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EDITORIAL

The first international network symposium on artificial intelligence and informatics in nuclear medicine: "The bright future of nuclear medicine is illuminated by artificial intelligence"

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Introduction

Artificial intelligence (AI) and informatics are rapidly gaining clinical relevance in healthcare and especially in medical imaging, with 76% of the currently FDA approved AI-enabled medical devices operating in the domain of radiology [1]. In radiology, facilitated by larger numbers of examinations and professionals involved, the significance of AI is also reflected by an ever-increasing number of papers in the scientific literature as well as available teaching sessions with related accreditation at conferences and from societies. In nuclear medicine, however, there is still much to be gained in terms of the development, validation and adoption of AI applications. In addition, the role of informatics translating into dedicated software packages (EPD and PACS) warrants further attention regarding challenges and opportunities. Continuous improvement in positron emission tomography (PET), single-photon emission computed tomography (SPECT) and their accompanying computed tomography (CT) or magnetic resonance imaging (MRI) hardware and software has resulted in improved diagnostic performance and wide implementation of these imaging techniques in daily clinical practice. However, the human ability to interpret, quantify and integrate these datasets is rather limited, and there would be much be gained from AI-assisted interpretation workflows. Also, identification of novel imaging biomarkers by application of machine learning (ML) algorithms, including deep learning (DL), has the potential to further improve diagnosis, therapy monitoring and prediction of the trajectory of various diseases. Finally, in addition to the potential impact of artificial intelligence for multidisciplinary patient care in nuclear medicine, also research, teaching and training might benefit from its potential.

Importance of AI with special focus on nuclear medicine

Historically, the field of nuclear medicine has pioneered countless innovations—from the transformative introduction of radionuclides, which reshaped the landscape of diagnostics and radioligand therapy, to contemporary molecular imaging modalities like PET and SPECT and a global breakthrough of theranostics—the nuclear medicine field has always positioned itself at the cutting edge of technological progress. These innovations have not only illuminated new paths to clinical insights and treatment modalities but also resulted in an exponential surge in data.

The ramifications of this data influx are manifold. With the growing volume and complexity of data, the medical community finds itself standing at the crossroads of opportunities and challenges. Consolidating this vast amount of data introduces both technical and ethical challenges. One of the paramount concerns is how to maintain quality, in terms of optimally exploiting all available information, while at the same time extracting meaningful insights

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efficiently. Addressing this concern necessitates the development of new computing technologies.

For multicenter studies, which are essential for developing high-quality, robust, and generalizable AI methods, strategies like federated learning (FL)—a technique where source data can remain in its original location and only resulting AI models and model updates are shared and centralized—have emerged as promising answers alongside other novel privacy-enhancing technologies exploiting concepts such as blockchain and differential privacy. As a whole, these technologies aim to reconcile the drive for innovation with imperatives for patient privacy.

The unique intersection of artificial intelligence and nuclear medicine results in a transformative point in time for healthcare. Their convergence promises advancements not only in diagnostics and therapeutics but may also signal a new dawn for preventive medicine. They promise unprecedented levels of diagnostic precision and therapeutic capabilities. However, the path is not without obstacles. The conservative nature of the healthcare industry, coupled with the societal trust vested in it, means that there is a natural caution when adopting new technologies, especially for dynamic technologies like AI. The robust regulatory frameworks, designed to uphold patient safety and ethical standards, sometimes act as barriers against both technology development and swift technology integration. A major question may be how to harness the full potential of dynamic AI systems within a largely static regulatory framework? The FDA, recognizing these challenges, has provided draft guidance on predetermined change control plans—a strategy that might offer some initial solutions (https://www.fda.gov/regulatory-information/search-fda-guidance-documents/marketing-submission-recommendations-predetermined-change-control-plan-artificial). Still, there remains a pressing need for science-driven evaluations and the establishment of future standardized benchmarks.

Transparency, robustness, accuracy, generalizability and accountability must be the cornerstones of clinical deployment as AI technologies weave their way into nuclear medicine. In such a critical domain, there is no room for opaque, "black box" technologies, and therefore, inspectable and explainable AI results are imperative. The fusion of AI and nuclear medicine is more than just an intersection of two fields: it is a synergy that leads to a future with groundbreaking opportunities. But to truly unlock this potential and transcend current limitations, a twofold approach is imperative: fostering a controlled cultural shift towards innovation and establishing synergistic partnerships to address scientific, technical and regulatory challenges. It is not merely about embracing change; it is about harnessing an alliance that can redefine healthcare for the better.

First conference on AI in nuclear medicine

Because of all the above mentioned challenges, it was inevitable that the nuclear medicine community had to take a step forward and to discuss these issues together. The Artificial Intelligence and Informatics in Nuclear Medicine (AINM) 2023 conference (https://nmmi-groningen.eu/), as it was recently (October 9–11) held at the University Medical Center Groningen, the Netherlands, was the first international networking symposium of its kind that gathered top experts in the field, i.e. clinicians, physicists, researchers and leading industries, to discuss the current advances, challenges and the future of AI and informatics in nuclear medicine.

The symposium intended to be a forum for expertise and knowledge exchange in the AI and nuclear medicine domains. AINM 2023 did showcase presentations of breakthrough discoveries and innovations in AI and nuclear medicine. In addition, it was a networking platform among stakeholders for brainstorming great ideas, collaborating in wider and stronger networks and realizing those new ideas.

