Uncertainty analysis of MR-PET image registration for precision neuro-PET imaging

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Abstract: Accurate regional brain quantitative PET measurements, particularly when using partial volume correction, rely on robust image registration between PET and MR images. We argue here that the precision, and hence the uncertainty, of MR-PET image registration is mainly driven by the registration implementation and the quality of PET images due to their lower resolution and higher noise compared to the structural MR images. We propose a dedicated uncertainty analysis for quantifying the precision of MR-PET registration, centred around the bootstrap resampling of PET list-mode events to generate multiple PET image realisations with different noise (count) levels. The effects of PET image reconstruction parameters, such as the use of attenuation and scatter corrections and different number of iterations, on the precision and accuracy of MR-PET registration were investigated. In addition, the performance of four software packages with their default settings for rigid inter-modality image registration were considered: NiftyReg, Vinci, FSL and SPM. Four distinct PET image distributions made of two early time frames (similar to cortical FDG) and two late frames using two amyloid PET dynamic acquisitions of one amyloid positive and one amyloid negative participants were investigated.

For the investigated four PET frames, the biggest impact on the uncertainty was observed between registration software packages (up to 10-fold difference in precision) followed by the reconstruction parameters. On average, the lowest uncertainty for different PET frames and brain regions was observed with SPM and two iterations of fully quantitative image reconstruction. The observed uncertainty for the varying PET count-level (from 5% to 60%) was slightly lower than for the reconstruction parameters. We also observed that the registration uncertainty in quantitative PET analysis depends on amyloid status of the considered PET frames, with increased uncertainty (up to three times) when using post-reconstruction partial volume correction. This analysis is applicable for PET data obtained from either PET/MR or PET/CT scanners.

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