European Journal of Nuclear Medicine and Molecular Imaging (2019) 46:2627–2629
https://doi.org/10.1007/s00259-019-04395-4

EDITORIAL

EJNMMI supplement: bringing AI and radiomics to nuclear medicine

Patrick Veit-Haibach[1] · Irène Buvat[2] · Ken Herrmann[3]

Published online: 25 June 2019
© Springer-Verlag GmbH Germany, part of Springer Nature 2019

This supplement to the *European Journal Nuclear Medicine and Molecular Imaging* (EJNMMI) is dedicated to two of the recently most "hyped" topics in the modern imaging era: artificial intelligence (AI) and radiomics. There are probably not many examples in the history of modern imaging where congress participants have lined up in long queues for sessions about different aspects of AI in imaging and radiomics. Almost every day, we hear news of discoveries using AI algorithms for different applications, and almost as much news of success stories on how radiomics has improved prognostication in a variety of disease conditions, ranging from oncology to vascular, cardiac and brain imaging. Even Wall Street's attention is drawn to the terms "AI" and "medical imaging" (https://www.wsj.com/pro/artificial-intelligence). At the same time, worries and conjecture about the end of diagnostic imaging professionals have been increasing expressed (https://www.diagnosticimaging.com/blog/end-radiologists, https://www.economist.com/leaders/2018/06/07/ai-radiology-and-the-future-of-work).

Thus, the guest editors and the EJNMMI editorial board are confident that this new supplement focuses on timely topics, both for the hybrid imaging community and for nuclear medicine in general. In fact, in medical imaging, nuclear medicine has the longest history and ongoing efforts towards quantification, standardization and harmonization [1, 2], whereas those topics are often controversial and not well laid out in morphological and functional radiological imaging procedures (except maybe for CT). Therefore, hybrid and nuclear medicine imaging should certainly be in the driver's seat when it comes to experience in quantification and data-mining (and thus radiomics) applications, as radiomics is based precisely on the extraction and analysis of large numbers of quantitative features from medical images. On the other side, AI, although having been around for quite some decades, has only recently gained momentum in imaging sciences in general with the introduction of new/advanced algorithms, creating a big wave of new (and hopefully clinically useful) scientific efforts in imaging. Although AI can be defined as the ability of a machine to correctly interpret data, to learn from those data, and to use that learning to achieve specific tasks through flexible adaptation, sophisticated algorithms for the performance of certain tasks, even if not explicitly based on training from examples, are often presented as AI, making AI omnipresent in current medical imaging research.

In this EJNMMI supplement, we bring together experience and opinions from explorers around the world and across continents. Several different topics concerning the terminology, the physics and instrumentation background, and possible clinical and research applications are discussed from multiple angles, showing the vast potential for AI and radiomics in hybrid imaging and nuclear medicine. All contributors are respected and experienced clinicians and researchers in their field, providing broad expertise on methodological and clinical applicability.

Starting with Visvikis and colleagues, the first article gives an excellent overview of the basic terminology of AI, machine learning and radiomics [3]. Specifically, different techniques and algorithms are described, along with several of their advantages and disadvantages, as well as some of the most significant (technical) applications. The article also highlights the technical challenges which still remain before further, true clinical integration can be achieved.

Zwanenburg et al. discuss the extremely important yet still underestimated topic of feature robustness, reproducibility and standardization/harmonization in radiomics [4]. These are topics which have haunted the medical imaging

This article is part of the Topical Collection on Advanced Image Analyses (Radiomics and Artificial Intelligence)

✉ Patrick Veit-Haibach
Patrick.Veit-Haibach@uhn.ca

[1] Toronto Joint Department Medical Imaging, University Health Network, Women's College Hospital, University of Toronto, Toronto, ON, Canada

[2] Imagerie Moléculaire In Vivo, CEA, Inserm, Univ Paris Sud, CNRS, Université Paris Saclay, Orsay, France

[3] Department of Nuclear Medicine, Universitätsklinikum Essen, Essen, Germany

community for decades, but huge improvements have now been made, especially in PET (e.g. the Evaluation and Report Language [EARL] initiative).

The article by Sollini and co-workers provides a systematic analysis of the AI and radiomics literature [5]. The authors conclude that there are indeed very promising results available but—considering the large amount of partly spectacular news—that the entire topic might be not as ready as one might think for integration in clinical routine and specifically for phase II/III trials. This view is shared by a number of other authors in this supplement. In addition, the review by Castiglioni and her group of researchers details the entire pipeline for radiomics feature extraction, from acquisition optimization, postprocessing and correction methods to radiomics-based multiparametric decision models [6]. This group, too, emphasizes the need for large-scale standardization and harmonization.

Zaharchuk meanwhile focuses strictly on the applications and possibilities arising from deep learning [7]. His article additionally takes a different turn compared to others in this supplement, as he describes how this specific AI technology can improve image quality in almost every imaging modality and how certain imaging modalities can be modulated/synthesized. The latter offers highly original opportunities in research and multimodal imaging in general.

Another interesting take on the topic is provided by Roland Hustinx. In his article, he sheds some light on how the human factor—the physician—is affected by the technologies discussed here [8]. While he describes a number of "threats" to the radiologist/nuclear medicine physician and cites opinions in the literature which see imaging specialists doomed, he also dissects the realistic opportunities arising from AI technologies. Although he is certain that the integration of radiomics, and specifically AI, will change the landscape and workplace for the imaging specialist profoundly (at least in the long run), he also highlights how it can complement the physician's diagnostic and prognostic abilities.

