Simultaneous PET/MR imaging: Automatic attenuation correction of flexible RF coils

René Kartmann[1], Daniel H. Paulus[1], Bassim Aklan[1], Susanne Ziegler[1], Harald Braun[1], Bharath Navalpakkam[1], and Harald H. Quick[1]

[1]*Institute of Medical Phyics, Erlangen, Bavaria, Germany*

Target audience: Researchers and physicians working in the new field of PET/MR hybrid imaging.

Purpose: Due to their unknown position and individual geometry, flexible radiofrequency (RF) surface coils used in simultaneous PET/MR imaging are currently omitted concerning PET attenuation correction (AC) although they attenuate the PET signal. We present an algorithm which automatically integrates CT-based attenuation maps (μ-maps) of up to three overlapping RF surface coils into PET AC. Phantom scans quantify the influence of the RF coils on PET emission data and volunteer scans are used to verify the accuracy and robustness of the algorithm in a clinical setting.

Methods: Cod liver oil capsules are used as MR visible markers by the presented algorithm to detect the individual shape and the position of flexible RF surface coils in MR images as proposed by Paulus et al.[1] (*Fig. 1*). The use of two differing marker patterns each using 23 markers per RF coil enables the registration algorithm (*Fig. 2*) to distinguish between up to three overlapping RF surface coils. To evaluate the AC of the RF surface coils, two different PET emission scans of 1) a NEMA standard body phantom with six active lesions and 2) a large rectangular body phantom first used by Braun et al.[2] were performed on a whole body PET/MRI scanner (Biograph mMR, Siemens Healthcare Sector, Erlangen). At first, the two phantoms were scanned using the MR body coil. For the second set of scans, one (NEMA phantom) or three (large body phantom) flexible 6-channel body matrix RF coils, which are optimized toward reduced photon attenuation, were fixed on top of the phantom. The RF coils and the phantoms were attenuation corrected by the combined CT-based μ-maps generated by the algorithm. In addition, four volunteers were scanned with three overlapping RF surface coils placed on top of the body to simulate typical clinical scanning conditions (*Fig. 1C*). Pre-acquired CT-based hardware template μ-maps of the RF coils were registered and added to the existing MR-based four-segment μ-maps of the volunteers by the registration algorithm. The accuracy of the algorithm was evaluated by calculating the difference between the coordinates of nine additional capsules, which are not used for position registration of the RF coils, in the registered CT images and the MR images.

Results: The global attenuation of the PET signal due to the presence of the not attenuation corrected RF coils was measured to be 5.1 % for the NEMA phantom and 3.3 % for the large body phantom. Local attenuation up to 15 – 20 % was measured in the top part of the phantoms close to the solid electronic components of the coils (*Fig. 3B*). Concerning the NEMA phantom scan (not shown), the mean activity of the largest lesion at the top of the phantom was underestimated by 6.6 %. Attenuation of the RF coils could mostly be corrected (*Fig. 3C*) by the combined μ-maps generated by the registration algorithm. *Fig. 4* shows different views of the combined μ-map of an exemplary volunteer. The mean deviation of the registered CT coordinates to the MR coordinates of the additional capsules in all four volunteer scans was 3.2 mm.

Discussion: Phantom scans show that the presence of not attenuation corrected RF surface coils leads to considerable local attenuation of the simultaneously acquired PET emission data especially in regions close to the coils. The attenuation becomes less prominent, when it is averaged over lesions or over the whole phantom. The combined μ-maps which are generated by the presented algorithm perform well concerning the AC of the RF surface coils. No user intervention is required except for only once determining capsule positions in the CT images. Furthermore, volunteer scans provide evidence that the registration of the CT-based μ-maps of the RF coils by the algorithm is accurate and robust.

Conclusion: In this work, an algorithm is presented which automatically corrects for the hardware attenuation of the PET emission data caused by flexible RF surface coils during simultaneous PET/MR imaging. The algorithm will now be evaluated and validated in PET/MR scans of oncologic patients as phantom and volunteer scans have provided promising results concerning its accuracy and performance.

