Artificial Intelligence and Radiology: What Will the Future Hold?

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Radiology has witnessed the introduction of amazing new discoveries such as ultrasound, CT, MRI, and PET. These technologies have vastly improved the care of patients across the world. However, the "next big thing" in radiology may not be a new scanner technology but rather new discoveries in the ways we utilize imaging data that many refer to as "artificial intelligence."

Artificial intelligence (AI) is defined as the theory and development of computer systems able to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision making, and translation between languages [1]. A major component of AI is machine learning, which is a subfield of computer science that enables computers to learn without being explicitly programmed. This exciting technology incorporates computational models and algorithms that are similar to the structure and function of our brain's biologic neural networks. These computational models are often referred to as "artificial neural networks." When these artificial neural networks process information (digital data) from numerous input flows, they have the ability to "learn" and alter their structure in much the same way the neurons in our brain are altered with memory.

Deep learning is a part of a broader family of machine learning methods that is based on learning representations of data such as recognizing characteristic images (ie, face recognition). Deep learning is very significant as it relates to radiology because of the ability to recognize objects in images.

Another important term in the world of AI is *big data*, data sets that are so large or complex that traditional data-processing application software is inadequate to deal with them. A typical example of big data is the amount of information in today's electronic medical records that contain huge digital imaging archives, pathology and laboratory archives, along with the millions of digital clinical notes and diagnoses.

Finally, it is important to note that there are also fast-moving advancements in computer hardware and processing such as ultrafast graphic-processing units and cloud computing that are enabling the accelerated applications of AI. In many cases, one can go online and buy access to these powerful advancements without the need to own or purchase these expensive and complex computer systems.

In this perfect storm of rapidly developing deep learning algorithms and artificial neural networks, along with the explosion of big data and the acceleration of processing power, we have witnessed the beginning of a new world of AI.

There has been an increasing focus of AI in radiology even to the point that some experts in the field are saying that someday AI may even replace radiologists [2]! These suggestions are very thought provoking and should give us reason to look more closely at this technology so we can better understand its potential, understand the drivers, and begin to understand where and how we can employ the exciting technology to discover new ways to improve the care of our patients.

AI in radiology will likely emerge in stages. The first stage is already happening and involves AI systems performing automatic segmentation of various structures on our digital CT or MR images. Segmentation of structures is the first step in any effort to isolate and analyze organs or pathologic lesions for analysis. Although segmentation of structures seems easy and readily apparent to human operators, it can take enormous amounts (hours) of time to perform by humans. To date, it has

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been very difficult to automate segmentation with conventional computer programs. Fortunately, AI systems have already been developed to solve this conundrum. AI systems are "learning" from a small number of reference data sets (segmented cases already performed by humans) and are going on to perform segmentation tasks on future cases with amazing accuracy. Similar efforts are under way with other forms of AI in imaging (texture analysis). Some are calling this first stage of AI "human-assisted artificial intelligence," which allows AI to learn from specific human-performed tasks or reference data and ultimately go on to replace that human doing the task, freeing up radiologists to transfer their uniquely human intelligence to more interesting and challenging endeavors. Future stages of AI in radiology will go on to develop complex integration of multiple data systems (pathology and radiology), more complex artificial neural networks, and deep learning algorithms such that AI in medicine and radiology will continue to progress and become more powerful.

So, what are the driving forces behind this exciting future of AI in medicine? The field of medicine has been striving for answers to the complex mechanisms of health and disease for millennia. This altruistic desire and perpetual quest to improve patient care will continue to be the driving force as we discover new applications of AI in radiology and medicine. Our historical search for answers to complex radiology challenges has always been accelerated by the discoveries of new technologies (ie, x-rays, contrast media, CT scans, ultrasound, molecular imaging, MRI, etc) and will continue with new discoveries aided by the exciting technology of AI.

AI will open new inroads into radiology diagnosis that have heretofore been impossible through mere image interpretation. Image texture analysis combined with pathologic and genetic correlation will allow AI systems to learn from vast amounts of data and help improve the accuracy and value of our diagnoses. AI will be able to perform mundane tasks with great accuracy and may even replace some things that radiologists currently do, such as reading chest x-rays, in much the same way that computers now read all routine electrocardiograms for cardiologists. AI's ability to perform these tasks in the future will not only free up time for radiologists, but will enable us to explore and employ more complex diagnostic imaging techniques and image-guided interventions. AI may be "the" new tool or technology, but the human qualities of intellectual curiosity, intuition, passion, and persistence will remain the real drivers of these new discoveries in radiology. Human expertise and intelligence will always be at the forefront in radiology, and AI will allow us to dive deeper and offer more than we have in the past in the pursuit of discovery and improved patient care.

Economic factors will also play a huge role in the advancement of AI in medicine and radiology. Health systems and payers are constantly looking for higher levels of efficiency and lower costs. This drive for more efficient and lower cost of care will definitely play a role in future AI applications in medicine and radiology. Entrepreneurs and venture capitalists are also constantly looking for new discoveries and applications in the medical world. These two economic factors of lowering the cost of care and entrepreneurship will also be big drivers in the advancement in AI in medicine and radiology. As a result, many new companies or start-ups are already being formed that are centered on new products incorporating AI into the practice of medicine and radiology. Large IT leaders such as Google, Microsoft, Facebook, and Amazon are also heavily investing trillions of dollars into AI. Although their focus of AI is heavily focused on self-driving cars, customer service, marketing, and other endeavors, there is no doubt they will invest more in medicine and radiology as the technology advances.

Radiologists must remain at the forefront of these developments relating to imaging and continue to provide the human intelligence that is necessary to make these applications improve the care of our patients and to keep radiology at the forefront of medical diagnosis and intervention.

Some have postulated that what might take an experienced radiologist 30 years of radiology-pathology correlation to master may only take an AI system hours or days to analyze and learn in the future! But, as many of us know, the medical profession of radiology is much more complex and demanding than what AI will be able to do in the future. Therefore, the human intelligence of a radiologist will always be at the

forefront of diagnostic imaging and patient care, but our roles as experts in image-based diagnosis and intervention will likely change over the coming years. If we, as radiologists, do not adapt to this change, we may become extinct. As W. Edwards Deming once stated, "It is not necessary to change. Survival is not mandatory" [3]. Therefore, radiologists must engage this exciting technology of AI, guide it, lead it, and enable it to improve patient care and advance our specialty to new levels of accuracy and helpfulness in the care of our patients. Whatever the outcome of AI in radiology is, the future is bright and very exciting for radiologists!

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