.9% in 2019,[56] Canada's total health expenditure is projected to reach $264 billion, representing 11.6% of Canada's GDP.[57] Despite the high cost of integrating AI and emerging technologies into health care, these technologies could bring long-term financial benefits.

These technologies can also indirectly assist in patient care by optimizing clinical workflows and improving data and inventory management.

Sensors, wearable devices and remote care can also play a role in early detection, prevention and more convenient care. One example of promising cost reductions relates to chronic disease management. According to the Canadian Chronic Disease Surveillance System, 44% of Canadian adults over 20 have at least one of 10 common chronic conditions.[58] By integrating such technologies into the health care system and using them for prevention, early detection and population health monitoring, the rate of chronic disease could be decreased. According to the World Health Organization, even if national chronic disease death rates were reduced by 2% per year, this reduction could save $1 billion over the next 10 years.[59]

"I think the College should be clarifying roles and responsibilities and directing all the different levels, from the individual to the specialty groups to the profession as a whole, on roles and responsibilities. I think that's what the Royal College does; it creates a framework for the whole system, and in partnership with the regulators and the academic institutions."

Dr. Salim Samanani, President and Medical Director, OKAKI (Stakeholder engagement interview, October 9, 2019)

The abrupt changes resulting from emerging technologies require a robust and comprehensive monitoring strategy. If left unsurveyed, these technologies could bring about many unintended consequences despite their numerous advantages. The following areas require close attention:

- **Ethics, privacy and trust:** Regulatory authorities and users of these technologies must collaborate and be adequately trained to ensure they are aware of the ethical guidelines and consider ethics in all interactions with technology. They must ensure patient privacy during all stages of technology use and avoid misuse, which would result in a loss of public trust.
- **Workforce preparation and impact analysis:** It is essential for the Royal College (in collaboration with its partners) to understand the implications of these technologies on the workforce and their effect on jobs, and to adjust training and education to meet future needs.

- **Market regulations:** Regulatory frameworks must be modified to monitor AI and digital innovations entering the market.[29]

"There is a fundamental new technology, and so either you take a leadership role in guiding that change and planning for it, or you react to it."

Dr. Salim Samanani, President and Medical Director, OKAKI (Stakeholder engagement interview, October 9, 2019)

The task force suggests that the Royal College also embrace the implications of AI and emerging technologies for its own operations. Data is one of the Royal College's most valuable assets, and AI has the potential to advance the effectiveness and efficiency of its programs by leveraging data for AI-related functions. Data collected as a component of regular operations of the Royal College could be used for data management and to identify important patterns that cannot be recognized by human analysis alone. Data could also be shared with Fellows and the greater health care community for quality improvement or research purposes.

The Royal College's role as an examining body may also be enhanced through AI. As a step toward automating the exam generation procedure, AI algorithms could be trained on a databank of all previous exam questions and relevant content for each specialty. Digital technologies and platforms could be used not only to generate exam questions but to automate the examination process, whereas technologies such as virtual reality and augmented reality could be used to facilitate live exams. Although these potential applications are exciting, they also bring challenges. For example, the Royal College will need to ensure safe, equitable access to its available data for all Fellows (e.g. policies re: open-vs. closed-source), do substantive work to make the current data sets more usable and address privacy concerns such as transparency, consent and de-identification of data.

This report is just the beginning

AI and emerging digital technologies will mean changes to medical practice in Canada that have profound implications for many of the Royal College's core functions. As such, the task force feels it is important that progress in this important area cannot end with this report; there is a need for more, continuous action from the Royal College. Our Fellows and Resident Affiliates have also asked the Royal College to actively participate and support them throughout their learning journey in this area. Nearly 600 Fellow respondents indicated that the Royal College should

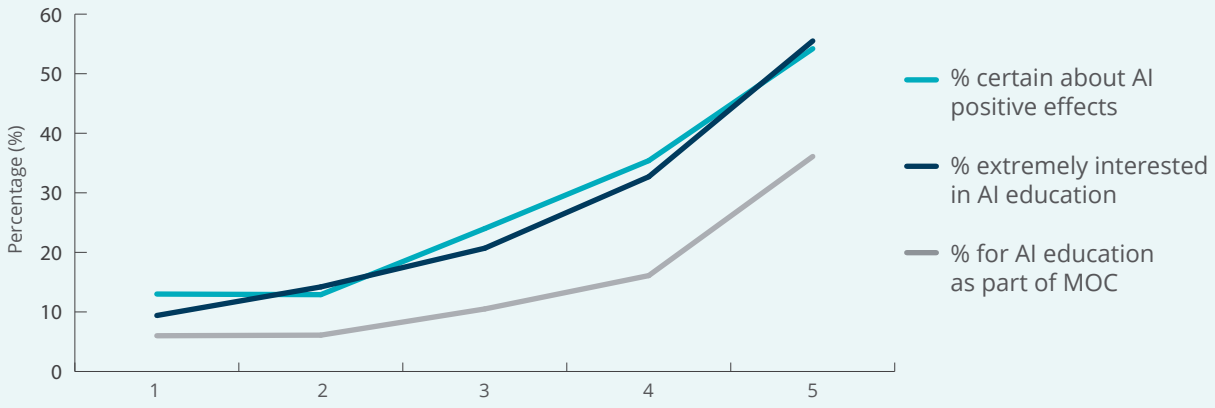
- provide training and education for Fellows on AI,
- raise awareness about AI and clarify its implications to promote better understanding,
- hold workshops, seminars, courses, conferences and online learning on AI, and
- frequently provide evidence and examples of effective AI.

Survey findings suggest that how familiar Fellows and residents are with AI and emerging technologies is critical to how they perceive them. The results (Figure 3) suggest there is a direct relationship between respondents' level of familiarity with AI and

- the degree to which they positively perceive the impacts of AI on their future roles as medical educators and patient care providers
- their degree of interest in learning more about AI, and
- their degree of support for incorporating AI into the Royal College's MOC program.

