Artificial Intelligence in radiography: Where are we now and what does the future hold?

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Introduction

Radiography is a dynamic profession, representing a synergy between technology, patient safety and patient care. Artificial Intelligence (AI) is being increasingly embedded within both diagnostic and therapeutic radiography and is already supporting aspects of radiology workflow management, image acquisition, therapy planning, data reconstruction and post-processing, image quality as well as contributing to improving diagnosis[1,2] and treatment [3,4].

The implementation of AI within medical imaging and radiotherapy is undoubtedly changing the roles of the radiographers now and in the future and it will be important for radiographers to be adaptable to, and welcoming of, new knowledge, new skills and new ways of working. This is vital so that systems and processes can optimise patient experience and outcomes. Understanding, at least at a basic level, of the development and applications of AI provides radiographers with insights into its potential risks and benefits. It is also critical for radiographers to know how to safely monitor AI operation and to be able to communicate to other healthcare professionals and service users its contribution to improving imaging and therapy pathways. Furthermore, it is essential that radiographers can sense check and validate decisions made by AI tools, in order to provide a safety net in cases where AI does not contribute as planned, but also to be in a position to embrace, appreciate and utilise the improvements AI can bring[5].

This paper will outline some basic principles of AI, provide a summary of the current status of AI within Radiography and present some thoughts and suggestions on what the future might hold. It is written by authors who are actively involved and interested in AI research and education. While the authors are not always able to separate the current status from future developments in this field, given the speed of innovation in artificial intelligence, every effort has been made to give a view to the present with projections to the future.

A) AI basic principles

Artificial Intelligence is defined as "the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages[6]. AI has become an umbrella term in recent years to refer to a multitude of technologies that incorporate machine-based decision making at their core. Within medical imaging and therapy, some of the earlier AI supported technologies were referred to using other terminology such as computer aided diagnosis or computer aided detection (CAD)[7]. Today, AI technologies contribute to a range of activities including the triaging of chest radiographs to prioritise reporting of abnormal cases first[8], segmentation of organs on images for further analysis and suggesting diagnoses[9,10].

AI underpinned by complex mathematical models and machine learning algorithms was commonly used until recently, when deep learning was developed and was able to offer improvements on traditional machine learning techniques. Deep learning has revolutionised AI development with more layers within the algorithmic model architecture to refine decisions when compared to traditional machine learning[9].

Artificial intelligence is only as good as the data used to train it, or, as computer scientists like to say, its performance and validity follows the "garbage in, garbage out" principle. There are many different ways of training AI algorithms. Supervised learning in medical imaging frequently uses image segmentation by experts to define anatomy and pathologies, but this technique is not limited to image interpretation or anatomical identification[9,11,12]. AI tools are based on the accuracy of the ground truth training data and using a consensus of segmentations from multiple users has the benefit to increase accuracy, but costs more to develop the tool[13]. However, this means that supervised learning can be very expensive because experts are required to define the ground-truth images.

In contrast to supervised learning, unsupervised learning generally requires a lot more data because the images are fed into the algorithm and the conclusions and trends the algorithm draws from the images are observed. Consequently, this does not rely on the expertise of professionals in data training and validation, but the amount of data needed can be a limiting factor. While these examples are drawn from image-based AI, other areas can benefit from AI such as workflow management and image acquisition. A variation on unsupervised learning is reinforcement learning. This does not define step by step how an algorithm should learn a task but gives feedback after the task is completed. A further concept that is increasingly used is deep learning. This is a form of machine-learning algorithm which uses more layers for decision making than traditional machine learning, providing the potential to work with more complex datasets[11]. To ensure that AI fulfils the purpose for which it was intended, it is imperative that the testing of AI is undertaken on independent datasets and preferably by persons independent to the group developing the AI as part of multi centre, multi-user trials to provide robust evidence for the efficacy of the AI tools along with post-implementation effectiveness assessment.

