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Cochlear implantation following temporal bone fracture

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Abstract

Seven cases of profound hearing impairment following either unilateral or bilateral temporal bone fracture are presented who were implanted with the Nucleus 22 channel or Ineraid devices. Six patients suffered bilateral temporal bone fractures. One patient had prior congenital unilateral profound hearing impairment. This patient suffered a unilateral temporal bone fracture. Six patients became regular users of their implants. One gained little benefit and became a non-user. Two of the regular users experienced facial nerve stimulation, which could not be programmed out. In these two cases the implant was removed and the contralateral ear successfully implanted. Implant-aided audiometry demonstrated a hearing threshold of 40–50 dB at nine months after switch-on. The reliability of computed tomography (CT) scanning in predicting cochlear patency in cases of temporal bone fracture will be discussed. The benefit of complimentary imaging with magnetic resonance (MR) is highlighted.

Key words: Cochlear implant; Temporal bone

Introduction

Temporal bone fractures often cause loss of audiovestibular function. Patients with such fractures may suffer bilateral profound sensorineural hearing losses and become candidates for cochlear implantation. Transverse fractures may cause direct trauma to the otic capsule resulting in destruction of the organ of Corti and stria vascularis, haemorrhage into the inner ear and subsequent labyrinthitis ossificans (Fredrickson *et al.*, 1963). The most frequent site of ossification is the basal turn of the cochlea (Green *et al.*, 1991). Longitudinal fractures may damage the same neural elements by concussion but the hearing loss is not normally severe. In a study of animals who had suffered fractures, hair cell loss was found to be greater than ganglion cell loss (Schuknecht *et al.*, 1951). The greatest loss occurred in the upper part of the basal coil. A well-situated intracochlear implant array is located in the scala tympani and wraps around the modiolus. It stimulates surviving neural structures although there remains some debate as to which neural structures are in fact stimulated. The number of surviving ganglion cells would seem to be a very important factor in determining the success of electrical stimulation. Nadol *et al.* have reported an average survival of only a third of the ganglion cell population after temporal bone fractures (Kerr and Schuknecht, 1968; Otte *et al.*, 1978; Nadol *et al.*, 1989).

Post-mortem studies of implanted temporal bones (Clark *et al.*, 1988; Linthicum *et al.*, 1991) have shown that relatively poor ganglion cell survival was seen in patients who had good performance with their implants. Linthicum *et al.* (1991) did not show a correlation between ganglion cell counts and auditory function in patients with single-channel electrodes.

We report the cochlear implantation results of seven cases of patients who presented with profound hearing impairment after temporal bone fracture.

Case reports

Case 1

This patient was a 36-year-old female with a history of total right-sided deafness of unknown cause since childhood. In 1992 she fell off a ladder sustaining a head injury with petrous bone fractures associated with CSF leak from the left ear which stopped spontaneously. She had severe bilateral tinnitus and profound hearing loss. She was assessed as suitable for cochlear implant.

A computed tomography (CT) scan was carried out using 1 mm thick slices through the temporal bones and with a bone window algorithm. The cochleas appeared normal and no fracture was seen. Surgery was carried out on the left ear in July 1994. A cochleostomy was attempted in front of the round window, but a lumen could not be identified despite extensive drilling. The electrode (Nucleus 22) was inserted into a drilled-out gutter in the promontory and 10 channels were inserted. Post-operative X-rays confirmed a poor insertion.

One month later initial switch-on of the implant was satisfactory considering the limited number of channels inserted at the time of surgery. Improvement in lip-reading and auditory discrimination was noted. However, at subsequent reviews, progress was disappointing. Successive channels had to be switched off because of facial nerve stimulation. After lengthy discussion and counselling, the need for revision surgery was agreed.

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The left ear was re-explored on October 10, 1994. Excision of the previous implant was difficult because of extensive granulation tissue. Following removal of the implant from the cochlea, the stapes superstructure was removed and despite further extensive drilling, a cochlear lumen could not be located. The procedure was abandoned and a right cochlear implant operation performed. The right cochleostomy revealed a patent basal turn enabling a good insertion of a Nucleus 22 device. Post-operative X-rays confirmed good insertion. Second switch-on, on November 9, 1994, produced good threshold and comfort levels and subsequently, she has developed enhanced lip-reading skills and some open set discrimination. Implant-aided audiogram (IAA) nine months after operation showed responses in the region of 50 dB.

