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Research Article

Role of High Resolution Computed Tomography and Magnetic Resonance Imaging of Temporal Bone in evaluating patients for Cochlear Implantation

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Abstract

Objective: To assess the role of imaging using High resolution computed tomography and Magnetic resonance imaging temporal bone for evaluating candidates for cochlear implantation.

Methodology: It was a prospective study conducted in the department of Otorhinolaryngology at a tertiary care centre 30 children up to 5 years of age with severe to profound sensorineural hearing loss, radiological evaluation using HRCT and MRI temporal bone was done in all children.

Results: 20(66.67%) were in 2-4 years age group with female preponderance. Radiological abnormalities were reported in 13(43.33%) children. Abnormalities of inner ear were seen in 8(26.67%) cases, which included bilateral cochlear nerve aplasia, unilateral cochlear aplasia with bilateral cochlear nerve aplasia, bilateral severe cochlear hypoplasia, mondini's dysplasia. Cochlear nerve deficiency was found in 3(10%) children and narrow Internal auditory canal in 4(13.33%) children.

Conclusion: Imaging is a fundamental part of the preoperative workup for CI, HRCT and MRI temporal bone are complementary to each other in evaluating children for CI as HRCT is excellent for demonstrating bony details but, lack in providing details of inner ear neural structures and MRI is better than CT in demonstrating vestibulocochlear nerves.

Keywords: Cochlear Implant; Inner Ear Anomalies; Candidacy for Cochlear Implant; HRCT Temporal Bone

Abbreviations

HRCT: High Resolution Computed Tomography; MRI: Magnetic Resonance Imaging; SNHL: Sensorineural Hearing Loss; CI: Cochlear Implantation; SCC: Semicircular Canal; IAC: Internal Auditory Canal

Introduction

Hearing is an essential sense bestowed to human, which enables us to communicate, socialize and stay connected to the outside world. SNHL is a malfunction of the inner ear or may be a retrocochlear condition. Children with bilateral congenital SNHL can suffer long term consequences as they fail to develop language skills also. The prevalence of SNHL is 2-3 per 1000 live births in India [1,2]. CI is one of the triumph of modern science as for the first time in history, an electronic device is able to vitalize sense of hearing. Cochlear implant surgery requires a wide selection process, for which imaging of the ear and the auditory pathway is an important

entity as any structural or functional disorder may hinder the signal from reaching the auditory cortex. Imaging evaluation plays major role in CI with regard to preoperative candidacy [3]. intraoperative monitoring, and postoperative evaluation. Dual modality imaging with high - HRCT and MRI of the temporal bone and brain can provide greatest amount of information to the operating surgeon and are often complementary to each other [4]. This study was conducted to assess the role of imaging by HRCT and MRI temporal bone for evaluating candidates of CI and finally to make surgical decisions regarding candidacy for CI and side selection.

Material and Methods

This study was a prospective observational study conducted at a tertiary care centre, MGM medical college and MYH hospital, Indore in the department of ENT and head and neck surgery from April 2018- July 2019. 30 prelingually deaf children upto 5 years of age who satisfy the inclusion criteria were included in the study.

Inclusion criteria

- Children upto 5 years of age.
- Children with bilateral severe to profound SNHL.
- No appreciable benefit with digital hearing aid.
- Motivated parents for surgery.
- No medical contraindications.

Exclusion criteria

- Active middle ear disease.
- Congenital aural dysplasia.
- Patient with mild or moderate hearing loss.
- Children more than 5 years of age.
- Patient medically unfit for CI.
- Benefit with digital hearing aid.
- Parents not willing for cochlear implant surgery.

A detailed medical history with primary focus on inability to hear was obtained with emphasis on previous hospital stays, developmental delay, maternal history, family history. Complete ENT examination and paediatric examination was done. Audiological work up was done, children with severe to profound SNHL with no benefit from hearing aid were selected and their radiological evaluation was done. The HRCT images were reconstructed in axial, coronal and sagittal planes. The acquired MRI sequences were visualised in an axial plane with multi planar reconstructions in oblique sagittal plane. Combined evaluation of HRCT and MRI was done for candidacy. Congenital inner ear malformations are classified by Ramos., *et al*. [5], into three groups with respect to their implications for the feasibility of cochlear implantation surgery. In this study we used this criteria of Ramos., *et al*. for classification of patients and evaluating patients with inner ear malformations as candidates for implantation:

- Gross malformations constituting surgical contraindications - complete labyrinthine aplasia, cochlear aplasia, and cochlear nerve deficiency
- Major malformations contributing to increased risks for complications - a common cavity or severe hypoplasia, the result of CI is often difficult to predict. Severe malformations often are associated with higher intraoperative risks for cerebrospinal fluid leakage, post-implantation meningitis, and potential electrode displacement.
- Minor malformations - include partition defects such as hypoplasia, abnormalities of the aqueduct, and abnormalities of the vestibule. If bilateral malformations are found, the surgeon will want to know which inner ear has the more normal structure and the larger cochlear nerve.

