Yonsei Medical Journal
Vol. 41, No. 3, pp. 299−303, 2000

Original Article

Three-Dimensional Image and Virtual Dissection Program of the Brain Made of Korean Cadaver

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Abstract

The three-dimensional (3D) structure of the brain needs to be understood for accurate diagnosis and treatment of brain diseases. The brain of a cadaver may not always be available for dissection when it is needed. To overcome this problem, we attempted to create a 3D image and virtual dissection program of the brain using a Korean cadaver. The brain extracted from a Korean male cadaver was embedded in gelatin solution. 130 MRI of the brain were taken and 130 serially-sectioned specimens were made. All of MRI and specimens were inputted into the computer, and 10 brain components were manually segmented. A 3D image and virtual dissection program of the brain was made. Various virtual dissection functions were established, such as 1) sectioning the 3D image of the brain at free angles to represent its plane as a real image, segmented image, and MRI, 2) identifying the brain components represented in the sectioned plane, and 3) rotating the 3D image of the whole brain or the selected brain components at free angles. The resulting virtual dissection program of the brain is helpful in better understanding the 3D location and shape of the brain components and it is expected to be used as a CD-title or through Internet as an educational tool for medical students and doctors.

Key Words: Three-dimensional image, virtual dissection, brain, Korean, cadaver

INTRODUCTION

In order to attempt accurate diagnosis and treatment of brain diseases, an understanding of the three-dimensional structure of the brain is required. Two-dimensional (2D) tools (e.g. anatomy books) or traditional 3D tools (e.g. plastic models) are not sufficient for understanding the 3D structure of the brain, yet the brain of a cadaver is not always readily available for dissection. To overcome this problem, virtual dissection programs of the brain have been made. However, most programs include either 2D images, which do not permit free dissection, or radiographs, which do not reveal true color and have limited resolution.[1] Moreover, it is necessary to make a separate virtual dissection program of each race. Thus, we attempted to create a 3D image and virtual dissection program of the brain using a Korean cadaver in order to help medical students and doctors better understand the 3D structure of the brain.

Received September 10, 1999
Accepted January 27, 2000
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MATERIALS AND METHODS

A brain extracted from a Korean cadaver (58-year-old male) was used as material (Fig. 1).

A brain block was made by embedding the brain in gelatin solution. After making the embedding box of acrylic plates, the brain was embedded in gelatin solution (14 gm%) and frozen. After removing the embedding box, brain block was put in formalin solution to become suitably solid at room temperature.

MRI of the brain were acquired and inputted into the computer. The brain block was serially-scanned at intervals of 1.4 mm-thickness using the MRI system (Signa Horizon 1.0 Tesla MRI System, G.E.™), which resulted in 130 MRI (proton weighted image). The MRI were inputted into the computer using a pi-view program with 300×360 resolution and 16 bit gray scale color.

Subsequently, serially-sectioned specimens of the brain were acquired and inputted into the computer.

The brain block was serially-sectioned into 1.4 mm-thick slices using a meat slicer (HFS-330L, FUJEE^{TM}), which resulted in 130 sectioned specimens. The sectioned specimens were inputted into the computer using a scanner (ScanJet 4c, Hewlett Packard^{TM}) with 300×360 resolution and true color. The images of the sectioned specimens were called the real images. The real images, which appeared in zigzag form, were aligned on the basis of MRI.

The real images of ten brain components (cerebrum, cerebellum, brain stem, lentiform nucleus, caudate nucleus, thalamus, optic nerve, fornix, cerebral artery, and ventricle) were manually segmented by an anatomist. After printing the real images on paper, the outlines of the brain components were drawn using a pen. Based on the drawn papers, the outlines of the brain components were drawn using a computer mouse with the CorelDRAW program (version 8.0). After segmentation, three sets of 2D images (real images, segmented images, and MRI) were prepared (Fig. 2).

