

Pro MR-PET

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Highlights

- Hybrid MR-PET in patients and volunteers
- 3T and 9.4T MRI combined with high resolution BrainPET
- Simultaneous anatomical, functional and metabolic imaging
- Meaningful acquisition protocol design for MR-PET in brain tumours

The new and upcoming imaging modality combining MRI (magnetic resonance imaging) and PET (positron emission tomography) to a hybrid MR-PET offers new perspectives in research and diagnosis in diseases such as cancer for example. Compared to the current reference modality PET/CT, MR-PET comes with the advantages of reduced radiation dose and a much better soft tissue contrast. In addition to anatomical imaging, MRI offers versatile functional information. The combination of MRI with the metabolic PET and its interpretation is an ongoing topic of pre-clinical and clinical research.

The debate here centres around whether (a) one needs MR-PET, and (b) whether it needs to be performed simultaneously.

Considering the need for MR-PET – as opposed to PET/CT can be answered unequivocally with a “yes”! The reduced radiation dose opens up new applications possibilities such as in paediatrics where exposure to additional radiation is a very serious concern.

Whether true hybrid capability – as opposed to two separate machines – is required is a somewhat more complex issue and requires more discussion. There are a number of considerations that point way towards true hybrid capability. These include the following:

- Only one scanner and therefore fewer siting problems and less space needed
- Very sick patients need only undergo one examination yielding two datasets leading to much lower dropout rates
- Much less radiation exposure compared to diagnostic PET/CT
- Less radiation exposure compared to separate MRI and PET measurements because of the absence of a “transmission scan”
- Elimination of physiological variability between two separate scans
- Enabling accurate receptor density mapping (CBF is an important parameter for quantification)
- Huge advantages for pharmacological MRI combined with PET
- Motion correction of PET data from MRI (e.g. navigator echoes)
- Cost savings in terms of reduced staffing levels

Different technical problems have to be overcome prior to the realisation of hybrid MR-PET. Besides the provision of an efficient environment, including the scanner room, radiochemistry and patient comfort, the main issues are the mutual interference of the highly sensitive devices MRI and PET. Furthermore, a robust MR based attenuation correction (MR-AC) has to be implemented, this being a major requirement for quantitative PET imaging. The RF coil design has to be optimized regarding geometry, frequency shifts and photon attenuation properties. Besides the hardware aspects, MR sequences as well as methods for quantitative and artefact-free PET imaging have to be developed. In particular for ultra high field (UHF) applications, such as 9.4T MRI, the requirements and constraints on RF-technology, but also on sequence development, are higher compared to a 3T MR-PET system. The advantages at UHF are an increased signal-to-noise ratio (SNR) allowing for a higher spatial resolution and a better separation of peaks when performing MR-spectroscopy.

All the above requirements for MR-PET of the brain have already been met; for body applications many are in place and the rest is well on its way to being solved.

With these more powerful instruments, it is an active field of activity in pre-clinical and clinical research to develop meaningful protocols for research and diagnosis. Here, the selection, combination and interpretation of information, such as fMRI, perfusion weighted imaging (PWI) or ASL has been verified with PET and can also be included in the set of parameters of tumour imaging. Results will be presented to underscore these aspects.

Besides anatomical imaging and quantitative perfusion measurements with MRI, it is also possible to perform quantitative water content mapping in tumours, for example. Furthermore, imaging of X-nuclei at UHF can also provide information on metabolism. In such instances, simultaneous measurement of FDG-PET and ^{31}P spectroscopy to investigate energetics, for example, is simply invaluable and cannot be replaced by sequential measurements where little is known about the underlying physiological parameters. Furthermore, cross-validation of PET methods with MRI methods will allow one to shift tasks from PET to MRI in order to allow for more sophisticated metabolic imaging with PET. Here, a variety of radiotracers allow for imaging of energy consumption applying a glucose analogue FDG (flour-desoxy-glucose) or the uptake of the amino-acid tracer FET (flour-ethyl-thyrosine). All these signals have to be evaluated carefully and may contribute to meaningful acquisition protocols.

Summary

Hybrid, simultaneous MR-PET with the 3T is a reality and is here to stay. Advances in hybrid MR-PET at UHF – such as 7T and 9.4T – are to be expected (an MR-BrainPET scanner operating at 9.4T already exists in Jülich, the home institution of the author. The technical challenges have been overcome and versatile MRI together with quantitative PET is technically possible. Results from several applications will be presented.

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