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3-D RECONSTRUCTION OF THE HUMAN COCHLEAR NUCLEAR COMPLEX

Hubert Martin, Karl Roth, Günter Wolf, Peter Hufnagl, Hans-Jürgen Gerhardt (*), Torsten Bätz (*)

Institute of Pathology and Clinic of Otorhinolaryngology (*), Humboldt-Universität (Charite), Schumannstrasse 20/21, 1040 Berlin, GDR

ABSTRACT

A report is given about a computer-aided 3-D reconstruction of the human cochlear nuclear complex. The structure of the cochlear nuclei is of growing interest, since it appears that it might be possible to electro-stimulate them by direct placement of an electro-auditory prosthetic device. The study is based on normal human brains of adults. A simplified system for serial section three-dimensional reconstruction using a picture processing system is described. Line drawings and continuous tone shaded images of a 3-D solid model of a cochlear nuclear complex are generated.

This study will contribute to a better understanding of the surface structure of the cochlear nuclei and will give some help towards the construction of an electro-auditory prosthesis.

Keywords: Cochlear nuclei, computer graphics, 3-D reconstruction

INTRODUCTION

From the very beginning of computer graphics development neuroscientists have been interested in the application of this new method to three-dimensional reconstruction of brain anatomy. They used computer graphics for an investigation of the whole brain as well as of parts of it based on serial light microscope specimens (Ware and LoPresti, 1975; Afshar and Dykes, 1982; Giorgi et al., 1982; Johnston and Capowski, 1983; Villa et al., 1987).

Among the anatomical structures in the cerebellopontine and pontobulbar area the cochlear nuclear complex has become of increasing interest, since it seems to be possible to electrostimulate the cochlear nuclear complex by direct placement of a central electro-auditory prosthesis to it. The potential recipients of such devices will be patients deafened from the bilateral loss of the cochlear nerves because of bilateral acoustic neurinomas. Since maximal stimulation should be reached, the surface and geometry of the electro-auditory prostheses have to be fitted to the shape of the cochlear nuclear complex. For this purpose investigations about the exact surface and structure of the cochlear nuclear complex are necessary.

Up to now Terr and Edgerton (1985 a, 1985 b) from the House Ear Institute of Los Angeles have contributed most to a better understanding of the three-dimensional structure of the cochlear nuclear complex in man. In this paper we describe our method for getting more accurate structural information about this nuclear complex.

MATERIAL AND METHOD

The material for this study consists of four brains from adults, who died from various diseases without brain involvement. In gross anatomy the brain proved unchanged, in particular the brain stems appeared normal and without any variations. The brains were fixed in 10% formaldehyde solution for at least three weeks after death.Tissue blocks including the pontobulbar junction, where the cochlear nuclei are located, were then dissected out from the entire brain and embedded in paraffin. The whole length of such specimens was about 20 mm. For orientation during the reconstruction three holes 0.5 mm in thickness were drilled through the paraffin blocks. The tissue blocks were cut perpendicular to the ventral surface of the pons and medulla using a rotation microtome. The sections were about 10 um in thickness. Every tenth specimen was stained with cresyl violet after Nissl. In one case additional to this a staining with Luxol fast blue according to Klüver and Barrera (1953) was done. Three series served for studying the boundaries of the cochlear nuclei and their relationship to the surrounding structures. One series was used for computerized three-dimensional reconstruction.

Today the 3-D reconstruction of bilogical structures has largely been overcome by advances in computer technology. However there is always the problem of a detailed yet economical data entry into the computer. Our method of data aquisition works directly on the microscopic picture of the histological slide and no tracing of the relevant structures onto graph paper is necessary.

The hardware system used for reconstruction is built around the A6471 image processing system and is completed by a digitizer and a scanning table for the microscope. All programs were developed at the author's institute and are all written in the "LAMBA" language. This is a special language for picture processing also developed at the author's institute (Roth and Wenzelides, 1989). The contours are entered into the computer using a light microscope with a drawing tube directed at the video screen. Data is digitized by tracing the boundary of the nuclei in microscopic picture using the image of the video screen cursor in the drawing tube. The resolution of data entered is not limited by the resolution of the graphics board in the computer. Where contours travel off the area covered by one microscopic field, we use the scanning stage to move the slide. Points from the adjacent area can now be digitized with an offset measured by the computer. The digitizer has both continuous and single point modes. We use the single point mode so that a point is recorded every time the operator presses the digitize key on the cursor producing a set of points describing a polygon for closed contours. The end of contour is reported to the program by pressing another key of the cursor.

The data from each section is stored in a constant-length array. Each section array contains also the coordinates of the three landmarks. After the acquisition of all contours the alignment of the sections was realized using these landmarks. On the basis of this transformed data the computer calculates an image of the cochlear nuclei area in 3-D space and displays a two-dimensional projection of that image on the video screen. A special algorithm removes the hidden lines in the picture. After each view is drawn, the user may enter new (x, y, z) rotation coordinates and the model is redrawn on the screen.

RESULTS

The described method has been used to create a reconstruction of the human cochlear nuclear complex. The average number of points per section was near 200 and the aquisition of one section lasted about 10 minutes. We digitized 40 sections starting at the caudal plane. Line drawings of the reconstructed model are shown in Fig.1, which provides an impression about the surface structure of cochlear nuclei from various positions. In Fig.2a continuous tone picture of the cochlear nuclear complex is shown.

