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Review

The future of radiology augmented with Artificial Intelligence: A strategy for success

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ABSTRACT

The rapid development of Artificial Intelligence/deep learning technology and its implementation into routine clinical imaging will cause a major transformation to the practice of radiology. Strategic positioning will ensure the successful transition of radiologists into their new roles as augmented clinicians. This paper describes an overall vision on how to achieve a smooth transition through the practice of augmented radiology where radiologists-in-the-loop ensure the safe implementation of Artificial Intelligence systems.

1. Background

Radiology is in need of a strategy to future-proof the profession. A diagnostic radiologist is a postgraduate subspecialty-trained medical doctor who is skilled in interpreting medical images such as Digital radiographs, CT scans, Ultrasounds, Nuclear Medicine studies and MRIs and using them to guide management of disease in patients. But recently, experts in Artificial Intelligence (AI) have warned that radiologists may soon be out of a job, one being none other than the grand master of deep learning himself, Geoffrey Hinton [1].

In some ways, Hinton may be right. Since 1895 when Wilhelm Roentgen first discovered ‘x-rays’ [2], nothing has come even remotely close to the disruption potential posed by Artificial Intelligence. It is a double-edged sword, which, if wielded expertly, will propel radiology and radiologists well into the next century. On the converse, the margin for complacency is narrow, and perils abound if radiologists choose to adopt a ‘wait-and-see’ approach and instead allow pure market forces to transform the industry.

A middle ground has to be achieved in the tug-of-war between a specialty whose aims has always been of a noble pursuit of cutting-edge technology put to good use in achieving the best possible care for patients, and a multi-billion-dollar imaging industry dominated by behemoths of the late, great industrial age, such as General Electric, IBM, Siemens, Samsung and Phillips [3].

The overall vision for this strategy is for the safe implementation of AI systems in radiology, where radiologists are mandatory as component human authorities, or simply put: ‘radiologist-in-the-loop’ systems. Professor David Autor described the ‘O-ring principle’ in his paper on the future of workplace automation: given a situation where a collection of tasks need to be done together to successfully accomplish a main task, if some of the tasks can be automated, the economic value of the human inputs for the other tasks that cannot be automated will increase [4,5]. For radiologists, examples of the most important tasks that cannot be automated would include leading multidisciplinary meetings and making judgement calls, along with the verification of reports. With automation, radiologists increase rather than decrease their value.

Machine learning in the form of image processing, computer vision and natural language processing are the key AI technologies forming the pillars of this new Augmented Radiology future. According to Porter's Generic Strategies model, there are three basic options available to organizations for gaining a competitive edge. These are: Cost Leadership, Differentiation and Focus [6]. Strategically, the use of Porter’s generic strategies to create a competitive advantage hinge upon the reduction of overall cost of imaging to the patient, by increasing the productivity of radiologists through the automation of time-consuming, low-value, mundane and repetitive tasks such as nodule-detection.

This automation also creates differentiation for radiology as a product, if it can be harnessed to deliver medical imaging which is more accurate, more convenient and safer than it is presently. Last, but not least, Augmented Radiology has the potential to form new niche areas for growth of the specialty, notably in radiogenomics, report data mining and research [7–9].

2. The current state of radiology and the need for a strategy

Radiologists are not unfamiliar with Artificial Intelligence, pioneering work in medical imaging perception in the 1980s [10]. We are

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domain experts in medical imaging, medical physics and radiation safety. But in the past 5–10 years, there have been substantial new innovations in imaging from deep learning methods of image classification. Current artificial neural networks have accuracy rates which surpass those of human radiologists in narrow-based tasks such as nodule detection [11,12].

The first step in formulating a strategy is defining our capabilities and identifying the competitive forces which pose a threat. We face competition from other medical specialties who spend more time interacting with patients and who may choose to purchase AI technologies. We also face competition from equipment vendors who manufacture imaging devices such as CT scanners.

Our greatest strength lies, counterintuitively, not in our ability to tap on experience to accurately detect or classify images of disease, but in our ability to make clinical judgements based on this data, and this is where we outshine diagnostic algorithms. Judgement is developed not only from knowledge gained from radiology practice but stems from many years of undergraduate medical training beforehand. Currently, radiologists differentiate ourselves by integrating multimodal streams of data, from electronic health records and discussions with other colleagues from different specialties. This is a very strong entry barrier.

AI technology in itself is a fundamental technology which should not be resisted e.g. by withholding domain expertise from software developers, on the contrary, our strategic goal should be to further differentiate ourselves by creating hybrid Radiologists and AI as a form of collective intelligence.

