been published. An incident involving a 61-year-old male user of the Nucleus 22-channel cochlear implant system provides experiential evidence of the effects of defibrillation and its impact on cochlear implant use, a Nucleus 22-channel patient suffered complete cardiac arrest, requiring cardiopulmonary resuscitation and repeated defibrillation. The maximum number of joules available for defibrillation (500) were required to restore his cardiac function. The patient suffered no other cardiac arrests during his recovery and returned to work on a half-day schedule on March 1, 1993. Complaining that he needed a new program (map), he returned to his implant center for reprogramming of his mini speech processor on April 29, 1993. As displayed in Table 1, the minor changes measured in his electrical thresholds and comfort levels were no more than those frequently observed at reprogramming sessions. When he received the new MPeak map, his cochlear implant performance returned to previous levels. His auditory performance scores before and after defibrillation are remarkably similar, as detailed in Table 2. He has continued to use his device without incident, and his electrical levels have remained stable, as shown in Table 3.

CONCLUSION

In summary, this user's experience suggests that the administration of defibrillation does not significantly affect the functioning of a Nucleus 22-channel cochlear implant system. If a Nucleus 22-channel user does undergo defibrillation, routine reprogramming of the speech processor should be conducted after recovery. No special testing or treatment appears to be required.

TABLE 3. CURRENT T LEVELS AND C LEVELS FOR PATIENT

<table>
<thead>
<tr>
<th>Electrode</th>
<th>T Level</th>
<th>C Level</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>61</td>
<td>99</td>
<td>38</td>
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<td>19</td>
<td>51</td>
<td>96</td>
<td>45</td>
</tr>
<tr>
<td>18</td>
<td>53</td>
<td>98</td>
<td>45</td>
</tr>
<tr>
<td>17</td>
<td>58</td>
<td>103</td>
<td>45</td>
</tr>
<tr>
<td>16</td>
<td>61</td>
<td>109</td>
<td>48</td>
</tr>
<tr>
<td>15</td>
<td>73</td>
<td>118</td>
<td>45</td>
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<tr>
<td>14</td>
<td>79</td>
<td>116</td>
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<td>13</td>
<td>66</td>
<td>111</td>
<td>45</td>
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<tr>
<td>12</td>
<td>72</td>
<td>116</td>
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<tr>
<td>11</td>
<td>72</td>
<td>123</td>
<td>51</td>
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<td>78</td>
<td>130</td>
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<td>9</td>
<td>68</td>
<td>123</td>
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<td>70</td>
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<td>64</td>
<td>113</td>
<td>49</td>
</tr>
<tr>
<td>6</td>
<td>72</td>
<td>116</td>
<td>44</td>
</tr>
</tbody>
</table>

All measurements were obtained with Nucleus 22-channel mini speech processor, in bipolar + 1 stimulation mode, on March 30, 1994. T level — threshold level, C level — maximum comfortable loudness level.

ASSESSMENT OF INTRACOCHLEAR OSSIFICATION BY THREE-DIMENSIONAL RECONSTRUCTION OF COMPUTERIZED SCANS

B. C. PYMAN, FRACS, DLO; H. L. SELDON, MD, PhD; R. O’SULLIVAN, FRACR; W. D. TILLNER; M. DONNELLY, FRCS; M. SCOTT, FRACR; K. F. MACK; G. M. CLARK, PhD, FRACS

From the Human Communication Research Centre and the Department of Otolaryngology, University of Melbourne, and the Cooperative Research Centre for Cochlear Implant, Speech and Hearing Research (Pyman, Seldon, Donnelly, Mack, Clark), and the Department of Radiology, Epworth Medical Centre (O’Sullivan, Tillner, Scott), Melbourne, Australia.

INTRODUCTION

The aim of the study was to investigate whether the three-dimensional (3-D) images from computed tomography (CT) scans of the ears could adequately define the site and extent of new bone in the cochlea, and how these images compared with those created by magnetic resonance imaging (MRI). The patients whose investigations were used in the study were being assessed for a cochlear implant and were selected on the basis of their history and the appearance of their two-dimensional (2-D) CT scans. Four patients had progressive mixed deafness, a family history of deafness, and stapedectomies. They were considered to be deaf from otosclerosis and needed further assessment because their scans showed either obstructed cochleas from new bone, or demineralized otic capsules to the point that we could not determine whether new bone was present or not. The fifth patient was being assessed within 3 months of suffering deafness from meningitis. In one ear he had extensive ossification, and in the other the degree of opacification shown in axial and coronal cuts of the basal turn was inconsistent. Essentially the problem is that at the magnification used in examination of the inner ear, the resolution of 2-D CT scans gives indistinct borders between bone and water. Magnetic resonance imaging has commonly been used in these cases. The study showed that it is now possible to confirm whether or not there is new bone and to demonstrate the site and extent of new bone with both 3-D and MRI images. It is not possible to give a degree of sensitivity and specificity for this observation because of the small group of subjects in the study. It should be worth applying the reconstruction software to scans from helical scanners with a view to assessing whether the resolution of the 3-D images can be improved further.

