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585

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Three-Dimensional Reconstruction of the Cochlea and Temporal Bone[1]

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In recent years, cochlear implantation has become an established method for the auditory rehabilitation of profoundly deaf patients and is used in ever more and younger patients.

High-resolution computed tomography is performed routinely on all prospective cochlear implant patients and provides important information about cochlear or mastoid pathology that will enable the surgeon to select a side for operation and alert him to surgical obstacles he might encounter [1–4]. In analysing the CT films he must still try to form a three-dimensional image in his mind by looking through a large number of different pictures [5]. Consequently, to make it easier to understand, we applied our own image analysis system to produce three-dimensional reconstructions of temporal bones from CT scans [6]. We focused on the use of this method for the preoperative examination and surgical planning for cochlear implantation as well as for our research purposes. This system and the results are presented here.

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Methods

Input for the reconstructions can be any series of CT scans. The images are usually stored on X-ray films, but can also be saved on magnetic tapes or floppy discs. This information can easily be transferred to a personal computer. These video images are then digitized and stored on the personal computer. By transferring the image data onto our independent workstation, we overcome the problem of blocking valuable scanning time on the CT scanner computer. The program now allows the interpolation of a variable number of slices and either automatic, interactive or manual edge detection in the CT images. By selecting regions of interest on a particular scan, these features can be easily recognised in the following three-dimensional reconstruction. For instance, the ossicles, the round window and the facial recess can be highlighted by being plotted alone or in a different color than the surrounding structures. To enhance the three-dimensional appearance of the object shading can be added with a virtual light source from any angle and at any intensity. The most plastic three-dimensional appearance image, however, can be achieved by producing a video imitating rotation of the object. Within the display mode of the reconstruction program the user can rotate the object around all axes, zoom and move it, cut off a section at any level, or drill a hole to display otherwise hidden structures. In figure 1, the posterior part of a reconstructed temporal bone is cut off to show parts of the labyrinth and middle ear cleft with the ossicles.

By defining points of interest with the computer mouse, distances and angles can be calculated even after additional rotations, magnifications, drilling, etc. and can thereby provide important information for the surgeon planning the cochlear implant operation. This was used to determine the accuracy of our three-dimensional reconstruction system.

Results

The CT scan images of six cadaver temporal bones from children of different age groups were recorded, digitized and transferred onto our microcomputer. We selected several anatomical and surgical landmarks relevant for cochlear implant surgery in children, measured the distances between them using our reconstruction program and compared the calculated data with those yielded by direct calliper measurements after anatomical dissection of the same bones. The results show close correlation between the two sets of data, and we intend to use this method for the evaluation of the long-term effect that cochlear implantation may have on the growing skull. In 1991, we could harvest the temporal bone from an adult patient that died of unrelated cause several years after implantation. A CT scan was performed on this autopsy bone prior to histological processing. The resulting reconstructions are shown in figures 2 and 3.

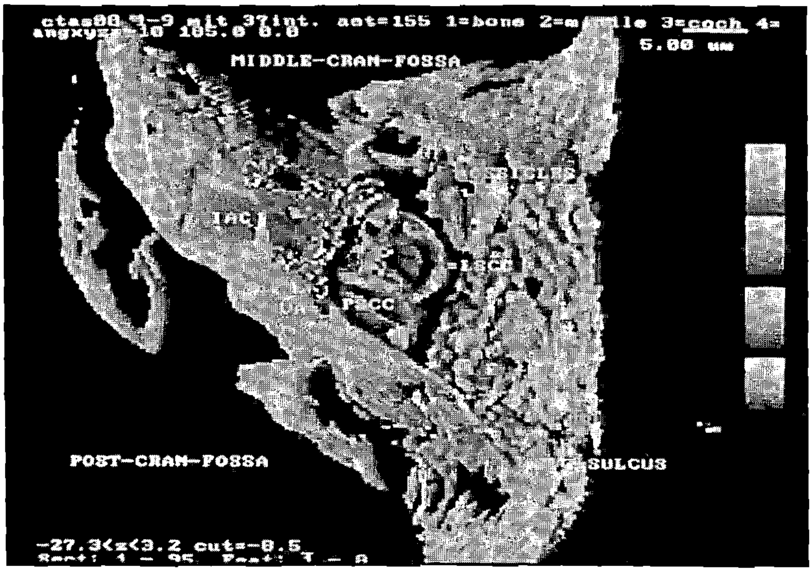
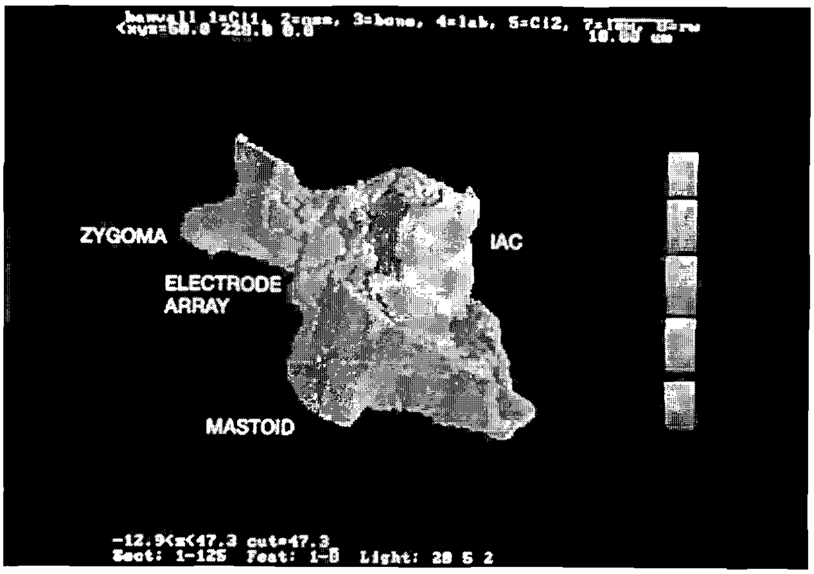


Fig. 1. Reconstructed image of a cadaver temporal bone with parts cut off to display otherwise hidden structures of the inner and middle ear.

