Volume Reduction of Subcortical Grey Matter After Death

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Introduction:
An increasing number of studies combine results of postmortem MR volumetry on cadaveric human brains with the findings of histological examination, and with clinical or imaging data collected in-vivo. However, the changes that occur in the volume of different brain structures after death have not been thoroughly investigated. The purpose of this work was to determine the relationship between the volume of sub-cortical grey matter structures measured with MR volumetry in-vivo and postmortem.

Materials and Methods:
Data: In-vivo, as well as postmortem high-resolution anatomical data was collected on 6 elderly human subjects (>70 years of age). All subjects were scanned in-vivo using a 1.5T GE scanner (<3 years before death). After death, a brain hemisphere from each of the six subjects, excluding cerebellum and brainstem, was immersed in formaldehyde solution and imaged with a 3T GE or Siemens scanner (all subjects were imaged postmortem between 31 and 103 days after death). All hemispheres remained stored with their medial aspect facing the bottom of the container. *Subcortical grey matter segmentation*: The following subcortical grey matter regions were segmented: thalamus, caudate, putamen, pallidum, hippocampus, amygdala, accumbens, ventral diencephalon. Eighteen manually segmented T1-weighted brain image volumes were used for the purposes of subcortical grey matter segmentation (Center for Morphometric Analysis at Massachusetts General Hospital, http://www.cma.mgh.harvard.edu/ibsr). Each of the 18 segmented image volumes was registered to the in-vivo and postmortem data from the 6 subjects, in two steps: affine registration (FSL, 12 degrees of freedom), and non-rigid registration (ART) [1]. The final spatial transformation was then applied to the labels of the 18 segmented image volumes using nearest neighbor interpolation, essentially transforming all labels to the space of each subject's in-vivo or postmortem data [2]. Thus, each subcortical grey matter region in an in-vivo or postmortem dataset was segmented 18 times. The information from the 18 segmentations of each region was combined to obtain a final segmentation, using a vote-rule based on maximum frequency. When a voxel received an equal number of votes for two or more labels, the final decision was made randomly. The results of the above process were further refined by incorporating the results of a grey-matter/white-matter segmentation obtained using FSL, and information from gradient maps of the anatomical images of the 6 subjects. The estimated in-vivo and postmortem volumes of the subcortical grey matter regions were normalized to the intracranial volume measured from the in-vivo data. The normalized postmortem volumes were plotted as a function of the normalized in-vivo volumes of the 6 subjects. Finally, the SPHARM-PDM UNC Toolbox was used to detect shape changes that occurred in the subcortical grey matter regions postmortem.

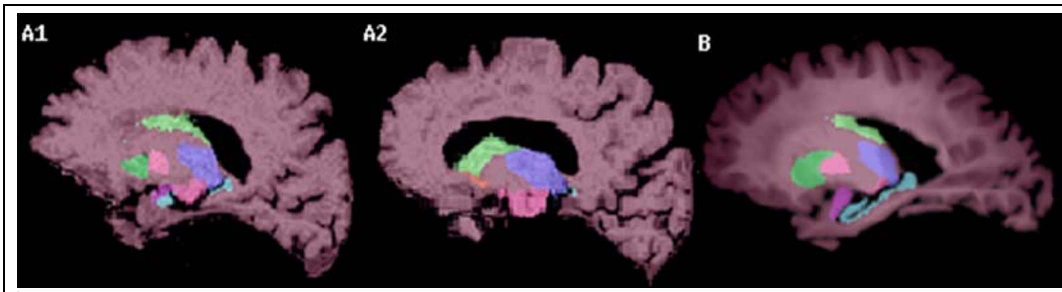

Figure 1: Segmentation of subcortical grey matter using in-vivo (A1, A2) and postmortem (B) data from the same human brain. The name of the region corresponding to each color is shown in Figure 2.

Results & Discussion:
A statistically significant linear relationship was demonstrated between the normalized postmortem and in-vivo volumes of the segmented subcortical grey matter regions, described by: $y=0.8791x+0.0086$, $p<10^{-10}$ (Figure 2). The slope of this linear relationship and the associated p-value suggest that the volume of the subcortical grey matter regions of interest was lower on average postmortem than in-vivo. This shrinking of subcortical grey matter may be due to a reduction in the water content of brain tissue after death. Shape analysis on the segmented regions demonstrates a contraction of the surface of these structures (Figure 3).

In conclusion, the results of this investigation provide an insight to the volume and shape changes that occur in subcortical grey matter structures after death. The number of studies combining postmortem MRI and histological or clinical data continuously increases. The findings of the present investigation will be crucial for the translation of MR volumetric measurements based on postmortem MRI data.

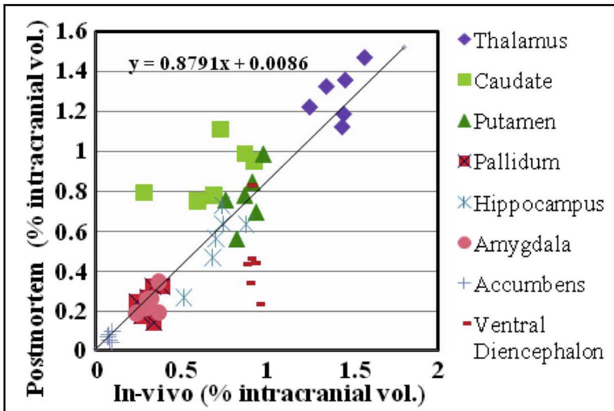

Figure 2: Postmortem vs. in-vivo normalized volumes of subcortical grey matter regions.

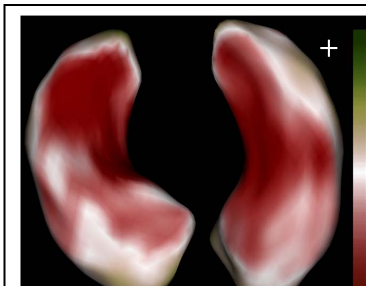

Figure 3: Shape analysis for the hippocampus. Red corresponds to contraction of the surface and green to expansion after death. The head of the hippocampus is shown at the bottom of the figure.

References: [1] Ardekani B.A., et al., Internat. Congress Series 2004;1265:49-59. [2] Goussias I.S., et al., Neuroimage 2008;40:672-684.