The aim of this study was to evaluate the quality of the images of inner ears produced by reconstruction of CT scans as 3-D images, and MRI. The resolution of the inner ear detail obtained in the images produced by a CT scanner is limited by two features. The interval between the slices is often 1.5 mm, which is greater than the width of structures in the inner ear. The second limitation is the partial volume effect. Since the thickness of tissue scanned for each slice is greater than zero, the presence of bone and intracochlear lumen within one slice thickness will yield a gray pixel at that point, which could be
**CASE DETAILS**

<table>
<thead>
<tr>
<th>Case</th>
<th>Disease</th>
<th>Hearing Loss</th>
<th>CT Scan</th>
<th>3-D Image</th>
<th>MRI</th>
<th>Surgical Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Meningitis</td>
<td>R profound</td>
<td>Faint opacity in coronal cut only</td>
<td>Narrow round window region</td>
<td>Narrow fluid for first 5 mm</td>
<td>None yet</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L total</td>
<td>Extensive opacity along basal turn</td>
<td>Gap at round window</td>
<td>Irregular fluid for 12 mm</td>
<td>Bone at 5 mm, 18-mm insertion</td>
</tr>
<tr>
<td>2</td>
<td>Otosclerosis</td>
<td>R total</td>
<td>Extensive opacity with dense region</td>
<td>Long gap in basal turn</td>
<td>Not done</td>
<td>Bone at 5 mm, 18-mm insertion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L total</td>
<td>Extensive opacity, less in upper basal turn</td>
<td>Short gap in basal turn</td>
<td>Not done</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Otosclerosis</td>
<td>R total</td>
<td>Opacity with blurred ends</td>
<td>Narrow fluid in basal turn</td>
<td>Gap in fluid at 5 mm</td>
<td>Bone at 5 mm, 24-mm insertion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L profound</td>
<td>Dense opacity in basal turn</td>
<td>Long gap in basal turn</td>
<td>Long gap in fluid</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Otosclerosis</td>
<td>R total</td>
<td>Demineralized capsule, spiral outline faint</td>
<td>No narrowing or gap in fluid</td>
<td>Normal spiral</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>L profound</td>
<td>Demineralized capsule, spiral outline faint</td>
<td>No gap, fluid in otic capsule</td>
<td>Perilymph space into otic capsule</td>
<td>Space found, 20-mm insertion</td>
</tr>
<tr>
<td>5</td>
<td>Otosclerosis</td>
<td>R total</td>
<td>Demineralized capsule, spiral outline faint</td>
<td>No gap or narrowing</td>
<td>Normal spiral narrowing</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>L total</td>
<td>Demineralized capsule, spiral outline faint</td>
<td>No gap or narrowing</td>
<td>Normal spiral narrowing</td>
<td>24-mm insertion</td>
</tr>
</tbody>
</table>

mistaken for intraco cochlear ossification. The volume effect in a normal cochlea is to some extent indistinguishable from a small amount of new bone along the cochlear spiral. When there is a history of meningitis or otosclerosis in a profoundly deaf person, this lack of definition is unacceptable, as it is important to be sure whether or not bone is present and whether it is obstructive. There were five profoundly to totally deaf individuals whose CT scans presented this problem and who were prepared to proceed to nuclear MRI. We were then in a position to compare the images from the MRI with 3-D images produced by a personal computer (PC) from the original CT data. Seidman et al. reported that in 32 cases of children with postmeningitis hearing loss, 2-D scans had only 53% accuracy in detecting intraco cochlear ossification.

There are two ways in which stacking the original images along with slices interpolated by the computer could help to sharpen the bone-water interface and define the extent of any

![Image A](image1.png)

![Image B](image2.png)

![Image C](image3.png)

*Fig 1. Computed tomograms. A) (Case 1) Coronal cut from scan of right ear. It is not possible to distinguish whether blurred opacification in lower part of basal turn is result of new bone formation or partial volume effect of scan technique. New bone is clearly demonstrated in 3-D image and magnetic resonance image. B) (Case 3) Coronal cut from scan of left ear. There is extensive opacification of basal turn (arrows), but partial volume effect or calcified fibrotic tissue have made limits of new bone indeterminable. C) (Case 4) Axial cut from scan of right ear. It was not possible to tell whether there was new bone in cochlea, because decalcification of otic capsule was so great.*
new bone in the cochlea. As a result of stacking images of the cochlea, the computer can produce a solid image that can be viewed from many aspects and assessed for changes that may not be obvious in a 2-D scan image. As a result of creating interpolated cuts between the original scans, the computer should weight the color of the new pixel on the basis of the shade in the original and enhance or fade out the shade of gray accordingly.