B) <u>Where are we now?</u>

1.Radiography practice applications

Radiography is one of the most technology enabled disciplines in healthcare, producing a wealth of imaging data annually and one where artificial intelligence is being increasingly implemented to address challenges, including validation and management of workflows, stemming from this abundance of data. AI-enabled automation has affected different aspects of radiography and different modalities in varying degrees, including but not limited to patient positioning, image acquisition, therapy planning, workflows and reconstruction processes across modalities[1],[2].

Taking computed tomography as an example, erroneous patient positioning, which may be associated with inaccurate vertical centring of the patient within the scanner as a consequence of differing patient body morphology, remains one of the biggest causes of poor image quality, increased radiation dose and repeated examinations. Booj et al (2019) explored this possibility of acquiring patient position data using a 3D camera system within the CT room thereby enabling AI to create a 3D patient body mesh from which the iso-centre could be automatically identified and the vertical positioning of the CT couch automated[14]. This automated system performed significantly better, although not technically perfect, than radiographers in accurately positioning the patient, potentially improving image quality and reducing patient dose. with ongoing computational improvements, more accurate and efficient 3D human body representations may be reconstructed from 2D images, which could lead to a wider adoption of this technology in cross-sectional imaging and beyond.

Use of camera-assisted patient positioning/isocentre for CT scanning[15], determining scan range[16], and virtual MRI cockpits could mean that for high volume low-complexity or routine imaging with patients who have previously undergone imaging that the entire episode of care could be delivered remotely/autonomously in the not-too-distant future. Further examples of AI contribution to practice include the automation of image post processing and dose optimisation[17]. Importantly, work continues to explore the potential of AI in dose reduction at CT by inferring high quality output images from low dose, noisy input image data. Similarly in MRI, AI enabled technology is supporting real-time automatic scan reconfiguration resulting in improved image quality, reduction in artefacts and repeat imaging and potentially the acceleration of scan duration and subsequently workflows[18-21]. Similar applications of AI have been presented in Ultrasound, radiotherapy, projectional radiography, mammography, and nuclear medicine. What is common in all these AI applications is that its use in Medical Imaging and Radiotherapy services has promoted the standardisation of practice and enabled processes to be more efficient and streamlined[22-24].

In addition to increasing efficiency, automation may also change the way we care for our patients and shape the expectations of service users of healthcare practitioners and healthcare provision. Enabling healthcare staff the “time to care” could be a significant potential benefit of the clinical adoption of AI. However, this is based on the assumption that all patient communication and interaction require human contribution, and only professional staff can provide this. A recent survey of American emergency care (n=1,154) exploring patient perceptions of remote/robot-enabled communication found that acceptability was generally high, particularly for non-invasive elements of care such as robot facilitated triage/history taking (acceptable 65%) and contactless vital sign assessment (acceptable 76%). Lower acceptability was found for invasive elements of care. The majority of survey participants were degree educated (survey 67%) and white (survey 71%) with a mean age of 48 years. Consequently there is uncertainty if the results are generalisable to the wider population or those referred to imaging and may vary with the nature of the examination, in particular when positioning patients for projectional radiography[25].

While we know that care communication is key to a high-quality care experience[26,27], the interaction may not always be directly with a human and Covid19 has accelerated and facilitated this transition. The need for social distancing and increased use of remote consultations due to Covid19 has already changed how patients and staff interact. With regards to imaging during Covid-19, a Chinese study proposed a complete non-contact, AI-empowered, automated Covid patient CT imaging pathway[28]. Such a pathway could easily be expanded to all radiography examinations, with AI technologies being used to optimise patient volumes and workflow efficiencies, directing and communicating with patients through smart phone apps or similar. In fact, a recently appointed Topol fellow with a therapeutic radiography background is proposing to do exactly this through supporting continuity of care for oncology patients via an online platform, enabling live chat with healthcare professionals to address any concerns during treament[29].

2.Scholarly activity (education, research, standards)

The radiography workforce, both diagnostic and therapeutic, has been perhaps initially reluctant to accept that AI will impact workflows, processes and services in the way that it has indeed done. This was perhaps due to inflexible service designs and the innate resilience the profession has built to constant adaptations to technological innovations such as digital radiography, multi-detector CT scanners, hybrid and high field MR imaging to name just a few. Despite this, AI has established itself as a seismic innovation in healthcare, an innovation that grows with us, for us and from us and we need to engage in a different, more synergistic way.

