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Invited Commentary

Preparing for Artificial Intelligence: Systems-Level Implications for the Medical Imaging and Radiation Therapy Professions

John French, MSc, FCAMRT, CHE*, and Leo Chen, MSc

Cancer Strategy & Capital Redevelopment, British Columbia Cancer Agency, Vancouver, British Columbia, Canada

ABSTRACT

Innovations in artificial intelligence (AI) are driving a new industrial revolution, and as a result, the medical radiation sciences is experiencing transformational, open, beneficial, yet disruptive changes. Many studies have already been published on specific frontline examples where AI will improve cancer care, but discussions of how AI will change the medical radiation sciences and its associated professions at the systems level have been comparatively sparse. In this article, the system-level implications of AI on the medical radiation sciences are discussed, and recommendations are made on how professionals in this field may need to adapt in preparation for a future where AI will be an integral part of the health care system at all levels.

Keywords: Artificial intelligence; AI; medical radiation sciences; radiation oncology; radiation therapy; systems; disruptive technology

Introduction

Artificial intelligence (AI) has been described as innovation driving the "fourth" Industrial Revolution; the three preceding revolutions being driven by the steam engine, science and mass production, and digital technology, respectively. Broadly speaking, AI can be defined as the application of computer science to program machines to accomplish tasks traditionally associated with human intelligence, such as the ability to learn and solve problems [1]. The growing capacity for AI to drive the next Industrial Revolution will result from the convergence of the following three technical prerequisites:

1) Increased computing power: the rapid increase of computing power and developments such as cloud computing allow for computers to analyze multiple data more quickly;
2) Availability of large datasets: the generation of large, curated, and representative datasets—the concept of "Big Data" provides the source material from which computers can "learn" how to analyse various scenarios; and
3) Advances in learning algorithms: essentially, the learning algorithms are the computer programs built to enable machine learning and AI.

However, it is the ability of humans to adapt to AI, at an individual, organizational, and systems level that will play an equally important role to the availability of technical advancements in the adoption of AI. This article will explore some of the advances that are occurring with AI, review some existing literature on the impact of AI in the medical radiation sciences (MRS), provide some additional context, and discuss some of the actions professionals working in the MRS may have to take to be successful in an emerging new world of AI-enabled health care.

In anticipation of the emerging clinical applications of AI and its direct impact on health care providers, the current body of literature on AI in health care is saturated with the possible uses of AI-enabled technologies in health care. These publications cover, in great detail, a diverse range of frontline applications including the utilization of machine learning to facilitate image recognition and analysis; the downstream implications of this capability are of clear interest to professionals in the MRS, with uses ranging from treatment planning to improving the precision of tumor targeting and making possible real-time field adjustments during treatment delivery [2]. Some publications also discuss the potential of AI for augmenting health care administration. One recent example was a scheduling program developed by a research team at the BC Cancer Agency, which was able to schedule daily chemotherapy appointments more efficiently and effectively than staff members, resulting in improved efficiencies and increased patient satisfaction [3]. The intent of this article is not to describe all the potential clinical applications of AI and will use selected examples to illustrate key points.

* Corresponding author: John French, MSc, FCAMRT, CHE, British Columbia Cancer Agency, Suite 500, 686 W. Broadway, Vancouver, British Columbia V5Z 1G1.

E-mail address: jfrench2@bccancer.bc.ca (J. French).

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However, it is certain that AI will be both a transformative and disruptive force that produces significant advancements in health care technologies and how they are used, and technologies using AI will change the practice of administrators and clinicians alike. Although the rich body of literature on AI-enabled frontline technologies is important for the implementation of practice-transforming frontline technologies, a vast knowledge gap exists on the impact of AI on the management, planning, and development of health care at the systems level. This impact will be twofold. First, AI will change the relationship between humans and their work: some jobs will disappear, whereas others will change dramatically, and new roles will emerge. This change is already happening, as outlined by a recent report by the BBC described a £250,000,000 (roughly equivalent to $400,000,000 CAD) initiative by the National Health Service in the United Kingdom to set up a national AI laboratory to enhance care for patients and research. The article described how AI is already revolutionizing health care in areas such as diagnosing patients and gleaning new insights into diseases. For example, some studies have suggested that AI is already as good as doctors at spotting lung or skin cancer [2]. These changes will clearly alter the roles of clinicians, automating some tasks while introducing new competencies; the net result is that workload and capacity planning for professions across health care will experience dramatic changes as the tasks performed by each role evolves.

