MRI-Based Attenuation and Background Correction in Nuclear Projection Imaging

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Purpose

Simultaneous MR and nuclear projection imaging allows for exact spatial and temporal co-registration to investigate a variety of biological processes [1]. Accurate radiotracer quantification in a region-of-interest (ROI) requires correction for the attenuation of gamma rays by the imaged object. Furthermore, since the projection image is a sum of the activity across the entire object, contributions from background regions must be removed to quantify the ROI. In this study, we utilized information from the co-registered MR image to perform this attenuation and background correction.

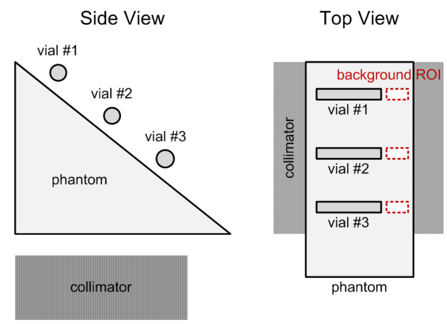

Fig. 1. *Schematic of the phantom*

Methods

3 mm diameter vials each filled with 5 mL of 750 μCi of ^{99m}Tc were placed on top of a hollow acrylic pyramid filled with a solution containing 4 mCi of ^{99m}Tc (Fig. 1). This phantom was then placed within a 4 T MRI system inside a specialized RF birdcage coil in which the separation between two rungs was opened to allow for the insertion of a lead parallel-hole collimator (Fig. 2.). This collimator was mounted to an MR-compatible cadmium-zinc-telluride (CZT) nuclear radiation detector unit (Gamma Medica, Inc., Northridge, USA) [2]. Radiation counts were acquired in list-mode over 10 minutes. A nuclear projection image was generated using a ±5% energy window about the 140 keV photopeak. Concurrent to this acquisition, an MR image of the phantom (Fig. 3) was acquired using a 2D spin-echo pulse sequence with the following parameters: TR = 500 ms, TE = 20 ms, matrix = 128x128, FOV = 50 mm, slice thickness = 3 mm, and NEX = 2.

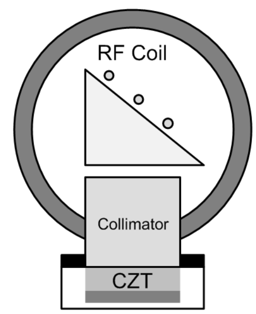

Fig. 2. *Imaging setup*

In the nuclear projection image, ROIs were drawn around the vials, and activity within each ROI was measured. To correct for the background activity, additional ROIs were drawn within the phantom and next to the vials to measure the counts from background (Fig. 1). The co-registered MR image was then used to measure the volume of the background contributing to the counts within these ROIs. The background activity per volume was calculated and used to determine the number of background counts within the ROIs around the vials. The background-corrected activities of the vials were then calculated. To perform attenuation correction, the distances between the vials and the detector within the phantom were measured using the co-registered MR image (Fig. 3). From these distances and the known attenuation coefficient of 140 keV gamma rays in water, the magnitude of attenuation was calculated and used for a correction factor.

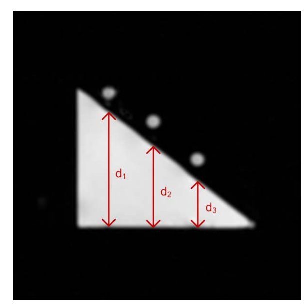

Fig. 3. *MRI of the phantom*

Results

The activities within the ROIs for the various vials and corrections are listed in Table 1. Without any corrections, the measured activities are significantly larger than the actual value of 150 μCi/cc due to the background activity from the phantom. For example, the ROI for vial #1 which contains the largest background volume has the highest measured activity. The measured activities after background correction are smaller than the actual value of 150 μCi/cc due to attenuation of the gamma rays by the water-filled phantom. The measured activates of the vials after both MRI-based background and attenuation corrections are significantly closer to the actual value of 150 μCi/cc.

Discussion

The results of this study demonstrate the importance of both background and attenuation correction for accurate radiotracer quantification in nuclear projection images. In more complex objects, such as small animals, the MR images could be segmented into different tissues types. The volume of each tissue region could then be measured and assigned its corresponding attenuation coefficient and average radiotracer uptake quantity. Further improvements to the measurements could be achieved by taking into account the depth-dependency of the detector sensitivity.

As an alternative to compensating for the measured activity from regions outside a desired ROI in a 2D nuclear projection image, a full 3D tomographic image could be acquired. However, reconstruction of such an image requires data from multiple views. For a single detector system, the corresponding increase in the data acquisition time would severely limit the ability to perform dynamic imaging. Thus, nuclear projection imaging will still be applicable when high-temporal resolution is desired.

	Activity (μCi/cc)		
	No Corrections	Background Correction Only	Attenuation and Background Correction
Vial #1	338.0	96.5	145.4
Vial #2	279.2	115.2	148.4
Vial #3	231.1	129.5	151.1

Table 1. *Measured activities after the different corrections*

References

1. Hamamura MJ, Roeck WW, Ha S, Hugg J, Wagenaar DJ, Meier D, Patt BE, Nalcioglu O. Simultaneous *in vivo* dynamic contrast-enhanced magnetic resonance and scinitigraphic imaging. Phys Med Bio 2011;56:N63-9.
2. Hamamura MJ, Ha S, Roeck WW, Muftuler LT, Wagenaar DJ, Meier D, Patt BE, Nalcioglu O. Development of an MR-compatible SPECT system for simultaneous data acquisition. Phys Med Bio 2010;55:1563-75.