

Preoperative High Resolution CT and MR Imaging in Cochlear Implantation

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Abstract

Introduction: Accurate preoperative imaging of the temporal bone in patients receiving cochlear implants is important. High resolution computed tomography (HRCT) and magnetic resonance (MR) imaging are the 2 preoperative imaging modalities that provide critical information on abnormalities of the otic capsule, pneumatization of the mastoid, middle ear abnormalities, cochlear ducts patency and presence of cochlear nerve. **Materials and Methods:** The HRCT and MR imaging in 46 cochlear implant patients in our department were reviewed. **Results:** Majority of our patients [34 patients (73.9%)] showed normal HRCT of the temporal bone; 5 (10.9%) patients had labyrinthitis ossificans, 2 (4.3%) had Mondini's abnormality and 2 (4.3%) had middle ear effusion. One patient each had high jugular bulb, hypoplasia of the internal auditory canal and single cochlear cavity, respectively. **Conclusion:** The above findings contribute significantly to our surgical decisions regarding candidacy for surgery, side selection and surgical technique in cochlear implantation.

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Key words: Labyrinthitis ossificans, Michel aplasia, Mondini deformity

Introduction

Candidates for cochlear implantation undergo a thorough audiological and medical assessment. The audiological assessment is done to ensure that these candidates who have bilateral profound or severe hearing loss have been given adequate hearing amplification, but show no significant benefit. A thorough medical examination is then carried out to ensure that there is no medical contraindication before surgery. As the aim of surgery is to insert an electrode into the scala tympani of the cochlea, it is important to assess the patency of the cochlear duct and the condition of the middle ear and mastoid air cells through which access to the round window is made. It is also important to ensure that the cochlear nerve is present and of normal calibre.

High resolution computed tomography (HRCT) and magnetic resonance (MR) imaging play an important role in the above assessment. In the Cochlear Implant Programme of University Kebangsaan Malaysia, all potential cochlear

implant candidates underwent HRCT, following which MR imaging was performed selectively. We review the HRCT and MR imaging findings in these candidates and discuss the surgical decisions based on these findings.

Materials and Methods

Between December 1996 and June 2001, all potential cochlear implant candidates underwent a thorough audiological and speech assessment at the Department of Audiology and Speech Sciences. Suitable candidates were then referred to the surgeon, where a thorough medical examination was performed. HRCT scan was requested in all candidates. MR imaging was not routinely performed when the HRCT findings were perfectly normal. MR imaging was performed selectively in cases of congenital cochlear deformities, such as Mondini's deformity or in cases with a history of meningitis or in cases with hypoplasia of the internal auditory canal. The HRCT and MR imaging findings, aetiology of the sensorineural loss and surgical decisions were reviewed.

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Results

Forty-six candidates underwent HRCT of the temporal bone prior to cochlear implantation. Of these, 8 required further assessment with MR imaging. The HRCT findings of the temporal bone for these candidates are shown in Table I. The majority (73.9%) of patients were found to have normal otic capsule, pneumatization of mastoid, middle ear and cochlear patency.

TABLE I: PREOPERATIVE HRCT FINDINGS IN THE TEMPORAL BONES OF COCHLEAR IMPLANT CANDIDATES

Findings	No. of patients (%)
Normal otic capsule, mastoid, middle ear and cochlear patency	34 (73.9)
Labyrinthitis ossificans	5 (10.9)
Mondini's abnormality	2 (4.3)
Middle ear effusion and mild mastoiditis	2 (4.3)
Hypoplastic internal auditory canal	1 (2.2)
High jugular bulb	1 (2.2)
Single cochlear cavity	1 (2.2)

HRCT: high resolution computed tomography

There were 7 cases of profound sensory neural hearing loss secondary to meningitis. Of these, 2 patients had normal CT scan findings and 5 (10.9%) had labyrinthitis ossificans (Fig. 1). Three patients had complete obliteration of the cochlea and another 2 had partial obliteration of the round window. Mondini's abnormality was discovered in 2 (4.3%) patients (Fig. 2). Interestingly, 1 (2.2%) patient had hypoplasia of the internal auditory canal (Fig. 3).

Of the 46 candidates who underwent assessment for CI, 44 received implants after clinical and radiological examinations. Two patients with profound hearing loss secondary to meningitis underwent HRCT only, as the HRCT had shown complete severe ossification. However, another 5 patients with profound hearing loss secondary to meningitis underwent both HRCT and MR imaging. MR imaging was able to confirm the CT scan finding of labyrinthitis ossificans in which high resolution T2-weighted images showed absence of fluid in the membranous labyrinth.