Case 2

This was a 34-year-old male allegedly assaulted on January 1, 1981 he was beaten with an iron bar, sustaining a head injury. He had bruising of both orbits, frontal region and bleeding with apparent CSF leak from both ears. X-rays taken in the Accident and Emergency Department at the time confirmed bilateral temporal bone fractures. He complained of dizziness and total deafness from the time of injury. In his past medical history he had had a left mastoidectomy carried out in London in 1977 and had a slight conductive loss in this ear since. Audiogram, on January 23, 1981 showed a hearing loss of greater than 90 dB in both ears. A CT scan carried out on August 26 1994 showed no abnormality of the inner ear, middle ear or internal auditory meatus on the right side. The left ear showed an operative defect in the mastoid region and middle ear cleft, a little soft tissue lining the medial wall including the region of the round window niche. However, there was no evidence of bony erosion and a fluid containing labyrinth on both sides was confirmed on magnetic resonance imaging (MRI).

Right implant surgery was performed on November 14 1994 using a Nucleus 22 device. At cochleostomy partial obliteration of the basal turn was noted, this was removed and although there was a little resistance to insertion, all of the active channels and the majority of the stiffening bands were inserted. Post-operative X-rays confirmed a satisfactory intracochlear position of the electrode array. Switch-on one month later produced an excellent result with open set discrimination. IAA nine months after operation confirmed a hearing level of 45 dB.

Case 3

A 13-year-old boy sustained a bilateral skull fracture when a metal goal post fell on the back of his head in March 1992. He was left with a profound bilateral hearing loss. Audiogram confirmed a hearing loss of greater than 90 dB. A CT scan showed no fracture line or abnormality of middle or inner ear.

Surgery was carried out on December 9 1993 at which time the promontory appeared flattened with a fracture line running in a superior-inferior plane. The round window niche could not be clearly identified. A cochleostomy was performed and insertion proved difficult but approximately 15 electrodes were inserted using a Nucleus 22 device. Check X-rays post-operatively confirmed partial insertion. At switch-on he showed improved lip-reading skills and he continues to do well at subsequent follow-up. IAA nine months after operation confirmed a response level averaging 45 dB.

Case 4

A 63-year-old male presented in 1993 having fallen off a ladder in March 1992. He had sustained bilateral basal skull fractures with bilateral haemotympanum and gross ataxia immediately after the injury. Three months later, he was profoundly deaf with tinnitus and bilateral vestibular failure. He was assessed as suitable for an implant. A CT scan showed patent cochleas and no fracture line. A right cochlear implant was carried out on March 10 1994 using a Nucleus 22 device. A post-operative X-ray confirmed a correct implant position. His lip reading skills continued to improve and nine months after operation, IAA confirmed a response level of 40 dB.

Case 5

A 69-year-old male suffered a severe head injury in a cycling accident. This produced a basal skull fracture and a subarachnoid haemorrhage. Air was noted inside his skull associated with a CSF rhinorrhoea and fluid in the middle ear. He had a bilateral sensorineural deafness. A CT scan showed no fracture line or abnormality in the middle or inner ear. The left ear was implanted in May 1994 using a Nucleus 22 device. A post-operative X-ray showed that a satisfactory implant position had been attained. Following switch-on and at subsequent reviews facial nerve stimulation occurred and electrodes were not able to be stimulated at a loud enough level without either reaching a maximum current level or causing facial twitching. On February 15 1995, the left intraocular device was explanted and reinserted into the right ear. At surgery, it was difficult to dissect the electrode array through the left mastoid because of fibrosis but the electrode was removed unharmed. Right implant surgery was performed without any problems. Correct positioning was confirmed by X-ray. No further non-auditory stimulation was noted. IAA, nine months after operation, confirmed a response level of 40 dB.

Case 6

A 44-year-old male was referred for consideration of cochlear implantation after being deaf since the age of 20. He had dived into a swimming pool and struck his head on the bottom of the pool with a resultant fractured skull, bilateral hearing loss, CSF rhinorrhoea and diabetes insipidus. On the CT scan, the cochleas were clearly identified and no fracture was apparent. On the left side there was no evidence of any middle ear structures. A right cochlear implant (the only Ineraid in our series) was performed on April 11 1991. A posterior tymanotomy and cochleostomy were performed but on passing the electrode through the basal turn an obstruction was encountered. The cochleostomy was extended and there was considerable new bone formation in the anterior basal turn. After further drilling over the anterior promontory the middle turn of the cochlea was found and freed of new bone. The electrode system was then passed into the middle turn without difficulty. A post-operation X-ray showed correct positioning and IAA revealed a response level of 40 dB.

