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Why Medical Physicists in Artificial Intelligence?

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Artificial intelligence (AI), the wide spectrum of technologies aiming to give machines or computers the ability to perform human-like cognitive functions, began in the 40s with the first abstract models of intelligent machines. Later it slowly began with being applied to imaging. Machine learning (ML), the branch of AI that involves algorithms capable of recognizing patterns in medical images, can analyze voxel intensity values or quantitative imaging features, also known as "radiomic features," to determine the optimal combination of these features and develop a model for classification or regression.

Deep learning (DL) is a subset of ML that relies on neural networks with numerous deep layers. These networks, often comprising hundreds of layers, progressively learn to identify increasingly complex features from an image. DL can be applied to tasks such as regression, classification, segmentation, and image registration. Various DL architectures offer exceptional flexibility in extracting information form images or other data types, often surpassing human performance.

Due to this flexibility of architecture, artificial intelligence is revolutionizing radiotherapy and radiodiagnostics. AI has achieved physician-level accuracy in a broad variety of diagnostic tasks, including image recognition, segmentation, and generation [1], modelling of response (tumor control, side effects), image guidance, motion tracking, and quality assurance in radiation oncology [2]. Additionally, it can be applied to analyse time series, prioritizing radiation oncology cases by improving workflows, and personalizing care by enhancing treatment decisions.

Currently artificial intelligence is continuously developing also due to the availability of Open Source and Free Libraries like PyTorch (wwwpytorch.org), which can be run on Python distributions (www.python.org), a high-level and easy-to-learn language. At the same time an increasing trend within the research community to make codes and data publicly available, enhanced collaboration and innovation. The advent of graphics processing units (GPUs) and cloud computing has also provided the substantial computational power necessary to train DL models on large datasets. Another critical driver is the availability of public medical databases such as the Cancer Imaging Archive (www.cancerimagingarchive.net) offering data to train and validate new DL models.

In spite of their continuous advance, AI tools are prone to risks as beautifully reviewed by Challen et al [3]. One of the first of these risks is AI can perpetuate or exacerbate existing biases in the data it is trained on, leading to unfair or discriminatory outcomes that it does not "understand" as problematic. Another risk arises from discrepancies between the training data used to develop the algorithm and actual patient data. This issue, known as input data shift, occurs when changes in patient or disease characteristics, or technical parameters (such as treatment management or imaging acquisition protocols) over time or across locations, impact the accuracy of AI. Other known issues involve the insensitivity to impact of AI, meaning that

AI systems may treat all possible errors equally. In breast cancer screening, this can result in an AI classifying a dubious image as lesion-free, where missing a malignant tumor (false negative) has much more severe consequences than incorrectly identifying a benign lesion as malignant (false positive).

Additionally, AI poses data management and cybersecurity challenges. In conclusion, Implementing AI requires effective risk management, as well as a comprehensive quality assurance program and quality management system.

Medical physicists can apply their technical, numerical, and didactic orientation in the safe and effective application of AI in medicine [4]. The technical skills involve knowing the physical processes at the root of contrast in images and dose deposition in radiotherapy as well as understanding the underlying technology. Also, they possess a number of numerical skills, such as mathematical statistical modelling but also quantitative analysis of images, useful in following the complex behaviour of DL an ML models applied to healthcare data. Finally, they are excellent communicators and divulgators of science.

The main tasks of the medical physicists in AI in radiation medicine and diagnosis include supervising the system installation, ensuring acceptance test before clinical use and provide quality checks at every system upgrade [5]. Moreover, medical physicists should also participate in risk management of the AI tools.

Physical and digital phantoms could also be used to periodically verify the performances of image-based ML algorithms. Physical phantoms could be a 3D printed realistic phantoms simulating a patient with a lung lesion, which can also investigate the dependence of AI from the imaging device used, acquisition modality and image reconstruction algorithms[1].

Digital phantoms, however, are usually representative scans of patients with known acquisition parameters. In contexts where it is necessary to simulate patient variability, such as in a computer-aided detection/diagnosis (CAD) system, a small retrospective cohort of patients representative of the clinical tasks may be used for validation. For example, this cohort can be employed to compare the AI system's outcomes—whether they involve segmentation, classification, or prognosis—with the expected results provided by expert clinicians. Therefore, the collaboration with the medical professional is essential, and it is crucial that the medical physicists participate in the multidisciplinary team of professional involved in AI.

Given their didactic capabilities, medical physicists can participate in educating and training other healthcare professionals in the use of AI. This is of utmost importance as AI-based tools are still perceived as a black box, due to their low level of interpretability. Medical physicist can facilitate interpretability by monitoring AI performance, testing the models in well-known situations, as well as getting and explaining the relevant information on the models used, e.g. the models used, their architecture and field of use. Risk management is also an important aspect of medical physicists' duties. An approach to risk management is, for instance, failure modes and effect analysis, which could consist in investigating possible errors in the automated workflow made possible by AI, such as operator errors and automation biases [6]. In AI research, medical physicists play a vital role in collecting and aggregating data for training AI models. Their involvement is essential for ensuring high-quality data, preventing the "garbage in, garbage out" problem where poor data quality leads to poor model performance.

As medical physicists are at the forefront of safely integrating artificial intelligence into healthcare, the curriculum of the medical physicists need to be updated to include the scientific background of AI. Moreover, they need to be familiar with the regulations pertaining to AI, such as though on medical devices and data protection [7]. Within the European Union (EU), the regulatory framework for medical devices in the is defined by European Medical Devices Regulation 2017/745, and the General Data Protection Regulation (EU) 2016/679 (GDPR), but the EU has also proposed "The Artificial Intelligence Act (AI Act)", with the objective of instituting a unified regulatory and legal structure for AI. The International Agency for Atomic Energy (IAEA) released a new guidance document also endorsed by the American Association of Physicists in Medicine (AAPM), It offers detailed guidance on the necessary competencies, outlines an elective module for postgraduate academic programs, and suggests ongoing professional development activities.

Similar efforts have been made by scientific societies such as European Federation of Organizations for Medical Physics (EFOMP), who developed an updated curriculum [8]. The Italian Association of Medical Physics (AIFM) has created the AI for Medical Physics (AI4MP) task group. Both ESTRO and EFOMP have recently established the permanent Special Interest Groups (SIG) on AI.

In conclusion, the involvement of medical physicists ensures the safe and effective use of AI in clinical settings, while also fostering improved communication, collaboration, and knowledge sharing with other healthcare professionals engaged with AI.

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