Thirty-four patients (73.9%) had normal HRCT findings. Five patients (10.9%) had labyrinthitis ossificans, but only 3 patients underwent implantation. Full insertion of the electrode was achieved in the 2 patients with partial obliteration. In 1 patient, complete obliteration of the cochlea was only discovered intraoperatively. A "drill out"

surgical procedure was performed and partial insertion of the electrode was possible. However, 2 of these post-meningitis labyrinthine ossifications were not considered for implantation due to severe ossification.

Two patients with Mondini's abnormality and 1 patient with single cochlear cavity underwent cochlear implantation. We encountered 2 cases of otitis media with effusion and mild mastoiditis during HRCT. Both patients were implanted after the conditions were fully treated. One patient with high jugular bulb underwent implantation without any intraoperative complication. High jugular bulb is not a contraindication for cochlear implantation.

Of the 46 patients, 39 had congenital sensory neural hearing loss and 7 had a history of meningitis. Two patients were not considered for implantation due to severe labyrinthitis ossificans. Another 5 patients underwent uneventful cochlear implantation.

Discussion

The aim of cochlear implantation is to insert the cochlear implant electrodes into the scala tympani of the cochlea. This is achieved through a mastoidectomy, followed by posterior tympanotomy to view the round window and promontory. A cochleostomy is then performed to enter the scala tympani. Preoperative radiographic study is important to determine the feasibility of the procedure. Abnormalities of the cochlea, middle ear and mastoid pneumatization have a bearing on surgical decisions in cochlear implantation.

CT scan of the temporal bone is useful to determine pneumatization of the mastoid and the extent of the development of mastoid cavity. A small mastoid cavity with an anteriorly placed sigmoid sinus will cause difficulty in viewing the round window through the posterior tympanotomy. A high jugular bulb, which was found in 1 patient, can give rise to the same problem. Although these abnormalities are not contraindications for cochlear implantation, it is useful to anticipate the problem preoperatively. A superiorly extended posterior tympanotomy may overcome the problem.

Although acute mastoiditis and middle ear effusion are usually diagnosed clinically, 2 cases were detected during the preoperative CT scan. In both cases, surgery was postponed until the condition resolved with medical treatment. Cochlear abnormality is visible on CT scan. Anomalies of the inner ear can be gross bony malformation, for example, in the case of Michel aplasia where there is complete agenesis of the temporal bone.¹ The lumen of the cochlea may be narrowed, obliterated or grossly dilated. The cochlea will appear as a single cavity shell when the bony partitions between the cochlear coils are absent,² as found in 1 of our patients.

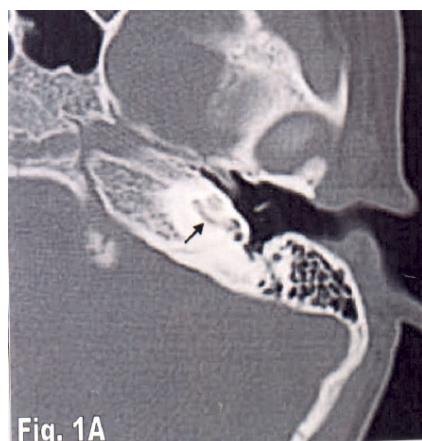


Fig. 1A. Axial CT scan shows that the lumen of the left cochlea is opaque (arrow).

Fig. 1. Labyrinthitis ossificans.



Fig. 1B. Axial T2-W MR image shows hyperintense fluid in the right cochlea (arrow) and a hypointense left cochlea (arrowhead).



Fig. 1C. Coronal T2-W MR image shows hyperintense fluid in the right cochlea (arrow) and a hypointense left cochlea (arrowhead).

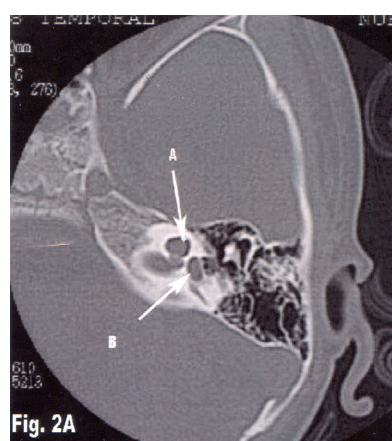


Fig. 2A. Axial CT scan shows a normal-sized left cochlea with no partitions giving the appearance of an empty cochlea (arrow A). The vestibule is moderately dilated (arrow B).