Apart from thinking of ourselves as a product, we can also position ourselves as buyers to exert a strategic force upon the market and by integrating backward. Software is much easier to create than machines, and deep learning models are already freely available as open source material online. Instead of buying expensive AI software, we have been creating our own, in house.

In the future, diversification of radiology into a broader field, utilizing all forms of data, including metadata (e.g. electronic health records), signals and biometrics to arrive at timely diagnosis around the clock is a probable strategy. Building an ecosystem to sustain this, together with other “information specialists” such as Pathologists [13,14], would create an even greater competitive advantage.

Psychologically, creating “brand identification” by connecting to our patients via community outreach, fostering awareness of our role in the healthcare team and by increasing face-to-face interactions would help to rebrand Radiologists augmented with AI as the new gold-standard in diagnosis.

3. General use cases, potential impact and implementation strategy

Broadly, several use cases should be targeted for implementation within the scope of radiology. They can be divided into task-based categories:

3.1. Detection and prediction automation

Machine learning (ML) is poised to automate detection of lung nodules on CT scans [15] and pneumonia on chest x-rays, with early results published in non peer-reviewed online archives showing some promise [16]. The next step is to increase the ability of these ML systems to predict the behavior of pre-cancerous lesions on CT scans by regression or modelling, to reduce the number of unnecessary invasive tests such as biopsy. This has the greatest potential for use in population screening for cancer, e.g. lung cancer, especially in countries where there is a shortage of radiologists relative to the populations they serve.

3.2. Intelligence augmentation

A buzzword replacing AI at the recent World Economic Forum was IA, or Intelligence Augmentation [17]. Combining AI and radiologists as a form of hybrid intelligence promises to achieve even higher levels of accuracy in diagnosis. A working paper by Nagar [18] showed that groups of human and AI agents working together make more accurate predictions compared to humans or AI alone. This observation may or may not hold true for radiological diagnosis and requires scientific validation and greater scrutiny with peer-reviewed studies. Perhaps even more crucially, having a radiologist-in-the-loop within these systems will help to ensure patient safety standards are met and creates judicial transparency, which allows legal liability to be assigned to the radiologist component human authority.

3.3. Precision diagnostics and big data

Research in precision medicine will create a need for precision diagnostics. As we discover how gene expression is linked to imaging features of tumours, machine learning will be required to mine the huge trove of data derived from imaging to assess tumour genetics and behaviour, as well as response to treatment [7–9,19–21]. Apart from cancer, precision diagnostics will conceivably be applied to chronic and degenerative diseases such as Alzheimer’s and coronary heart disease, or indeed any disease with genetic and imaging biomarker correlation.

3.4. Radiological decision support systems

The number of imaging studies performed each year has skyrocketed over the last two decades, almost doubling every ten years [22,23]. Machine learning is already used in advanced driver assist systems on roads, increasing safety and reducing the number of accidents. Similarly, a form of ‘driver-assist’ or decision support can be applied to diagnostic imaging, which may be particularly valuable for studies performed after office hours, when radiologists are either unavailable or operating on a skeleton-crew. This reduces information overload and burnout amongst radiologists, who already interpret one image every 3–4 s [24]. These systems can also aid the rapid detection of emergency conditions such as stroke in neuroimaging, in which AI has been used to analyse non-enhanced CT images and MRI images to automatically detect infarcts, segment infarct volumes and even differentiate thrombus from plaque in carotid arteries on CT images [25,26]

4. Impact upon cost leadership, differentiation and focus

One of the most obvious strategies to drive radiology forward is cost leadership. The integration of machine learning in imaging diagnosis has the potential to cut costs for patients and insurance companies by half [27]. It may cost as little as $1000 USD to install machine learning enabled chips capable of processing 260 million images per day [28]. Put into perspective, that is more than the sum of all MRI and CT scans performed in the USA daily. A thousand dollars is the current cost to payer for a single MRI study in some countries, such as the USA.

Radiologists utilizing AI to diagnose disease, or Augmented Radiology, could be applied as a differentiation strategy especially if patients (buyers) perceive this as having value. Apart from creating value by increasing diagnostic accuracy, this form of hybrid intelligence may increase patient access to imaging especially in remote areas and provide round-the-clock services for routine studies, increasing convenience.

Finally, projecting far forward into the horizon, finding a niche for hybrid Augmented Radiologist systems is an important focus strategy which can synergistically increase the impact of the first two strategies. As alluded to earlier, there are many research and clinical applications in radiology which cannot progress without the aid of machine learning, particularly those which involve data-mining. This is true of molecular imaging, radiomics, radiogenomics and large population cancer screening.