The second way in which AI will alter health care at the systems level is by directly affecting the way that health care itself is planned. For example, a recent collaboration between Google and Stanford University, the University of California San Francisco, and the University of Chicago Medicine used a deep learning approach to use AI to make predictions on patients' health care outcomes using all data within an electronic health care database [4]. This study found that compared with traditional methods, a deep learning approach made superior predictions compared with traditional prediction models. These predictive capabilities are important because if a deep learning AI is augmented with the functionality to allocate or plan health care resources, it is possible for a hospital to allocate resources in real-time based on probabilistic modelling of how much resources need to be available and when. Such an approach would help hospitals to optimize capacity to ensure that anticipated patient needs are met and to reduce waste because of excess capacity. For the MRS professions, this capability could help to predict staff hours required for any given day and how long each room or piece of equipment may need to be in use. Although this type of planning can already be considered to be systems-level, multicenter organizations such as BC Cancer may take advantage of data from its numerous sites to make even higher level predictions, such as when and where capital investments in equipment such as linear accelerators and magnetic resonance imaging may be needed or where new facilities may need to be built altogether.

There are many other instances where AI has been applied in the field of medical imaging and radiation therapy. For example, Google's "DeepMind" research initiative partnered with University College Hospital in London to explore the potential benefits that AI technology could have in planning radiation treatments for patients with head and neck cancers. The goal of the study was to use AI technology to analyze images and reduce the requirements to perform segmentation (image delineation, typically an "expert" manual process) from 4 hours per task to 1 hour per task performed by an algorithm. If successful, this research would have wide applicability and implications in the radiation therapy world [5]. Similarly, in the medical imaging domain, a number of start-up software companies exist, which have software solutions that detect abnormalities in a range of imaging scenarios. One such company is Kheiron Medical, a UK-based company that offers software that can use machine vision to detect abnormalities in mammograms and reduce the number of false positives and negatives from such mammograms [6].

Although these changes will impact many professions, it is important to consider how they will impact the MRS professions in particular, as both medical imaging and radiation therapy will be heavily impacted by advances in AI. Fortunately, the MRS professions have a history of adapting to rapid change, which results from the introduction of new technologies. Historic examples include the introduction of equipment such as computed tomography, magnetic resonance imaging, and positron-emission tomography-computed tomography; radiation therapy planning, treatment, and associated areas such as electronic medical records; and Picture Archiving and Communication Systems and workflow management systems. The adaptability demonstrated by these historic examples is important, as it is anticipated that innovations in AI will require an even greater level of adaption. This article will debate the use of AI in the MRS, provide contextual background, and make recommendations for how professions within the MRS will need to adapt for the future.

Contextual Background

Consistently with most other developed nations, the demographics of the Canadian population are changing significantly. Specifically, the population will be older and greater in number in the coming years. In British Columbia, for example, the percentage of the population aged over 65 years will be over 25% by 2041, compared with 19% in 2018, representing a 76.3% increase from 912,944 to 1,609,676 persons [7]. These changes will increase demand for oncologic health care services, influenced by factors such as diagnostic imaging services needing to serve a larger population and an increased proportion of people being diagnosed with cancer. In fact, it is noted that anticipated cancer incidence will increase by 57% between the years 2012 to 2030 in BC alone [8]. Concurrently, the proportion of the population available as part of the workforce to provide these services is shrinking, and as such, the predicted volume of services required will outstrip the ability of the health care system to both fund

and provide these services. Consequently, if health care is delivered in its current model, it is unlikely that health care providers would be able to provide the same level of services to patients without superproportional increases in funding, infrastructure, and human resources. The message is clear: health care must change, whether or not that change is desired, and the adoption of AI technologies will be a part of that change. These changes will include AI taking over roles and tasks that are traditionally performed by MRS professionals and the emergence of new roles and tasks that may or may not be categorized under the same professional umbrella. The very definitions of professions may well change, and the lines between some professions may blur, whereas other roles partition into their own new umbrella of professions. Regardless of how these changes occur, the following question remains: are the MRS professions able to adapt to the changes that will occur as a result of AI?

The Role of AI in the MRS

Two recent publications provide excellent descriptions of the current state of AI in both diagnostic imaging and radiation oncology. The first, a white paper by Tang et al, was published in the Canadian Association of Radiologists Journal last year and provided an extensive overview of the changes that have occurred and will continue to occur as a result of AI. The paper notes that in the field of radiology, AI is rapidly moving from an experimental phase to an implementation phase, citing areas such as image recognition, caption generation, and speech generation. The paper posits that over the next decade, the use of AI in radiology will improve the quality, value, and depth of contributions made by radiology to health care and population health and will revolutionize the workflows of radiologists [9].

In the same year, Thompson et al published a radiation oncology study that explored whether the application of AI in radiation oncology would result in a disruptive transformation. Radiation oncology is a field rich in data, and the paper outlines specific areas where AI is currently being implemented, including image segmentation, dose optimization, clinical decision support and outcomes prediction, and quality assurance (QA). The paper argues that certain skills, which are critical for MRS professionals, such as contouring, will not be required in the future; instead, professionals may need to develop fluency with AI and novel human–machine interfaces [1].