To address these findings, the Royal College should dedicate resources to AI and emerging digital technologies to stay abreast of this rapidly changing technological transformation of patient care through a thoughtful monitoring and surveillance strategy of the field. This work could include frequently releasing educational material regarding AI and technological advances in specialty medicine.

Figure 3. Familiarity with AI and related concepts associated with Fellow opinion toward specialty-specific AI



It could also mean providing training on these technologies for residents and Fellows, including curating or partnering on the development of online educational content and courses. The Royal College should also advocate for policies that ensure the adoption of these new technologies is informed by evidence and driven by ethics. It may also be beneficial to consider convening working groups or other task forces to advance the Royal College's agenda in AI and emerging digital technologies.

The Royal College may also need to play a role in helping Fellows understand the limitations of AI in health care. As previously mentioned, this technology could be misleading and cause harm if not monitored and guided correctly. Specifically, including inaccurate or misleading data in the data sets used to train AI models could result in misleading outputs. The Royal College could also monitor the evolution of new technologies and promote and support only those whose use is informed by diverse forms of evidence, and in so doing, guard Fellows against misinformation and endorse best practices.

Given its role in medical education and care, the Royal College will need to play an active and balanced role in supporting current and future Fellows in delivering the best patient care throughout their careers in a rapidly evolving health care system.

Summary of Findings and Recommendations

The task force's findings and recommendations are summarized below. Given the limitations of scope and fiscal considerations, the recommendations have been streamlined to align with achievable fiscal goals and foreseen resources.

Anticipated impacts on medical practice

Key findings:

- AI and emerging digital technologies will not replace a physician's presence, intuition, creativity, judgment and compassion.
- AI and emerging digital technologies will become more integrated into the practice of specialty medicine, supporting the daily routines of a health care team.
- AI and emerging digital technologies could liberate physicians from repetitive tasks, allowing time for more patient care, including compassionate care, and improving the safety and quality of patient care.

Recommendation:

- That the Committee on Specialties of the Royal College of Physicians and Surgeons of Canada continue to regularly monitor the health of individual disciplines, assessing the impact of AI and emerging digital technologies. At this time there are no recommendations to alter the number and complement of specialist physicians being trained in Canada.

A new fundamental competency

Key finding:

- AI and digital technologies will become fundamental to the practice of medicine. To continue to meet patient needs, physicians will need a basic understanding of the available technologies, a stronger background in mathematics and statistics, and the ability to find and understand health information from electronic sources.

Recommendation:

- Digital health literacy competencies should be integrated into the CanMEDS Framework.

Changes to physician practice

Key findings:

- Career transitions in the health workforce will become more common. It is unlikely that physicians will remain in the same area of practice for their whole careers.
- Frequent training and new skill acquisition will be required to adapt to the rapid pace of change imposed by emerging digital technologies.

Recommendation:

- As a matter of urgency, develop processes to address the current challenges faced by all specialties in developing new competencies or making career changes that may be needed as a result of the impact of AI and emerging digital technologies on specialty medicine.

Emerging careers

Key findings:

- New technology-oriented roles and specialties will emerge.
- Survey respondents expressed significant interest in this area of work either as early adopters, innovators or enrolment in a new technology-focused specialty.

Recommendations:

- Consider introducing a new discipline in the area of Clinical Informatics.
- Partner with Canadian medical schools to promote AI and MD/PhD programs and clinician investigator programs focused on digital technology to ensure opportunities for training in this area and encourage a cadre of "clinical innovators" in AI in health care.

AI in health is team science

Key findings:

- Responsible AI tools for medicine are co-developed by teams that include members of the health care team and specialists involved in the development of AI systems, such as computer scientists, engineers, mathematicians and professionals working in other technology-oriented disciplines.
- The majority of Fellows and Resident Affiliates of the Royal College who responded to a survey see themselves as adopting AI technologies now and would like to be more involved in the development, refinement, validation and deployment of AI technologies in the future.

Recommendation:

- Play an active role in supporting Fellows and Resident Affiliates to co-develop, refine, validate and spread AI-enabled technologies.

New products and advancements

Key findings:

- Approvals for the use of AI-based medical technologies in medical settings are increasing. These technologies, and new ones under development, hold great potential to assist in diagnosis, clinical decision-making, training, early prediction and prevention, treatment and personalized medicine.
- Physicians and other members of the health workforce must be up to date on advancements in these fields and understand the capabilities, limits and risks of AI and emerging digital technologies in medicine.

Recommendation:

- Working with individual disciplines and the Committee on Specialties, develop guidelines and principles for integrating the teaching of AI and emerging digital technologies across all residency training programs, and incorporate these teachings as a component of continuous professional development (CPD) for current Fellows.

A complementary addition to the medical team

Key findings:

- AI and emerging digital technologies will become a "member" of the future health care team by supporting its daily routines.
- Health care will become increasingly multidisciplinary. Teams will comprise individuals with diverse backgrounds, including engineering, robotics and data science.

Recommendation:

- Promote the development of new opportunities that support Fellows and Resident Affiliates in working with innovators in the public, not-for-profit and private sectors to co-develop, refine, validate and spread AI and emerging digital technologies and take into account considerations for conflict of interest.

AI – a potential democratizer of health care

Key findings:

- Given that patients will increasingly have access to health data, including their own, AI and digital technologies could have a positive impact on the physician–patient relationship, creating a data-centered partnership that further enables a patient-centered approach to health.
- More and more, physicians will need to embrace their new roles as guides and coaches to empowered patients.
- Despite its great potential for democratizing health care, AI could exacerbate the "digital divide" of marginalized, historically under-represented and other underserved populations if its implementation is not conducted responsibly and monitored.

Recommendation:

- Implement mechanisms to include patients' perspectives in all facets of AI-related decision-making to ensure that multiple, diverse perspectives are represented.

