Comparison of the accuracy of PET/CT and PET/MR spatial registration in multiple metastatic lesions

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Target Audience: Nuclear Medicine physicians and body MR Radiologists.

Introduction: Precise spatial registration is imperative for diagnosing pathology and to avoid errors of interpretation. Exact registration is also important for quantification of metabolic activity, which has prognostic significance and is paramount for assessment of treatment response comparison. Moreover, correct spatial registration is helpful for surgical planning, delineating radiation therapy margins¹, and also has implications for multi-parametric quantitative analysis. While PET/CT registration has been shown to be adequate^{2.3}, to our knowledge, this is the first study to quantify PET/MR spatial registration. The purpose of this study is to compare the accuracy of spatial registration of PET/CT and PET/MR in patients with FDG-avid metastatic lesions.

Methods: Thirteen patients with known metastases underwent 18F-FDG-PET/CT (Siemens mCT 40) followed by a PET/MR scan with a hybrid whole-body system (MR with integrated PET system, Siemens Biograph mMR) using the remaining tracer activity. Inclusion criteria for tumor analysis were as follows: FDG-avid tumors were clearly defined on both CT and MR, tumors were anatomically spherical or oval, and tumors demonstrated spherical or ovoid homogeneous tracer uptake. The spatial coordinates (x,y,z) of the visually estimated centers of the lesions were determined for PET/CT (PET and CT independently) and PET/MR (PET, T1-weighted, T2-weighted, and diffusion weighted images independently). T1-weighted gradient echo images were acquired using a prototype radial 3D gradient echo sequence⁴ (stack-of-stars trajectory, slice thickness 2.5 mm, TR/TE 4.5/2 ms, 80 axial slices, voxel size 1.4 x 1.4 x 2.5 mm, quick fat-saturation mode). T2-weighted TSE images were acquired with STIR fat suppression (TI=220 ms, 36 coronal slices, thickness 2.5 mm, TR/TE 6250/56 ms, voxel size 2.9 x 1.8 x 5 mm, GRAPPA factor of 2), and DWI was acquired using a single shot spin echo EPI sequence (slice thickness 6 mm, TR/TE 5900/54 ms, 30 axial slices, voxel size 2.6 x 2.1 x 6 mm, GRAPPA factor of 2, fat-saturation mode, b-values of 0, 350 and 750 s/mm², lesion detection based on b0 images). All MR sequences were obtained during free breathing. Total distance between the isocenters of the lesions were calculated between PET and each specific anatomical modality. Differences in PET/CT and PET/MR registration were assessed with a paired t-test.

Results: Nineteen lesions were evaluated. On PET/CT, the average of the total shift in all planes of CT compared to PET was 4.13 ± 4.24 mm, while for PET/MR and T1-weighted radial VIBE it was 2.41 ± 1.38 mm; for PET/MR with DWI b0 it was 5.97 ± 2.83 mm compared to PET. Similar results were calculated using eleven lesions with T2-STIR; shift in T2-STIR as compared to PET was 2.24 ± 1.12 mm. Paired t-test calculations of PET/CT compared to PET/MR T1-weighted radial VIBE, DWI b0, and T2-STIR sequences were significant (p<0.05 respectively).

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Table 1	DET/CT	PET/MR		
	FEI/CI	T1 Rad Vibe	T2-STIR	DWI b0
			-	-
X-axis	0.74 ± 1.88	-0.44±2.09	0.13±1.15	0.44 ± 1.87
			-	
Y-axis	1.43 ± 2.51	0.22±1.84	0.08 ± 1.56	1.28 ± 5.90
Z-axis	1.63 ± 4.54	0	0.95 ± 1.42	1.25 ± 1.96
TOTAL	4.13±4.24	2.41±1.38	2.24±1.12	5.97±2.83

Table 1. Difference in millimeters between the registrations of lesion isocenters measured in three axes with PET/CT and PET/MR. Figure 1. Fused PET/CT (1a), fused PET/MR T1-weighted gradient echo with radial stack-of-stars trajectory (1b), and fused PET/MR DWI b0 (1c) showing more accurate registration of a left lower lung lesion on PET/MR T1-weighted radial VIBE (1b) as compared to PET/CT (1a) and PET/MR DWI b0 (1c) sequences.

Discussion: We demonstrated that PET/MR with morphologic sequences—T1-weighted radial VIBE and T2-STIR—showed more accurate spatial coregistration than PET/CT. This is most likely related to the simultaneous acquisition of PET/MR, while PET/CT has sequential acquisition. However, the EPI-based DWI b0 images demonstrated significant misregistration as compared to PET/CT, especially in the thorax. PET/MR readers who may be less familiar with typical MR artifact appearance should be aware of the potential for misregistration with EPI-based sequences due to respiratory motion and the inherent spatial distortion associated with this type of MR acquisition⁵, which is even increased for higher b-values.

Conclusion: Accurate PET/MR spatial registration as described by our study is important for future research and clinical use of PET/MR. The authors hypothesize that the simultaneous acquisition of PET and MR data is the principal contributing factor for an improved spatial registration as compared to PET and CT sequential acquisition.

References:

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