Automatic Internal Carotid Arteries Segmentation for Estimation of an Image Derived Input Function with MR-PET

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Target Audience: Researchers interested in quantification of MR-PET using non-invasive methods.

Purpose: Quantification of PET data often requires an input function in order to be fully quantitative. An image derived input function (IDIF)[1], in which the input blood information is acquired from the dynamic PET data, is an attractive non-invasive alternative to arterial blood sampling and consequent cannulation. The introduction of hybrid MR-PET systems is an excellent pre-requisite to obtain an IDIF due to an excellent co-registration between MR and PET data in the internal carotid arteries (ICA) region[2,3]. By segmenting the ICAs based on MR data and transferring it to the dynamic PET, the IDIF can be obtained[1-4]. However, segmentation of ICA is laborious and non trivial to perform in an automatic way. The aim of this work is to explore an automatic segmentation algorithm in order to segment the ICA and obtain an IDIF to reduce workload and intra/inter-observer variability.

Methods: Data from four tumor patients were acquired in the 3T MR-BrainPET (Siemens, Erlangen, Germany). ***PET Acquisition Details:*** A bolus of 3MBq/Kg of body weight of $[^{18}F]$-FET was administrated to each subject and a dynamic scan was performed during 60min. The PET data were reconstructed in 23 time frames with variable frame length (8x5s, 2x10s, 2x15s, 1x30s, 1x60s, 1x120s, 5x300s, 3x600s) using OP-OSEM with 32it and 4sub including all the corrections and it was post filter with a Gaussian filter of 2.5mm. The final matrix size was 256x256x153 with an isotropic pixel size of 1.25mm. ***MR Acquisition Details:*** Two MPRAGE images were acquired pre and post contrast agent injection within an acquisition time of 4:40min each. The matrix size was 256x256x192 to achieve a voxel size of 1x1x1 mm^3. A TE/TR/TI of 3/2250/900ms and a flip angle of 9 deg were used. Both images were used in the manual segmentation and the pre-contrast image in the subsequent segmentation. ***Segmentation Algorithm Details:*** 1) MPRAGE bias field inhomogeneity was corrected with SPM12 and images were normalized; 2) initial guess was achieved with a multiscale Hessian-based filter for vessel enhancement[5]; 3) the distance regularized level set evolution method (DRLSE)[6] was applied with Δ = 0.2 and μ= 0.1. The parameters λ and α of the algorithm were changed in order to optimize the segmentation. ***Segmentation Evaluation:*** The segmentation algorithm results were compared against a manual segmentation of ICA in terms of dice coefficients, sensitivity and specificity for the different λ and α. The parameters that allowed the best segmentation were used to estimate the IDIF. ***IDIF Estimation and Evaluation:*** To obtain the IDIF, the Volume of Interest (VOI) from MR was transferred to PET data and the mean value and the 4 hottest pixels per plane approach[4] were used to obtain an IDIF, here respectively named mIDIF and hpIDIF. The obtained IDIFs were then compared against the IDIF resulting of manual segmentation in terms of time to peak (TTP), total area under the curve (tAUC), peak (0-90sec) AUC (pAUC) and tail (90-3600sec) AUC (tAUC) using the ratio between automatic and manual metrics. All the data were processed using MATLAB.

Results: The parameters that show the best result (Dice = 79,2+/-4,2%, Sensitivity = 81,5+/-7,7% and Specificity = 99.9+/-0,1%) were $\lambda = 25$, $\alpha = -5$. Figure 1 shows the good co-registration between MR and PET data in the region of ICA. In figure 2, the IDIFs obtained using the different approaches are presented for a representative subject. Table 1 shows the metrics related to AUC and TTP ratios.

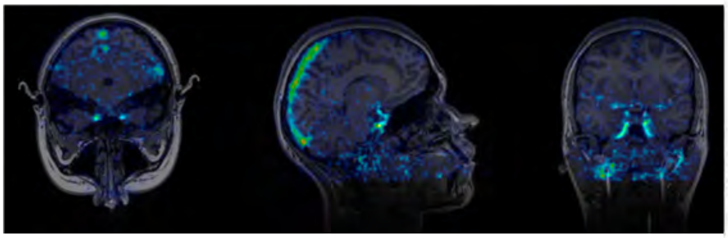

Figure 1. MR-PET data showing the good agreement between MPRAGE and PET (summed 1-5min) in ICA region.

Metric	Ratio	
	aIDIF	hpIDIF
TTP	1	1
tAUC	1,00+-0.01	0,99+-0.04
pAUC	1,00+-0.01	0,97+-0.04
tAUC	1,00+-0.01	0,99+-0.04

Table 1. Metrics used to evaluate the IDIF obtained with manual and automatic segmentation.

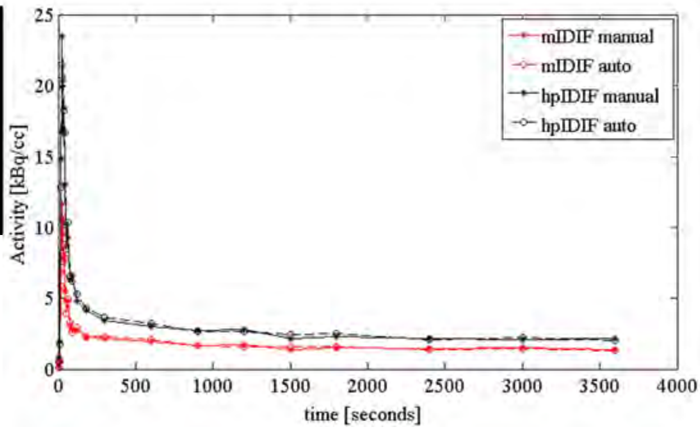

Figure 2. IDIF from a representative subject with manual and automatic segmentation for both mIDIF and hpIDIF.

Discussion: The proposed method to segment the ICA in order to obtain an IDIF shown similar results to the manual segmentation (table 1). Such results encourage the use of the method in the segmentation of ICA based on MPRAGE data, which reduces considerably the workload and avoids intra/inter-observer variability. Furthermore, simultaneous acquisition allows avoiding registration problems that might be demanding for this application due to the elastic properties of the vessels[4]. In this work, no partial volume correction was applied and it should be taken into account due to the small ICA diameter (~5mm) and scanner resolution (~3mm).

Conclusion: With this work, we have shown an automatic approach to estimate an IDIF, reducing the workload related to segmentation and intra/inter-observer variability. Nevertheless, the obtained IDIF must be corrected for partial volume effect for further quantification.

References: [1]Zanotti-Fregonara P, et al. J Cereb Blood Flow Metab. 2011;31(10):1986-98; [2]da Silva NA and Herzog H, et al. NIMA 2013;702:22-25; [3]Mauler J and da Silva NA, et al. EJNMMI Physics 2014, 1 (Suppl 1):A30; [4]Mourik JE, et al. NeuroImage 2008;39:1041-1050; [5]Frangi A, et al. MICCAI Proceedings 1998 , 130–137; [6]Li C, et al. IEEE Trans Image Processing 2010;19(12):3243-3254;