Ethical and legal considerations

Key findings:

- Current governance (legal, ethical, policy) of AI may not be agile enough to support the adoption of AI into health care systems, or to appropriately safeguard privacy, quality and safety and prevent discrimination against historically underserved populations.
- New regulatory frameworks are required that emphasize timely implementation of legal and ethical considerations, such as explainability and transparency, prevention of bias and discrimination, data-related matters, privacy and security, and liability and accountability.

Recommendation:

- Collaborate with partner organizations to develop, tailor, curate and distribute educational offerings related to privacy, discrimination, safety and other ethical and legal concerns arising from adopting AI into health care systems.

Social accountability

Key findings:

- Adoption of AI in health care is predicted to improve the efficiency and effectiveness of health care, leading to improved patient outcomes.
- Current health data, however, does not always include data from all patient populations.
- There is therefore a risk that the integration of AI into health care may pose a risk to the safety and quality of care of historically under-represented populations, or that these populations will be excluded from the anticipated benefits of AI, or both.

Recommendation:

- Promote, enable and extend scholarship, education and other forms of support to physicians that increase their knowledge of the social justice implications of AI-based technologies.

Institutional considerations

Key findings:

- The Royal College is a data rich organization. It generates and collects a large amount of data through its various programs, from accreditation and examinations to its Continuing Professional Development (CPD) and Maintenance of Certification (MOC) programs.
- Increases in data volume are anticipated in an era of competency-based medical education (CBME). The implications for standards of training and for examinations are profound.

Recommendation:

- Establish a working group to review how best to apply AI to support elements of the Royal College's operations, particularly in relation to its role as an examining body. The working group should also consider ways AI could improve the analysis of data collected by the Royal College and address issues pertaining to data governance and ownership.

Surveillance and monitoring of AI advancements

Key finding:

- The rapidly evolving nature of AI and emerging digital technologies will require adaptive action and ongoing monitoring from the Royal College.

Recommendation:

- Develop an ongoing monitoring and development strategy to address the need for further recommendations in the field of AI and emerging digital technologies.

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Appendix A: Glossary of Terms

In this section, a brief overview of some of the main technologies that the task force believes will have the most significant impact on health care is provided. The areas named below are the main technologies when referring to "AI and emerging digital technologies" throughout the report.

Artificial intelligence (AI) and machine learning (ML)

Artificial Intelligence (AI) is the term given to systems that have the ability to learn through making inferences about what they receive in terms of input information. By doing so, AI systems mimic the way humans understand information in order to perform tasks normally associated with humans.[60] Machine learning (ML) refers to the process of computers learning to recognize patterns in data using different pattern recognition algorithms. In other words, machine learning is a sub-essential component of AI.[7] Algorithms such as deep neural networks (DNN) and artificial neural networds (ANN) are all different ML algorithms.

Augmented reality (AR) and virtual reality (VR)

Augmented reality (AR) is a technology that integrates computer-generated graphics into the real-world environment, creating an enhanced version of the real-life situation. So in AR settings, the user is looking at a real-world environment that also includes computer imagery and objects to complement the scene. Virtual reality (VR) on the other hand is the technology that creates a virtual environment using 3D imagery, placing the user in a computer-generated simulation of a real-world environment.[61] Both these technologies have shown promise in enhancing the level of training and medical education, especially in surgical training.

Big data

Big health data management is the ability to analyze large volumes of different types of data from a variety of sources that are continuously generated. Big data can be characterized by the amount of information available, the speed at which data can be generated and exchanged and the variety of forms that the data are generated in. Big health data can have a wide range of applications in precision medicine, developing AI models, public health management and chronic disease management.[62]

Digital health (health apps and wearables)

As defined by the World Health Organization, health apps are "medical and public health practices supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices."[63] Health apps can be used for monitoring the state of health, disease management, data collection for preventive and diagnosis purposes, health and fitness promotion, and could even provide primary diagnosis.[64] It is predicted that with the availability of more advanced health apps there will be a sharp rise in the use of such apps by Canadians.

"Omics"

"Omics" is the general term given to technologies/fields that study the behaviour of the building molecules of organisms, mainly at the cellular level. The term "omics" includes technologies such as genomics, metabonomics and proteomics, all of which are powerful tools that use large sets of genetic data to help our understanding of cell-level activities and disease pathways and mechanisms.[65] Omics have also shown great promise to enhance disease prediction and prevention.

Precision medicine

In the current world of medicine, individuals diagnosed with the same disease are likely prescribed the same treatments, drugs and drug dosage. It is a known fact, however, that each person's body is unique and responds differently to medication. Precision medicine refers to patients receiving the most effective treatment based on their medical profile, taking into account factors such as genetics, medical history, diet, physical and mental conditions, etc. Precision medicine is heavily dependent on big data, including the patient's genomic profile and medical information obtained from health apps, sensors and wearables. A personalized approach toward treatment based on such information would surely result in better outcomes and less negative consequences and side effects for patients.[66]

Robotics

Robotics is a general term given to machines that have the potential to assist in the performance of human tasks, or fully substitute/replicate human action.[30] Robotics is a multidisciplinary field by nature, integrating different branches of engineering and other sciences based on context of use. In health care and medicine specifically, robotics can be applied to a variety of areas such as minimally invasive surgery, remote surgery, rehabilitation, etc.

3D printing

3D printing is the manufacturing process in which objects are created by laying down several successive layers of thin materials atop each other.[30] 3D printing has great potential in creating diverse objects because of the flexibility in the range of materials that can be used as printing "ink," in addition to the level of model complexity achievable due to advanced 3D-model creation software. Health care and medical applications of 3D printing have experienced exponential growth in recent years with advances in using biological material and cells as printing material, leading to applications in prosthetics, implants, regenerative medicine and organs and medical devices and tools.

Appendix B: Stakeholder Engagement

In order to accompany the discussions within the task force, the task force identified four methods of engagement to interact with the primary stakeholders of this report. In what follows, each engagement strategy will be discussed.