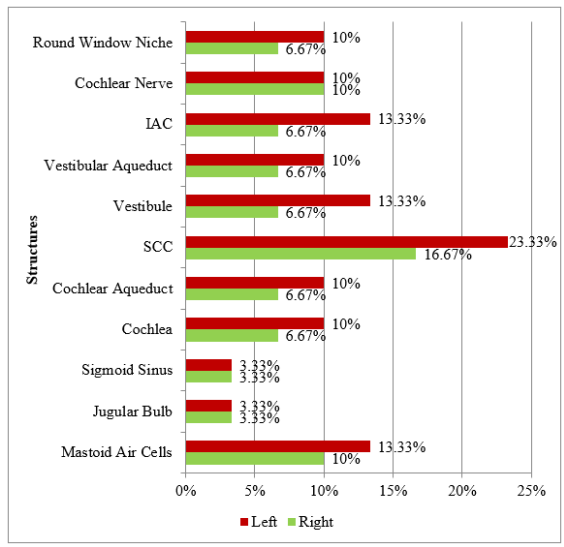
The observations of HRCT and MRI were analysed and managed using an excel spreadsheet and observation tables.

Results

Majority 20(66.67%) of the children were between 2-4 years of age, 19(63.33%) were females and 11(36.67%) were male. Radiological abnormalities were seen in 13(43.33%) children (Table 1) (Graph 1).

Parameter	Number	Percentage
Abnormal	13	43.33%
Normal	17	56.67%
Total	30	100%

Table 1: Distribution of study participants with either abnormal HRCT or MRI temporal bone.



Graph 1: Overview of abnormalities seen in CT and MRI.

Out of the 13 patients with abnormal HRCT and MRI, 8(26.67%) children demonstrated various inner ear malformations (Graph 2) including cochlea, vestibular system, internal auditory canal and cochlear nerve.

Graph 2: Distribution of study subjects based on inner ear malformations.

As per classification by Ramos., *et al*. (Graph 3) the inner ear malformations found in our study were-

- Gross malformations (Figure 1 a-d) in 2(6.67%) patients 1 with bilateral cochlear nerve aplasia and 1had left side cochlear aplasia with bilateral cochlear nerve aplasia along with malformed SCC and dilated vestibule and both were not the candidate for cochlear implantation.

Graph 3: Distribution of Congenital inner ear malformation and feasibility of CI based on classification by Ramos., *et al*. [5].

a b

c d

Figure 1: 1a HRCT temporal bone demonstrating a normal cochlea on the right side with left sided cochlear aplasia (red arrow), the optic capsule is also not seen on the left side, narrow IAC can also be seen; 1b Image of the same patient showing a dilated vestibule (white arrow). 1c MRI demonstrating normal cochlea with vestibule on right side with aplastic cochlea (red arrow) on left side. 1d Absent cochlear nerve bilaterally, only single nerve seen (yellow arrow).

- Major malformation (Figure 2 a, b) in 1(3.33%) patient which included bilateral severe hypoplasia of cochlea with dilated vestibular aqueduct and enlarged endolymphatic sac and dysplastic vestibule.

a b

Figure 2: 2a HRCT temporal bone axial image showing cochlear hypoplasia (yellow arrow). 2b HRCT image with an enlarged vestibular aqueduct (white arrow).

