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Radiology for cochlear implants

R. F. Gray F.R.C.S., R. A. Evans F.R.C.S., C. E. L. Freer, F.R.C.R., H. E. Szutowicz H.D.C.R., G. F. Maskell, F.R.C.R. (Cambridge)

Abstract

One fifth of patients selected for cochlear implants have such bony irregularities in the cochlear duct that full insertion of a multichannel electrode array is impossible. Three cases of cochlear deafness are presented where pre- and post-operative radiology played an important part in the management.

Standard CT at 2 mm cuts is compared with ultra high resolution CT at 1 mm cuts. The pitfall of poor definition is that the inexperienced surgeon may find himself unexpectedly drilling out an obliterated cochlear duct. Sections 30 degrees caudal to Reid's infra orbito-meatal base line at 1 mm intervals give maximum information for minimum radiation.

Plain films show the placement of individual platinum electrode contacts in relation to the spiral 'frequency map' of the cochlea. This is vital information for the audiologist who has to route specific frequencies to specific sites within the ear for a good hearing result.

Introduction

About a fifth of deaf patients selected for cochlear implantation have partial or complete obliteration of the basal turn of the cochlea (14% in a series by Balkany *et al.*, 1988, 28% of selected patients in a series by Harnsberger *et al.*, 1987). Balkany recommends drilling out the obstruction and reports good results in terms of hearing gain. While this may be true in experienced hands many surgeons and units have begun to offer a cochlear implant service within the last two years. Tucci *et al.*, (1990) reviewing over 1400 patients report that 42% of cochlear implant centres responding to a questionnaire on rehabilitation have five patients or less each. Most surgeons would wish to defer a patient with partial obliteration of the cochlear duct until experience had been gained on easier cases. This paper is based upon experience of ultra high resolution computerized tomography (CT) on 12 patients, half of whom came to implantation.

Pre-operative radiology

Plain films give a poor view of the cochlea. Complex movement tomography can demonstrate the round window and first turn of the cochlea (Chakeres and Kapila, 1984) but CT has now supplanted this technique. The cochlea and adjacent structures have been well demonstrated on CT but only recently has it been used in the pre-operative assessment of cochlear implant patients (Harnsberger *et al.*, 1987; Jackler, *et al.*, 1987; Rosenberg *et al.*, 1987). Magnetic resonance (MR) is unlikely to be helpful as there is no signal from the ossified cochlea, but may be of value in demonstrating the VIIIth nerve in the internal auditory meatus (IAM) or cerebellopontine angle.

Radiological methods

Using the ultra high resolution algorithm of the Siemens Somatom Plus CT scanner, twelve contiguous 1 mm sections of the labyrinth at an angle of 30 degrees caudal to Reid's infraorbito-meatal baseline were obtained. The images were presented on bone settings (Window 4000, level 800).

Material and methods

Three cases are presented, with pre- and post-operative films with observations on the results of surgery.

Case 1

A 29-year-old man deafened by meningitis at the age of eight received an Ineraid® Multichannel cochlear implant in March 1990. The pre-operative scan (Fig. 1a) shows a clear electrode path with no sign of osteoneogenesis. No difficulties were encountered at operation and the post-operative plain film (Fig. 1b) shows satisfactory electrode resting sites. The patient hears well using the deepest four of the six electrodes.

Case 2

A 12-year-old girl deafened by meningitis at the age of seven received an Ineraid® multichannel cochlear implant in December 1989. The pre-operative scan (Fig. 2a) is misty and no distinction can be made between inadequate radiology and the appearance of osteoneogenesis. Bony obliteration was suspected on the left side so the implant was inserted in the right ear. The operation was made very difficult by bony obstruction of the basal turn and no scala tympani was found beneath the

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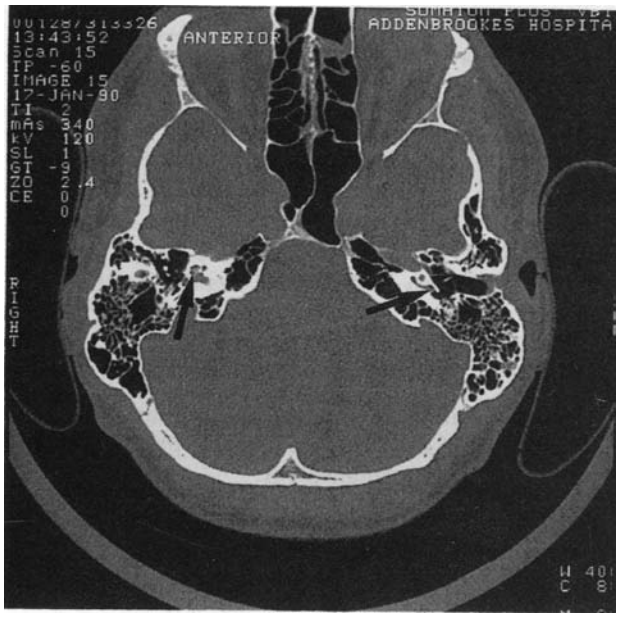