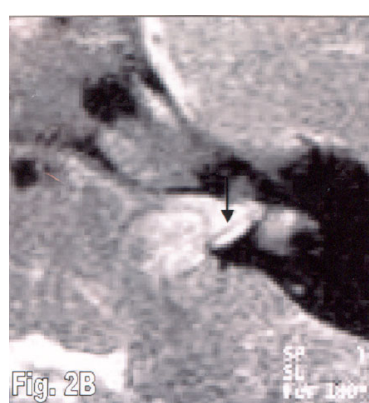


Fig. 2B. Axial T2-W MR image shows the presence of the auditory nerve within the widened internal auditory canal and

Fig. 2. Mondini's abnormality.

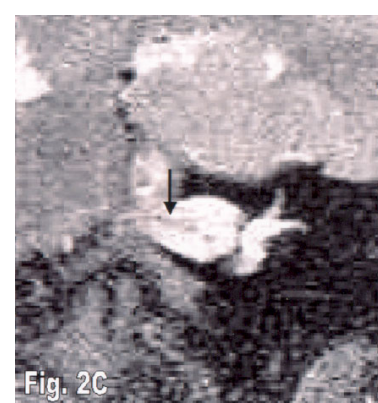


Fig. 2C. Coronal T2-W MR image shows the presence of the auditory nerve (arrow) within the widened internal auditory canal.

We encountered 2 cases with Mondini's deformity. It is characterised by an abnormal development of the cochlea and is often associated with an abnormality of the vestibular aqueduct, vestibule and semi-circular canal.² The cochlea may be hypoplastic or normal in size, but the bony partition between the cochlear coils is hypoplastic or absent. The vestibule may appear larger and the contour is more globular than normal.² The surgeon needs to anticipate perilymph leak or gusher during cochleostomy. In our 2 cases, the operations were uneventful.

MR imaging is able to further evaluate the pathological process or congenital abnormalities affecting the inner ear, auditory nerve and central auditory pathway. We have 1 case of hypoplasia of the internal auditory canal that was discovered on CT scan. Further evaluation by MR imaging confirmed that there was hypoplasia of the auditory nerve.

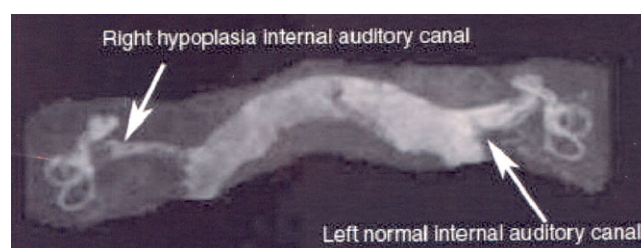


Fig. 3. Axial CISS three-dimensional MR image shows hypoplasia of the right internal auditory canal. The right internal auditory canal is markedly hypoplastic compared to the normal internal canal on the left side.

Therefore, the ear was not suitable for cochlear implantation.

All the above congenital cochlear abnormalities are rare. However, the most common abnormality found in the cochlea is labyrinthitis ossificans in patients with deafness following meningitis. Hearing loss following an episode of bacterial meningitis is a well-documented phenomenon, with an incidence ranging from 5% to 35%.³ Fortnum and Davis⁴ reported that up to 10% of children who suffer acute

bacterial meningitis would sustain some degree of permanent unilateral or bilateral deafness. The site is almost always cochlea with loss of organ of Corti, and not the auditory nerve, as previously reported.⁵

Infection in the subarachnoid spaces (meningitis) reaches the cochlea through the cochlear aqueduct, internal auditory canal or via haematogeneous spread.^{5,6} The infective process in the cochlea and labyrinth may produce a reaction in the endosteum that results in new bone formation. As early as 2 weeks after the onset of meningitis, fibrosis is present followed by new bone formation within 2 months.⁷ Ossification initially develops in the basal turn of the cochlea at the region of the scala tympani near the round window.^{5,8} Radiographic evidence of ossification can be found as early as 2 months after the acute infection, indicating that the intracochlear process probably begins much earlier.⁶

However, CT scan sometimes underestimates the extent of obliteration because, early in its evolution, the new bone is relatively radiolucent compared to the dense bone of the otic capsule. A partially obliterated lumen can appear patent.⁹ MR imaging can resolve this problem.⁵ A labyrinth that has undergone fibrous obliteration may appear normal on CT, but lacks the high signal on T2-weighted MR imaging.^{10,11} Therefore, it is advocated that MR imaging is performed in all post-meningitis cases for cochlear implantation. We have 5 cases with labyrinthitis ossificans. As mentioned earlier, all of them had a history of bacterial meningitis. Two of them did not receive a cochlear implant as both have complete bilateral cochlear ossification.