- Minor malformations in 5 (16.67%) patients - Bilateral Mondini's deformity (Figure 3 a, b) was present in 1 patient with cochlea demonstrating 1.5 turns, dilated vestibule and dysplastic SCCs. 2 patients had isolated bilateral SCC dysplasia, 1 patient presented with unilateral SCC dysplasia and dilated vestibule (Figure 4 a, b), all these 3 patients had normal anatomy of cochlea and 2 had narrow IAC with hypoplastic cochlear nerve bilaterally (Figure 5 a, b).

a

b

Figure 3: 3a Bilateral incomplete partition type 2 - Mondini's deformity. HRCT showing 1.5 turns of cochlea with confluence of the middle and apical turn resulting in cystic apex (green arrow). 3b CT image showing normal sized IAC (yellow arrow) on both sides in mondini's deformity patient and dilated vestibule (red arrow).

a b

Figure 4: 4a and 4b Image showing a normal lateral SCC (green arrow) and vestibule (yellow arrow) "signet ring appearance" on right side; A dilated vestibule (yellow arrow) on left side in HRCT temporal bone.

a

b

Figure 5: 5a Bilateral narrow IAC (red arrow) as seen in HRCT temporal bone. 5b Oblique sagittal image of MRI showing hypoplastic cochlear nerve (yellow arrow).

Out of 30 patients, 2(6.67%) had narrow IAC (Graph 4). Cochlear nerve aplasia (Figure 6 a-c and Figure 7) was found in 2 patients (6.67%) on right side and 2 (6.67%) on left side. Hypoplastic cochlear nerve (Figure 5b) was reported in 1(3.33%) patient bilaterally (Table 2). A total of 60 ears were studied in which only 1 patient had hypopneumatised mastoid unilaterally (3.33%), 2

children had unilateral mastoidits. 2(6.67%) patients had bilateral mastoiditis, treatment was given and repeat CT was done (Figure 8 a-c).

Graph 4: Distribution of study participants by internal auditory canal status.

a

b

c

Figure 6: 6a An axial image of MRI showing bilateral IAC demonstrating the 7th and 8th nerves. The facial nerve (green arrow) is seen anteriorly and superior vestibular nerve (branch of 8th nerve) posteriorly (yellow arrow). The cochlea and vestibule can be partially seen. 6b An axial image of MRI temporal bone demonstrating branches of vestibulocochlear nerve within bilateral IAC, the cochlear nerve (red arrow) present anteriorly entering cochlea and inferior vestibular nerve (blue arrow) posteriorly entering the vestibule. 6c A sagittal image of IAC in MRI showing cochlear nerve along with facial nerve and superior and inferior vestibular nerve.

Figure 7: The MRI image showing absent cochlear nerve.

Cochlear nerve	Right		Left	
	Number	Percentage	Number	Percentage
Aplasia	02	6.67%	02	6.67%
Hypoplasia	01	3.33%	01	3.33%
Normal	27	90%	27	90%
Total	30	100%	30	100%

Table 2: Distribution of study participants by status of cochlear nerve.

a

b

c

Figure 8: 8a HRCT temporal bone image with left side hypopneumatised mastoid cavity. 8b and 8c HRCT temporal bone showing bilateral mastoiditis.

2(6.67%) patients had high riding jugular bulb and 2(6.67%) had forward lying sigmoid sinus unilaterally (Figure 9).

Figure 9: Forward lying sigmoid sinus (yellow arrow) and high placed jugular bulb (green arrow) on right side.

White matter lesions, parenchymal lesions like periventricular leukomalacia were found in 7(23.33%) patients on MRI brain which guides us to probable etiology of SNHL like congenital cytomegalovirus infection and patient's parents attention on guarded prognosis of cochlear implantation.

2(6.67%) patients out of 30 were not the candidates for CI, they had bilateral absent cochlear nerve which is an absolute contraindication for cochlear implantation. 28(93.33%) patients were evaluated as candidates for CI.

Discussion

Age and sex incidence

In our study majority, 20(66.67%) children were in 2-4 years age group with female preponderance, which is well correlating to a study by Gupta A., *et al*. 2018 [5], and Shrivastava., *et al*. 2018 [1], who reported maximum patients in this age group with female preponderance. Contrary to this male preponderance has been shown in most previous studies - Bamiou., *et al*. [6], reported 70 males (59.8%) and 46 females (40.2%), Vaid., *et al*. [7], study included 27 female subjects (49.1%) and 28 male subjects (50.9%). This may be attributed to the fact that nowadays awareness for female child has been increased as compared to past.

Radiological findings

Out of the total 30 children abnormalities in HRCT and MRI were reported in 13(43.33%) children. Sennaroglu., *et al*. [8], reported 13(48.15%) children with abnormal inner ear findings (Table 3).