In total, around 250 participants from more than 20 countries attended the 3 days of AINM 2023. AINM 2023 consisted of two parallel tracks, one for clinicians and the other for physicists and technical specialists, interchanged by planar sessions and a joint panel discussion at the end. Although AINM 2023 was a local initiative—with upfront the appreciated input from some colleagues as Michel Koole, Stefan Vandenberghe, Dimitris Visvikis and Habib Zaidi—a large representation of EANM-affiliated professionals reflected the attention and interest within this association for the topic. Furthermore, the organizers were happy to see the attendance of NM professionals from far beyond Europe, as for example, from Asia, the Americas and the Middle East.

AINM 2023 proudly presented two special lectures, the Willem Vaalburg and Anne Paans lectures, to honor these two Groningen-based founders of PET in The Netherlands. The visionary Willem Vaalburg lecture by EJNMMI editor-in-chief Arturo Chiti was entitled "The bright future of nuclear medicine is illuminated by artificial intelligence", a quote the authors added to the title of this editorial as they believe it very accurately represents the vision and conclusion of this symposium. The inspiring Anne Paans lecture by Dimitris Visvikis was entitled "AI for data corrections in nuclear medicine imaging". Other plenary lectures included, for example, "The potential applications of ChatGPT in nuclear medicine by Irene Buvat" and "The legal boundaries and complexities of using AI to transform medicine" by Ritumbra Manuvie. All selected abstracts will be published in "Frontiers in

Nuclear Medicine" that opened a special issue on "Nuclear Medicine Advances Through Artificial Intelligence and Intelligent Informatics".

The key messages learned from the AINM conference

Throughout these 3 days, clinicians, physicists, AI experts and industry delegates presented innovative AI, ML and DL tools to be used to advance software, hardware and daily clinical practice. We learned that although nuclear medicine is some steps behind as compared to radiology in terms of commercially available algorithms, there are strong NM teams working on tomorrow's solutions. Moreover, we may learn rapidly from the experience obtained and crystallized in other specialties. We discussed together the tough balance between model complexity, performance and explainability. We learned that PET and SPECT images have fundamental differences with CT and MRI, and as such, transfer of AI developments from radiology to nuclear medicine is not straightforward. On the other hand, we were triggered by the fact that there is already a great range of open source segmentation models available.

With the recent development of large-axial-field-of-view (LAFOV) PET/CT camera systems and the huge amount of data these systems deliver, this is an area where we could rapidly benefit from AI applications. In fact, AI seems to be essential to analyze the huge LAFOV PET datasets in order to extract all the potential clinical and research benefits the data offers.

By combining total body segmentation on CT with quantitative parameters derived from compartmental analysis of LAFOV [^{18}F]FDG-PET, it might be possible to create a quantitative topographical overview of metabolic health. AI is particularly useful for image-related tasks, such as lesion detection, segmentation and attenuation correction. On the other hand, at this stage, it is less suited for deriving quantitative molecular parameters from a (dynamic) scan.

AI models can also be used to enhance comparability and standardization of PET studies acquired in different study settings, where EARL standardization is not able to solve all these differences. However, one should be aware that also AI models need to be trained for each new scanner.

The future of AI in nuclear medicine

The time to implement AI in medicine has come. Nuclear medicine and molecular imaging are no exception to that development. AI is not a hype and is here to stay, and with it, nuclear medicine will likely thrive in the foreseeable future. AI shows great promise to improve image quality, to personalize dosages (both in diagnosis and theranostics) and to help in image interpretation. EANM strongly supports this development, while at the same time safe-guarding that AI is responsibly used for the benefit of the patients. This has been clearly defined in a recent position paper [2] and a future perspective [3] published by the EANM, and by a recent position paper, jointly published by EANM and EACVI, on AI applications in the cardiovascular field [4].

Particularly mentioned in the position paper is the need for training and education. The transmission of knowledge for implementing AI in nuclear medicine and molecular imaging is dearly needed. These educational programs should target both the scientific and clinical aspects. Such educational programs will ensure that current and next-generation scientists and clinicians will become familiar and grow-up with AI and thereby further enhance its potential adoption and development. But there should also be enough understanding to recognize potential flaws and pitfalls. Moreover, the nuclear medicine physician should be able to explain results to the patient and the public. ESMIT, the education branch of EANM, has already started with education initiatives like webinars and advanced courses at the EANM Educational Facility in Vienna, such as "Artificial Intelligence in Imaging: Making the Future" in 2023. Finally, it was decided by the EANM board in the end of 2023 that a project group lead by Margarita Kirienko will advise the board on AI and help coordinate related efforts. Within this setting, much can be gained also from collaboration with others, and depending on the topics at hand, this may be done in collaboration with other societies such as our sister societies in nuclear medicine, partner societies such as EFOMP or industry and many other stakeholders in the setting of, for example, multi-omics approaches.

Next AINM conference?

The AINM 2023 meeting in Groningen was considered both rewarding and successful as shown by both oral feedback and a written evaluation by the participants. Knowledge, connectivity and new ideas on AI in nuclear medicine were central themes, which were embraced by the participants. Due to the speed of developments in the field, there was a wide agreement in aiming for an AINM symposium at least once every 2 years. A next location should shortly be identified, and we encourage everyone who is interested in organizing a next conference on AI in nuclear medicine to move forward and start organizing. The organizing committee of AINM in Groningen is of course willing to give feedback and help with this wherever possible. Let us continue working together on "the illumination by AI of the bright future of nuclear medicine".

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lively interactions making AINM the desired forum for connection and inspiration on AI in nuclear medicine.

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