Evidence of ossification was previously considered a relative contraindication to cochlear implantation. It was considered difficult or impossible to achieve safe electrode insertion because of bony obstruction. Either the electrodes or the inner ear structures could be damaged. These may complicate the surgical procedure and affect the long-term outcome.

However, depending on the experience of the surgeon, cochlear implantation has been attempted even in grossly ossified cochleas. Balkany et al¹² reported, in 15 patients with partially ossified cochleas, that the result of cochlear implant was similar to that achieved in a patient with normal cochlea. Electrodes were fully inserted in 14 patients and partially in 1 patient.¹² Becker et al¹³ reported that mild labyrinthine ossification is not a contraindication to cochlear implantation.

Novak et al⁶ found that timing of the implantation may be critical. A delay of even a few months would probably have allowed ossification to develop to the extent that standard implantation procedures would have been impossible. Therefore, the potential benefit of cochlear implantation

can be reduced.^{5,6} CT scan and MR imaging findings forewarn the surgeon on these potential complications. This information is useful in preoperative counselling for the patients or parents.

Conclusion

The above findings highlight the importance of HRCT and MR imaging in surgical decisions regarding candidacy for surgery, site selection and surgical technique in cochlear implantation. HRCT and MR imaging findings also forewarn the surgeon on possible complications. In our institution, HRCT is performed in all patients undergoing cochlear implantation. MR imaging is not performed when HRCT shows normal findings. However, MR imaging is performed at the slightest doubt on the status of the inner ear, auditory nerve and central auditory pathways.

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REFERENCES

1. Clark G, Pyman B C. Cochlear implantation for infants and children. Cochlear implant. London: Singular Publishing, 1997:71-82.
2. Valvassori G E, Mafee M F, Carter B R. Congenital abnormalities of the temporal bone. Imaging of the Head & Neck. New York: Georg Thieme Medical Publishers, 1995:36-56.
3. Hartnick C J, Kim H Y, Chute P M, Parisier S C. Preventing labyrinthitis ossificans: the role of steroids. Arch Otolaryngol Head Neck Surg 2001; 127:180-3.
4. Fortnum H, Davis A. Hearing impairment in children after bacterial meningitis: incidence and resource implications. Br J Audiol 1993; 27:43-52.
5. Dodds A, Tyszkiewicz E, Ramsden R. Cochlear implantation after bacterial meningitis: the dangers of delay. Arch Dis Child 1997; 76: 139-40.
6. Novak M A, Fifer R C, Barkmeier J C, Firszt J B. Labyrinthine ossification after meningitis: its implications for cochlear implantation. Otolaryngol Head Neck Surg 1990; 103:351-6.
7. Mabrie D C, Niparko J K. Quiz case 1. Meningitis-related labyrinthitis ossificans. Arch Otolaryngol Head Neck Surg 1999; 125:912-5.
8. DeSouza C, Paparella M M, Schachern P, Yoon T H. Pathology of labyrinthine ossification. J Laryngol Otol 1991; 105:621-4.
9. Green J D Jr, Marion M S, Hinojosa R. Labyrinthitis ossificans. histopathologic consideration for cochlear implantation. Otolaryngol Head Neck Surg 1991; 104:320-6.
10. Harnsberger H R, Dart D J, Parkin J L, Smoker W R, Osborn A G. Cochlear implant candidates: assessment with CT and MR imaging. Radiology 1987; 164:53-7.
11. Weissman J L, Kamerer D B. Labyrinthitis ossificans. Am J Otolaryngol 1993; 14:363-5.
12. Balkany T, Gantz B, Nadol J B Jr. Multichannel cochlear implants in partially ossified cochleas. Ann Otol Rhinol Laryngol Suppl 1988; 135:3-7.
13. Becker T S, Eisenberg L S, Luxford W M, House W F. Labyrinthine ossification secondary to childhood bacterial meningitis: implications for cochlear implant surgery. AJNR Am J Neuroradiol 1984; 5:731-41.