1. Key informant interviews

Leaders in the field of artificial intelligence were engaged in 30-minute telephone interviews, where they provided their insights on a series of questions to help the task force articulate its strategy and recommendations. The interviews were held between the experts, the chair and two other task force members. The task force would like to thank the following individuals for participating in our engagement interviews (in order of the dates interviews were conducted):

Dr. Bernard Meyerson, Chief Innovation Officer, IBM Corporation

Dr. Randy Goebel, Associate Vice-President Research, University of Alberta, Amii Fellow

Dr. Eric Topol, Executive Vice-President, Scripps Research Institute

Kimberly Hanson, Executive Director, Diabetes Canada

Dr. Joelle Pineau, Associate Professor, McGill University, Lead of Facebook's Artificial Intelligence Research Lab

Dr. An Tang, Associate Professor, University of Montreal; Chair, Canadian Association of Radiologists Artificial Intelligence Advisory

Dr. Lionel Tarassenko, Head of the Department of Engineering Science, Oxford University

Dr. Michael Hillmer, Executive Director, Ontario Ministry of Health

Dr. Brad Wouters, Executive Vice-President Science and Research, Princess Margaret Cancer Centre

Dr. Bertalan Meskó, Director, The Medical Futurist Institute

Dr. Hugh Harvey, Managing Director, Hardian Health

Dr. Carrie Bourassa, Scientific Director, Institute of Indigenous Peoples' Health, Canadian Institutes of Health Research

Dr. Yoshua Bengio, Founder and Scientific Director, Mila

Dr. Tom Chau, Vice-President Research, Holland Bloorview Kids Rehabilitation Hospital

Dr. Puneet Kapur, RCPSC Fellow, Software Architect/Engineer

Dr. Jonathan Kanevsky, RCPSC Fellow, Co-Founder of Imagia

Dr. Salim Samanani, RCPSC Fellow, President and Medical Director, OKAKI

Dr. Jay Shaw, Assistant Professor, University of Toronto. Research Director, Artificial Intelligence, Ethics & Health, Joint Centre for Bioethics

Dr. Devin Singh, RCPSC Fellow, Physician Lead for Clinical AI and ML, PEM

Dr. Christina Luong, RCPSC Fellow, Research Partner with UBC Biomedical Engineering

Dr. Gregory Walker, RCPSC Fellow, AI Researcher

Dr. Sheila Wang, RCPSC Resident Affiliate, AI Researcher

A qualitative content analysis approach was used to analyze the interviews. The process included verbatim transcription of the interviews and performing continuous content analysis on the transcriptions to identify the common themes within them. All the data was captured using an online proprietary software called "NVivo." Two Royal College staff coded each interview transcript independently, and after completion the coders would meet to reach coding consensus for each interview. Thus, three assessments were performed in total per transcript. The following were identified as the main themes emerging from the interviews.

Competencies of future physicians

- Develop competencies for all physicians related to digital literacy: uncertainty exists at the level of understanding required
- Competencies related to digital literacy considered in new framework
- Ability to function in partnership with AI tools and understanding of basic principles behind AI decision-making
- Ensure education of all physicians regarding fundamentals of statistics relevant to AI (e.g. logistical regression)
- Expression of empathy, communication skills, collaboration, judgment, compassion

Specialties undergoing the most change

- Radiology and pathology
- Specialties using digital data
- Eventually every specialty will be affected

Preparing the next generation of physicians for changes in competencies and some strategies to reflect these changes in their education

- The Royal College to create online courses for the fundamentals of AI education
- Establish multidisciplinary programs to create leaders in AI and health care
- Need to reconsider diversity with admission processes
- Suggestion to increase students from disciplines including engineering, computer and data science

Changes in policy

- Include digital technology education at all stages of medical training
- Encourage patient empowerment
- Need for Canadian data regulation policy
- Greatest changes faced by specialists
- Communication challenges from increased interdisciplinary work
- Shift to role of interpreter, guide, coach; shift to equal partnership between physician and patient
- Increased focus on competencies such as compassion, empathy, judgment

Advice for authority that oversees training/ maintenance of competence

- Need basic level of digital literacy across all specialties
- The Royal College to establish a communication strategy to debunk myths about at-risk specialties
- Uncertainty in how to respond to this question

Benefits and pitfalls of technology

- Benefits
  - "The gift of time"
  - Offloading of repetitive tasks to machines
  - Data sharing
- Pitfalls
  - Privacy issues
  - Overreliance on technology – deskilling
  - Lack of existing infrastructure

Additional emerging themes

- Timeline of change
- Ethics
- Role of specialists will be redefined; new roles will emerge
- Change in numbers of workforce
- Shift to humanistic care
- Specialists will need basic level of understanding of AI technologies

2. Fellow survey

As key stakeholders of the final recommendations, Royal College Fellows were surveyed on their thoughts and perspectives on AI and emerging digital technologies. Their responses to the questions designed by the task force provided significant insight toward the drafting of the recommendations. The survey was available in English and French, and consisted of nine Likert scale questions, one drag-and-drop ranking question and two optional open-ended questions exploring the perceptions of AI both generally and associated with the participant's specialty. The survey was pilot tested and revised on three separate occasions by task force members, Fellows and internal staff of the Royal College.

The survey was sent out on July 22, 2019, and remained open for a period of just over three months (closing on October 27, 2019). A robust communication strategy was adopted to encourage wide participation, including e-blasts (emails) to all Fellows of the Royal College, followed by three reminder e-blasts, one every month. A reminder for participation was also included in the September 2019 edition of *Dialogue*, the e-newsletter of the Royal College.