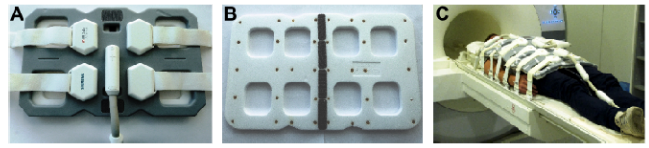

Fig. 1: (A) Flexible 6-channel RF surface coil. (B) Standard foam support which is attached to the bottom of the RF surface coil and contains up to 36 markers. (C) Clinical setup with three overlapping surface RF coils (on a volunteer).

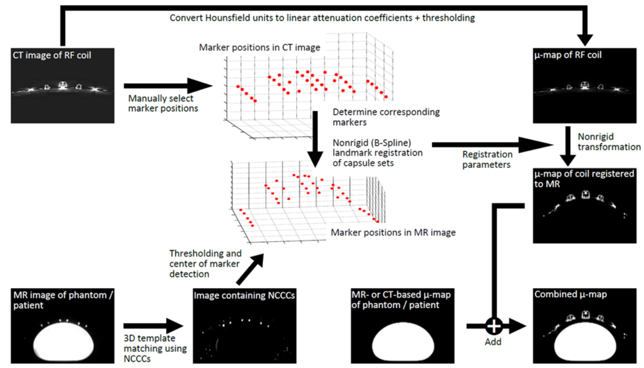

Fig. 2: Overview over the MATLAB algorithm which registers pre-acquired CT-based μ-maps of RF surface coils to current MR- or CT-based μ-maps of phantoms or patients. The registration parameters, which are obtained by non-rigid landmark registration of the marker positions in the CT image to the current individual marker positions in the MR image, are used for the transformation of the CT-based μ-map of the RF coil.

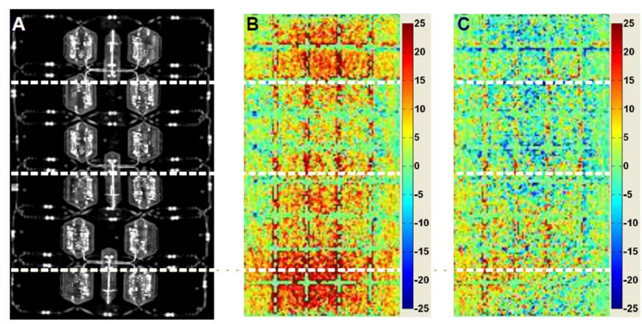

Fig. 3: Large body phantom scan. (A) Maximum intensity projection of the RF coil μ-map showing the relative position of RF coils (coronal view). (B,C) Attenuation of PET emission data as difference image (%) of two PET scans with/out RF coils. (B) No AC of RF coils was performed. (C) With AC of RF coils using the algorithm. Note that the algorithm provided very good AC for the three overlapping flexible RF coils

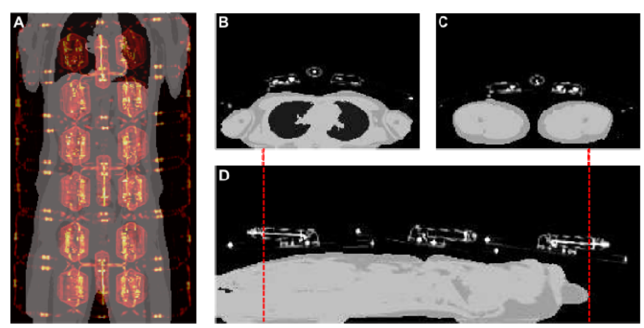

Fig. 4: Combined μ-map of an exemplary volunteer containing the registered CT-based μ-maps of the three overlapping RF coils and the MR-based μ-map of the human tissue. (A) Coronal view with maximum intensity projection of the coils (red color). (B, C) Two axial views as marked in sagittal view (D).

References

1. Paulus DH, Braun H, Aklan B, et al. Simultaneous PET/MR imaging: MR-based attenuation correction of local radiofrequency surface coils. Med Phys. 2012;39(7):4306-4315
2. Braun H, Ziegler S, Paulus DH, et al. Hybrid PET/MRI imaging with continuous table motion. Med Phys. 2012;39(5):2735-2745