Study	Abnormal	Normal
Our study	43.33%	56.67%
Gupta A., *et al.* 2018 [5]	54%	46%
Bamiou., *et al.* [6]	28.4%	71.6%
Sennaroglu., *et al.* [8]	48.15%	51.85%
Jallu., *et al.* [9]	27.5%	72.5%
Abdullah., *et al.* [10]	26.1%	73.9%

Table 3: Comparison of radiological abnormalities from other studies.

Inner ear anomalies found in radiology

Inner ear anomalies were seen in 8(26.67%) children. Sennaroglu., *et al*. [11], states that inner ear malformations constitute about 20% of congenital sensorineural hearing loss. 15% and 22% of the children had inner ear anomalies in a study by Taha., *et al*. [12], and Woolley., *et al*. [13], respectively (Table 4).

Study	Inner ear abnormalities
Our study	26.67%
Sennaroglu., *et al*. [11]	20%
Taha., *et al*. [12]	15%
Woolley., *et al*. [13]	22%

Table 4: Comparison of inner ear abnormalities with other studies.

Ramos., *et al*. classification of congenital inner ear malformations and feasibility of Cochlear implant surgery

Gross malformations were found in 2(6.67%) patients, 1 patient had bilateral cochlear nerve aplasia and other patient had left sided cochlear aplasia(3.33%) with bilateral cochlear nerve aplasia and were not the candidate for cochlear implantation as both patients had deficient cochlear nerve. As evident from a study by Shamsheena., *et al*. [14], who states that a hypoplastic cochlear nerve is a relative contraindication while the absence of the cochlear nerve is considered an absolute contraindication for cochlear implantation. Young., *et al*. [15] states that Cochlear aplasia is a rare finding, constituting less than 3%, of cochlear bone abnormalities.

1(3.33%) patient presented with major malformation, bilateral severe hypoplasia of cochlea, in this patient the cochlear implant surgery was feasible but with increased intraoperative risks like CSF leaks and post implantation meningitis.

Minor malformations were present in 5(16.67%) patients and the side with less severe inner ear malformation like isolated SCCs dysplasia, dilated vestibule partition defect like mondini's deformity (3.33%) can be selected for implantation. Abdullah., *et al*. [10], reported 4.3% (2 patients) with mondini's deformity in his study. Wu., *et al*. [16], in their study, concluded that cochlear implantation can be done in patients with Mondini's deformity.

Anatomical variation found in radiology which may affect the process of cochlear implantation

Mastoid pneumatization and candidacy evaluation: out of the 30 radiological scans done 1(3.33%) patient had hypopneumatised mastoid on the left side making him a better candidate for right side cochlear implantation. Patients with unilateral mastoiditis

can be implanted on normal side after conservative management and patients with bilateral mastoiditis should be given appropriate treatment before implantation and repeat CT scan should be done. Al-Rawy., *et al*. [17], study showed mastoiditis in 3 ears (5.2%). Young., *et al*. [15], stated that sclerotic or hypopneumatized mastoid air cells may limit exposure of the middle ear and acute mastoiditis requires treatment before implantation to decrease the risk for infection and meningitis.

Internal auditory canal and cochlear nerve status

Narrow IAC < 2 mm was seen in 4(13.33%) patients. Cochlear nerve deficiency either aplasia or hypoplasia was found in 3(10%). Gupta A., *et al*. 2018 [5], observed abnormal internal auditory meatus in CT scan in 6(10.91%) on right side and 5(9.09%) cases in left ear. Jallu., *et al*. [9], reported 2 patients (5%) with internal auditory canal stenosis with cochlear nerve hypoplasia on CT and MRI.

Relationship between narrow IAC and Cochlear nerve deficiency

2(6.67%) patients had bilateral narrow IAC with absent cochlear nerve. 1 patient had narrow IAC on left side with hypoplastic cochlear nerve and another patient had narrow IAC with normal cochlear nerve relating that a narrow or stenotic cochlear canal may or may not be associated with a hypoplastic or aplastic cochlear nerve. In our study cochlear nerve was not visualised in 4 out of the 6 narrow IAC. Glastonbury., *et al*. [18], found in his study that hypoplasia of the IAC was observed in association with congenital deficiency of the cochlear nerve in 11 of 12 patients. Nelson., *et al*. [19], study findings suggests that cochlear nerve aplasia can occur in both narrow or a normal sized IAC.

