Sequential integrated PET/CT-MR system: Comparison of image registration accuracy of PET/CT versus PET/MR

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Fig. 1: Patient transfer shuttle with special transfer-board on top in front of the PET/CT-system (GE Discovery 690) in the room on the left and the 3T-MR (GE Discovery 750) in the adjacent room to the right. The special transfer board allows for surface coil placement/removal between the exams even underneath the patient without patient repositioning.

Fig. 2: Patient on the transfer-board with dedicated RF coils for head, neck and torso imaging installed.

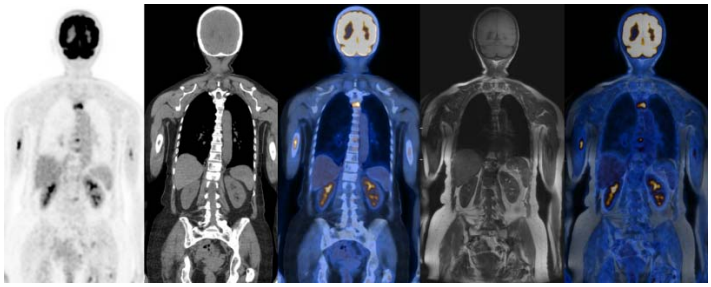

Fig. 3: Example of PET/CT and PET/MR image registration. From left to right: Coronal FDG-PET, unenhanced CT, PET/CT fusion image, Dixon-based T1w MR, and PET/MR fusion image of a 70-year-old female patient referred for staging of breast-cancer.

Purpose: Multi-modality imaging combines morphological and functional information originating from different imaging platforms and is based on the critical assumption of accurate registration. In the presented work a tri-modality PET/CT+MR system is used to investigate the hardware registration performance between sequential PET and MR versus gold standard PET/CT. In particular, the impact of the longer timespan between sequential PET/MR versus PET/CT in terms of motion-induced misalignment is investigated in both phantoms and patients.

Materials and Methods: The evaluated tri-modality PET/CT+MR setup (time-of-flight Disocovery PET/CT 690, 3T Discovery MR 750, both GE Healthcare, Waukesha, MI) uses a front-loading shuttle system with flexible placement and removal of dedicated RF coils. This allows for fast and high SNR MR coverage of head, neck and torso and enables PET/CT scanning free of RF coil induced artefacts. Ten patients underwent a CT-scan (80mA/120keV) followed by a PET (total scan time 16 minutes), a shuttle-transfer to the MR-system in the adjacent room, and a MR-scan (Dixon based T1w gradient echo sequence). The accuracy of the PET/CT and PET/MR registration was assessed separately for head/neck and torso by using a commercial software-based registration tool (Integrated Registration, Advantage Workstation, GE Healthcare). To assess the intrinsic registration accuracy phantom measurements were performed using a multi-modality phantom (CIRS, Norfolk, VA).

Results: The time delay between the start of the CT and the start of the PET was 2 minutes, whereas the MR started 2 minutes after completion of the PET. The mean lateral registration inaccuracy for the phantom was 1.2 mm ± 1.2 mm. The mean lateral registration inaccuracy between PET and CT images was 1.8 mm ± 1.1 mm for the torso and 0.3 mm ± 2.2 mm for head/neck in the lateral direction. Two patients rotated their head (< 20°). Between PET and MR images registration inaccuracy was 0.7 mm ± 3.4 mm for the torso and 1.4 mm ± 4.3 mm for head/neck, with three patients who had rotated their head (< 20°). No significant differences were found for the misalignment of PET with CT compared to PET with MR in the head/neck ($p = 0.833$; Wilcoxon Signed Ranks Test) and in the abdomen ($p = 0.917$). Due to a fixed table height and consistent laser light landmarking on the top of the transfer-table there were no offsets in the longitudinal or the anterior-posterior direction.

Conclusion:
Despite the relatively long duration of a sequential PET/CT+MR exam (approx. 30 minutes) the image registration accuracy was excellent with less than 4 mm lateral misalignment between CT, PET and MR data sets and similar to the intrinsic error assessed with phantom measurements. In a clinical setting such values can be considered not relevant for appropriate image interpretation in most situations. Therefore comparison of PET/CT and PET/MR data using this tri-modality system is feasible even without using a dedicated software-based registration tool.