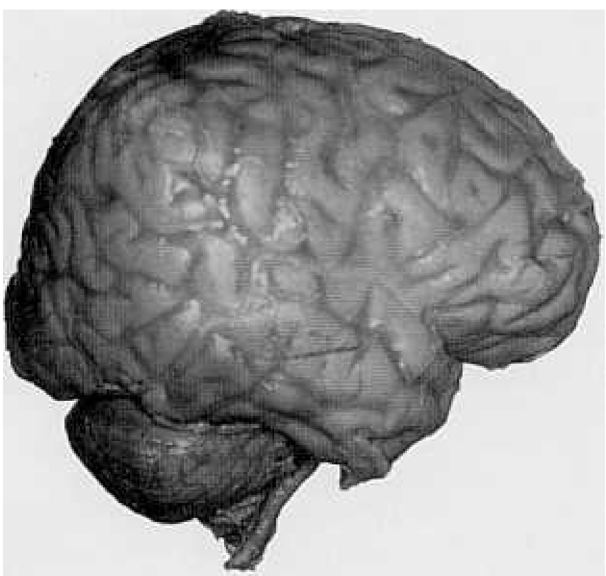

Fig. 1. Brain used as the material.

Text comments about the brain components were written and inputted into the computer. For example, the text comment about the brain stem was 'Brain stem is densely packed with many vital structures such as long ascending and descending pathways, and specific nuclear groups including the nuclei of the cranial nerves'.

A three-dimensional image and virtual dissection program of the brain was made. After stacking 2D images of the brain, a 3D image was reconstructed through volume-based rendering. Using the 3D image of the brain as the main feature, a virtual dissection program operating on the personal computer Windows 98 system was composed. The programming language for making the 3D image and virtual dissection program was IDL (version 5.0).

RESULTS

On the virtual dissection program, the 3D image of the brain could be sectioned orthogonally (horizontally, coronally, and sagittally) or at free angles. The sectioning was also possible after rotating the 3D image of the brain. The sectioning was followed by its plane represented as a real image, segmented image, and MRI (Fig. 3).

It was possible to zoom in on the sectioned plane of the brain. The zooming plane could be represented by the nearest neighbor method in which pixels were distinguished or by the bilinear method in which

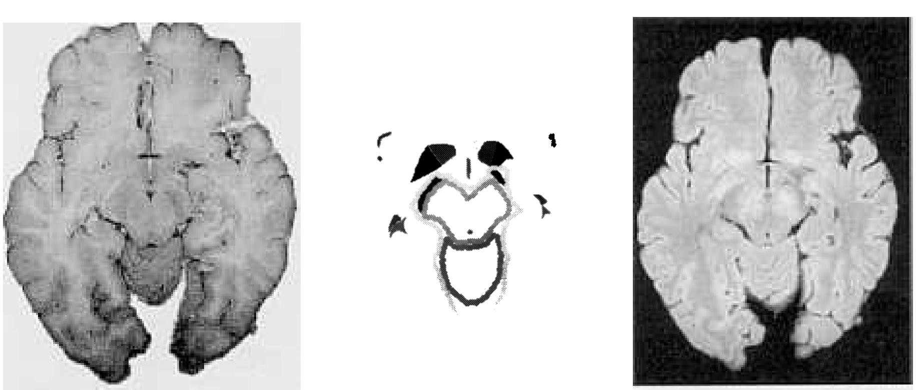

Fig. 2. Real image (left), segmented image (middle), and MRI (right) of the brain.

