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EDITORIAL

# Current status and future perspectives of PET/MRI hybrid imaging

Maria Picchio[1] · Miguel Hernandez Pampaloni[2]

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The success of hybrid PET/CT imaging over the last decade was mainly based on the complementary information it provided. The integration of a primarily morphologic technique such as CT with a functional modality like PET enabled the better and more accurate characterization and localization of in vivo processes. It appears therefore natural to believe that the recent development of combined PET/MRI devices would represent the next step in hybrid imaging by capturing the unique characteristics offered by MRI. By combining the exquisite anatomical and functional information offered by MRI with metabolic data from PET imaging, a new era of exciting new research and clinical possibilities seems to be unfolding.

While the full scope of PET/MRI applications remains to be defined, the recent initial experience has shown advances in protocol design, image reconstruction, data processing, and image interpretation. Despite these promising results suggest that the medical community could now focus in an optimization and standardization of the patient workflow for developing new clinical indications, incomplete resolution of attenuation correction protocols and the search for the incremental value of PET/MRI when compared to the current standard of care PET/CT still need to be entirely sort out.

This concurrent imaging protocol facilitates the MR acquisition of not only morphological information but also pathophysiological data. When combined with the biochemical, metabolic, and kinetic biodistribution changes provided by PET, this synergy of added functional information could surpass what PET/CT has currently to offer. Multiple efforts are underway to gather the required prospective instrumentation and clinical data to delineate the most cost-effective applications of this new technology. The available data show that PET/MRI is clinically feasible and performs as well as PET/CT in most types of cancer. However, in the majority of PET/MRI clinical researches, MRI images were used to provide anatomic details for PET signal, rather than focusing on the potential synergy between the capabilities of functional MRI and molecular PET [1].

In addition, given the potential for technological development, efforts should also be made by researchers to compare the diagnostic performance of the two hybrid imaging technologies and their influence on further clinical management, in particular by fully exploring the potential of PET/MRI.

Although there is still a lack of clearly defined PET/MRI key applications, there are some obvious advantages on using PET/MRI over PET/CT that cannot be unnoticed: there are all the clinical cases where patients need to perform both PET and MRI studies for the evaluation of their disease. The opportunity of performing both examinations in the same study session is a clear benefit in term of patient convenience, being easier than having to go for a PET and MR separately, and much less time-consuming. Another great advantage of PET/MR with respect to PET/CT is that patients have much less radiation exposure: MR involves no high energy radiation and the tracer dose with PET/MR is generally lower than what is used with PET/CT. Taking this advantage of reducing radiation exposure, pediatric oncology is an expanding application of PET/

✉ Maria Picchio
picchio.maria@hsr.it

1 Department of Nuclear Medicine, IRCCS San Raffaele Scientific Institute, Milan, Italy

2 Department of Radiology and Biomedical Imaging, University of California San Francisco, San Francisco, CA, USA

MRI. In addition, for patients who need to repeat PET studies for their clinical management, the opportunity to do so with less radiation could be a key to the long-term survival. But perhaps the most important advantage is the superior information that can be acquired during a PET/MR study where the unique features of MR imaging provide a powerful imaging evaluation in specific clinical settings [2].

Several clinical indications have been proposed, particularly in the field of oncology, cardiology, and neurology. In oncology, PET/MRI might show improvements in regions and tumors where MR is known to be superior to CT (i.e., soft tissue sarcomas, head and neck cancer, and pelvic tumors), while maintaining the degree of functional information provided by PET. Prostate cancer patients will particularly benefit from PET/MRI thanks to the combined simultaneous acquisition of multiparametric MR and PET-targeted radiopharmaceuticals such as choline-labeled ligands and those that target specific tumor molecules, such as the prostate-specific membrane antigen [3].

Further, expanded availability of somatostatin receptor radiopharmaceuticals such as 68Ga-DOTA-TOC and 68Ga-DOTA-TATE for neuroendocrine tumors has invigorated targeted imaging, particularly with the development of peptide receptor radiotherapy. In these patients, PET/MRI is an important option for optimal imaging. Both diffusion-weighted imaging and hepatobiliary phase imaging provide improved lesion detection compared to conventional MRI and CT, and the results can alter therapeutic decisions [4].

MRI is the modality of choice for the evaluation of brain tumors. The inclusion of diagnostic MR sequences of the brain with PET protocols focused to evaluate the content of hypoxic tissue or amino acid synthesis would enable the phenotypic characterization of the treatment response of cerebral metastases in a one-stop-shop examination. Simultaneous PET/MR brain scans are an exciting possibility for research applications, by combining metabolic markers with receptor binding, perfusion, and neurotransmitter release.

In cardiology, the simultaneous acquisition of PET and MR could significantly reduce the misalignment between the two modalities, resulting in more accurate data interpretation. Multiple MR-based attenuation maps and respiratory gating could be generated during the PET emission, helping to mitigate motion correction artifacts. In addition, with cardiac PET/MRI, the patients could benefit from the complementary information provided by MR on the assessment of the left ventricular function and tissue characterization, with the perfusion and metabolic evaluation of PET component for the assessment of ischemic heart disease, ischemic burden, infarct size measurement, and other chronic heart processes.

In addition to the development of new radiopharmaceuticals, multiparametric imaging could have implications for PET/MRI imaging in oncology, for instance by comparing abnormalities in MRI diffusion imaging to the magnitude of FDG uptake in neoplastic lesions, as well as in other fields such as cardiology and neurology.

An interesting point is that the final potential utility in specific research and clinical settings of PET and MR data simultaneously acquired rather than with a minimal offset in time is still to be defined. The neurology applications are probably those where the simultaneity of data acquisition, allowing both temporal and spatial correlation of PET and MR measurements, may be of particular interest, by offering a better understanding of functional and metabolic interaction in different neurological conditions.

Like any new technology, there are still challenges to be resolved. Elevated costs, uncertain reimbursement, patient throughput, standardization of imaging protocols, and reconstruction processes will have to be considered in detail to ensure that the full capability of this emerging imaging modality translates in the best possible patient care. Data acquisition is actually prolonged relative to the current standard when using PET/MRI, thus impacting patient throughput.

However, general expectations for this technology remain high, considering its high potentiality in impacting medical research and patient management. Recent initial reports on new areas of potential clinical application, including infection and inflammation and the emerging science of radiomics highlight the need of a comprehensive approach between the clinical expertise provided by nuclear medicine physicians, and diagnostic radiologists with the industry and clinical researchers to provide the much needed data analysis to assess for potential and sustainable areas of growth within the current healthcare framework.

**Compliance with ethical standards**

**Conflict of interest** Maria Picchio declares that she has no conflict of interest.
Miguel Hernandez Pampaloni declares that he has no conflict of interest.

**Ethical approval** This article does not contain any studies with human participants performed by any of the authors.

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