

Cochlear implantation in the irradiated temporal bone

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Abstract

Objective: To demonstrate the feasibility and complexities of cochlear implantation in the setting of bilateral temporal bone osteoradionecrosis.

Study design: Case report.

Setting: Tertiary care referral centre.

Case description: A 66-year-old woman with bilateral temporal bone osteoradionecrosis and profound hearing loss, following treatment for tonsillar cancer, underwent cochlear implantation. Prior canal wall down mastoidectomy and subsequent temporal bone resection with free flap reconstruction had been performed on the implanted ear. The contralateral ear received a canal wall down mastoidectomy. A completely dehiscant mastoid segment of the facial nerve and extensive fibrosis were evident in the implanted ear. Only minimal fibrous reaction was found within the cochlea, allowing for full electrode insertion. At three months, speech recognition testing documented a consonant-nucleus-consonant (CNC) word score of 54 per cent.

Conclusions: This report demonstrates the feasibility of cochlear implantation after temporal bone surgery and free flap reconstruction in the setting of diffuse osteoradionecrosis. The patient's excellent open-set speech understanding using the cochlear implant implies that radiation did not severely damage the central auditory pathways. Thus, some patients with radiation-induced hearing loss may be appropriate cochlear implant candidates. Special attention should be paid to surgical planning, as complications related to wound healing, electrode insertion and facial nerve injury may be more likely.

Key words: Temporal Bone; Osteoradionecrosis; Cochlear Implant; Hearing Loss

Introduction

Ionizing radiation is a commonly used therapeutic modality for malignancies involving the head, neck and brain. Application of radiation to the temporal bone can result in pathological changes in the external auditory canal, tympanic membrane, middle ear, inner ear and structures of the central nervous system (CNS). Radiation-induced obliterative endarteritis reduces tissue vascularity, impeding healing. For the external auditory canal, prevention and early detection of radiation-induced changes are essential. Careful management with water precautions, frequent otoscopic examinations and aural toilet, as well as the application of weak antiseptic solutions, are often used to resolve skin irritation. Persistent symptoms such as pain and otorrhoea are usually due to osteoradionecrosis of the temporal bone – a serious complication of radiation therapy.¹ Osteoradionecrosis frequently develops after irradiation dosages of 60 to 70 Gy.^{2,3} Although doses of less than 60 Gy are not considered to cause temporal bone osteoradionecrosis, other otologic complications, such as otitis media, facial paresis and sensorineural hearing loss, have been described.⁴

Hearing loss following temporal bone irradiation can result from pathological changes within the external auditory canal, tympanic membrane, ossicles, cochlea, cochlear nerve and brain.³ Thus, both conductive and sensorineural hearing losses following radiation have been described.^{1,4–6} Ho *et al.*⁵ used pure tone audiometry to

demonstrate delayed sensorineural hearing loss in a relatively large cohort of patients who received irradiation for nasopharyngeal malignancies. Akmansu *et al.*⁷ used otoacoustic emissions (OAEs) to demonstrate the detrimental effects of radiation on hair cell function in an animal model, thus implying a cochlear site of lesion. Results from animal studies in the past^{8,9} are in agreement with these findings. It has been presumed that progressive intracochlear fibrosis and hair cell loss are responsible for the observed long-term functional changes. Finally, a recent report by Low *et al.*¹⁰ used auditory brainstem response audiometry to demonstrate an absence of retrocochlear effects following therapeutic irradiation for nasopharyngeal carcinoma in 27 patients. The investigators concluded that these findings effectively cleared the way for cochlear implantation in patients with severe to profound hearing loss following radiation therapy.

Successful cochlear implantation in the setting of previous temporal bone irradiation presents a number of potential obstacles. Pathological changes in the skin could impede wound healing, resulting in implant extrusion. Necrotic bone can provide a nidus for subsequent infection as well as place important neurovascular structures at risk of injury, such as the facial nerve, carotid artery and jugular venous system. Inner-ear fibrosis could provide a barrier to effective electrode insertion. Finally, cochlear nerve and brain damage from irradiation may result in an inability to use the electrical signals effectively.

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The present report describes a patient with bilateral temporal bone osteoradionecrosis with subsequent sensorineural hearing loss who underwent successful cochlear implantation. This report serves to outline the complex surgical considerations for such patients. Importantly, previous irradiation does not preclude consideration for cochlear implantation, even in the setting of osteoradionecrosis.

