Analysis of Regional Brain Atrophy in A Single Case of Semantic Dementia Using Serial MRI with Inverse-Consistent Non-Rigid Registration

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Introduction

Non-rigid image registration is typically utilized in brain mapping for spatial normalization of imaging data. This step reduces subject-specific anatomic differences by deforming individual images onto a population average brain template or a neuroanatomic atlas. With the same procedure, maps visualizing structural brain change over time can be generated by comparing baseline scans to subsequent scans of the same patient. Traditionally, the registration of two images requires arbitrarily assigning a deforming image and a target image. However, if order of the deforming/target images is switched, then two different mappings may result, challenging validity. Thus, mappings constructed to be inverse consistent (i.e., the computed correspondences are independent of the choice of deforming/target images) may be advantageous over inverse inconsistent mappings is studying longitudinal change in brain volume.

Method

G.C. is a 57 year-old male patient diagnosed with semantic dementia (fronto-temporal dementia), whose neuropsychological profile has been described previously. A total of four magnetic resonance imaging (MRI) scans were obtained (baseline scan in 02/1993; follow-up scans in 10/1994, 02/1996, and 08/1999) using gradient echo T1-weighted imaging (TR 25ms, TE 5ms, slice thickness 1.5mm, FOV 24x18cm, flip angle 40 degrees, no gaps).). An inverse consistent non-rigid image registration program was developed that maximizes the mutual information (MI) between two images with the deformation regularized by a penalty function in the form of the linear elasticity operator. The non-rigid registration program was then utilized to deform later MRI scans (10/1994, 02/1996, and 08/1999) back to the first baseline MRI scan (02/1993). This temporal normalization allows the assessment of tissue expansion/loss in a voxel-by-voxel manner by looking at the determinant of the Jacobian operator (Jacobian map) applied to the resulting deformation field (values larger than 1 indicate tissue expansion; values less than 1 indicate atrophy or tissue loss). A region of interest (ROI) analysis using manual tracing by a trained rater was performed to compute average atrophic rates from the Jacobian maps in regions with observed atrophic changes.

Results

The MRI scans (Figure 1) showed existing left temporal lobe atrophy (marked by ***L***) by visual inspection, although no active atrophy was detected in the Jacobian maps during the time period. By contrast, active atrophy was observed in the right temporal lobe (marked by ***R***). Closer inspection showed a posterior progression of the atrophy starting from the right temporal pole. Figure 2 shows the Jacobian map for the right temporal lobe in 02/1996 (relative to the baseline scan), while Figure 3 shows the posterior progression in 08/1999. Bilateral tissue loss was also noted in the caudate head, putamen, and thalamus (Figure 4). Table 1 shows the results of the ROI analysis (not performed on the left temporal lobe). An annualized atrophic rate (as a percentage) is calculated by least-square linear regression.

Conclusion

Here we developed and tested an MI-based inverse consistent registration method that can be used to assess and visualize local tissue changes over time. This technique was applied to the serial scans of a patient with semantic dementia and the results showed bilateral temporal lobe

and striatum/thalamus involvement.

	Mean Jacobian (10/1994)	Mean Jacobian (02/1996)	Mean Jacobian (08/1999)	Percentage change/year
Sup. temporal(Rt)	0.975	0.946	0.927	-1.08%
Mid. temporal (Rt)	0.907	0.860	0.805	-2.88%
Inf. temporal (Rt)	0.911	0.826	0.768	-3.48%
Occipitotemporal(Rt)	0.833	0.776	0.785	-2.88%
Parahippocampal(Rt)	1.044	0.984	0.964	-0.84%
Caudate (Rt)	1.03	0.924	0.917	-1.56%
Putamen (Rt)	0.981	0.901	0.833	-2.76%
Thalamus (Rt)	1.03	0.932	0.831	-3.00%
Caudate (Lt)	1.024	0.952	0.936	-0.96%
Putamen (Lt)	0.956	0.895	0.799	-3.12%
Thalamus (Lt)	0.947	0.900	0.836	-2.52%