# Magnetic Resonance Imaging Deformation-Based Segmentation of the Hippocampus in Patients With Mesial Temporal Sclerosis and Temporal Lobe Epilepsy

Robert E. Hogan, Kevin E. Mark, Indrajit Choudhuri, Lei Wang, Sarang Joshi, Michael I. Miller, and Richard D. Bucholz

**We compared manual and automated segmentations of the hippocampus in patients with mesial temporal sclerosis. This comparison showed good precision of the deformation-based automated segmentations.**


MAGNETIC RESONANCE imaging (MRI)-based hippocampal volumetric measurements are helpful in the diagnosis and treatment of patients with mesial temporal lobe epilepsy. In the clinical setting of an epileptic seizure history compatible with mesial temporal lobe epilepsy, a significant hippocampal volume asymmetry is predictive of mesial temporal sclerosis, and a favorable outcome after epilepsy surgery.[1]

The difficulty in manual segmentations lies in the subjective interpretations of anatomical variations. The emerging field of computational anatomy founded on general pattern theory[2] provides tools and a framework for accommodating and studying this variability.[3] In this framework, an electronic atlas of the hippocampus is used as a deformable template, which is matched to an individual MRI to extract and study the individual hippocampal areas.

## MATERIALS AND METHODS

Five patients with mesial temporal lobe epilepsy had MR imaging. Hippocampal segmentations were performed twice for each hippocampus using both a deformation-based and manual technique. We then calculated the percentage overlap and hippocampal volume differences to compare the two segmentation techniques.

For the deformation segmentations, using a Unix-based software system (Broomfield, CO), the mapping algorithm employed a coarse-to-fine procedure for generating a transformation field from an atlas reference MRI to patient MRI. The "coarse" aspect of the procedure relied the landmark information provided by expert segmenters to provide an initial low-dimensional coregistration of atlas and patient images. The landmark information was provided in the form of the global and hippocampus-specific landmarks, which were used to derive a coarse manifold transformation from the reference to the patient images.

Having completed the coarse first step in the transformation, the volumes were roughly aligned and attention was focused on the fine-featured substructures. The "fine" procedure involved the next two steps. The second step was to solve the registration problem using a linear elastic basis formulation and the full-volume data, as previously described.[4] This was fully automatic and only driven by the volume data itself. The three-dimensional whole-brain maps corresponded to the maximizer, whose variation solution corresponded to a solution of a nonlinear partial differential equation (PDE), consisting of between $10^7$ and $10^8$ parameters. The third and final step of the algorithm was to solve the nonlinear PDE corresponding to the bayesian maximizer associated with the fluid formulation at each voxel of the full volume.[5]

## RESULTS

The overall percentage overlap between automated segmentations was 92.8 (SD 3.5), between manual segmentations was 73.1 (SD 9.5), and between automated and manual segmentations was 74.8 (SD 10.3). Absolute percentage volume differences between automated segmentations were 4.3 (SD 2.7), between manual segmentations were 13.3 (SD 11.0), and between automated vs. manual segmentations were 11.0 (SD 6.4). Table 1 shows volume measurements and between-method hippocampal volume differences.

## CONCLUSION

Manual and deformation-based segmentations produced comparable results in hippocampal segmentations. Deformation-based hippocampal segmentations for patients with mesial temporal sclerosis provide an efficient, precise, and reproducible method of hippocampal volume measurement.

*From the Department of Neurology and Division of Neurosurgery, Saint Louis University, St Louis, MO; IntellX, Broomfield, CO; Department of Psychiatry, Washington University School of Medicine, St Louis, MO; and Center for Imaging Science, Whiting School of Engineering, Johns Hopkins University, Baltimore, MD.*

*Address reprint requests to Robert E. Hogan, MD, 3635 Vista Ave, Department of Neurology, Saint Louis University, St Louis, MO 63110. E-mail: hoganr2@slu.edu.*


*0897-1889/00/1302-1058$10.00/0*
*doi:10.1053/jdim.2000.6897*

**Table 1. Volume Measurements and Between-Method Hippocampal Volume Differences**

| | Automatic Segmentation | | | Manual Segmentation | | | Between Method Percentage Difference |
|---|---|---|---|---|---|---|---|
| Hippocampus | A1 Volume (mm³) | A2 Volume (mm³) | Absolute Percentage Difference | M1 Volume (mm³) | M2 Volume (mm³) | Absolute Percentage Difference | |
| 1R | 2,622 | 2,765 | 5.5 | 2,512 | 2,397 | 4.6 | 4.4 |
| 2L | 2,592 | 2,429 | 6.3 | 2,792 | 2,513 | 10.0 | 7.2 |
| 3R | 3,240 | 3,423 | 5.6 | 2,984 | 3,349 | 12.2 | 8.6 |
| 4L | 2,306 | 2,224 | 3.6 | 2,433 | 2,494 | 2.5 | 5.2 |
| 5R | 2,863 | 2,908 | 1.6 | 2,704 | 3,324 | 22.9 | 5.9 |
| 1L* | 1,537 | 1,687 | 9.8 | 1,880 | 1,294 | 31.2 | 18.2 |
| 2R* | 1,696 | 1,741 | 2.7 | 1,431 | 1,387 | 3.1 | 18.5 |
| 3L* | 1,307 | 1,292 | 1.1 | 1,605 | 1,239 | 22.8 | 18.6 |
| 4R* | 1,683 | 1,763 | 4.8 | 1,427 | 1,430 | 0.2 | 17.9 |
| 5L* | 1,553 | 1,527 | 1.7 | 1,646 | 1,256 | 23.7 | 5.7 |
| Normal hippocampi | | | | | | | |
| Mean | 2,725 | 2,750 | 4.5 | 2,685 | 2,815 | 10.4 | 6.2 |
| SD | 349 | 463 | 1.9 | 221 | 478 | 8.0 | 1.7 |
| Sclerotic hippocampi | | | | | | | |
| Mean | 1,555 | 1,602 | 4.0 | 1,598 | 1,321 | 16.2 | 15.8 |
| SD | 157 | 196 | 3.5 | 186 | 84 | 13.7 | 5.7 |
| Overall | | | | | | | |
| Mean | 2,140 | 2,176 | 4.3 | 2,141 | 2,068 | 13.3 | 11.0 |
| SD | 667 | 692 | 2.7 | 604 | 851 | 11.0 | 6.4 |

## REFERENCES


1. Watson C, Jack CR Jr, Cendes F: Volumetric magnetic resonance imaging. Clinical applications and contributions to the understanding of temporal lobe epilepsy. Arch Neurol 54;1521-1531,1997

2. Grenander U: General Pattern Theory. London, UK, Oxford University Press, 1993

3. Miller MI, Grenander U: Computational anatomy: An emerging discipline. Q Appl Math 5:617-694, 1998

4. Christensen GE, Rabbitt RD, Miller MI: (3D) Brain mapping using a deformable neuroanatomy. Phys Med Biol 39:609-618, 1994

5. Christensen GE, Joshi SC, Miller MI: Volumetric transformation of brain anatomy. IEEE Trans Med Imaging 16:864-877, 1997