Case report

A 66-year-old woman developed osteoradionecrosis approximately 10 years following therapeutic irradiation for left tonsillar cancer. Because of persistent otalgia, otorrhoea and exposed necrotic bone within the external auditory canal, she underwent right canal wall down mastoidectomy, but her disease progressed. Approximately two years later, she underwent labyrinth-sparing temporal bone resection with rectus abdominus free-flap obliteration, meatal closure and a full course of hyperbaric oxygen therapy. During this surgery, necrotic, infected bone surrounding the facial nerve resulted in nerve sheath exposure in the mastoid segment. One year later, persistent otorrhoea and otalgia in the left ear necessitated canal wall down mastoidectomy. Over the ensuing two years, the left ear remained mostly dry and the patient was asymptomatic except for gradual hearing loss, managed with amplification. Ultimately, her hearing deteriorated to profound levels, and a trial of an external bone conduction hearing device resulted in no detectable hearing for the patient. A computed tomography image of the right temporal bone, demonstrating mastoid segment facial nerve dehiscence and normal cochlear anatomy, is shown in Figure 1.

Because of an open mastoid cavity on the left that required periodic cleaning, right cochlear implantation was undertaken. At the time of surgery, dense cavity fibrosis and adherence of the mastoid segment of the facial nerve to the free flap was encountered, thereby limiting middle-ear access. Facial nerve stimulation resulted in free flap contraction, indicating flap neurotization. Upon

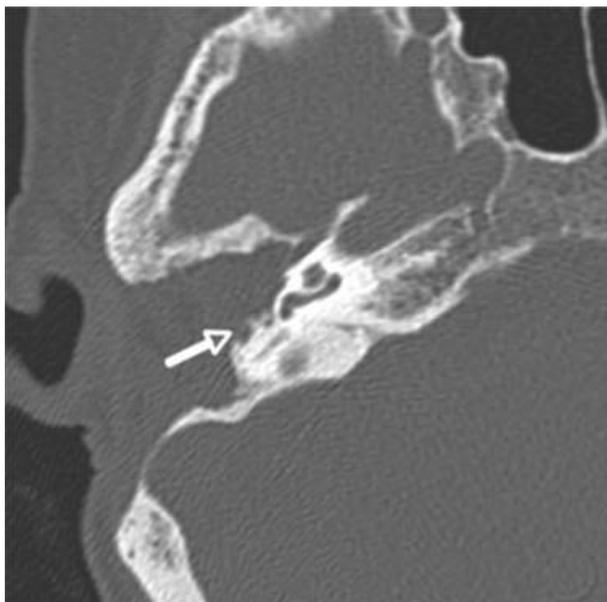


FIG. 1

High resolution computed tomography scan of the right ear, showing a regular inner ear; the arrow marks the dehiscence of the mastoid segment of the facial nerve.

transecting these attachments, an appropriate cochleostomy location was visualized and undertaken. Some fibrosis was encountered in the first segment of the basal turn of the cochlea but complete insertion of an electrode array (Nucleus Freedom[®], Cochlear Corp, Inverness, Colorado, USA) was accomplished. Intra-operative telemetry revealed elevated impedance measures and evoked intracochlear compound action potentials (Neural Response Telemetry[®], Cochlear Corp). Prior to implant activation, the patient's post-operative course was complicated by paroxysmal facial spasms, which resolved with a brief course of gabapentin. Facial function was normal. The patient was fitted with the Advanced Combination Encoder (ACE) coding strategy, with both 'comfort' and 'threshold' levels within the normal range. The results of auditory testing prior to and following cochlear implant activation are shown in Table I. Significant improvements in speech perception were demonstrated early in the post-operative period. The patient used the implant during all waking hours, in place of contralateral amplification.

Discussion

Careful consideration must be given to the myriad of factors that can preclude effective surgical placement and retention of a cochlear implant in an irradiated patient. As previously mentioned, therapeutic irradiation of the head and neck can result in pathological changes to the ear, temporal bone, skull base, meninges and brain.^{1,4,11,12} In this regard, obstacles to cochlear implantation may include radiation dermatitis, impaired wound healing, osteoradionecrosis, chronic suppurative otitis media with or without cholesteatoma, cochlear fibrosis or necrosis, and CNS affects. All of these complications have been previously described following therapeutic irradiation treatment for parotid, CNS, nasopharyngeal and other head and neck and skull base tumours.^{1,3}

Prior to implantation, the skin in the proposed implant region should be free of open wounds and well healed. Careful planning of skin incisions is critical. Incisions through erythematous, atrophic skin should probably be avoided. Minimal access, limited incision approaches should be considered in order to limit skin devascularization and prolonged healing. Gentle handling of the skin flaps, avoidance of flap-thinning procedures and judicious use of electrocautery must be considered in order to avoid further compromise of the scalp. Following surgery, careful monitoring of the skin in the region of both the magnet and the incision is also needed.