Case 7

A 46-year-old male presented having had a head injury aged 11 and immediately becoming totally deaf in both ears. A skull X-ray at the time showed a fractured left occipital bone. A CT scan later showed a linear oblique lucency through the petrous bone immediately medial to the superior semicircular canal on the left side. It was the only evidence of fracture, the petrous bones, IAMs, middle-ear structures as well as the cochleas appeared

TABLE I

TABLE OF RESULTS

	BKB			VCV			FFA		
Patient No:	Pre-op %	1 month post implant %	9 month post implant %	Pre-op %	1 month post implant %	9 month post implant %	Pre-op dBs	1 month post implant dBs	9 month post implant dBs
1	14		61	35		79	90	45	50
2	6		95	25		66	106	51	45
3	12		68	39.6			94	47	45
4	0	92	100	22.9	60.4	89.5	96	45	40
5	0		90	37.5		66.6	90	55	45
6	74		44			31.25	102		40
7	46		56	33.3		43.75	98	53	50

normal. On the May 19 1994 a right cochlear implant was performed using a Nucleus 22 device. A posterior tympanotomy and cochleostomy were carried out and 22 channels were implanted. Post-operation X-ray was satisfactory and a response level of 50 dB was attained. This patient has now become a non-user.

Discussion

Seven patients are described who became totally deaf as a result of temporal bone fracture from head injury. All were implanted with a multichannel cochlear implant system (6 Nucleus 22 channel, 1 Ineraid). Six of the seven are regular users of the implant system. Patient 7 has discarded his system, and it is probably significant that he had by far the longest duration of total deafness (35 years against a mean of 2.5 years).

This small subset of patients appears to perform in parallel with patients with other aetiologies (Summerfield and Marshall, 1995). The mean implant-aided audiogram thresholds were 44 dB compared with an 'all aetiology average' of 46 dB from one of our two centres. The BKB and VCV scores show worthwhile improvement. The nine month post-implant BKB scores (implant alone) mean was 71 per cent (range 42–100 per cent). Environmental sound recognition had a mean of 12/20 (range 5.5–17.5/20).

Attention should be directed to surgical and rehabilitation problems which are likely to be encountered. In cochlear implantation of patients who have sustained a fracture involving the otic capsule, osteoneogenesis may follow haemorrhage into the cochlear lumen or may be the result of reaction at the point where the fracture line involves the cochlea. As in the situation following meningitis new bone is most commonly encountered at the basal turn of the cochlea. In this small series new bone formation was found in two cases at the anterior end of the basal turn and in another case total obliteration was encountered during surgery.

In all three cases mentioned above high resolution computed tomography (HRCT) failed to predict the patency of the cochlea. In *Case 3*, a fracture in the promontory was seen at operation which was undetected on the HRCT scan. This is in keeping with the report by Siedman *et al.* (1994) who found that in up to 22 per cent of cases HRCT failed to show luminal obstruction subsequently found at surgery. In post-meningitic cases, the HRCT incorrectly predicted a patent cochlea in almost half of cases (47 per cent).

Theories for this inaccuracy have been postulated. Firstly the mineralization of the obstructing bone may render it less opaque than the dense surrounding otic capsule. Secondly the small size of the structures to be imaged and the problems caused by partial volume averaging may combine to reduce the resolution of HRCT.

The role of MRI in differentiating between intracochlear fluid, fibrosis or new bone is currently under evaluation in a number of centres. With a T2-weighted image it is possible to visualize several elements - the cochlea, the semicircular canals, the internal meatus and the cerebello-pontine angle. All spaces have the same signal. In a variety of cases, the reliable detection of the absence of fluid has shown to be promising and to warrant further evaluation (Laszig *et al.*, 1988).

The facial nerve stimulation rate is higher than expected. In a series of 459 Nucleus device operations (Cohen *et al.*, 1988) only four patients experienced facial nerve stimulation. In this small study two patients suffered facial nerve stimulation. It is assumed that current leaks from the electrode through the low resistance of the fracture line to stimulate the facial nerve in the region of the geniculate ganglion or in the horizontal portion. It may be overcome by programming out the responsible channels but in these cases the patients had to be explanted with reimplantation of the same or a different device in the opposite ear.

Case 1 has important implications with regards to the plasticity of the auditory system. The ear originally implanted was the ear that had been responsible for the sole input to the auditory cortex for the full duration of the patient's life. When it was deafened from the skull fracture, it seemed the obvious side to implant. When a poor outcome resulted, the opposite ear, which had never had any previous hearing, was implanted with a good outcome (BKB 60 per cent). This observation has important implications for choice of side when one ear has been deaf since birth.

To conclude, cochlear implantation following temporal bone fracture in this small series of cases has proved to have good audiometric and psychoacoustic results. These compare favourably with other aetiologies. We recommend that in patients with temporal bone fractures, preoperative imaging with both HRCT and MRI is performed. There is a significant risk of facial nerve stimulation and patients should be warned that this might require programming adjustments, reducing the number of active electrodes and therefore potential benefit. In severe cases explantation and re-implantation may be necessary.

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