This initial lack of appreciation of the potential impact of AI led to a lack of visibility of the radiography profession within AI initiatives, including educational provisions, research projects and entrepreneurial opportunities in that field. Consequently, we might acknowledge that we are entering the AI arena later than our professional counterparts in Radiology or Medical Physics. For example, the work examining the use of AI-assisted scan planning and optimisation in CT did not involve a radiographer researcher nor were the readers that assessed planned scanning parameters radiographers[30].

Radiographers are recognising the need to adapt to and adopt AI. The recommendations and priorities for radiographers in the UK have been developed by the SCoR AI working group and are published in their shortened version in this issue of the journal. There are currently radiography-led research studies at different stages (running under the auspices of the ASRT, ISRRT and SCoR) exploring the understanding, perceptions and expectations of radiographers from AI trying to acquire baseline data with the help of which we can build the future, addressing needs, highlighting preferences, using our strengths and tackling challenges. The EFRS is leading a project on AI competences which will be seminal for the understanding and design of future educational provisions on AI. Furthermore, AI radiography led doctoral projects are ongoing in fields like patient acceptability of new technology, decision support, patient safety and implementation strategies and their results are eagerly awaited by the radiographic community. Increasingly more Medical Imaging and Radiotherapy conferences include AI CPD sessions or are directly aimed at AI innovations within these fields of practice. Different higher education institutions have already informally started to teach AI principles in their undergraduate curricula in the form of lectures. New postgraduate modules on AI for radiography have been established[31] and more institutions include data science postgraduate degrees in healthcare. Finally different auditable standards for AI in healthcare are under development from the British Standards Institute, different HEIs and NHS Trust consortia, sometimes with the contribution of radiographers. This is by no means enough in the organic culture of innovation and change surrounding AI but we are starting to set the cornerstones for the future.

C) <u>What does the future hold?</u>

1.Future priorities for radiographers in relation to AI technology

With the current growth rate of AI tools many of these applications in radiography will gradually move from the bench to the bedside subject to validation and regulatory approvals. Alongside efficiency and increased patient throughput, emphasis on patient-centred care and precision medicine will enable AI to not only deliver a faster, seamless, user-friendly clinical service but also one that will have the patients at its heart.

This growth and innovation can and should be driven by increasing the evidence base on key priorities arising in the field, where radiographers may play a huge role given their critical position on the interface between patients and technology. This in an opportunity we cannot allow to be missed.

These priorities include:

i) robust validation of current AI tools in real unseen data,
ii) more prospective interdisciplinary research studies in medical imaging and radiotherapy,
iii) more comprehensive and more widely accepted regulatory approvals of AI products to safeguard their safe and effective use,
iv) more involvement of service users, including practitioners, patients and their carers, in the design and implementation of AI tools,
v) concerted efforts by industry towards explainable AI solutions, to provide better understanding and adoption by healthcare practitioners and service users,
vi) clearer accountability and medicolegal frameworks in case of erroneous results from the use of AI-powered software and hardware,
vii) tailored, evidence-based educational provisions for all healthcare practitioners, including radiographers, using AI technology
viii) increased transparency of processes to gain patient trust and acceptability and finally,
ix) clearer career pathways and role extension provisions for healthcare practitioners, including radiographers, into a future where AI will be central.

Some of these topics are discussed further below but for many only the future can show us how they will organically evolve into an integrated AI ecosystem.

2.Explicability/explainability of AI

AI systems should be designed so that the decision-making process is transparent and explainable. Radiographers should have sufficient understanding of AI techniques and applications but also maintain their knowledge of fundamental imaging principles to be in position to act as validators of AI technology. This knowledge will also enable them to have a role in quality assurance and quality control in AI-powered software or hardware, similar to the work they currently undertake for medical imaging and radiotherapy equipment.

