ENHANCEMENT OF THE RADIOGRAPHIC CHANGES IN THE OTIC CAPSULE AND COCHLEA DUE TO OTOSCLEROSIS USING THREE DIMENSIONAL RECONSTRUCTION OF CT SCANS

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The otic capsule changes of cochlear otosclerosis are occasionally such that standard high resolution CT scans are not clear enough to determine the significance of edge blurring as a predictive factor for implantation. The use of a software package to produce three dimensional enhancement of the CT images has resolved some of these difficulties in specific cases.

Otosclerosis is associated with new bone formation in the cochlea and demineralization of the otic capsule. The images produced by high resolution CT scans have not been clear enough to define the better ear for cochlear implantation in some of these cases or to evaluate the number of electrodes that could be inserted, or the possibility of stimulating the facial nerve. The new bone may be confused with the blurring of sharp edges from the scanner's averaging technique. The decalcification can make it difficult to distinguish the cochlea's outline. We have found that three dimensional enhancement of CT scan images by the use of a software package developed in the Human Communication Research Centre has resolved some of these difficulties.

The software package was originally developed for use in histology in order to reconstruct the tissue in three dimensions (3-D) from microscopic sections and x-rays (Seldon 1991). It has now been applied to the examination of CT scans of the ear. The technique was successfully applied to the reconstruction of computerised radiographic scan (CT scan) images of the temporal bone (Dahm et al 1992, 1993). The technique has been applied preoperatively to the assessment of patients deafened by otosclerosis. In addition, the detail of the cochlea disclosed by the technique was compared with the detail produced in Magnetic Resonance Images (MRI) of these cases (Pyman 1995).

Method

The original CT scans are prepared as high resolution images, with bone contrast, at 1 to 1.5mm intervals in both the coronal and axial planes. The digital data to be used in the reconstruction software is derived either by recording the data from the scanner or by taking a video image from the emulsion films produced by the scanner. When the data is copied to a tape and transferred to the personal computer, it may be necessary to convert the scanner's format to a form compatible with the computer and the quality of the resolution is preserved. When the data is recreated by a frame grabber from the films, the process is time consuming and the quality of the final image is coarser. Within the software package, the image of the cochlea is reconstructed by setting the program to detect the boundary between fluid and bone in the region of the cochlea for each CT slice. The boundary is defined on the basis of the gray scale representing the radiotranslucency of water, bone and new bone. The program overcomes the blurring of these boundaries found in the emulsion images by interpolating several new images between each of the original cuts. The process may be repeated for other structures, such as the internal meatus or severely otospongiotic bone, in the otic capsule. Each structure may be coloured differently in the reconstruction. Finally, the 3-D image may be rotated in steps or continuously and presented on either the computer or television screen.

The patients in this study were two adult males who had been totally deaf for less than five years. Patient 1 had irregularity of the edges of the cochlear spiral in both ears, but particularly the left ear. The changes were suspicious of new bone formation but at no point did the opacity cross from side to side of the cochlear spiral itself. The image appeared as an irregularity of the wall of the cochlear spiral which made the changes difficult to distinguish from the averaging effect of the CT scanner. The changes were noticeable in both axial and coronal sections (Figure 1). Patient 2 had irregular curvilinear demineralization of the otic capsule so as to produce the “double barrel appearance”. The
irregularity made it difficult to know which area of radiotranslucency in the otic capsule represented the cochlear lumen. We could not be sure whether the calcium visible on the scan was the result of new bone formation in the cochlea (Figures 2 and 3).

Results

The result of three dimensional enhancement of the images for Patient 1 gave clear cut evidence for obstruction of the basal turn of the cochlear (Figure 4). The software package was set to detect fluid-filled regions within the bony structure. Thus, the cochlear lumen, otosclerotic lesions, the internal auditory meatus, etc. would be displayed. A bony obstruction in the cochlear lumen appears as an 8 mm long gap in the fluid space of the lower basal turn, a gap through which the internal auditory meatus can be seen. We interpreted this appearance as a gross obstruction of the basal turn and implanted the other ear. Only a small amount of bone was encountered in the basal turn and the array passed to a depth of 24 mm. For Patient 2, the reconstruction showed a naturally shaped cochlear spiral of a normal width without new bone accumulation but with extensive otosclerotic lesions around the internal auditory meatus (Figure 5). No new bone was found at the operation and the array passed to 24 mm.

Discussion

The 3-D reconstruction procedure is not necessary for all cases as the CT scan images, presented life size and at 1 mm intervals, are usually adequate. The preparation of 3-D images is time consuming but worthwhile in some circumstances. One such circumstance would be any case in which there is a vague spatial relationship of lesions or obstructions to the cochlea, the facial nerve or other intricate temporal bone structure. Then the advantage of different viewing angles, different feature...
Three dimensional reconstruction of the same ear of Patient 1. The software has not detected a fluid bone boundary for about 8 mm along the basal turn. As a result, the image of the cochlea was comprised of fluid space at the round window and a separate space representing the upper basal turn continuing as the middle and apical turns. The new bone had the effect of making a part of the basal turn transparent, so that a larger part of the internal meatus could be seen instead.

**FIG. 3.**

**FIG. 4.** Three dimensional reconstruction of the same ear of Patient 1. The software has not detected a fluid bone boundary for about 8 mm along the basal turn. As a result, the image of the cochlea was comprised of fluid space at the round window and a separate space representing the upper basal turn continuing as the middle and apical turns. The new bone had the effect of making a part of the basal turn transparent, so that a larger part of the internal meatus could be seen instead. Bar upper right = 10.00 mm.
“colours” and the spatial perception enabled by video motion sequences becomes considerable. As demonstrated here, we have found that clinical assessment of patients with severe bony changes from otosclerosis has been significantly aided by the 3-D technique.

References

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FIG. 5. Three-dimensional reconstruction of the right ear of Patient 2. The software discriminated between the regions of translucency caused by cochlear fluids and demineralization of the osic capsule, with the result that the outline of the whole cochlea is sharp.
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