DISCUSSION

Recent advances in computer graphics technique have made possible imaging of three-dimensional structures. In otology, three-dimensional computer graphics were used for getting more exact information about the anatomy of the temporal bone (Casper et al., 1987; Archer et al., 1988; Ohmichi et al., 1988; Harada et al., 1988), the cochlear nerve root (Sinha et al., 1987), and the cochlear nuclear complex (Terr and Edgerton, 1985 a, 1985 b). In this paper our own method for creating a reconstruction model of the cochlear nuclear complex is described.

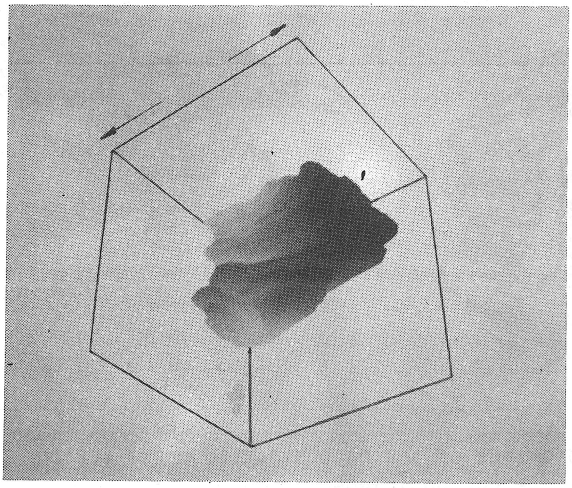

Fig. 1. Continuous tone picture of the cochlear nuclear complex.

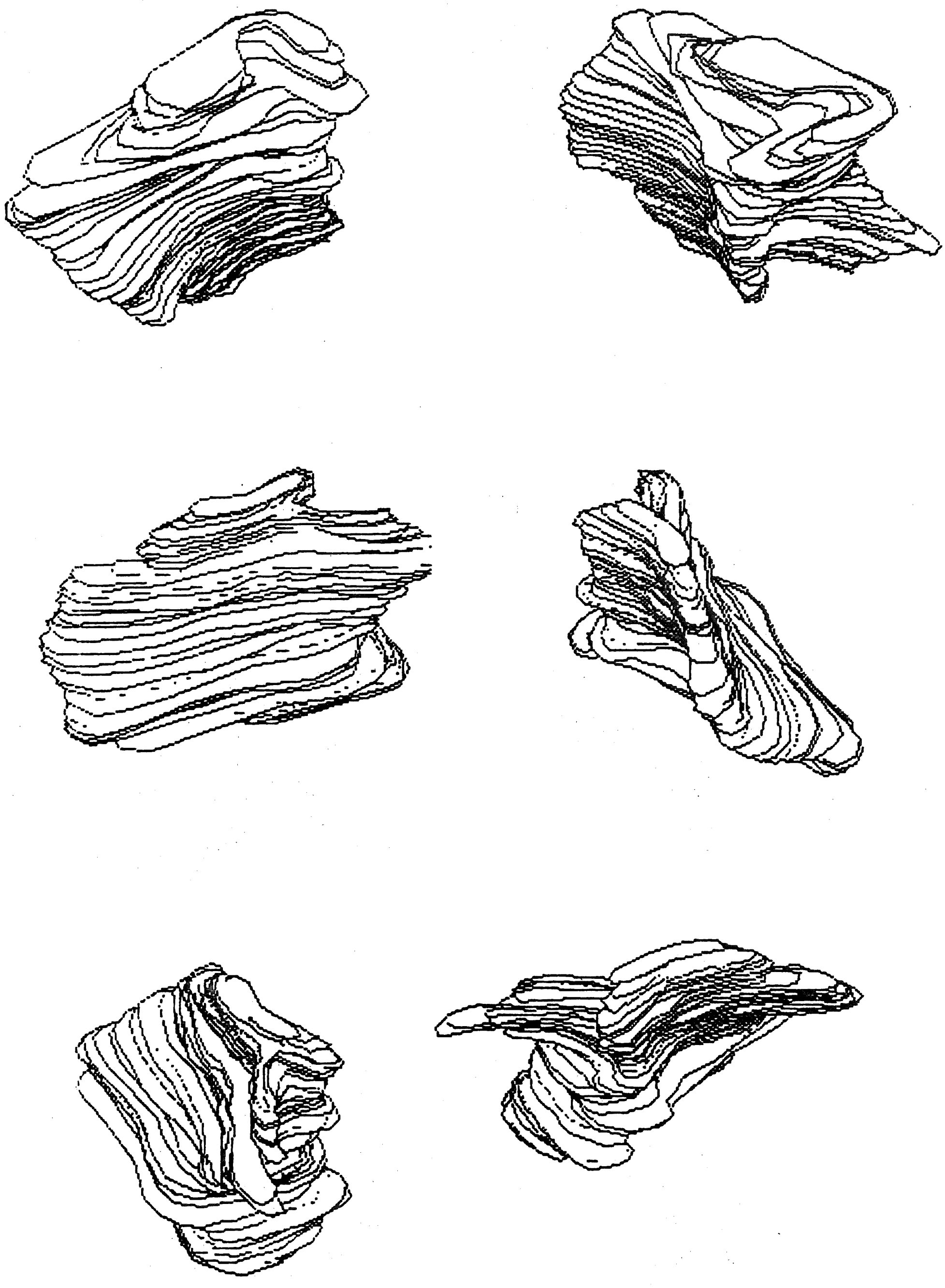

Fig. 2. Line drawings of the reconstructed model seeing from different positions.

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