MR-based Attenuation Correction in an Animal for Radiotracer Quantification

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Purpose

Accurate radiotracer quantification in single-photon emission computed tomography (SPECT) and planar imaging (scintigraphy) requires correction for the attenuation of the gamma rays by the object. Determination of an accurate, object-specific attenuation map is required to perform such an attenuation correction (AC). Strategies for obtaining this attenuation map include 1) importing and registering the map derived from another modality, 2) acquiring transmission data for estimating the map using an external source, and 3) estimating the map solely from the emission data. For this study, we utilized the first method through the simultaneous acquisition of MR and scintigraphic images using a novel MRSPECT system (*1*). To our knowledge, this is the first reported use of simultaneously acquired data in an animal for AC.

Methods

Two small vials each 1.5 mm in diameter were filled with 460 and 840 µCi of ^{99m}Tc-Sestamibi. These vials were then placed inside a specialized RF birdcage coil within a 4 T MRI system in which the separation between two rungs was opened to allow for the insertion of a lead parallel-hole collimator. The collimator was mounted to a cadmium-zinc-telluride nuclear radiation detector unit (Gamma Medica, Inc., Northridge, USA). The vials were positioned 2 cm away from the end of this collimator. Radiation counts were acquired in list-mode over 10 minutes.

The two vials were then implanted in a female Fischer rat. This animal was placed inside the RF coil, 3mm from the end of the collimator, as diagramed in Fig. 1. A second set of radiation counts was acquired in list-mode over 10 minutes. Axial and coronal MR images were also acquired using a 2D spin-echo pulse sequence with the following parameters: TR = 1 s, TE = 40 ms, FOV = 80 mm (axial) or 100 mm (coronal), matrix = 256 × 256, slice thickness = 5 mm.

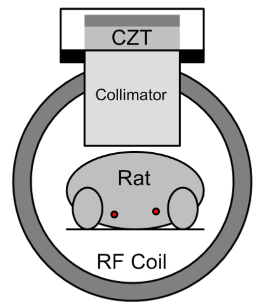

***Fig. 1.** MRSPECT setup*

Scintigraphic images of the vials both outside and inside the animal were generated from the radiation count measurements using a ±5% energy window about the 140 keV photopeak. From the coronal MR images, two ROIs each encompassing a vial were generated. The raw number of radiation counts within each ROI in the co-registered scintigraphic images was then measured. Scatter compensation (SC) was performed using the triple-energy window method with a ±2% scatter rejection window (*2*). For each vial, the axial MR images were used to measure the average distance d through the animal from the center of the vial to the detector. AC was then performed by scaling the radiation counts by a factor of exp(µd), where µ is the linear attenuation of water at 140 keV.

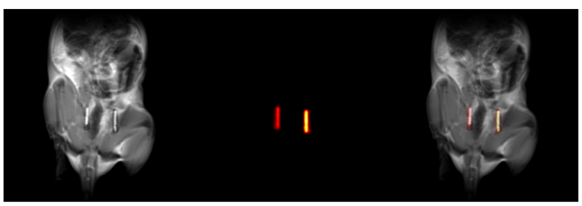

***Fig. 2.** MR (right), scintigraphic (middle) and fusion (right) images*

Results

The coronal MR, co-registered scintigraphic, and fusion images of the vials implanted within the rat are shown in Fig. 2. An axial image of the rat containing some of the parameters and dimensions is shown in Fig. 3. The radiation counts within the ROIs for the various configurations and corrections are listed in Table 1.

ROI	OA raw	OA SC	IA raw	IA AC	IA SC	IA SC+AC
Vial #1	466326	**403416**	385310	497228	312047	**402685**
Vial #2	836503	**731467**	713352	880047	599447	**739525**

***Table 1.** Radiation counts for the vials outside the animal (OA), implanted inside the animal (IA), without corrections (raw), with scatter compensation (SC), and/or with MR-based attenuation correction (AC).*

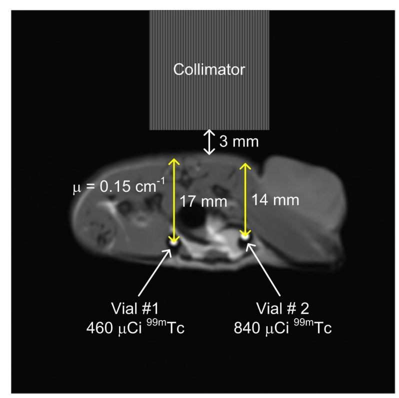

***Fig. 3.** Parameters and dimensions*

Discussion

The results demonstrate that without any corrections, the difference in the quantification of the same vial measured outside and within an animal (OA raw vs. IA raw) is over 14%. However, with the use of both SC and MR-based AC (OA SC vs. IA SC+AC), this error was reduced to less than 0.2%.

In this study, the tissues attenuating the radiation counts were modeled as a single bulk media equivalent to water. The average distance through the animal from the center of each vial to the detector was also utilized. For improved quantification, especially in more complex objects, segmentation of the MR images into different tissues types (with their corresponding attenuation coefficients) could be used to generate a more detailed attenuation map. The distances from each voxel within the ROI to the detector through each tissue type could also be measured. Never the less, even with the simplified AC utilized in this study, a significant improvement in the radiotracer quantification was achieved.

Simultaneous acquisition of MR and single-photo emission data allows for exact co-registration of an MRI-based attenuation map and a scintigraphic/SPECT image, and eliminates the extra time required for 2 sequential scans. As such, we anticipate that such a dual-modality MRSPECT system will play a significant role in radiotracer quantification in small animals and humans in the near future.

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References

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