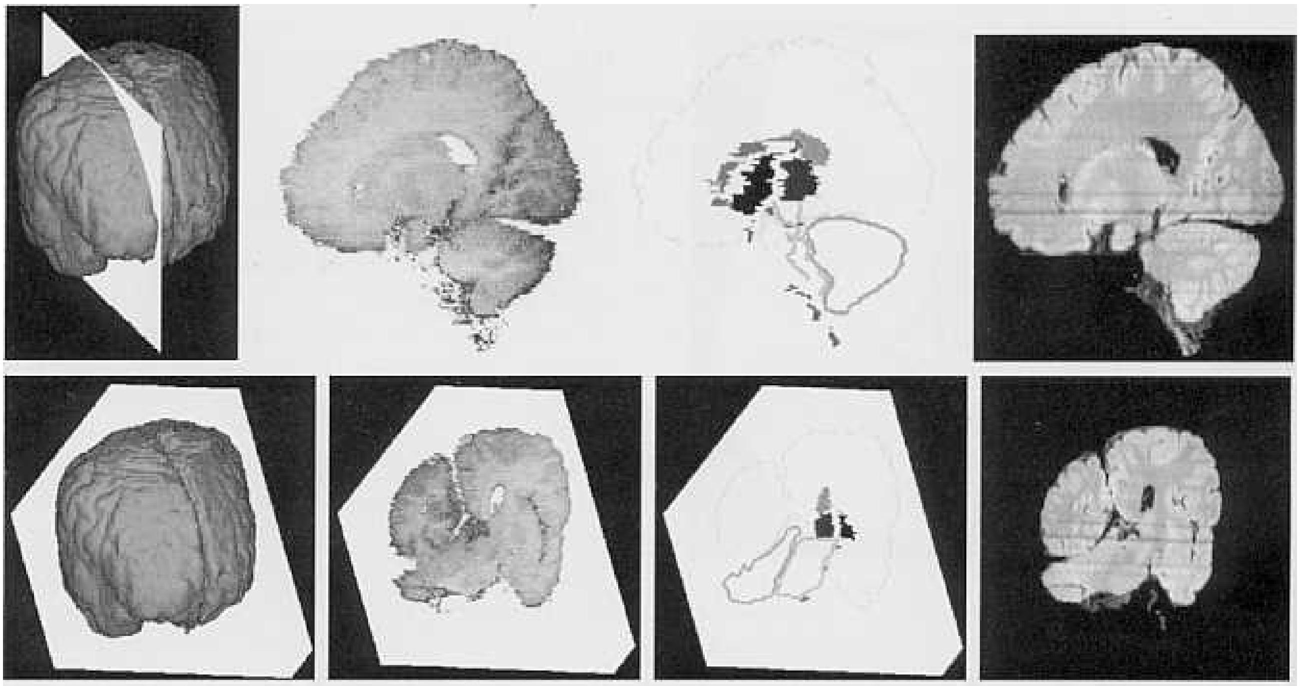

Fig. 3. Sagittal sectioning (top row) and free angle sectioning (bottom row) of 3D images of the brain, followed by their planes represented as real images (second column), segmented images (third column), and MRI (fourth column).

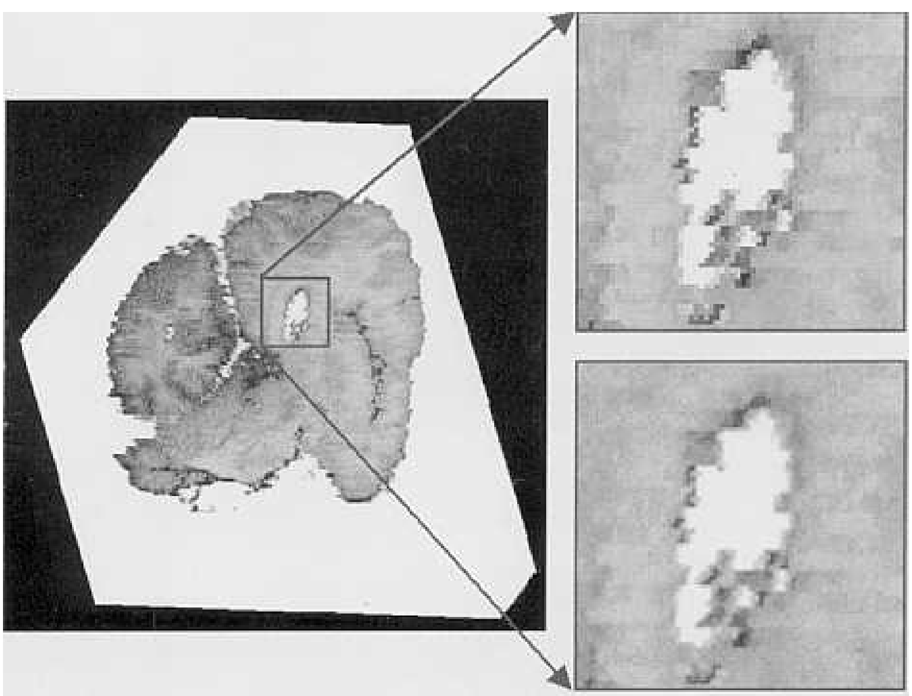

Fig. 4. Sectioned plane of the brain (left) and its zooming plane represented by the nearest neighbor method (right top) or by the bilinear method (right bottom).