Most AI innovations currently in clinical use (often characterised as Class I/IIa) are decision support tools, to be used by clinicians in patient management. However, the professional/practitioner retains responsibility and is required to be able to effectively communicate “how” and “why” a decision was made, including how an algorithm has arrived at its decision or why it was overruled by a human end-user. This is also knowledge radiographers need to possess to be able to participate, shape and define AI workflows.

Explainability requires knowledge which must be acquired through education and our involvement in AI research and innovation. This means we need to understand AI before we can explain it to others, including our patients. This knowledge can range from how and why we position our patients and how and why an exam might take longer or why it needs to be repeated. This knowledge is power but also comes with accountability and responsibility to deliver care that is safe and effective. The more we know, the more we can explain, the more our patients will be able to trust us in the delivery of their care. Knowledge and explainability are also vital to ensure we create an integrated human-AI loop which magnifies benefits than amplifies limitations[32-35].

3. Better research and education for better practice

Collaborative, interdisciplinary research is vital for the seamless integration of AI technology in healthcare. Radiography-led research is also instrumental for radiographers to discover what AI means for their practice and to explore how to optimise service delivery, patient safety, patient care and workflows in medical imaging and radiotherapy. Furthermore, as translational AI is still in its baby steps, better quality, prospective research projects are needed to involve patients and practitioners early on in the design and co-development of clinically relevant AI solutions, ones that address real practice needs. In addition, strong clinical-academic-industry partnerships will be required to facilitate practice-driven AI research.

Similarly, education needs to be more agile, flexible, and adaptive to cope with increasing demands of the ever-changing evidence base of AI. This could be achieved in different ways: a) with a modular course format, b) with intercalation of degrees, c) different streams of specialisation within radiography, including AI and person-centred care, d) with formalised industrial internships as part of credit bearing modules, e) funded AI apprentices and fellowships, such as the Topol digital fellowships[36]. Furthermore, the knowledge, skills and competences frameworks for radiographers should be revisited and futureproofed.

The Topol Review (2019) provided an overview and future vision for technology enabled healthcare practice including the need for upskilling of the current workforce with regards to computer technologies[37]. As radiography is so dependent on technology from patient referral through image acquisition, reporting and patient onward discharge, it is vital to prioritise learning to support future practice, particularly while imaging demand continues to outstrip capacity across many regions of the world.

4. Careers and role extension

While fully autonomous radiography practice (scanning, reporting, or treatment planning) using AI is not supported by current technology, radiographers will note changes in their role as AI tools are gradually being refined and further developed. AI may take over labour intensive and repetitive activities such as image processing and also provide “a second pair of eyes” in some areas of reporting[19].

The new technologies will inevitably make old roles redundant but equally provide an opportunity for create new or extended roles. Working in the interface between patients and technology means that radiographers are uniquely positioned to become the knowledgeable translators of the requirements and outputs of technology to service users, optimise their safety and personalise their care.

Technology can also be seen as an opportunity to update career structures within radiography. With AI automation and assistance, radiographers might see that the traditional career progression framework will be altered. Current promotion and progression routes are often linked to proficient use of different modalities e.g. higher banding when competent in cross-sectional imaging. As the user-interfaces develop and technology provides greater assistance, there might not be any more a distinction between projectional radiography and CT/MRI but there might be one between those radiographers with knowledge of AI technology and applications and those without.

Conclusion

The AI-enabled future in medical imaging and radiotherapy is already here. Radiographers should not be fearful of AI or approach it as a competitor; it is a powerful tool which, with high quality data input, the right validation processes and regulatory framework can reduce inefficiencies, standardise processes and support growth. It may even help address staffing shortages, given increasing demand for medical imaging and radiotherapy services, and enable more time and space for truly person-centred care.

Radiographers should be proactive and willing to engage with AI and radiography educational provisions should be updated to further the knowledge and understanding of AI functions and applications. Furthermore, radiographers should be involved in every aspect of development, implementation and evaluation of AI tools as central to patient care, patient safety, service user experience and health outcomes, whether diagnosis or treatment.

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