FIG. 1a

Ultra High Resolution CT scan, 1 mm sections at 1 mm intervals, Siemens Somatom Plus. 30 degrees caudal to Reid's infraorbitomeatal baseline.

The first and second turns of the left cochlea (arrowed) can be seen one above the other like a cottage loaf. A capacious first turn can be seen on the right and the round window niche and membrane are shown by the arrow in this slightly lower cut. Sufficient space is demonstrated for an multichannel intracochlear electrode.

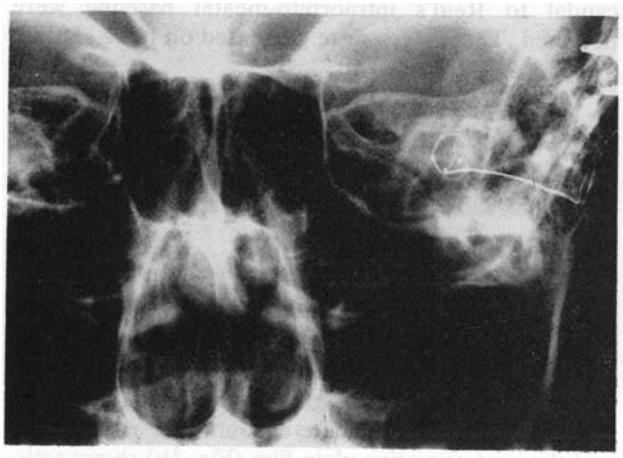


FIG. 1b

Plain film. A P per-orbital projection. Same patient as 1a. Postoperative view showing electrode within the first and part of the second turns of the cochlear duct. The conducting elements are 0.5 mm platinum balls and the first one hs penetrated the cochlea to a depth of 25 mm.

round window until the drill path was six millimetres long, almost reaching the carotid canal. This is a poor surgical result and the plain film shows the electrode resting site in Figure 2b. The patient can only perceive sound on the most apical electrodes. Her hearing gain is limited to two frequency domains instead of four.

Case 3

A 43-year-old man deafened by chronic otitis over many years was scanned for consideration of a cochlear implant. Sections at 1 mm intervals show partial oblit-

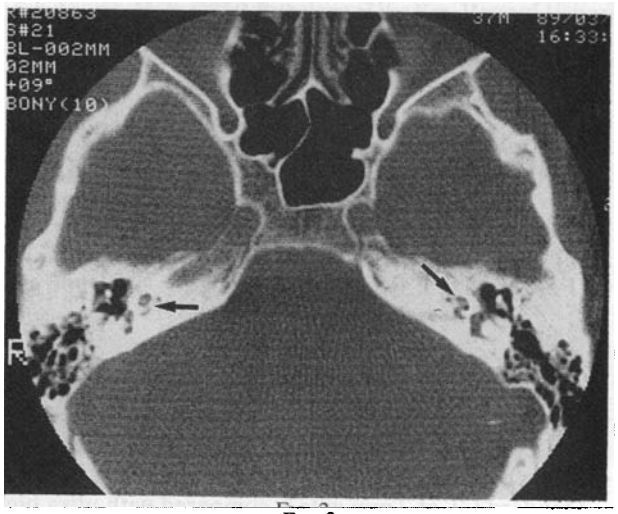


FIG. 2a

Inadequate image or inadequate cochlea?
Standard Resolution CT scan at 2 mm sections, IGE 9000 Bone Target. 30 degrees to Reid's baseline.

The cochlea is poorly defined on the right. The middle of the first turn (arrowed) cannot be clearly seen. The 'cottage loaf' appearance on the left is seen (arrow) but less clearly than in Fig 1a.