Cochlear anomalies

Cochlear anomaly was found in 3(10%) patients, 1(3.33%) child had an aplastic cochlea on left side, 1(3.33%) child had hypoplastic cochlea bilaterally, and 1(3.33%) had 1.5 turns of cochlea bilaterally suggestive of Mondini's dysplasia**.** Gupta A., *et al.* 2018 [5], observed abnormal cochlea in CT scan in 4% cases in bilateral ears. In one case (2%) enlarged cochlea was observed in bilateral ears and in one case (2%) fusion of middle and apical turns cochlea (Mondini Deformity) was observed in bilateral ears. Casselman., *et al*. [20], found cochlear aplasia in 3% of their patients which is similar to our study in which we reported 3.33% patient with cochlear aplasia.

Vestibular and semicircular canals anomalies

2(6.67%) children had vestibular abnormalities on right side and 4(13.33%) children on left side which were associated with other congenital malformations. SCC was found dysplastic or malformed in 12 inner ears. Gupta A., *et al*. [5], reported vestibular abnormality in 16.05% on right side and 18.31% on left side. Abnormal semicircular canals in CT scan were observed in 8% cases in right ear and 10% cases in left ear. Young., *et al*. [15], highlights that although the risk for CSF leakage increases in the presence of inner-ear malformations but isolated anomalies of the vestibule or semicircular canal typically do not affect surgical planning.

Aqueductal anomalies

Bilateral dilated Vestibular aqueduct with bilateral enlarged endolymphatic sac was found in 1(3.33%) patient which pose a risk during CI surgery by causing perilymph leaks but Padma Shri Dr. Jitender Mohan Hans [21], states that the large vestibular aqueducts presents as a mild pulsatile leak of perilymph which is self-limiting and can be easily sealed using tissue.

Vascular anomalies (Jugular bulb and sigmoid sinus) and candidacy evaluation

Among 30 children who participated in the study 2(6.67%) patients reported high riding jugular bulb, 1 on the right side and 1 patient on left side. Patient with high jugular bulb on left side also had a forward lying sigmoid sinus which may complicate the implantation on left side and hence was selected for right sided CI. Woolley., *et al*. [13], found 6% of the children with high riding jugular bulb, 1.6% of children had anteriorly placed sigmoid sinus.

MRI brain

In our study white matter lesions, parenchymal lesions like periventricular leukomalacia was found in 7(23.33%) patients in MRI which guides us to probable etiology of SNHL like congenital cytomegalovirus infection [4], and patient's parents attention on guarded prognosis of cochlear implantation. Moon., *et al*. [23], stated that preoperative brain MRI may have a role in improving the prediction of adverse outcomes in paediatric CI recipients.

Side recommended for cochlear implantation: Based on the radiological findings the most appropriate side was recommended for implantation. The ear with any anatomical variants which may hamper implantation and can cause intraoperative difficulty to the surgeon were noted at the time of side selection and in case of bilateral abnormalities the better side is selected. CI surgery was recommended on the Right side when identical findings were found in both ears [24].

From our study we state that HRCT and MRI temporal bone are complementary to each other as CT scan can outline the bony borders of the malformed labyrinth and MRI provides the cochlear nerve status therefore both should be performed in a child with congenital SNHL for cochlear implant candidacy as reported by other studies also- Wu., *et al*. (2015) [16], notes that the combination of these two modalities provides reliable anatomical information regarding the bony and membranous labyrinths, as well as the auditory nerve. Junior., *et al*. [22], stated that evaluation by imaging methods is critical in the preoperative care of CI surgery, providing safety to surgeons when indicating and performing this procedure. The ideal imaging study consists of an association between HRCT and MRI.

Conclusion

We conclude that radiological evaluation is a fundamental component for Cochlear Implant candidacy. Imaging remains indispensable for- judging the feasibility of surgery, influence the side of implantation and the surgical approach. Identification of the inner ear abnormality has significant effect on decision making and prognosis of implantation. HRCT and MRI temporal bone are complementary to each other in evaluating children for CI surgery because HRCT is excellent for demonstrating bony details but lags in providing details of inner ear neural structures and fluid. MRI is better than CT in demonstrating vestibulocochlear nerves but it fails to provide information about bony structures. Therefore a dual modality approach should be followed whenever radiological assessment of child for Cochlear Implant surgery has to be done.

Conflict of Interest

There were no conflicts of interest.

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