Artificial intelligence and nuclear medicine

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The industrial revolution divided opinion, but machine manufacturing is now commonplace and has led to an improved standard of living worldwide. Artificial intelligence (AI) has created a similar division that is the cause of much current debate. There are those who say it will be the best thing that ever happened while there are those who predict disaster [1]. The hyperbole should be removed from the debate as AI is developing quickly. It is therefore timely that we consider what is involved and how we should prepare if we are to harness the advantages of nuclear medicine.

AI has many definitions but basically, it is a computer system that shows intelligent behaviour similar to humans – it will understand problems, perform tasks and adapt to create solutions. Scientists have been working on AI theories since Godel in the 1930s and Turing in 1950 who first asked whether machines could think. In 1956, a group of scientists held a 2-month summer project to explore AI and develop some of the theories. The proposal for the project makes interesting reading over 60 years later (<http://www-formal.stanford.edu/jmc/history/dartmouth/dartmouth.html>).

AI can organize and classify data (both verbal and non-verbal) quickly and efficiently including unstructured data such as that found in reports. It can mine data for patterns and anomalies and then use this to make predictions and recommendations. All of these functions can be done at speeds far greater than humanly possible. Machine learning (ML) is a branch of AI and is the ability of a nonhuman to learn from experience and change without requiring explicit programming in an iterative process. It does this in two main ways – by supervised or unsupervised learning. Supervised learning is where training data are given so that the input can be mapped to an output, for example, where numerous images with labels are studied so that it can recognize and classify things. Unsupervised learning is where previously unlabelled data are given and it learns to recognize things for itself. The learning can then be reinforced by feedback so that the machine refines further what it understands to be correct.

The broad term artificial intelligence covers many different methods and requires knowledge of mathematics, algebra, statistics and computing. There is a plethora of

new terminology and subtle differences between the terms. Much of the AI in imaging involves the use of neural networks. This was originally inspired by the nervous system (interconnected neurons) and is a group of processing elements called nodes networked together. Data (e.g. an image) are fed into the network and is mapped to the desired output. Where there are several layers of nodes this is termed deep neural networks or deep learning. Here, the input data are mapped to successive ‘hidden’ layers with a variety of operations/learning at each level and the output will be a more refined prediction or end-point. Neural networks perform better than classical ML methods, coping with large amounts of data without stagnation. For image analysis, a variant called convolutional neural networks is most successful. More meaningful results are generated when imaging, pathology and clinical information from different databases are merged.

Within imaging, there is much potential for ML but at the moment it is not widespread. A review in 2015 looked at the clinical impact of ML in medicine and the conclusion was that while there was much promise, no significant impact on clinical practice had yet been made [2]. However, a note of caution is that the growth rate in this field is much faster than in medicine. One of the biggest differences in AI compared with medicine is the way in which advances are freely published on accessible sites such as arXiv so that all can learn and progress faster. The reasons for this are well covered in the article by Bostrom [3]. In general, medicine would profit hugely from this more transparent approach.

Healthcare is just starting to see the impact of AI yet nuclear medicine has been using intelligent systems for some years – voice recognition which ‘learns’ your voice and improves over time is one obvious example. One word that is increasingly used is Radiomics – this is the conversion of quantitative features from images into data to get diagnostic or predictive information [4]. Machine learning has been attempted in several areas of nuclear medicine including nuclear cardiology, oncology and neurology. There has been a success with automatic edge detection and tumour volume delineation plus automatic detection of anatomy and pulmonary nodules on PET/CT. Improved diagnosis, staging and assessment of

treatment response using PET/CT has had some success and textural analysis has helped differentiate benign from malignant disease. Detection of ischaemia and improved diagnosis of Parkinson's disease are a few of the many possible future clinical uses. Predictive algorithms such as FRAX (Fracture Risk Assessment Tool) are already in clinical use and over the last 2–3 years there have been a growing number of publications covering a variety of clinical AI applications in imaging.

The nonclinical parts of nuclear medicine are also benefitting from AI. Improved methods of monitoring doses, dose limit compliance and algorithms leading to dose reduction have all been enabled. Reduction of waste in the form of improving patient flow and predicting which patients will fail to attend is also possible. A couple of excellent reviews on the use of AI in radiology have been published this year and these give further explanation and examples [5,6].

One of the issues highlighted with AI is the need for accurate data entry and consistency. Unfortunately, the error rate in data entry can be high and similar systems are not always used in the same manner across sites. This would need to be addressed for the most effective AI outcomes. Likewise, if imaging data are to be used then a standard protocol should be followed. As imagers, we are aware that this is reasonably achievable within a centre but almost impossible between centres. Personal experience appears to be more important to some than evidence-based practice. Some centres may not have updated their protocols for many years despite much research and changing evidence. Adoption of guidelines and standardization of practice is poor yet likely to become more important. It would be helpful for our small specialty to have national databases so that larger volumes of clinical data could be mined for more effective teaching and outcome prediction.

Multiple academic institutions and companies both large and small are now engaged with the AI journey, but there are some warnings needed during the implementation of new intelligent systems. Before any new drug is used, it undergoes extensive testing to make sure it is safe for use in humans. AI also requires testing and therefore clinical trials are required to ensure that it does what it intends. As more data are inputted into an AI system, the output will vary over time; it is not fixed therefore future monitoring is needed. When software or AI is used to impact clinical management it requires licensing as a medical device (<https://www.gov.uk/government/publications/medical-devices-software-applications-apps>). Once in use clinically, ongoing review and audit of its impact and efficacy are required. It is essential that nuclear medicine practitioners from all disciplines become involved in the development of AI so that the applications are relevant as well as effective.

One of the concerns expressed by some is that the AI will become more intelligent than humans—a state called ‘superintelligence’. This may lead to accelerated technological advancement surpassing human control with goals that may not fit with current societal norms [1]. Although this is the stuff of Hollywood movies, in reality, this has not happened and there is a growing branch of AI safety that concerns itself with AI containment.

In summary, then, another revolution is upon us with guaranteed disruption, change and opportunity. My knowledge of quality in healthcare has shown me that both machines and humans can make errors so systems need to be in place to prevent, detect and correct these. Now is the time to ensure that our input data (or ground truth) are good. We should ensure high accuracy with routine data entry and cleanse any databases that exist, developing national databases for improved clinical utility. We should all be willing to question and change our own practice, improve standardization and adhere to guidelines where possible. An element of education about ML would benefit nuclear medicine staff along with a willingness to try new things so that we are in a good position to embrace all that AI has to offer.

Within the next 10 years, I hope that AI including ML will bring about a change in our current practice by replacing it with something better. We could have improved attendance rates, better patient flow, fewer delays, waste and errors. The imaging quality could improve along with dose reduction, increased speed and accuracy of reporting with the prediction of outcomes. AI could be deeply embedded in many aspects of our work and we should have the genie under control, working hard to deliver our patients a better future. In the words of Bill Gates, ‘We always overestimate the change that will occur in the next two years and underestimate the change that will occur in the next ten. Don’t let yourself be lulled into inaction’.

Acknowledgements

Conflicts of interest

Dr M. Hall is the medical director of BAC partners – a company harnessing the power of AI in multiple settings including healthcare.

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