In the reconstruction of the whole temporal bone you can easily see the mastoidectomy cavity and the electrode array in situ (fig. 2). By only displaying the electrode array, the ossicles and the inner ear spaces, the orientation of the implant inside the inner and middle ear becomes obvious (fig. 3).

In comparison to these postmortem studies, we could also reconstruct the temporal bone of a living implantee. In an 8-year-old child with a bilateral Mondini's malformation of the inner ear we performed a CT scan postoperatively and used this series for our reconstruction. Here also the receiver/stimulator is easily recognized. In the mastoid cavity the electrode array builds a loop to accommodate the expected growth of the skull and even the thin platinum wire used in Melbourne for the fixation of the electrode array at the fossa incudis is visible.

The presented system can be used without modification for the reconstruction of any set of serial section as MRI or histological sections. By connecting the video camera to a microscope we were able to examine a



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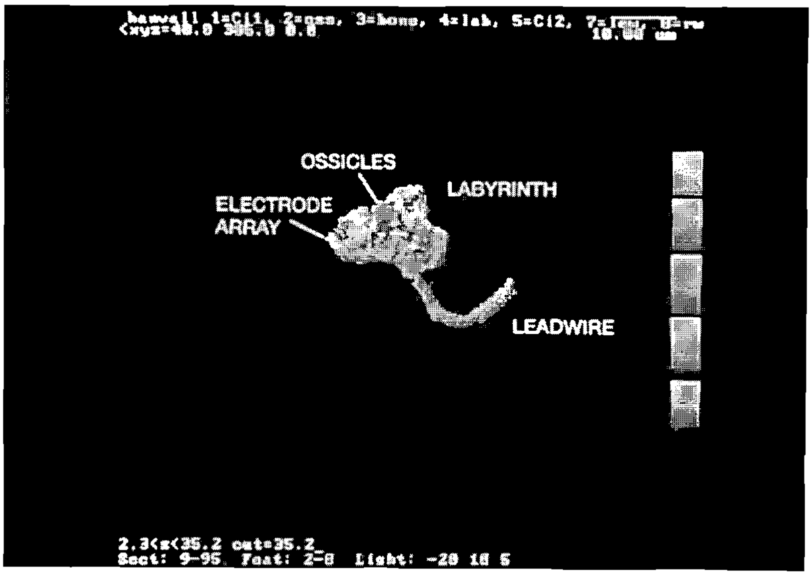

3

Fig. 2. Three-dimensional reconstruction of the cadaver temporal bone of a cochlear implant patient displaying the mastoidectomy cavity and the electrode in situ.

Fig. 3. The same object as in figure 2. Only the cochlear implant, the inner ear spaces and the ossicles are plotted, displaying the orientation of the electrode array in the inner and middle ear.

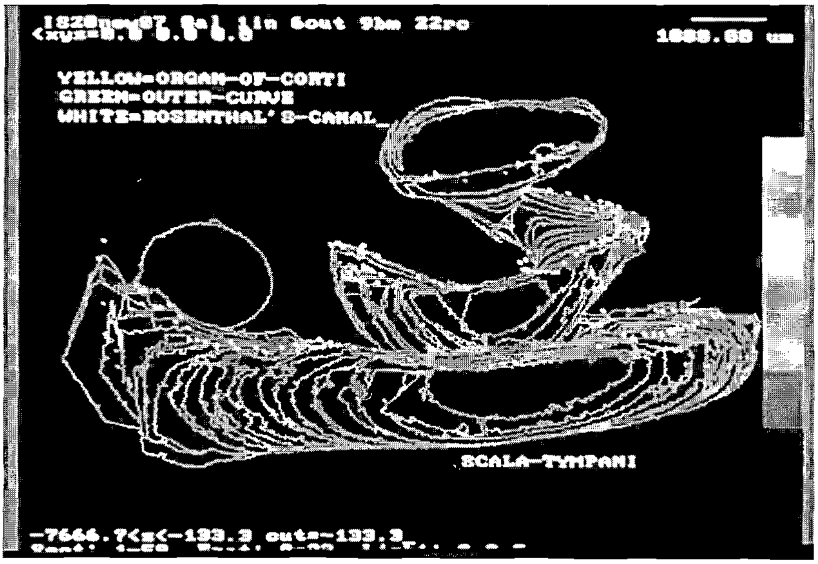

Fig. 4. Reconstruction of serial histology sections of a cochlea showing the spatial orientation of different structures.

series of histological sections of the cochlea. The resulting reconstruction is shown in figure 4.

The spatial relationship between the organ of Corti, the scala tympani and the spiral ganglion cells in Rosenthal's canal are visualized. Measurements along these structures can provide important information for future cochlear implant electrode design.

Discussion

By its nature the three-dimensional reconstruction can only detect features already present on the plain two-dimensional CT scan. But we believe it facilitates significantly the conceptualisation of the complicated anatomy of the ear and supplements plain CT scans. The presented program is an accurate and rapid method, providing helpful information for the implant surgeon and the researcher with interest in the anatomy of the temporal bone and cochlea.

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