FULLY AUTOMATIC SEGMENTATION OF THE AMYGDALA ON HIGH RESOLUTION T1 IMAGES USING A SHAPE MODEL

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Target audience: Neuroscientists, neuroradiologists with research interest

Purpose: The amygdala is a small brain structure involved in processing of e.g. memory and emotion. It plays an important role in psychiatric disorders and is affected in preclinical Alzheimer's Disease[1]. Manual tracing of the amygdala on MRI is too time-demanding to be of practical use. Recently, deformable surface models have been introduced for automatic segmentation of subcortical brain structures, e.g. [2,3], but amygdala segmentation has not been studied in detail. The aim of this work was to evaluate fully automatic segmentation of the amygdala with a shape model, compared to manual tracing and an atlas-based approach.

Methods: T1-weighted MRI was obtained for 73 normal elderly subjects (age 65.5±6.6y; 32% female). For each subject, 4 images were acquired consecutively using a 3D turbo field echo sequence with 0.8 x 0.8 x 0.8mm^3 resolution using an 8-channel SENSE head coil (3T Achieva, Philips, Best, Netherlands). Images were motion corrected and averaged to increase the SNR. Manual tracing of the amygdalae was performed with high intra-rater reliability (r=0.98) as described before[1]. For automatic segmentation, a shape-constrained brain model[2] was adapted to each image, resulting in binary masks of left and right amygdala. The shape model had been trained on an independent dataset of manually segmented, normal brain scans. To evaluate model-based segmentation, binary masks were compared to manual tracings. Correlation between volumes as well as overlap (Dice coefficients) and mismatch were determined. For comparison, results were also obtained for a state-of-the-art atlas-based segmentation using SPM8 with DARTEL and AAL atlas.

Results: Processing time of the shape model was ca. 30 seconds per subject on a standard PC. Shape model segmentation failed in 4 subjects (5%), leaving n=69 for final analysis. Segmented volumes were larger for the shape model than the manual segmentations (average: 30%, see table). Correlation was good (0.79) for left vs right and moderate for shape model vs manual (left: 0.63, right: 0.54). Overlap was good (Dice coefficients 0.72 and 0.73, figure 1). The shape model segmentation generally contained the manually delineated volume. This was tested by calculating the relative volume of the manual masks outside the automatic mask ("mismatch"). On average, only 14% (18%) of the left (right) manual tracing was not covered by the corresponding shape model volume. The atlas-based segmentation yielded greater volume correlation but less overlap to manual tracings than the shape model.

	manual		atlas-based		shape model	
mean(std)	left	right	left	right	left	right
volumes in ml	1.38(0.24)	1.34(0.24)	1.22(0.14)	1.51(0.18)	1.88(0.32)	1.64(0.29)
correlation L/R	0.82		0.75		0.79	
corr. (to manual)			0.69	0.62	0.63	0.54
Dice (to manual)			0.59(0.04)	0.56(0.04)	0.72(0.07)	0.73(0.07)
mismatch (manual)			0.44(0.05)	0.40(0.04)	0.14(0.09)	0.18(0.09)

Discussion: Shape model segmentation was more consistent with manual tracing than the atlas-based approach. Dice coefficients and correlations are comparable to those reported for automatic segmentation of the hippocampus[4]. Volume differences between manual and automatic segmentations are a known effect, most likely due to different protocols for manual tracings[5]. Both shape model and atlas-based approach are fully automatic, requiring no manual input.

Conclusion: Fully automatic segmentation of amygdalae is possible with reasonable concordance to manual tracing. This enables reproducible and observer-independent analysis of the amygdala. In particular, automatic segmentation is expected to benefit regional analysis of multimodal (PET-MR) or multiparametric imaging. For exact volumetry on high resolution MRI, standardization of the definition of anatomical brain structures like the amygdala is required.

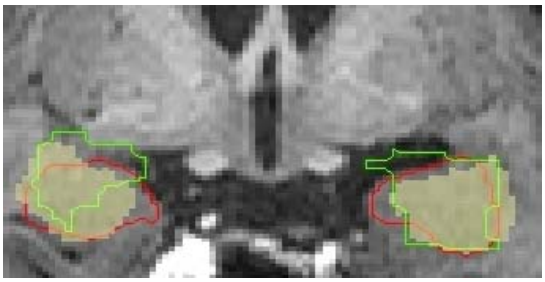

Figure 1: Example for segmentations on coronal slice: manual (yellow), shape model (red), atlas-based (green)

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