Use of multi-spectral MR data to generate an attenuation map for application to PET/MR hybrid imaging

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Introduction

Intensive research is currently ongoing to develop hybrid PET/MR imaging systems. A handful of small animal studies have been published and the first human brain PET/MR images were recently obtained [1]. However, to generate quantitatively accurate PET images, gamma ray attenuation must be corrected. In PET/CT, this is done by taking advantage of the electron density information obtained from the CT data in order to generate an attenuation map. Unfortunately, MR images are not clearly related to electron density, so this method cannot be applied to the PET/MR platform. An alternative approach is to determine the position of anatomical structures from the MR images and then to assign these structures known attenuation coefficients. Thus far, this technique has only been attempted using single-spectral MR and has only been applied to the brain [2]. In the present work, we used canine multi-spectral MR data to generate abdominal and thoracic attenuation maps for PET.

Methods

Three adult mongrel canines were anesthetized and immobilized on a moveable platform. The canines were subsequently imaged using CT (Siemens Symbia T6 6-slice) and MR (Siemens Avanto 1.5T). Four MR data sets were acquired: T1-weighted (w), T2-w, proton density (PD) w, and water-suppressed (WS) PDw. The CT data were converted to mono-energetic (511 keV) attenuation maps and registered to the MR data sets. Four tissue types (hard tissue, soft tissue, lung, and air) were segmented from each MR data set using a k-means algorithm [3] (6 clusters) in order to generate mono-energetic attenuation maps. Further, clusters from various combinations of individual MR data sets were merged using a probabilistic model to yield attenuation maps. Each MR-derived attenuation map was compared to the CT-derived attenuation map by comparing their respective radon transforms on a pixel-by-pixel basis.

Results

Figure 1 depicts a visual comparison of the attenuation maps generated via CT versus multi-spectral MR. An example of a quantitative comparison via the Radon transform is presented in Figure 2. Finally, Table 1 summarizes the quantitative comparisons. For abdominal slices, single and multi-spectral MR derived attenuation maps were of comparable accuracy; for thoracic slices, multi-spectral techniques yielded superior results. In general, it was more challenging to obtain attenuation maps for thoracic slices than abdominal slices.

MRI parameters	Line of best fit	R^2
Abdominal Slice		
T2w	Y=0.933x+0.273	0.938
T1w & T2w & WSPDw	Y=0.958x+0.307	0.938
T1w & PDw & WSPDw	Y=0.949x+0.271	0.937
T2w & PDw & WSPDw	Y=0.961x+0.302	0.939
Thoracic Slice		
T2w	Y=0.534x+0.691	0.596
T1w & T2w & WSPDw	Y=0.789x+0.581	0.756
T1w & PDw & WSPDw	Y=0.833x+0.540	0.772
T2w & PDw & WSPDw	Y=0.763x+0.523	0.732

Table 1: Results of Radon transform comparisons. R^2 values were significantly improved for multi versus single-spectral derived maps at the thoracic level.

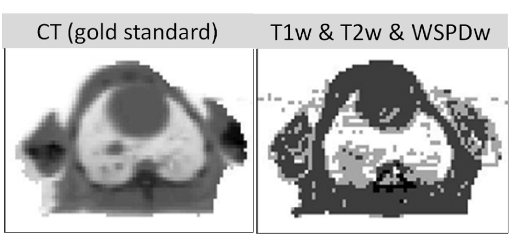

Figure 1: CT derived attenuation map and an example of a multi-spectral MR derived attenuation map (thoracic transaxial slice shown).

Discussion

We have demonstrated that multi-spectral MR data can yield better PET attenuation maps than single-spectral data, at least at the thoracic level. This supports prior evidence that multi-spectral MR can improve segmentation algorithm performance [4]. The best combinations of MR data were T2w & PDw & WSPDw for abdominal slices and T1w & PDw & WSPDw for thoracic slices (as judged by the highest R^2 and proximity of the line-of-best-fit to Y=X). We found that, in general, PDw was most helpful for identifying soft tissue and lung while WSPDw aided greatly in edge and marrow detection. Segmentation was weak for bones and cartilage, but the use of alternate MR sequences may improve performance (e.g. ultra-short TE imaging [5]). This work clearly demonstrates that using multi-spectral MR data to generate attenuation maps is a feasible approach for the purposes of PET correction in PET/MR systems.

References

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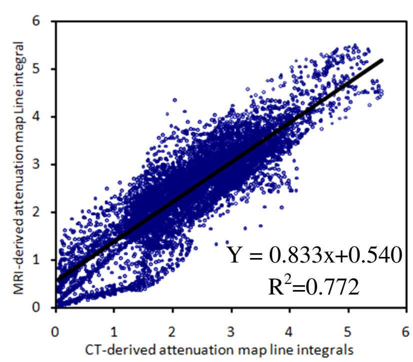

Figure 2: Pixel by pixel correlation between CT and T1w & PDw & WSPDw derived attenuation map Radon transforms for thoracic slice.