MATERIALS AND METHOD

The CT scans were made on a GE 9800 scanner using bone contrast and high resolution. The technique included both coronal and axial images where possible. They were presented on the film as life-sized images with a slice thickness of 1.5 mm and slices taken at intervals of 1 to 2 mm. The data from the scanner must be reformatted before applying them to the PC. It is notable that the GE 9800 model does not provide a helical format.

The technique we used to present CT scan images as a 3-D image exploits software designed for reconstructing, on a PC, video images of histology slides. The 3-D images of the
patients were prepared from either their digital scan image data or from the emulsion films via a video camera attached to a frame-grabber board in the PC. These data were converted to GIF format (Graphics Interchange Format, CompuServe). The software allows for the creation of any desired number of interpolated slices for each pair of slices from the original scan. 2 For each slice, the borders of features of interest were detected and stored. The borders are discriminated by the computer on the basis of their contrast or radiopacity. In the final 3-D reconstructions the features could be colored differentially.

Magnetic resonance imaging is established as a sensitive technique for evaluating the presence, site, and extent of new bone in the inner ear.3-7 The MRI images were prepared by a Siemens Magnetom device. The cochlear fluids were distinguished from bone by using a T2-weighted imaging. The technique was modified to distinguish structures within the inner ear as follows. The table increments of the original image data were 3 mm, but successive sequences were performed with a 50% overlap. In effect, this gave a slice thickness of about 1.5 mm. The high resolution is achieved with a temporomandibular joint coil in conjunction with a turbo spin echo sequence in an angled coronal orientation, with TR = 5,000 milliseconds, TE = 91 milliseconds, and Matrix = 480 × 512.

The subjects were selected for this study because their CT scans showed changes in the cochleas or otic capsule. Their degree of hearing loss, presumed pathologic findings, and CT scan results are set out in the Table. In case 1 obvious new bone had formed in the left cochlea as a result of meningitis only 3 months before the scans were taken. It was necessary to confirm whether or not there was new bone in the basal turn of the right cochlea, as the images in the coronal and axial cuts in the right ear were equivocal. The axial cuts showed only blurred bony walls, whereas opacification in the round window region suggested the presence of bone in the cochlear fluid space (Fig 1A).

Cases 2 and 3 were thought to have new bone accumulation in both cochleas, so it was necessary to find a technique that most clearly showed the extent and density of the changes (Fig 1B).

Cases 4 and 5 had CT scans that showed severe demineralization from otosclerosis. The loss of calcium in the otic capsule reduced the contrast between the images of the bone and fluid spaces, so it was necessary to find a technique that defined the cochlear spiral sharply (Fig 1C).

RESULTS

The results are set out in the Table and include comments from the 3-D images in all cases, MRI results in four cases, and surgical observations in the four cases that have had an operation so far.

Detection of New Bone. In case 1, where CT was limited in its ability to detect new bone or define its extent, MRI confirmed the presence of new bone in both cochleas. An MRI scan was not performed for case 2. In case 3, MRI detected bone as regions of gray within the white of the cochlear spiral and clearly defined its extent (Fig 2A). In cases 4 and 5, MRI confirmed that there was no new bone present, as the fluid spiral was homogeneously white and relatively smooth-edged (Fig 2B). In case 4 this technique also demonstrated the presence of a fluid-filled space outside the cochlea, in the region of the round window. The space appeared as a distinct bright spot in the otic capsule (Fig 2B). The axial cuts of the original CT scan showed this to be a completely demineralized region. No bone was found at operation for cases 4 and 5.

The 3-D reconstruction of case 4, with no new bone, is shown in Fig 3A. There is a complete spiral and an extension of the fluid into the otic capsule. The structure representing these changes caused by demineralization of the otic capsule lies parallel to the basal turn and almost completely obscures the structure representing the internal auditory meatus (Fig 3B).

The 3-D reconstructions of cases 1, 2, and 3 all showed some change, from total absence of fluid for a section of the spiral to reduction in the width of the spiral. Even in case 1, where there was so little new bone that it was not detectable in the axial scans of the right ear, the 3-D image showed the loss of a bite-shaped section of the spiral at the round window end of the basal turn.