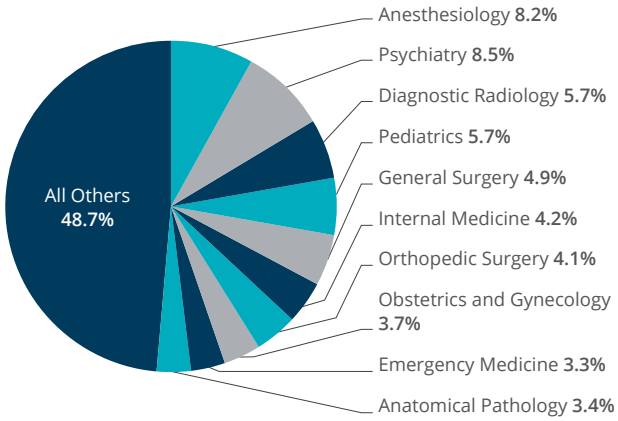
The survey was distributed among 50,835 Royal College Fellows. In total, from the 4,297 Fellows who opened the survey, 3,754 fully completed the survey, 470 partially completed it and 73 did not give consent and their survey was thus eliminated. A content analysis approach was used to analyze the open-ended responses independently by two project staff. This approach seeks to systematically read text and assigns identifiers to information that may be perceived as important or clustering around particular themes.

Table 2. Fellow survey participation by province

Province	Percentage (%)
Ontario	39.2
Quebec	17.8
British Columbia	14.8
Alberta	14
Manitoba	4.9
Saskatchewan	3.4
Nova Scotia	3.2
Newfoundland and Labrador	1.2
New Brunswick	1.1
Prince Edward Island	0.4

The top specialties by participation are displayed. At least one response was received from each of the 67 specialties.

Figure 4. Fellow survey participation – top specialties



Fellows were asked how they would rate themselves on familiarity with AI and related concepts from a scale of 1-5, 1 meaning no/limited familiarity and 5 meaning they are experts in the field.

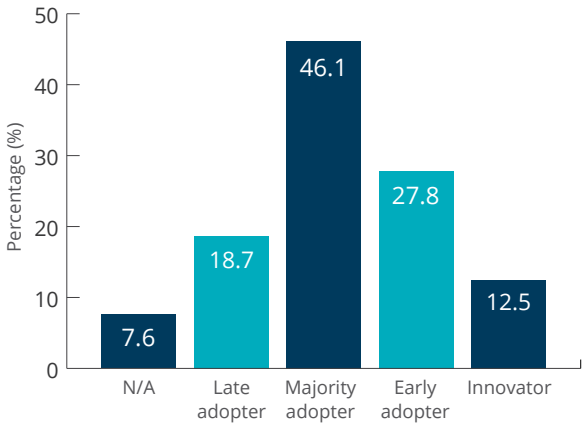
Table 3. Fellows' level of familiarity with AI

Level of Familiarity	Percentage (%)
3	35.1
4	20
2	22.3
1	18.6
5	3.9

N = 3,928

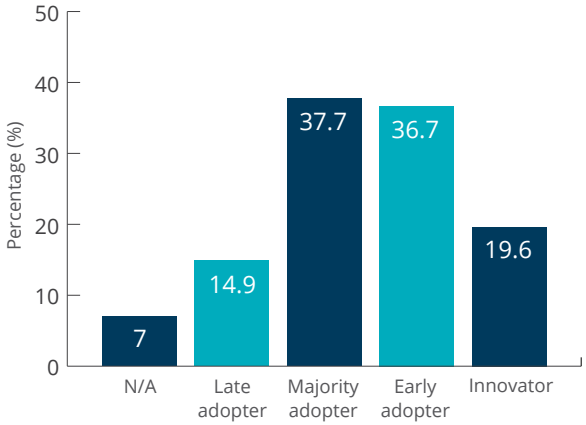
Fellows were asked what AI-related role(s) they imagined themselves positioned to take on with their current level of knowledge, expertise and experience in AI and digital technologies.

Figure 5. AI roles Fellows imagine for their future given current training



Fellows were asked what AI-related role(s) they would like to take on in the future, given training and education would be provided.

Figure 6. AI roles Fellows would like to have in future



Fellows were asked to describe which phrase best described their belief on how AI will affect their specialty.

Table 4. Fellow opinion on how AI will affect their specialty

Opinion on Change	Percentage (%)
4 (It may disrupt the current workflow in a positive manner)	49.2
5 (It will definitely have a positive effect on my practice and patient experience)	23
2 (It may disrupt the current workflow in a negative manner)	12.6
3 (It won't affect my specialty)	10.6
1 (I worry that my specialty is at risk)	4.6

N = 3,919

Fellows were asked if they would be interested in participating in AI education/continuing professional development concepts or principles relevant to the practice of medicine education. They were asked to express their levels of interest on a scale from 1-5, 1 meaning no interest and 5 indicating a very high level of interest.

Table 5. Fellows' level of interest in AI education

Level of Interest	Percentage (%)
4	27.5
5 (Extremely interested)	20.9
3	21.1
1 (Not interested)	18.2
2	12.3

N = 3,920

Fellows were asked to provide their opinion on the extent to which they believe the Royal College should be studying and taking steps to integrate AI education/competencies within residency training on a scale from 1-5, 1 meaning the Royal College should play no role and 5 meaning this is a central mandate of the Royal College.

Table 6. Fellow opinion on how involved the Royal College should be in AI education in residency

Opinion	Percentage (%)
4	37.9
3	26.5
5 (This should be a priority of the Royal College; this is central to its mandate)	22.5
2	9.5
1 (No steps should be taken; this is not the role of the Royal College)	3.6

N = 3,918

Fellows were asked about how strongly they believe AI education should become part of every Fellow's maintenance of competence on a scale from 1-5, 1 meaning no steps should be taken toward this direction and 5 conveying this should be a priority.