Radiation-induced pathology in the external auditory canal, tympanic membrane, middle ear and mastoid must be completely addressed before considering cochlear implantation. This should include complete removal of necrotic bone sequestration and provision for adequate tissue vascularity through hyperbaric oxygen therapy⁸

TABLE I

PRE- AND POST-OPERATIVE SPEECH PERCEPTION RESULTS*

Test interval	CUNY sentences (%)	HINT [†] sentences (%)	CNC words (%)
Pre-op	57	12	2
1 Month post-op	97	82	54
3 Months post-op	96	89	56

*At 65 dB hearing loss; [†]in quiet. CUNY = city university of New York-sentences; HINT = hearing in noise test; CNC = consonant-nucleus-consonant; pre-op = pre-operative; post-op = post-operative

and possibly free tissue transfer.⁹ It is the authors' opinion that, in the presence of severe to profound hearing loss, labyrinth-sparing temporal bone resection with free tissue transfers provides an effective means for alleviating the debilitating symptoms that many of these patients are plagued by. Moreover, eliminating infection effectively prepares the ear for subsequent cochlear implantation. In ears with usable hearing, canal wall down mastoidectomy with subsequent hyperbaric oxygen therapy may be effective, although prolonged healing and difficult cavity maintenance should be expected. In our experience, routine tympanoplasty/canaloplasty techniques are rarely effective. It should also be presumed that, when undertaking surgery on previously operated and irradiated temporal bones, osteitis and bone resorption will serve to expose previously covered structures, thereby placing them at risk of injury. In the present case, facial nerve exposure was evident beneath soft, gelatinous bone during the patient's temporal bone resection procedure. During subsequent cochlear implantation, significant facial nerve manipulation was needed to access the middle-ear space.

Cochlear patency may present another potential obstacle to successful cochlear implantation in patients with previous temporal bone irradiation. Hoistad *et al.*¹³ demonstrated intracochlear fibrosis in a number of temporal bones from patients irradiated for a variety of malignancies. Obviously, extensive fibrosis could preclude electrode placement, in a manner similar to that seen in patients with post-meningitic obstruction. For this reason, the authors believe that magnetic resonance imaging (MRI) is most appropriate for evaluating cochlear patency in these patients.^{14–16} Although not obtained in the present case, we believe that MRI would have correctly identified the short segment of basal turn fibrosis encountered. Surgeons undertaking these cases should be prepared for impassable scalar obstruction similar to that encountered in post-meningitic cases.¹⁷ A variety of electrode arrays and cochleostomy options should be available.^{18,19}

- **This paper describes the case of a 66-year-old woman with bilateral temporal bone osteoradionecrosis and profound hearing loss, following treatment for tonsillar cancer, who underwent cochlear implantation**
- **Prior canal wall down mastoidectomy and subsequent temporal bone resection with free flap reconstruction had been performed on the implanted ear**
- **The patient's excellent open-set speech understanding using the cochlear implant implies that radiation had not severely damaged the central auditory pathways**
- **Some patients with radiation-induced hearing loss may be appropriate cochlear implant candidates**

For patients with severe to profound hearing loss following radiation therapy, a trial of amplification should precede cochlear implantation. For patients with normal ear canals, great care should be exercised in fashioning earmoulds, as improper pressure may predispose to otitis externa, ulceration and osteoradionecrosis. In patients with pre-existing radiation-induced ear canal pathology, hearing aid moulds can be a more difficult consideration since ear canal discharge, ulceration and pain may preclude effective retention and utilization of the device. Complete canal occlusion, as required for effective amplification, can further predispose to bacterial colonization and

infection, thereby worsening the temporal bone pathology. Venting of hearing aid moulds may be effective in preventing the detrimental effects of occlusion but may not allow for adequate gain because of troubling feedback. In the case reported here, feedback and worsening infection were major factors in the patient's open cavity ear. For the ear canal that had previously undergone blind sac closure, a trial of conventional amplification was not possible. A trial of bone conduction amplification using both a conventional bone conduction hearing aid and the bone-anchored hearing aid test device (Cochlear Corp) was also attempted but proved unsuccessful due to insufficient gain of the devices.

The excellent performance of the cochlear-implanted patient presented here serves to validate the notion that limited central auditory pathway involvement by irradiation was present. At the time of surgery and at subsequent follow-up visits, robust evoked intracochlear compound action potentials were elicited and excellent speech perception scores were evident as early as three months post-activation. In contrast to a previous report, elevated stimulation levels were not needed to achieve these results.¹² These findings support those reported by Low *et al.*,¹⁰ who failed to demonstrate detrimental retrocochlear effects in patients having undergone irradiation for nasopharyngeal carcinoma. Nonetheless, the authors believe that review of the radiation portals and imaging studies of the brain may help to better delineate radiation-induced CNS pathological changes such as demyelination and gliosis. In cases in which radiation changes are evident, especially in the brainstem and central auditory regions, counselling of patients regarding prognosis for cochlear implant performance should be appropriately guarded.

Conclusion

This case report demonstrates the feasibility of cochlear implantation in a patient with temporal bone osteoradionecrosis and sensorineural hearing loss. Prior to implantation, careful surgical planning is needed and staged temporal bone surgery should be considered to eliminate infection and pain. Radiation may result in intracochlear fibrosis. Techniques similar to those used in post-meningitic cochlear obstruction may be needed to achieve electrode insertion. In the present case, detrimental CNS effects did not preclude effective implant usage.

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