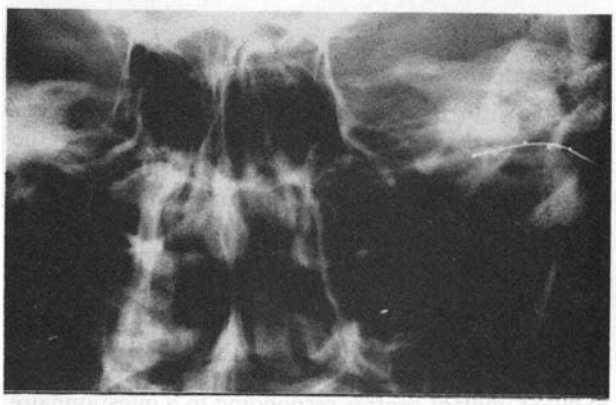


FIG. 2b

Plain film. AP per-orbital projection. Same patient as 2a. The first platinum 0.5 mm ball has penetrated to a depth of 11 mm. Poor surgical result due to osteoneogenesis. The patient can only use two out of six electrodes.

eration of cochlear duct (arrowed) on both sides (Fig. 3a). The patient was not therefore suitable for a long intracochlear electrode but was offered the single channel extracochlear device (Fig. 3b).

Causes of obliteration

Pus in the cochlea is the leading cause of adhesions and of bony narrowing. Pus under pressure from the middle ear gains access through the cochlear windows and via fistulae in the lateral semicircular canal. Infection from the subarachnoid space enters the cochlear aqueduct when meningitis turns CSF to pus. Sensory hair cells are destroyed in a few hours as replicating bacteria fill the perilymphatic spaces. It is not known how long it takes for obliterative bone to form in the scala tympani. Two types of new bone are described by Kotzias and Linthicum (1985) metaplastic and osteoplastic bone. Metaplastic bone forms in inflammatory tissue not previously bony and osteoplastic bone forms at the site of disrupted endosteum. If pus in the cochlea is analo-

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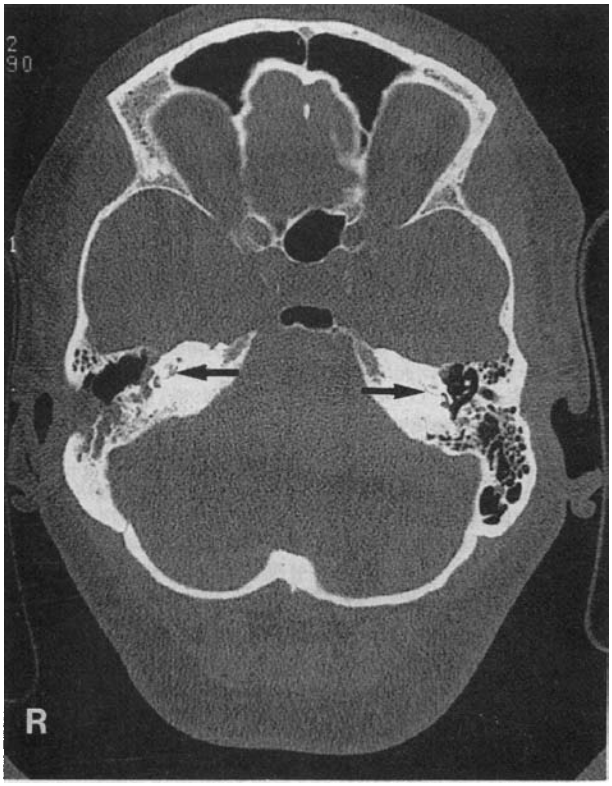


FIG. 3a

Ultra High Resolution CT scan. Siemens Somatom Plus. 30 degrees to Reid's base line. Sections at 1 mm intervals show marked obliteration of cochlear duct (arrowed) on both sides. Note the surgical cavity replacing the left middle ear space. 'White Cochleae' are the leading contraindication to a multichannel implant.

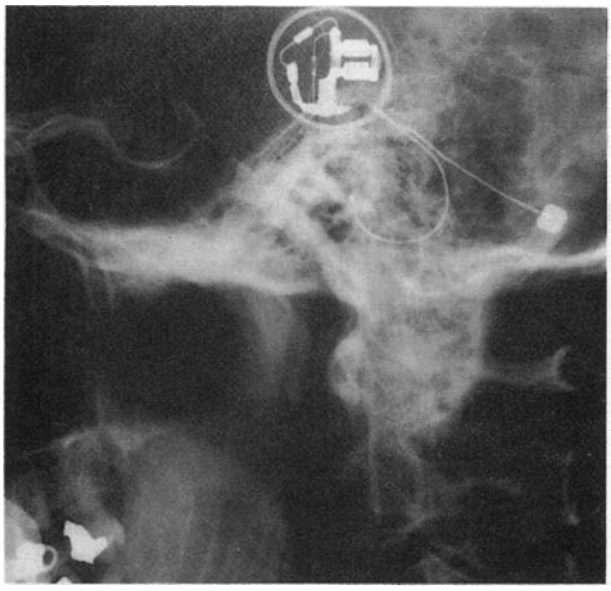


FIG. 3b

Plain film. Lateral skull view. An RNID/UCH single channel extra cochlear round window device.

