Simultaneous Whole-Body PET/MR: Challenges and Opportunities

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Purpose:

1) To review the challenges associated with integrating positron emission tomography (PET) and magnetic resonance imaging (MRI) hardware and acquisition workflow
2) To discuss the opportunities enabled by simultaneous PET/MR for scientific studies and clinical routine

Outline of Content:

Motivation: The integration of PET and MRI links complementary aspects of image information [1,2]. Strengths and weaknesses of either modality will be discussed with a focus on resolution, sensitivity and specificity, quantitative and functional image information content.

Technical challenges: The principles of key advances for integrated PET/MR hardware, such as magnetic field insensitive PET detectors will be explained [2]. Further, results from performance tests comparing integrated PET/MR to stand-alone systems, will be presented [3]. PET emission data must be attenuation corrected (AC). Segmentation algorithms for AC based on MR images will be reviewed [4,5].

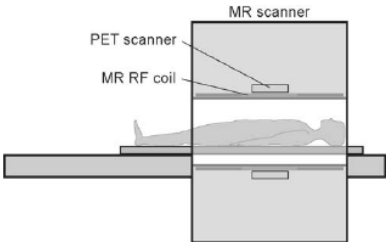

Figure 1. Recent hardware developments enable integrated PET/MR systems. The PET detector ring is incorporated within the MR scanner magnet.

Opportunities in clinical routine: The potential added value of PET/MR will be discussed. The superior soft-tissue contrast of MR as compared to CT bears potential for a higher clinical value of PET/MR as compared to PET/CT for many clinical indications. The replacement of diagnostic CT-sequences by MR-sequences can reduce the radiation dose, which is especially important in pediatric imaging. There is potential of improving response assessment to therapy in oncology by replacing anatomical biomarkers such as measurements of tumor size (RECIST criteria) by multi-parametric functional biomarkers combining diffusion (MRI), perfusion (MRI and PET) and metabolic (MRS and PET) information [1,6]. Limitations of PET/MR are, for example, in the detection of small lung lesions or the complexity of MR protocols and the long scan times.

Opportunities in scientific research: Especially in research studies, simultaneous PET/MR opens exciting new opportunities. These include methodological topics such as real time motion correction of PET data using fast MR volume acquisitions [7]. Moreover, simultaneous, dynamic data acquisition gives opportunity to validate biological modeling or to characterize tissue microenvironment utilizing complementary functional information. Examples include simultaneous PET receptor imaging and fMRI during an identical paradigm in neurology [8], plaque imaging and assessment of remodeling and perfusion measurements in cardiovascular applications [9] or multi-parametric imaging of tumor microenvironment in oncology utilizing DCE-MRI, DWI and MRS in combination with PET using targeted tracers [6]. Potential applications include early response assessment in drug development or therapy planning.

Summary:

Simultaneous PET/MR is a technical revolution. However, the scientific and clinical added value by simultaneous imaging has yet to be proven. The goal of this presentation is to give the reader the necessary background to understand, critically evaluate and participate in this exciting development in multi-modality imaging.

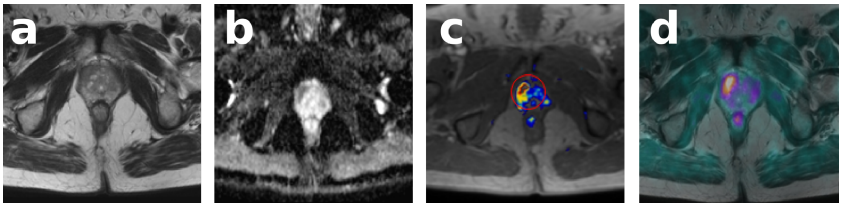

Figure 2. Rising PSA and negative prior sextant biopsy of the prostate. Multi-parametric data support clinical decision making by combining anatomical information from T2w MRI (a) with functional information from diffusion weighted MRI (b), dynamic contrast enhanced (DCE) MRI (c) and C11-Choline-PET (fused with a) (d).

References: [1] Judenhofer MS, et al. Nat Med 14, 459-65 (2008). [2] Drzezga A, et.al. SNM Meeting Abstracts 52:262 (2011). [3] Delso G, et. al. SNM Meeting Abstracts 52:320 (2011). [4] Martinez-Möller A, et al. JNM 50, 520-6 (2009). [5] Delso G, et al. Phys Med Biol 55, 4361-74 (2010). [6] Antoch G, et.al EJNMMI 36, 113-120 (2009). [7] Tsoumpas C, et al. Phys Med Biol 56, 6597 (2011). [8] Heiss WD. EJNMMI 36, 105-112 (2009). [9] Nekolla SG, et.al. EJNMMI 36, 121-130 (2009).

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