A very special topic is discussed in the article by Goh and Cook [9]. Some of the radiomics parameters are based on very (and maybe even overly) complex equations, which at times makes it difficult to understand how these imaging metrics relate to underlying molecular mechanisms of disease. The article outlines reasons why knowledge of the underlying biological and molecular mechanisms is still important for our overall clinical understanding.

Last but definitely not least is the manuscript from Holzinger, Haibe-Kains and Jurisica [10]. The authors make a compelling case as to why radiomics or imaging-based omics is not enough for a thorough disease characterization. Multiple other omics are being researched and have shown tremendous value in diagnosis, disease characterization and prognostication. It is time that we as imaging specialists are aware of this potential and try to integrate it, together with the radiomic features, into our clinical and diagnostic pathways.

It certainly remains to be seen how fast AI and radiomics in medical imaging will continue to grow and enter clinical practice. Because of the sheer dominance of these topics in recent years, AI and radiomics will make their way into routine applications at multiple levels of our clinical lives, including acquisition protocol and image quality optimization, workflow improvement, disease detection and classification, and probably reporting. Actually, AI is already operating in current scanners during the process of image acquisition, for instance to optimize patient position or make the most of the detected signal. By virtue of combining radiomics and AI/machine learning in medical imaging, these techniques will undoubtedly improve patient management and foster academic and clinical research interest in the years to come. We as the guest editors believe that AI and radiomics provide more opportunities than threats, and it is our joint responsibility to shape the future and translation of AI and radiomics in nuclear medicine. This requires the sharing of knowledge not only through publications, but also through contribution to databases, enabling collective learning from the large variety of images we work with. Maybe even more importantly, this will require passing around well-documented radiomic and AI models so that they can be tested independently by different groups to gain the level of evidence needed for clinical acceptance.

Acknowledgements We would like to thank all authors and contributors and additionally would like to extend our gratitude to the reviewers for their help with this EJNMMI supplement.

Compliance with ethical standards

This article does not contain any studies with human participants or animals performed by any of the authors.

Conflict of interest Ken Herrmann: personal fees from Bayer, other from Sofie Biosciences, personal fees from SIRTEX, other from ABX, personal fees from Adacap, personal fees from Curium, personal fees from Endocyte, grants and personal fees from BTG, personal fees from IPSEN, personal fees and nonfinancial support from Siemens Healthineers, and nonfinancial support from GE Healthcare, all outside the submitted work.

Patrick Veit-Haibach: personal fees, travel support and IIS grants from GE Healthcare, IIS grants and non-financial support from Siemens Healthineers, IIS grants and non-financial support from Bayer, ISS grants from Roche Pharmaceuticals. All support outside the submitted work.

Irène Buvat: none.

References

1. Aide N, Lasnon C, Veit-Haibach P, Sera T, Sattler B, Boellaard R. EANM/EARL harmonization strategies in PET quantification: from daily practice to multicentre oncological studies. Eur J Nucl Med Mol Imaging. 2017;44(Suppl 1):17–31. https://doi.org/10.1007/s00259-017-3740-2.

2. Kaalep A, Sera T, Oyen W, Krause BJ, Chiti A, Liu Y, et al. EANM/EARL FDG-PET/CT accreditation—summary results from the first 200 accredited imaging systems. Eur J Nucl Med Mol Imaging. 2018;45(3):412–22. https://doi.org/10.1007/s00259-017-3853-7.
3. Visvikis D, Cheze Le Rest C, Hatt M. Artificial intelligence, machine (deep) learning and radio(geno)mics—definitions and imaging applications. Eur J Nucl Med Mol Imaging. 2018 (Suppl). https://doi.org/10.1007/s00259-019-04395-4
4. Zwanenburg A. Radiomics in nuclear medicine—robustness, reproducibility, standardisation and how to avoid data analysis traps and replication crisis. Eur J Nucl Med Mol Imaging. 2018 (Suppl). https://doi.org/10.1007/s00259-019-04395-4
5. Sollini M, Antunovic L, Chiti A, Kirienko M. Towards clinical application of image mining: a systematic review on artificial intelligence and radiomics. Eur J Nucl Med Mol Imaging. 2018 (Suppl). https://doi.org/10.1007/s00259-019-04395-4
6. Castiglioni I, Gallivanone F, Soda P, Avanzo M, Stancanello J, Aiello M, Interlenghi M, Salvatore M. AI based applications in hybrid imaging: how to build small and truly multi-parametric decision models for radiomics. Eur J Nucl Med Mol Imaging. 2018 (Suppl). https://doi.org/10.1007/s00259-019-04395-4
7. Zaharchuk G. Next generation research applications for hybrid PET/MR and PET/CT imaging using deep learning. Eur J Nucl Med Mol Imaging. 2018 (Suppl). https://doi.org/10.1007/s00259-019-04395-4
8. Hustinx R. Physician centred imaging interpretation is dying out—why should I be a radiologist/nuclear medicine physician? Eur J Nucl Med Mol Imaging. 2018 (Suppl). https://doi.org/10.1007/s00259-019-04395-4
9. Cook GJR, Goh V. What can artificial intelligence teach us about the molecular mechanisms underlying disease? Eur J Nucl Med Mol Imaging. 2018 (Suppl). https://doi.org/10.1007/s00259-019-04395-4
10. Holzinger A, Haibe-Kains B, Jurisica I. Why imaging data alone is not enough—AI-based integration of imaging, omics and clinical data. Eur J Nucl Med Mol Imaging. 2018 (Suppl). https://doi.org/10.1007/s00259-019-04395-4

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.