Table 7. Fellow opinion on AI becoming a part of MOC

Level of Agreement	Percentage (%)
3	33.8
4	20.6
2	18.8
1 (No steps should be taken; Fellows should drive their learning needs)	16.1
5 (This should be a priority of the Royal College; this should be directed by the Royal College as a mandatory core learning need)	10.8

N = 3,918

Fellows were asked to rank potential educational topics based on their level of interest. Each participant was allowed to select three topics and rank them in order of priority, with the highest-ranking topic receiving a score of 3 and the lowest receiving a score of 1. The total scores for each topic and the number of times each topic was ranked among the top 3 overall is presented in the "Score" and "No. of Rankings" columns, respectively. As observed, the final rankings are calculated based on the overall scores.

Table 8. Fellow ranking of AI educational topics

Rank	Topic	Score	No. of Rankings
1	**The Basics of AI – technical training related to your specialty** [e.g., Training that would help you have sufficient understanding of AI to be an innovator or early adopter]	3,834	1,844
2	**Ethics and Legal Considerations** [e.g., Health privacy, Liability, Human rights]	3,589	1,545
3	**Human Factors** [Topics could include Physician-machine trust/Patient trust, Maintaining humanity, Human presence and Patient engagement, Health provider burnout/Human implications]	3,548	1,718
4	**New Models of Patient Care** [e.g., Preventative care, Community/home-based care, Rural/ Remote care, e-consult, Digital/virtual care delivery, Health system organizational implications]	3,485	1,788
5	**Data Considerations** [e.g., Data collection, Quality, Integration, Collaboration]	2,294	1,143
6	**The Basics of AI – for execs** [e.g., How AI works at a high-level, How AI makes decisions, Responding to diff. between clinical opinion and AI decision]	1,853	963
7	**Emerging Educational Approaches** [e.g., Augmented reality, Virtual reality, Online training, Automated examination/evaluation]	1,792	1,000
8	**Health and Specialist Workforce Considerations** [e.g., Human resource planning, Changes to scope of practice/ future of work, Autonomous machines]	1,329	762

Fellows were asked to provide their input on what they believed would be necessary for the Royal College to better prepare them for integrating AI into their practice. After performing qualitative analysis on all responses (approximately 800 responses), the top categories were as follows:

- Providing training and education for Fellows
- Providing clarification and understanding on AI, and creating awareness
- Workshops/seminars/courses/conference/ e-learning
- Evidence and examples of effective AI

Fellows were asked to provide their input on what they believed would be the most significant changes of AI on their specialty. The top categories were as follows:

- Diagnostics
- Automation
- Early detection, prediction and evaluation
- AI as an assistive tool

3. Resident survey

As the future generation of Fellows who will most likely be on the front line of exposure to emerging technologies, Resident Affiliates were engaged in a survey to assess their educational needs and qualitatively measure their current level of expertise and exposure with regards to AI. The survey was distributed to the 2,011 Resident Affiliates of the Royal College. A total of 255 Resident Affiliates accessed the survey, 222 fully completed it, 32 partially completed it and one resident did not give consent.

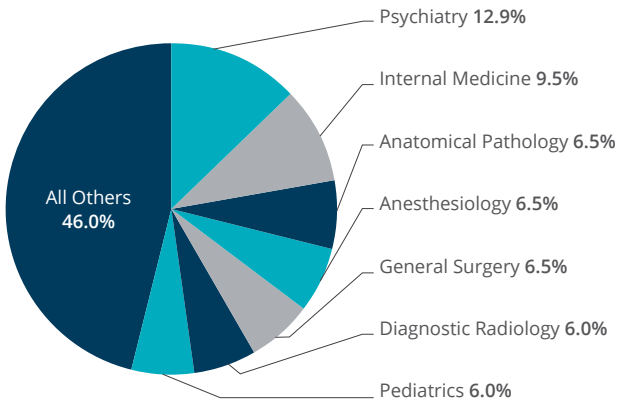
The survey was available in English and French, and consisted of nine Likert scale questions, one drag-and-drop ranking question and two optional open-ended questions exploring the perceptions of AI both generally and associated with the participant's specialty. The survey was pilot tested and revised on three separate occasions by task force members, Fellows and internal staff of the Royal College. The survey was sent out on September 3, 2019, and remained open for a period of three months (closing on November 3, 2019). A reminder e-blast was sent on September 27, 2019.

Table 9. Resident survey participation by province

Province	Participation
Ontario	41.1%
Quebec	19.6%
Alberta	11.6%
British Columbia	10.7%
Nova Scotia	6.2%
Newfoundland and Labrador	4.5%
Saskatchewan	3.6%
Manitoba	1.8%
New Brunswick	0.9%

The top specialties by participation are displayed below.

Figure 7. Resident survey participation – top specialties



Residents were asked how they would rate themselves on familiarity with AI and related concepts on a scale from 1-5, 1 meaning no/limited familiarity and 5 meaning they are experts in the field.

Table 10. Residents' level of familiarity with AI

Level of Familiarity	Percentage (%)
3	31.5
2	24.1
1	19.0
4	18.5
5	6.9

N = 232

Residents were asked how much exposure they had to conversations on AI in their work/education environment on a scale from 1-5, 1 meaning no/limited discussion and 5 meaning it was a common topic.

Table 11. Resident exposure to AI conversations in work/education environment

Level of Exposure	Percentage (%)
1	33.6
2	33.6
3	22.4
4	7.3
5 (Amongst the most commonly discussed topics)	3.0

N = 232

Residents were asked about the extent to which they have received information/teachings that might have prepared them for using AI and emerging digital technologies. They were asked to respond on a scale from 1-5, 1 meaning they had gone through none/limited preparation interest and 5 indicating they feel fully prepared.

Table 12. How well residents have been prepared for AI during training

Level of Training	Percentage (%)
1	56.9
2	27.2
3	11.6
4	3.4
5 (Fully trained by program to prepare for future technological advances)	0.9

N = 232

Residents were asked to rate themselves on their level of understanding and interpretion of statistics on a scale from 1-5, 1 meaning they have difficulty with statistics and 5 meaning they are fully comfortable performing statistical operations.