pixels were not distinguished. The bilinear method compensated for the relatively low image resolution (Fig. 4).

If a brain component was selected by the computer mouse in the sectioned plane, text comment about the selected component appeared, a helpful function in identifying the brain components represented in the sectioned plane (Fig. 5).

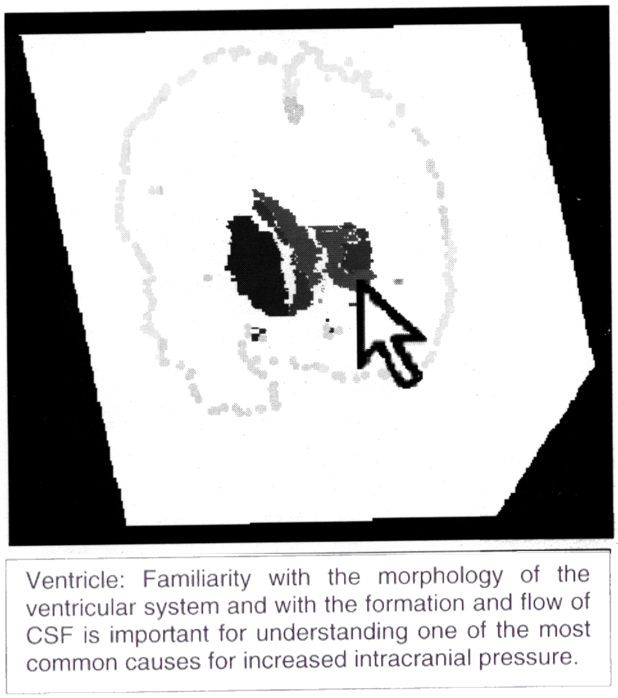

Fig. 5. *Sectioned plane of the brain (top) and text comment about a selected brain component (bottom).*

The three-dimensional image of the whole brain and that of the selected brain components could be rotated at free angles (Fig. 6).

DISCUSSION

For the purpose of accurate diagnosis and treatment of brain disease, one of the leading causes of death, it is essential for doctors to understand the 3D structure of the brain. To understand this structure, medical students and doctors have used various methods. Firstly, an anatomy atlas; however, a 2D anatomy atlas does not provide sufficient information/ perspective for understanding the 3D anatomical structure. Secondly, an anatomy model; however, an anatomy model is not detailed, and does not permit free sectioning. Thirdly, cadaver dissection; however, cadaver dissection is not always available even to medical students and doctors. Fourthly, a virtual dissection program including 3D image; however, previously released virtual dissection programs have had some problems.

