An atlas-based automatic brain segmentation method for regional SUV quantification in hybrid PET/MR

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Abstract

Background Quantitative analysis of brain positron-emission tomography (PET) depends on structural segmentation, which can be time-consuming and operator-dependent when performed manually.

Previous automatic segmentation methods usually fitted subjects' images onto an atlas template for group analysis, which changed the individuals' images and affected regional PET segmentation. We proposed an automatic segmentation method, registering atlas template to subjects' images (RATSI), which created an individual atlas template and may be more accurate for PET segmentation. We segmented two representative brain areas in twenty Parkinson disease (PD) and eight multiple system atrophy (MSA) patients performed in hybrid positron-emission tomography/magnetic resonance imaging (PET/MR). The segmentation accuracy was evaluated using the Dice coefficient (DC) and Hausdorff distance (HD). and the standardized uptake value (SUV) measurements of these two automatic segmentation methods were compared, using manual segmentation as a reference.

Results The DC of RATSI increased and the HD decreased significantly ($P < 0.05$) compared with the traditional method in PD, while the results of one-way analysis of variance (ANOVA) found no significant differences in the SUVmean and SUVmax among the two automatic and the manual segmentation methods. Further, RATSI was used to compare regional differences in cerebral metabolism pattern between PD and MSA patients. The SUVmean in the segmented cerebellar gray matter for the MSA group was significantly lower compared with the PD group ($P < 0.05$), which is consistent with previous reports.

Conclusion The RATSI was more accurate for the caudate nucleus and putamen automatic segmentation, and can be used for regional PET analysis in hybrid PET/MR.

Full-text

Due to technical limitations, full-text HTML conversion of this manuscript could not be completed.

However, the manuscript can be downloaded and accessed as a PDF.

Tables

Table 1. The Dice coefficient (DC) and Hausdorff distance (HD) (mean $\pm$ SD) for evaluating the accuracy of automatic brain segmentation quantitatively

			¹ CAU_L	² CAU_R	³ PUT_L	⁴ PUT_R
DC	Methods	Traditional	0.48 ±0.13	0.51±0.06	0.62±0.09	0.49±0.12
		RATSI	0.64±0.06	0.70±0.05	0.75±0.05	0.69±0.05
P<0.001						
DH (pixels)	Methods	Traditional	11.80±0.74	12.42±1.19	11.03±0.88	12.73±1.87
		RATSI	9.61±0.75	9.56±0.69	8.89±0.68	9.39±0.75
P<0.001						

¹CAU_L: left caudate nucleus; ²CAU_R: right caudate nucleus

³PUT_L: left putamen; ⁴PUT_R: right putamen

Table 2 The lists of mean and max ¹⁸F-FDG-SUVs in segmented regions extracted with manual segmentation, RSIAT and RATSI.

			CAU_L	CAU_R	PUT_L	PUT_R
SUV_mean	¹ manual segmentation		7.45 ±1.39	7.42 ±1.42	9.03 ±1.69	9.08 ±1.76
	² Traditional		6.61 ± 1.38	6.72 ±1.37	8.60 ±1.63	8.44 ±1.71
	³ RATSI		6.60 ±1.37	6.84 ±1.36	8.59±1.72	8.48 ±1.67
	<i>P</i>		0.090	0.233	0.642	0.419
	(among groups)					
	<i>P</i>	1 vs 2	0.059	0.111	0.419	0.239
		1 vs 3	0.055	0.187	0.415	0.272
		2 vs 3	0.974	0.778	0.995	0.937
SUV_max	manual segmentation		11.29 ±2.04	11.73 ± 2.32	12.95 ± 2.47	12.90 ± 2.59
	Traditional		11.29 ± 2.12	11.68 ±2.38	12.92 ±2.44	12.90 ± 2.63
	RATSI		11.32 ± 1.93	11.74 ±2.32	12.97 ±2.47	12.78 ± 2.66
	<i>P</i>			> 0.90		

Table 3. The SUV_{mean} quantification in brain nuclei for PD and MSA patients

		CAU_L	CAU_R	PUT_L	PUT_R	¹ CGM_L	² CGM_R
SUV_mean	PD	6.60 ±1.37	6.84 ±1.36	8.59 ±1.72	8.48 ± 1.67	5.49 ± 0.70	5.32 ± 0.70
	MSA	5.46 ±1.78	5.87 ±1.77	7.27 ±1.81	7.32 ±1.83	3.93 ±1.05	3.59 ± 1.05
	F	0.50	0.39	0.80	0.83	0.19	0.39
	P	0.07	0.21	0.15	0.15	0.00	0.00

¹CGM_L: left cerebral gray matter

²CGM_R: right cerebral gray matter

Figures

Figure 1

The brain atlas template, which segments the brain into 70 regions, labeled with numbers from 1 to 70 and showed with different colors. It was used for the following automatic segmentations.

Figure 2

The diagram displaying the processing steps of the RATSI method for whole brain automatic segmentation and regional 18F FDG PET quantification.

Figure 3

The boxplots displaying distributions of the Dice coefficient (A) and Hausdorff distance (B), which were used to evaluate the brain segmentation accuracy in compared with the ground truth, the manual segmentation results. The red and green boxplots represented the results of traditional method and RATSI, respectively. Representative nucleus including caudate nucleus (left: CAU_L, right: CAU_R) and putamen (left: PUT_L, right: PUT_R) were segmented for analysis

Figure 4

Representative visualization of segmented brain nuclei including caudate nucleus (green: CAU_L, red: CAU_R) and putamen (blue: PUT_L, yellow: PUT_R) by using manual segmentation (B), traditional method (C), and RATSI (D). The areas in the white box in T1 images (A) were the regions shown below. And the segmented regions of interest (ROIs) for nuclei were overlapped on T1 images in coronal (left), sagittal (middle) and axial views (right) respectively for better visualization

Figure 5

The boxplots displaying the distribution of the SUVmean (A) and SUVmax (B) in caudate nucleus (left: CAU_L, right: CAU_R) and putamen (left: PUT_L, right: PUT_R) from twenty PD patients with manual segmentation (red), the traditional method (green) and RATSI (blue).

Figure 6

Bland Altman graphs to evaluate the SUVmean consistency of the traditional method (A) and RATSI (B) in comparison with the manual segmentation in the four representative regions including the left, right caudate nucleus and putamen. The SD represents the standard deviation.