Low 511keV-Attenuation Array Coil Setup for Simultaneous PET/MR Imaging of the Monkey Brain

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Target Audience: PET/MR engineers, animal imaging researchers & RF coil developers.

Purpose: Simultaneous imaging with MRI and PET offers the opportunity to obtain complementary functional data in human or animal models, such as non-human primates (NHP). However, current PET/MR scanners are limited in the selection of PET-optimized RF coils and provide only a few coils for human imaging studies. Thus, functional imaging of NHP can show substantial degradation in SNR and parallel imaging performance compared to coils with the appropriate size and shape for a given monkey head. Hence, we developed two PET compatible 8-channel array coils for simultaneous PET/MR imaging of anesthetized NHP. Our goal is enhanced MRI sensitivity and acceleration improvements compared to commercial MRI human coils, with minimal impact on the PET image quality.

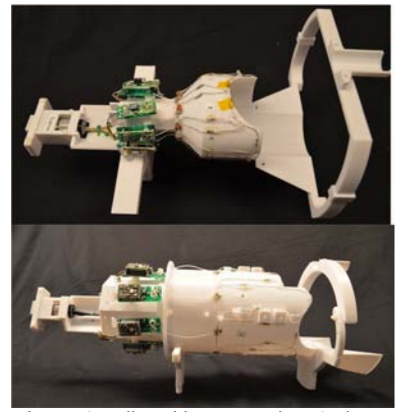

Fig. 1: *Small and large monkey 8 channel arrays for simultaneous PET/MR imaging.*

Methods: Two PET compatible 8-channel coil arrays for NHP brain imaging were constructed for use with two simultaneous PET/MR scanners (whole-body and brain-only). Both coils were optimized to reduce 511 keV γ-ray attenuation by locating dense electronic components (e.g. preamplifiers) outside the field-of-view (FOV) of the PET camera and by utilizing lightweight housing materials. The monkey coils were built on two tight fitting cylindrical helmets, with diameters of 11.5 cm and 15 cm, respectively (Fig. 1). The small coil was targeted to closely fit macaques and small baboons in a helmet shape, whereas the large cylindrical coil was designed to accommodate a larger MR FOV and growth towards large baboons. The coil housing was designed in a 3D CAD program and 3D printed using polycarbonate plastics. The monkey's lower face remains unobstructed to facilitate anesthesia ventilation. Coil elements were built in an overlapped loop design using rectangular coils distributed around the cylindrical helmets. Low impedance preamplifiers were used to decouple next-nearest neighbor elements. The loops were kept sparse in conductive material (18-awg thin cooper wire) to reduce attenuation properties. CT scans of the final coils were carried out to evaluate the final coil attenuation and to create maps for attenuation correction. A bilinear transformation was applied to calculate 511 keV attenuation maps [2] and sinograms of attenuation correction factors were computed by applying the Radon transform. We compared the coil performances to a commercially available 16-channel "PET-friendly" human head-neck coil.

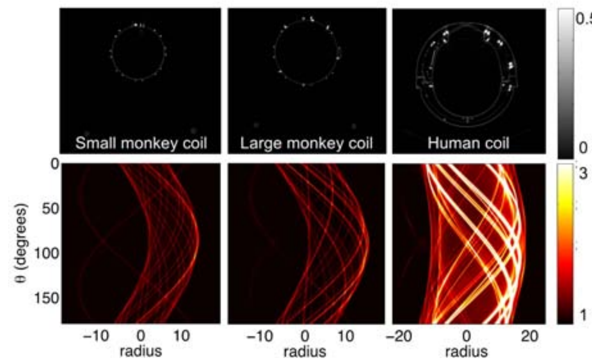

Fig. 2: *Top: 511 keV attenuation map of cross-section of small and large monkey coil and mMR human coil. Bottom: Sinograms of attenuation correction factors for each coil.*

Results: Fig. 2 shows the attenuation maps of a representative cross-sectional slice derived from a CT scan of the small and large monkey coils compared to the human head-neck coil, with the latter coil being much larger and containing more material. The bottom row of Fig. 2 shows the sinograms of attenuation correction factors that provide an estimate of the total attenuation of the coil. The average attenuation coefficient values for the small 8-channel, the large 8-channel and the head-neck coil are 1.06, 1.06 and 1.65, with maximum values of 2.8, 3.2 and 27.3. Fig. 3 shows the SNR and g-factor maps (R=2) for both 8-channel monkey coils in comparison to the head-neck coil. The small and large coil showed an average SNR increase of 3.6-fold and 2.2-fold, respectively, when compared to the commercial coil. 1/g-factor maps in Fig. 3 show substantial lower noise application using the dedicated monkey coil with moderate acceleration (R=2). Fig. 4 shows the images of two simultaneous PET/MR studies that were acquired in two baboons with the small 8 channel coil: On the left, we show a summed PET image of the radiotracer [^{11}C]raclopride (specific to D2/D3 dopamine receptors) with basal ganglia clearly visible and on the right, the radiotracer [^{11}C]CW4 (specific to orexin OX2 receptors).

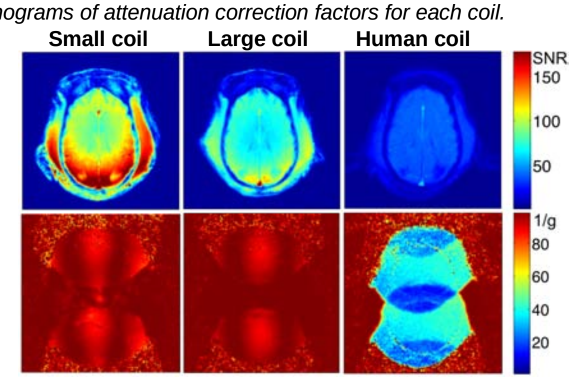

Fig. 3: *SNR maps (top) and 1/g factor maps (bottom) of the small and large monkey coil compared to the human head-neck coil.*

Discussion: Smaller brain structures in NHP brain imaging demand higher spatial resolution with a corresponding reduction in sensitivity from the smaller voxel size. Thus, attempting to image small monkey head sizes in human arrays is suboptimal. In simultaneous PET/MR imaging, attenuation of RF coils can be a source of artifacts that is challenging to correct for. It is thus important to develop specific PET compatible coils that take into consideration attenuating properties. Moreover, coils that are matched to the size of an animal provide increased sensitivity, which is especially important in dynamic functional studies.

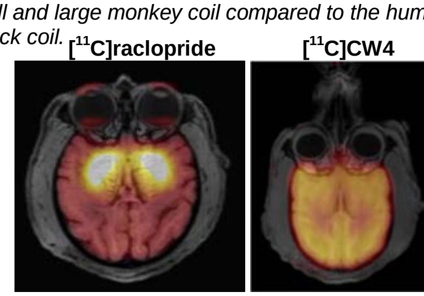

Fig. 4: *PET/MR images acquired with the small monkey coil on the Siemens mMR with a young male (left) and female (right) baboon.*

Conclusion: We developed two array coils for PET/MR imaging in NHP studies, which provide high sensitivity and moderate parallel imaging capabilities, with minimal γ-ray attenuation. These coils are well suited for simultaneous functional PET/MRI applications in NHPs.

References: [1] Sander et al. (2011) *Proc. ISMRM 11*. [2] Burger et. al (2002) *Europ. JNM*.