The radiology and the radiation oncology papers both draw similar conclusions in this regard and also highlight the following areas of relevance:

- Data availability, equity, reliability and security: AI relies on the availability of large, representative datasets. These need to be properly curated, standardized, and made available across jurisdictions. Thompson et al noted that data have limitations, in that it has a half-life; this has been estimated to be approximately 4 months, meaning that datasets need to be continually monitored and updated [1]. Data equity is also a concern, as demographic variables may exist and datasets derived primarily from one data source may not be representative of all countries, regions, or cohorts. In addition, effective AI requires data sharing across multiple jurisdictions and institutions. Existing challenges regarding privacy, willingness to share data, and interoperability of data will need to be addressed to facilitate the availability of reliable data.
- Education and training: machine learning, data science, and the use and limitations of AI will need to be incorporated into the curriculum for entry to practice professionals, along with opportunities for professionals to gain further knowledge and expertise in the area. This will require collaboration across academic domains such as computing science and data analytics.
- New roles: with advancements in AI, new roles will emerge. Expertise will be required in developing AI solutions, and this requires both programming and clinical skillsets. In addition, the curation and management of datasets will be a critical requirement, as will the ongoing QA of various AI-enabled technology.
- Ethical and legal issues: The Canadian Association of Radiologists AI working group also recently published an article on the ethical and legal issues related to AI in radiology [10]. The group concludes that most of the challenges relate to the use of data, such as who owns the data; privacy and intellectual property rights; and how such data are curated, shared, maintained, and ensured to be representative of the patient population in question. The other emerging issue is one of liability. In the event of a misinterpretation of an image, where does liability lie? With the manufacturer of the software, the institution or the practitioner that oversees the patient?

How Should the MRS Professions Prepare for AI?

So, what is required for MRS professionals to thrive in the future AI-enabled world, where the increasing workload has surpassed available resources? Certainly, the work that MRS professionals perform now will not be the same as the work that MRS professionals do in the future, just as the work that they are performing today has evolved from the work that they had completed in the past. The extent of the difference may be hard to accurately predict, but the fact that there will be change is a certainty. As such, the capacity for continuous general adaptability to emerging roles and technologies will be a critical skillset for the MRS professions, both collectively and as individual practitioners.

AI will undoubtedly impact the MRS professions in the future. Job roles, responsibilities, and scopes of practice will change, just as they have done with the introduction of new technologies in the past. It is highly probable that the rate of technological change will advance, meaning that MRS professionals will need to be able to adapt more quickly than they

did in the past. Skillsets that once were in high demand (such as dosimetry or radiographer image review) are perhaps more likely to be replaced by AI technologies than other routine tasks that do not require the analysis and manipulation of large amounts of data. New roles will emerge, not dissimilar to the emergence of PACS administrator roles in the past. Data curation and QA will likely be critical skillsets. Adapting to new technology will itself become an important skillset, which will in turn drive an increased need for people with project management, change management, and clinical education skillsets.

It follows that the education facilities need to prepare for change. Core entry to practice competencies will need to incorporate and reflect the emerging role of AI in the imaging and treatment domains, and postgraduate education programs will be beneficial in providing the necessary upgrade to skills and competencies for qualified professionals. In addition, the need for research skills to evaluate the feasibility, reliability, and efficacy of AI methodologies will be required. Moreover, at an administrative level, those responsible for health care systems planning should be incorporating AI as a planning parameter, along with the aforementioned changes in demographics and future demand.

Ultimately, technologies that use AI should be embraced, rather than feared. As Sahiner et al concluded, the future is bright; but with all revolutions, the change may be dramatic, rapid, and require adaption skills [11]. Those prepared for the change will likely prosper, career-wise, but those unprepared or unwilling may get left behind.

It should also be noted that although the ability to recognize and manipulate image data is a rich domain for the application of AI, the contextualization of such data along with clinical histories and other tests still requires human intervention, and the human connection, empathy, and simple acts of caring that occurs between health care provider and patient cannot easily be replicated. Soft skills, such as effective communication, empathy, problem solving, systems thinking, and so on, will still be in high demand in an AI-enhanced world. MRS professionals who can use these skills alongside technical skills will continue to be in high demand in the future.

Conclusion

AI is an existing and rapidly evolving technology that has multiple applications in the medical imaging and radiation therapy fields. It may well be a revolutionary, rather than evolutionary technological change, and may well help manage the increasing volume of work associated with an aging and increasing population. AI will require that the professions adapt to change, and it is likely that the ability to manage technological change will be in great demand as a result. However, AI is a technology and does not reduce the need for strong patient care skills that have been the hallmark of the MRS profession for many years.

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