Table 13. Residents' level of statistical knowledge

Level of Statistical Knowledge	Percentage (%)
2	30.6
3	28.4
4	18.5
1 I have difficulty understanding base statistical concepts	14.7
5 I fully understand and comfortably perform all statistical operations	7.8

N = 232

Residents were asked to rate themselves on their level of knowledge and understanding of computer science (e.g., familiarity with programming logic, languages and algorithms) on a scale from 1-5, 1 meaning no/limited familiarity and 5 meaning they are experts in the field.

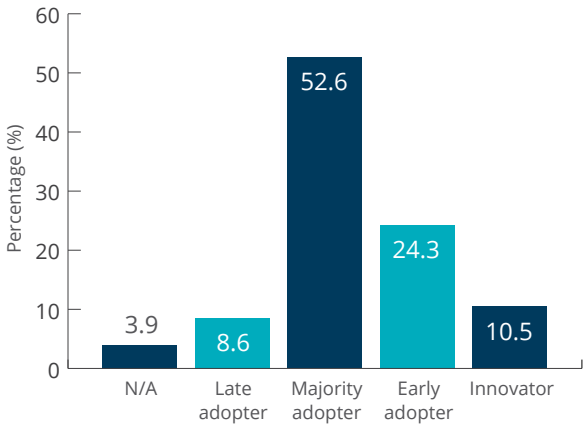
Table 14. Residents' level of computer science knowledge

Level of Expertise	Percentage (%)
1	40.9
2	27.2
3	17.7
4	7.8
5 (Able to code and design software)	6.5

N = 232

Residents were asked what AI-related role they imagined themselves positioned to take on with their current level of knowledge, expertise and experience in AI and digital technologies. Residents were asked what AI-related role they would like to take on in the future, given training and education would be provided.

Figure 8. AI roles residents imagine for their future given current training



Residents were asked to describe which phrase best described their belief on how AI will affect their specialty.

Figure 9. AI roles Fellows would like to have in future

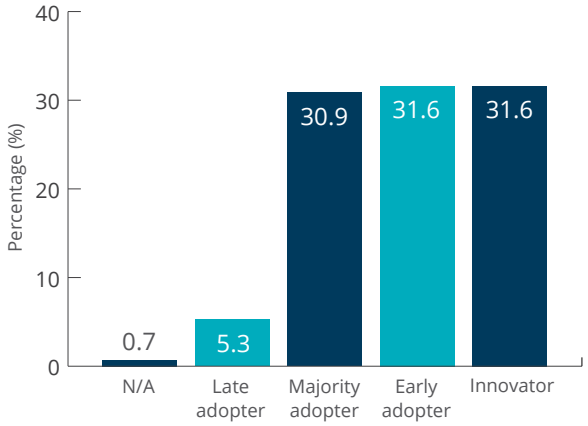


Table 15. Resident opinion on how AI will affect their specialty

Opinion	Percentage (%)
4 (It may disrupt the current workflow in a positive manner)	48.7
5 It will definitely have a positive effect on my practice and patient experience	28.0
3 (It won't affect my specialty)	11.2
2 (It may disrupt the current workflow in a negative manner)	8.6
1 (I worry that my specialty is at risk)	3.4

N = 232

Residents were asked if they would be interested in participating in AI education/continuous professional development concepts or principles relevant to the practice of medicine education. They were asked to express their levels of interest on a scale from 1-5, 1 meaning no interest and 5 indicating a very high level of interest.

Table 16. Residents' level of interest in AI education

Level of Interest	Percentage (%)
5 (Extremely interested)	34.5
4	22.0
3	22.0
2	12.1
1 (Not interested)	9.5

N = 232

Residents were asked to rank potential educational topics based on their level of interest. Each participant was allowed to select three topics and rank them in order of priority, with the highest-ranking topic receiving a score of 3 and the lowest receiving a score of 1. The total scores for each topic and the number of times each topic was ranked among the top 3 overall is presented in the "Score" and "No. of Rankings" columns, respectively. As observed, the final rankings are calculated based on the overall scores.

Table 17. Resident ranking of AI educational topics

Rank	Topic	No. of Rankings	Score
1	**The Basics of AI – technical training related to your specialty** [e.g., Training that would help you have sufficient understanding of AI to be an innovator or early adopter]	146	331
2	**New Models of Patient Care** [e.g., Preventative care, Community/home-based care, Rural/ Remote care, e-consult, Digital/virtual care delivery, Health system organizational implications]	115	226
3	**Human Factors** [Topics could include Physician-machine trust/ Patient trust, Maintaining humanity, Human presence and Patient engagement, Health provider burnout/Human implications]	180	94
4	**Ethics and Legal Considerations** [e.g., Health privacy, Liability, Human rights]	84	179
5	**The Basics of AI – for execs** [e.g., How AI works at a high-level, How AI makes decisions, Responding to diff. between clinical opinion and AI decision]	60	110
6	**Emerging Educational Approaches** [e.g., Augmented reality, Virtual reality, Online training, Automated examination/evaluation]	56	106
7	**Health and Specialist Workforce Considerations** [e.g., Human resource planning, Changes to scope of practice/ future of work, Autonomous machines]	55	99
8	**Data Considerations** [e.g., Data collection, Quality, Integration, Collaboration]	50	95

Residents were asked to provide their input on what they believed would be necessary for the Royal College to better prepare them for integrating AI into their practice. Sample responses included:

- "Educational sessions, basic education on AI and its relevance"
- "Help trainees and physicians prepare for this coming practice change"
- "Focus on AI as a useful tool and adjunct to practice rather than a threat to our jobs"
- "Integrate into medical training"
- "Increase communication between physicians and private business so that we can be part of the transition, as opposed to having the transition forced upon us"
- "We need statistics refreshers"
- "Who is legally responsible for misdiagnosis or malpractice related to AI decision-making"
- "Exposure, dialogue, lectures, access to basic computer science teaching"

Residents Affiliates were asked to provide their input on what they believed would be the most significant changes of AI on their specialty. Sample responses included:

- "Changing clinical decision-making process towards a more individualized patient approach"
- "Risk prediction and stent graft placement"
- "Patient education and safe discharge, moving flow efficiently"

- "Diagnosis and predicting treatment outcomes"
- "Analysis of large data sets"
- "Screening for depression, anxiety, suicidality, psychotic features"
- "Automation and patients self-diagnosing with AI apps"

4. AI roundtable

Following the Fellow and Resident Affiliate surveys, numerous Fellows and Resident Affiliates contacted the task force and declared interest in further participation. To leverage this interest and engagement, the Royal College organized an AI Roundtable meeting to review and discuss the task force's findings and emerging recommendations, and provide a platform for the representatives of Fellows and residents to provide their opinion on the topic. The roundtable was held as a full-day event on December 18, 2019, at the Royal College's main building in Ottawa. The roundtable consisted of 22 Fellows and residents who were identified as early adopters and innovators of AI, in addition to the task force leadership team, and two members of the Royal College Ethics Committee. A comprehensive process was undertaken to select the list of invitees from the almost 100 correspondences received. The process involved communication with all those who responded, a careful review of all CVs focusing on academic and industry background, and categorization based on level of expertise and experience in AI. The roundtable engaged in extensive discussions regarding the task force's preliminary findings and recommendations, and all suggested modifications were taken back to the task force for further deliberation.

5. Scoping review

While conducting background research relating to the AI task force, the Royal College recognized that an unprecedented level of artificial intelligence (AI) systems are being developed for applications within medicine, but there are currently no comprehensive reviews published on this topic. The Royal College believes more than ever, it is imperative to systematically collect, summarize and map what is being published regarding AI and medicine and to define any gaps in the literature and address the confusion and anxiety regarding the use and impact of AI on health care and its workforce. To meet this need and complement the work of the Task Force on Artificial Intelligence and Emerging Digital Technologies, the Royal College is conducting a national research study on AI and medicine. Using a technique called a "scoping review," all recent literature related to AI and medicine will be summarized to help inform the current state of AI in medicine by illustrating what is research/evidence-informed or opinion and articulate where gaps in the literature exist. The scoping review will serve as an evidentiary base to inform a strategy on the impact of emerging technologies in specialty medical education and implications for ongoing professional development of current Fellows. This can help propel clinical validation of AI systems and ultimately, it may provide insight on how AI will be realistically integrated into health care.

The scoping review will be conducted using approaches guided by Arskey and O'Malley[67] and Levac et al.[68] The review approach is designed to examine and summarize the extent, range and nature of research activity in a particular area. The benefit of a scoping approach is that it aims to produce a comprehensive profile of the literature (particularly in nascent areas) and builds a foundation for other types of reviews or other forms of primary research. Due to the nature of this review and anticipated high citation set, the InsightScope platform will be used to screen abstracts and full text articles. This platform facilitates crowdsourcing to recruit reviewers to screen a large number of articles. This software has been validated for use in systematic reviews.[69] InsightScope is an innovative method to allow individuals to be part of an exciting project which will advance the field of AI and medicine. The link to the software can be found at http://insightscope.ca.

Appendix C: Terms of Reference

Role

The Royal College Council charged the Task Force on Artificial Intelligence and Emerging Digital Technologies (TFoAI) with studying the impacts of AI and emerging digital technologies on the training of future medical specialists and the practice and professional development of current physicians and formulating recommendations to address these impacts.

Terminology

For the purposes of the task force and this report, "AI and emerging digital technologies" refer to such technologies that intersect with medicine. These include machine learning, augmented reality (AR), virtual reality (VR), health apps, omics, precision medicine, robotics, 3D printing, computer vision and intelligent medicine. Specific exclusions will be changes in approaches to disease emanating from the use of data science and or bioinformatics. Other terms used in this report are defined in Appendix A.

Responsibility and authority

Reporting to Council, the task force was convened to:

- study, collate and form recommendations to inform the Royal College Council, standing committees and management on the implications of AI and emerging digital technologies for the training of future medical specialists;
- learn from other sectors that are anticipated to bring AI benefits to the health sector in the near future;
- explore and identify the innovations that will impact specialty medicine education;
- define the approaches, partnerships and sources of data required to continuously monitor emerging advances in AI-related technology and assess the impact on specialty medical education, training and delivery of care;
- define strategies to monitor and assess the impact of emerging digital technologies on specialty medicine;
- identify, engage and integrate with other internal and external initiatives, including other task forces, initiatives and national-level organizations working to develop AI strategies; and
- bring a focus on AI to other aspects of the strategic plan.

Composition

The TFoAI is chaired by Dr. Richard Reznick, MD, MEd, FRCSC, FACS, FRCSEd (hon), FRCSI (hon) (Dean, Faculty of Health Sciences, Queen's University). The task force is supported by Royal College staff, including Dr. Ken Harris, MD, FRCSC as Executive Sponsor (Executive Director, Office of Specialty Education) and Dr. Tanya Horsley, PhD, MBA as Committee Coordinator (Associate Director, Research Unit).

The task force will comprise no more than 13 members, in addition to the chair, who are perceived to be leaders in artificial intelligence and emerging digital technologies as they relate to medicine and more specifically, specialty medical education and training. Depth of strategic perspectives nationally is an imperative. Given the specificity of expertise it is anticipated that the constitution of the committee will be a mix of Royal College Fellows and AI scientists with the latter predominating.

Task force term

The task force will convene for the duration of 18 months (October 2018 – March 2020).

Meetings

The task force will convene monthly; the majority of meetings will be via teleconference, with a minority (two to four) meetings occurring in person.

Quorum consists of a majority of the voting members of the committee (i.e., 50% plus one). The chair is counted as a voting member in constituting quorum. However, as the presiding official of the committee, the chair does not move motions. Furthermore, the chair shall only vote when the vote is conducted by secret ballot or when it is necessary to break a tie.

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