gous to the former many months may elapse before mataplastic bone takes up its final shape. This suggests that once profound meningitis deafness has been diagnosed implantation of a long electrode array to a depth of 25 mm would be easier weeks after the acute illness than months or years later when new bone has formed although one case has been described by Phelps *et al.*, (1990) where after five years new bone was limited to a 3 mm section of the basal turn and the passage was clear deeper in.

Obliteration from long-standing chronic suppurative otitis media probably occurs as a result of many minor episodes rather than a single catastrophic one and a 'best time for implantation' does not arise. Osteoplastic bone would probably result from tearing of endosteum by an electrode and may form as quickly as callus in a long bone fracture. Otosclerosis may obliterate the cochlear duct by invading the otic capsule.

Post-operative assessment

The Ineraid device depends for optimum function on the placement of the platinum ball electrodes, to which the sounds of speech are delivered through four band pass filters. A plain perorbital radiograph clearly demonstrates the position of the six electrodes from which the audiologist chooses four and their appropriate frequency bands. This examination is best performed on the first post-operative day so that misplacements in pericochlear air cells or through fracture lines can be corrected as soon as possible. Ball *et al.*, (1986) describe the use of post-operative CT but conclude that routine evaluation was unnecessary.

Discussion

Inserting long electrodes

The two commercially available intracochlear long electrode arrays differ in structure and in philosophy. The 22 channel Nucleus device has 32 smooth ring like conducting elements which do not have to be inserted all the way into the cochlea. The last ten are non-functional. The 4 channel Ineraid (formerly Symbion) device has a long electrode array from which protrude six 0.5 mm platinum balls. It is important to have a scala tympani of sufficient calibre to accept this array and allow it to pass deep into the cochlea. For optimum function each ball should lie alongside that part of the cochlear partition which used to handle acoustically the frequency band that will now be delivered electrically. In short the Ineraid device requires better pre-operative radiology than the Nucleus device. Balkany *et al.*, (1986) report the use of CT in assessing implant candidates and Harnsberger *et al.*, (1987) and Laszig *et al.*, (1988) report the use of high resolution CT scanning and have used it to detect patients with 'white cochleae' before surgery. Our experience in twelve patients is that only ultra high resolution CT at 1 mm cuts gives sufficient detail to choose the side and implant with confidence that not even a partial bony obstruction will be met.

White cochleae

Patients with bilateral total or subtotal obliteration of the cochlear duct on CT are best treated with an extra-

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cochlear single channel device such as that seen in Figure 3b.

Electrode resting sites

The plain film shows the electrode sites and penetration. Rehabilitation of the implanted patients begins with careful routing of signals to appropriate electrodes and in the case of the Interaid device the plain film is compared with what is known of the 'frequency map' of the cochlea and changes made to the wiring of the speech processor to take account of this. For example, in Figure 2b, the two lower frequency channels could be routed to the deepest (first) electrode and the two higher frequency channels routed to the second electrode. This would be a better strategy than stimulating electrodes 1, 2, 3 and 4 because numbers 3, 4, 5 and 6 are outside the cochlea.

Radiation doses

The lens of the eye is sensitive to radiation, a dose of 2000 milli Grays (mGy) is associated with cataract formation. CT exposure was up to 70 mGy. Taking care to avoid the lens by using Reid's baseline (the line joining EAM to the orbital floor) plus 30 degrees, a dose to the lens of only 0.2 mGy per section was achieved. The perorbital plain film generated a dose of 4.6 mGy to the lens in the AP direction which is unusual on the first post-operative day.

Conclusions

Ultra high resolution CT scanning is required for pre-operative assessment of deaf patients needing long intra cochlear electrodes. A series of 12 1 mm contiguous sections at an angle of 30 degrees to Reid's infraorbitomeatal baseline gives maximum information for minimum radiation, especially to the lens of the eye. A single post-operative perorbital radiograph of the electrode is sufficient to see its position and plan the strategy of electrical stimulation for comprehension of speech.

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Address for correspondence:
Mr. R. F. Gray F.R.C.S.,
Department of Otolaryngology,
Addenbrooke's Hospital,
Cambridge CB2 2QQ, UK.

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