WAVELET-BASED METHODOLOGY FOR [15O]-H20 PET BRAIN ACTIVATION ASSESSMENT

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Introduction: Statistical parametric mapping (SPM) is a voxel-byvoxel analysis method commonly used for the detection of brain activation patterns. An alternative approach is the use of multiscale information by means of wavelet analysis. In this study, we have compared the detection of brain activations using conventional SPM and a statistical wavelet analysis in a set of realistic simulated [15O]-H20 positron emission tomography (PET) phantoms.

Material and Methods: Simulated PET Phantoms: Three baseline [15O]-H20 PET scans were simulated starting from a single MR image of a healthy subject: Firstly, the magnetic resonance imaging (MRI) was segmented into grey matter, white matter, and cerebral spinal fluid using a thoroughly validated automatic method. Relative tracer concentrations were assigned to 100:25:2, respectively, and blur effect was introduced with a smoothing Gaussian filter (FWHM=8x8x6mm). This image was projected at 128 angles and, after 2:1 decimation, the global count level was set to 5·10^6. Finally, Poisson noise was added before applying the inverse Radon transform. Activated [15O]-H20 PET scans were similarly generated from the same MR image by manually segmenting the thalamus and increasing the original intensity with factors of 2, 5, 10, 15, and 20%. Three scans were obtained for each activation factor.
Statistical Wavelet Analysis: A 3-D Discrete Wavelet Transform (DWT) was applied to all simulated PET scans (Symlets-2; 4th decomposition level) for every activation factor. In the wavelet domain, Student's t-test was performed to detect coefficients showing significant differences between baseline and activation conditions. In addition, a difference volume was obtained by subtracting the average coefficients of each condition. In this difference volume, wavelet coefficients not showing significant differences were set to zero before applying the inverse 3DDWT.
As a result, brain regions showing significant activations were obtained in the image domain.
Evaluation: Comparison between SPM and the wavelet approach was carried out for each activation level measuring the area under the receiver operating characteristic (ROC) curve, obtained varying the a-level of the statistical test, and the sensitivity rate at 90% of specificity. The comparison was also performed using a pre-smoothed version (FWHM=5mm) of simulated images.

Results: The statistical wavelet-based method performed substantially better than SPM (see Table I). An increase in sensitivity was observed for both methods when operating on smoothed images.

Discussion: The DWT decomposes a signal into different resolutions, clustering spatially correlated pixels into few coefficients with higher SNR. These features are expected to yield higher statistical power than SPM, even without a previous smoothing step. The ROC curve provides a valid index for comparing statistical method's performance because it is independent of the activated region size and decision threshold.

Conclusions: Statistical wavelet-based methods outperforms conventional SPM analysis in the detection of brain activity in simulated [15O]-H20 PET studies.

Table 1. Area under the ROC curve (Area Under the Curve: AUC) and sensitivity at 90% of specificity for each activation level.

	AUC				Sensitivity (%)			
	SPM		SYMLETS2		SPM		SYMLETS2	
Activation	No Smooth	Pre-Smooth	No Smooth	Pre-Smooth	No Smooth	Pre-Smooth	No Smooth	Pre-Smooth
2%	0.4983	0.4806	0.4748	0.5456	10.31	7.97	3.00	1.87
5%	0.5089	0.5886	0.6840	0.8517	10.87	17.90	0.75	38.43
10%	0.5216	0.7221	0.9096	0.9058	12.02	37.58	50.05	83.41
15%	0.5462	0.8272	0.8253	0.8872	13.50	54.17	50.33	83.41
20%	0.6144	0.9096	0.9519	0.9641	20.15	75.45	83.41	91.28