

A simple semi-automated method for caudate volume and shape analysis

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Introduction: Volumetric changes in structures of the brain such as the caudate nucleus have been implicated in a number of MR neuroimaging studies.¹⁻⁷ However, shape analysis may provide further information about structural neuroanatomy and brain development, complimenting the information available from volumetric measures. Shape may also represent a more sensitive marker for subtle differences in brain structure and development.⁸ Here we present a simple, semi-automated method for evaluating the volume and shape of the caudate nucleus, which can be applied to standard dual-echo or volumetric T1-weighted MR images. This method was applied to a group of 17 healthy adult subjects and the accuracy and inter-rater reproducibility of the method was assessed.

Methods: The subject group consisted of 17 healthy males (mean age 30 years, range 22-42), with no history of psychiatric or neurological illness. Imaging was performed with a 1.5 T GE Signa Echospeed MRI scanner (GE Medical Systems, Milwaukee, WI, USA). Structural MR images were acquired using a dual echo fast spin echo (FSE, TE=20/100 ms, TR=4 s, FOV=24 cm², matrix=256², slice thickness=3.5 mm, gap=0.5 mm) and a fast inversion-recovery prepared spoiled gradient echo volume (IR-SPGR, TI=450 ms, TE/TR=1.9 / 11 ms, slice thickness/gap=1.5/0 mm, FOV=24 cm², matrix=256², flip angle=90°). The IR-FSPGR and dual echo FSE images were segmented into grey matter (GM), white matter (WM), and cerebrospinal fluid (CSF) maps using statistical parametric mapping (SPM2, Wellcome Dept of Cognitive Neurology), and Brain Activation and Morphological Mapping (BAMM, <http://www-bmu.psychiatry.cam.ac.uk/BAMM>), respectively. The edge of the caudate was defined from the GM segmented images using an automatic contouring routine and then saved to a text file for further analysis. A locally written IDL programme (Research systems Inc, Boulder, CO, USA) was then used to read the contour file and calculate the perimeter and area of the caudate in each slice, and the overall caudate surface area (SA), volume (Vol), and surface area to volume ratio (SA/V). Finally, an image file containing the segmented caudate was then written out for 3-D display. The shape analysis was performed by 2 independent raters and the coefficient of variation (%CV) and intraclass correlation coefficient (ICC) were then used to assess the inter-rater reproducibility of the surface area, volume, and SA/V measurements.

Results: Figure 1 shows a 3-D rendering of the segmented caudate nucleus from a representative subject, in radiological orientation. The average caudate volume, surface area, and ratio measures are given in table 1. The volume measures are in good agreement with those reported previously⁹, and demonstrate the laterality differences described in previous studies, with the right caudate volume significantly larger than the left (p<0.005, paired t-test). In addition, significant laterality differences emerged for the surface area and SA/V ratio, with the right caudate surface demonstrating significantly higher SA and significantly lower SA/V (p<0.005, paired t-test), relative to the left caudate. The inter-rater reproducibility (quantified by the ICC and %CV) is given in table 2. The volume, surface area and ratio measures demonstrate comparable or improved reproducibility relative to that associated with manual tracing methods.⁹

Discussion: We have introduced a simple, semi-automated method for caudate volumetric and shape analysis. This method is quick and easily implemented in the subject's native space and demonstrates good reproducibility relative to manual tracing methods.

Table 1. Mean SA (mm²), Vol (mm³), and SA/V (mm⁻¹) across the subject group

| | SA (left) | SA (right) | Vol (left) | Vol (right) | SA/V (left) | SA/V (right) |
|------|-----------|------------|------------|-------------|-------------|--------------|
| Mean | 2155 | 2269 | 4618 | 5159 | 0.47 | 0.44 |

Table 2. Inter-rater Reproducibility

| | SA (left) | SA (right) | Vol (left) | Vol (right) | SA/V (left) | SA/V (right) |
|-----|-----------|------------|------------|-------------|-------------|--------------|
| ICC | 0.83 | 0.85 | 0.90 | 0.90 | 0.85 | 0.88 |
| %CV | 6% | 7% | 7% | 5% | 4% | 5% |

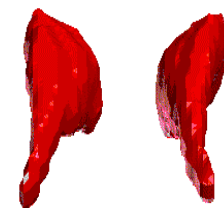


Figure 1. 3-D rendering of the left and right caudate nuclei from a representative subject (pictured in radiological orientation)

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