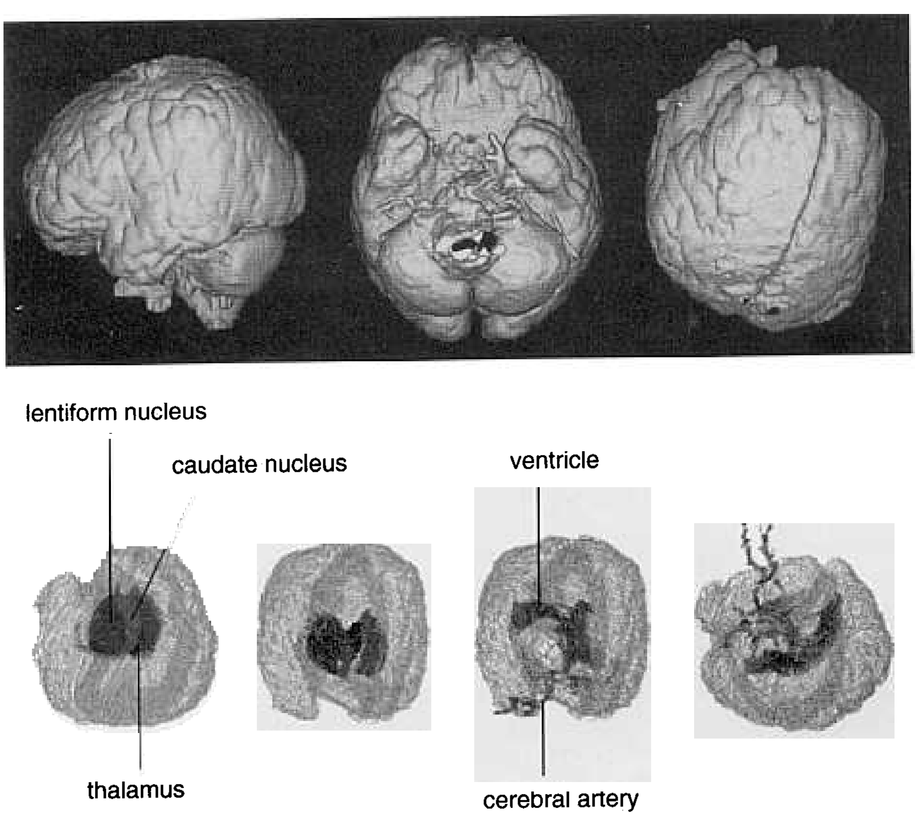

Fig. 6. *Free angle rotation of 3D image of the whole brain (top row) and the selected brain components (bottom row).*

In this study of making a new virtual dissection program, the following materials and methods were used to overcome the problems of the previous virtual dissection programs.

First, a Korean brain was used. The shape and size of human organs differ according to race. Thus, the virtual dissection program made of a Korean brain is more helpful in diagnosis and treatment of Korean patients than that made of a foreigner's brain. In this respect, the Visible Human data made of American subjects is not suitable in Korea.[2]

Second, a new serially-sectioning method was developed. To make serially-sectioned specimens of a large human organ like the brain, the serially-grinding method using a cryomacrotome after freezing, which was used for making the Visible Human data,[2] and the serially-sectioning method using a polycut after embedding in celloidin solution[3,4] have been developed. However, in this study, a new serially-sectioning method using a regular meat slicer after embedding in gelatin solution was developed. This method is cheap, quick, and able to make permanent models of serially-sectioned specimens.

Third, both real images and MRI of the cadaver were used. The real images reveal true color and have no limit in resolution unlike MRI. Thus, the virtual dissection program involving real images produces more realistic images than that involving MRI.[1] It is desirable to create such a virtual dissection program, involving not only real images but also MRI, which is helpful in studying brain MRI (Fig. 2 and 3). Furthermore, MRI is helpful in aligning the real images.

Fourth, the brain components are manually segmented. Manual segmentation, which has the disadvantage of being time consuming, has the advantage of accuracy.[5] Manual segmentation is suitable in medical education or research while automatic segmentation is suitable in clinics. Semiautomatic segmentation involving the advantages of both manual and automatic segmentations will be more desirable.[6,7]

Fifth, virtual dissection is possible on the personal computer. This virtual dissection program can be used on any personal computer, and can be easily improved by adding new functions. On the other hand, virtual dissection programs belonging to 3D CT or MRI system can not be used on any personal computer, and can not be easily improved.[8]

This virtual dissection program of the brain is helpful in better understanding the 3D location and shape of the brain components; it is expected to be used as a CD-title or through the Internet as an educational tool for medical students and doctors.

In the future, this virtual dissection program will be improved as advances are made in computer hardware and software. The image resolution can be raised and the virtual dissection function can be enhanced with the development of rapid personal computers and good programming algorithms.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the technical support of Ji Hyung Kim, Department of Radiology, Ajou University School of Medicine and the financial support of Ajou University Graduate School of Medicine (1997).

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