Evaluation of Extent of New Bone. In cases 1 and 3, MRI showed the regions of total obstruction as a gray band along the fluid space (Fig 2A). The regions of narrowing were represented as a loss of homogeneity of the white spiral.

In the 3-D reconstructions, the region of total obstruction appeared as a sharp-edged gap in the cochlear spiral. This is apparent in cases 1, 2, and 3, with at least one cochlea with bone totally obstructing the spiral (Fig 3C). In the color-coded 3-D images, the image of the internal meatus was visible where it should have been obscured by the color of the basal turn. This transparency was even more obvious when the computer created a rotating image of the color-coded cochlea and internal meatus. The extent of the transparent regions matched the MRI image of the extent of new bone formation. New bone was found as expected at operation for cases 2 and 3.

DISCUSSION

The 3-D and MRI images in this series of five patients confirmed the absence of new bone where there was none. They detected fine amounts of new bone in the right ear of case 1, and they clarified the extent of obstructive new bone in cases 1, 2, and 3. In these features the 3-D images matched those obtained by MRI. They also demonstrated the fluid-containing space in the otic capsule of case 4, first detected on MRI and later confirmed at operation.

Magnetic resonance imaging remains as a valuable method for assessing new bone formation, but it may not be necessary if there is access to the appropriate software and provided a larger series of implanted cases confirms the value of the 3-D reconstructions. This could be important in young children who are deaf from meningitis or dysplasia of the cochlea, for whom MRI would require a second general anesthetic and is
not always available. The images produced by helical scanning should help the problem created by the fact that the slice thickness is the same order of dimension as the structures of the inner ear. Nevertheless, it will be interesting to see whether the technique for creating 3-D images at the scanner directly from helical scan data gives even more confidence about the state of ossification of the inner ear.

REFERENCES

IMPLANTS IN CHILDREN: THE FIRST TWO YEARS OF THE SOUTH AUSTRALIAN PROGRAM

J. C. RICE, MB, FRCS; S. J. GIBKI, BSC, DIPAUD; T. MARCIANO, BA, DIPAPP PSYCH; R. K. SHAKES BED, B(SP)ED; K. A. BISSAKER, B(SP)ED, DPT

From the Women's and Children's Hospital (Rice, Gibki, Marciano) and the Cora Barclay Centre for Hearing Impaired Children (Rice, Shakes Bed, Bissaker), Adelaide, Australia.

INTRODUCTION

The South Australian Cochlear Implant Programme commenced in 1986 with adult patients at Flinders Medical Centre. The first patient, Shirley Ackehurst, has written lucidly of her experiences in her book Broken Silence.1 In 1990 it was felt that sufficient experience had been gained to move into the field of prelingually deaf children. As an audiology clinic has been running at the Adelaide Children's Hospital (now the Women's and Children's Hospital) for the diagnosis and continuing support of children deaf enough to require the use of hearing aids and/or special education, it seemed sensible to base the pediatric program at that hospital.

The hospital has for many years had good relations with the Cora Barclay Centre, formerly the South Australian Oral School, which was founded in 1945 by a group of mothers who had hearing-impaired children, mostly as a result of maternal rubella contracted in the worldwide epidemic of 1944.2 These parents wished their children to be educated orally. From its earliest days one or other of the otolaryngological surgeons from the Adelaide Children's Hospital has been Honorary Otologist to the school. Although it was not envisaged that all children who might receive a cochlear implant would be educated at that school, a significant number of the potential candidates were already attending, and the close association both geographically and philosophically between the school and hospital would be an advantage. The school's philosophy has always been totally dedicated to the aural-oral approach. The staff of the school includes not only teachers of the deaf, but also an audiologist and a speech pathologist, and it seemed appropriate to install the cochlear implant mapping equipment at the school as well as at the hospital.

It was recognized from the start that the children's program would have considerable differences from the adult one. These include selection of patients suitable for implantation, including the obtaining of informed consent from the parents, and the mapping process in very young prelingually deaf patients. It was also recognized that very young children (less than 6 or 7 years) would be the majority of our patients, because prelingually deaf children older than this have, as a rule, lost the developmental plasticity necessary to develop speech, however good the hearing obtained with an implant.

Fig 1. Cause of deafness for patients in South Australian program.

Fig 2. Age at surgery for patients in South Australian program.
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Author/s:
Pyman, B. C.; Seldon, H. L.; O'Sullivan, R.; Tillner, W. D.; Donnelly, M.; Scott, M.; Mack, K. F.; Clark, Graeme M.

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1995

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